

Inox Clean Energy Ltd.

Assessment of Indian Renewable IPP and solar module manufacturing landscape

Final Report

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1	OVERVIEW OF INDIAN MACROECONOMIC LANDSCAPE	1
1.1	OVERVIEW ON GLOBAL MACRO-ECONOMIC LANDSCAPE.....	1
1.2	INDIA-GVA PERFORMANCE	3
1.3	OUTLOOK ON OTHER ECONOMIC FACTORS	4
1.4	OVERVIEW OF OTHER DEMOGRAPHIC FACTORS	11
1.5	GLOBAL RENEWABLE CAPACITY ADDITION	12
1.6	INDIA'S EMERGENCE AS A GLOBAL MANUFACTURING HUB	13
1.7	INCREASING INTEREST RATE ADDING TO BORROWING COSTS FOR RENEWABLE IPPS.....	15
1.8	AATMANIRBHAR BHARAT ABHIYAN	16
2	OVERVIEW AND OUTLOOK OF POWER SECTOR IN INDIA	18
2.1	OVERVIEW OF GLOBAL POWER SECTOR.....	18
2.2	OVERVIEW OF INDIAN POWER SECTOR	21
2.3	REVIEW OF POWER DEMAND-SUPPLY IN INDIA.....	23
2.4	DISTRIBUTION SECTOR REFORMS	29
2.5	OUTLOOK ON POWER DEMAND – SUPPLY SCENARIO.....	32
2.6	GOVERNMENT'S INITIATIVE FOR CLEAN ENERGY GROWTH.....	37
3	ASSESSMENT OF THE RENEWABLE IPP BUSINESS IN INDIA	42
3.1	OVERVIEW OF RE CAPACITY ADDITION IN INDIA.....	42
3.2	SOLAR POTENTIAL ACROSS STATES.....	43
3.3	ASSESSMENT OF KEY POLICIES AND REGULATIONS IMPACTING RE IPP BUSINESS IN INDIA	45
3.4	BUSINESS MODELS ADOPTED BY RENEWABLE IPPS	52
3.5	OVERVIEW OF UTILITY SCALE MARKET.....	56
3.6	OVERVIEW OF C&I/OPEN ACCESS MARKET	68
3.7	CRITICALITY OF HAVING PRESENCE ACROSS THE VALUE CHAIN TO SUPPORT BUSINESS GROWTH.....	82
3.8	OUTLOOK ON RENEWABLE CAPACITY ADDITION	89
3.9	COMPETITIVE LANDSCAPE	96
3.10	CHALLENGES AND RISK ASSESSMENT.....	102
4	ASSESSMENT OF RE (SOLAR & WIND) EPC AND O&M MARKET IN INDIA	105
4.1	RE (SOLAR AND WIND) EPC	105
4.2	HISTORICAL RE EPC MARKET IN INDIA.....	107
4.3	ASSESSMENT OF EPC CONTRACT IN SOLAR AND WIND SPACE.....	107
4.4	OUTLOOK ON RE (SOLAR AND WIND) EPC MARKET FISCAL 2025-2031	114
4.5	RE (SOLAR AND WIND) O&M MARKET IN INDIA	115
4.6	EVOLUTION OF O&M SERVICES FOR SOLAR AND WIND SECTOR IN INDIA.....	116
4.7	OUTLOOK ON RE O&M SERVICES MARKET IN INDIA FISCAL 2027-2031	118
5	OVERVIEW AND OUTLOOK ON MERCHANT POWER PRICE	120
5.1	OVERVIEW OF PRODUCTS/ OPTIONS AVAILABLE ON EXCHANGES	120
5.2	PRICE TREND OF DIFFERENT PRODUCTS	122
5.3	DEMAND AND SUPPLY CURVE PROJECTION	126
5.4	POTENTIAL DEMAND TO BE MET FROM PPAs AND THAT FROM POWER EXCHANGES	127
5.5	ASSESSMENT OF SOURCE WISE VARIABLE COST OF GENERATION.....	128
5.6	POTENTIAL TRANSMISSION CONSTRAINTS	129
5.7	ESTIMATION OF AVERAGE POWER EXCHANGE PRICE FORECAST AT A NATIONAL LEVEL	129
6	OVERVIEW OF INDIAN SOLAR PV CELL AND MODULE MANUFACTURING SECTOR	131
6.1	OVERVIEW OF SOLAR MODULE MANUFACTURING VALUE CHAIN IN INDIA	131

6.2	SOLAR PV MODULE MANUFACTURING PROCESS.....	132
6.3	INDIAN SOLAR PV MODULE MANUFACTURERS	137
6.4	POLICY AND REGULATORY FRAMEWORK	140
6.5	IMPACT OF DOMESTIC CONTENT REQUIREMENTS (DCR) AND IMPORT DUTIES	142
6.6	INSIGHTS ON PLI SCHEME	144
6.7	OVERVIEW OF SOLAR PV INTEGRATION AND CAPITAL INTENSITY	145
6.8	ADVANTAGES OF FULLY INTEGRATED SOLAR PV MANUFACTURING	146
6.9	ASSESSMENT OF SHARE OF DOMESTIC & IMPORTED MODULES IN INDIAN MARKET.....	147
6.10	PRICE TREND OF SOLAR PV CELLS AND MODULES.....	149
6.11	SUPPLY CHAIN AND TECHNOLOGY TRENDS.....	152
6.12	THREATS AND CHALLENGES FOR PV MANUFACTURING SECTOR	154
6.13	FUTURE GROWTH OPPORTUNITIES.....	155
6.14	OVERVIEW OF GLOBAL SOLAR MARKET	157
6.15	MAJOR EXPORT DESTINATIONS FOR INDIAN SOLAR MODULES.....	158
6.16	OUTLOOK FOR INDIA-SOLAR MODULE MANUFACTURING	179
7	COMPETITIVE ASSESSMENT OF RE IPP AND SOLAR MODULE MANUFACTURING	180
7.1	ABOUT INOX CLEAN ENERGY LTD. AND INOX GFL GROUP	180
7.2	COMPETITIVE MAPPING	185
8	CHALLENGES AND THREATS FOR THE SECTOR	198

List of Tables

Table 1: Inflation rate across countries and global (in %)	1
Table 2: Historical and projected growth of real GDP for major economies (figures in %)	3
Table 3: Per capita GDP vs Global economies (in USD)	10
Table 4: Sector-wise focus of <i>Aatmanirbhar Bharat</i> Vision	16
Table 5: State wise solar energy potential and installed capacity for key states (as of March 2026)	44
Table 6: Summary of key policy and regulations implemented by GoI and their impact	46
Table 7: RPO targets by MoP notified in October 2023	47
Table 8: WSH policy comparison for select states	52
Table 9: Result of key standalone storage tenders	65
Table 10: Tentative ISTS sub-station margin connectivity, as of December 2025	67
Table 11: Comparison of MoP's green open access rules with state notified RE open access regulations	74
Table 12: Status of implementation of rebate during solar hours by various SERCs for fiscal 2026	77
Table 13: RE players' presence across renewable supply chain	83
Table 14: Key players in RE IPP business	97
Table 15: Key players in C&I open access	98
Table 16: Recent equity and M&A investments	100
Table 17: Key drivers of short-term power market in India	127
Table 18: Overview of Solar PV production process	131
Table 19: Key domestic solar module manufacturers with capacity as of June 2026	137
Table 20: Key players in solar module manufacturing and their presence	139
Table 21: Safeguard and customs duty trajectory	140
Table 22: Capacity awarded (in MW) under the PLI scheme (Tranche-I and II)	144
Table 23: Relative Capital Intensity increases with degree of integration	145
Table 24: % Share of export of solar modules (in value terms USD Mn)	159
Table 25: Summary of Tariff imposed by USA on various SA countries	163

Table 26: Operating parameters of key players in RE IPP with similar offerings	185
Table 27: Comparative summary of domestic module manufacturers	188
Table 28: Existing and planned capacity additions of leading players	190
Table 29: Comparative summary of global module manufacturers	191
Table 30: Competitive analysis of key solar cell manufacturers	192
Table 31: Financial and operational parameters of key players with similar offerings	194

List of Figures

Figure 1: Comparison of India's economy with other major nations	2
Figure 2: GVA at basic prices	3
Figure 3: CPI inflation (% , y-o-y)	4
Figure 4: Current account deficit (as a % of GDP)	4
Figure 5: Fiscal Deficit as % of the GDP	5
Figure 6: Interest rates increasing (%)	6
Figure 7: Exchange rates USD and INR	6
Figure 8: Major currencies vs dollar % y-o-y (As of July 2026)	7
Figure 9: Trend of Index of Industrial Production	7
Figure 10: The improvement in IIP growth was driven by manufacturing (in %, month on month)	8
Figure 11: Manufacturing PMI (in %)	8
Figure 12: Urban population as a % of total population of India	11
Figure 13: Per capita electricity consumption (in kWh)	12
Figure 14: Per capita electricity consumption 2024	12
Figure 15: Global renewable annual capacity addition (in GW)	13
Figure 16: Global power mix- installed capacity as of 2025	18
Figure 17: Growth in cumulative global electricity installed capacity	19
Figure 18: Share of solar and wind increasing whereas fossil fuel decreasing in energy generation	20

Figure 19: Installed capacity of major countries	20
Figure 20: Top 5 countries installed base in total renewable (incl. Hydro) CY2024	21
Figure 21: Institutional and structural framework	22
Figure 22: Installed capacity as of March 2026 (GW, %)	23
Figure 23: Growth in India's electricity installed capacity (in GW)	23
Figure 24: Annual RE capacity addition trend by key states (in GW)	24
Figure 25: Historical trend of Energy requirement in India	25
Figure 26: Historical trend of Peak demand and supply in India	25
Figure 27: Correlation between GDP and energy consumption	26
Figure 28: Consumer segment-wise energy sales in India	27
Figure 29: Energy and peak demand shortage trends during the past 10 years	27
Figure 30: Category wise historical average billing rate at national level	28
Figure 31: Share of revenue from sale of power in FY2025	29
Figure 32: Central government support to states under discom relief package	30
Figure 33: Key objectives under RDSS	30
Figure 34: AT&C loss trajectory (%)	31
Figure 35: ACS-ARR gap	32
Figure 36: Factors influencing power demand	32
Figure 37: Energy demand outlook (fiscals 2027-31)	33
Figure 38: Peak demand to increase by around 100 GW between fiscals 2027 and 2031 to cross 300 GW ...	34
Figure 39: All India installed estimated capacity addition by fiscal 2031 (in GW)	36
Figure 40: Estimated capacity and generation breakup as of FY2031	37
Figure 41: Breakup of investments in power generation sector expected between FY2027-FY2031	37
Figure 42: CO2 emissions from the Indian energy sector, 2019	39
Figure 43: Government of India allocation towards MNRE	41
Figure 44: India's RE (incl. large hydro) capacity was 51% at the end of March 2026	42
Figure 45: India's RE (incl. large hydro) penetration was about 27% at end of March 2026	43

Figure 46: State wise solar potential	44
Figure 47: RPO compliance status across states for FY2023	48
Figure 48: Potential RE zones identified by MNRE/SECI	50
Figure 49: Leading project developers (As of March 2026)	53
Figure 50 : Top 10 renewable energy players operational capacity in India as of March 2026	54
Figure 51: Hybrid and FDRE bids won by key players for period between Apr 2021 – March 2026	55
Figure 52: Increasing share of hybrid tenders in total tendered capacity	58
Figure 53: Weighted average solar tariff trend	60
Figure 54: Weighted average wind tariff trend	61
Figure 55: Recent trend in competitively bid out wind-solar hybrid tariff (weighted average tariffs)	61
Figure 56: Tariff discovered in recent WSH tenders	62
Figure 57: Key policy measures for storage projects	63
Figure 58: State wise BESS capacity allocation	64
Figure 59: Quantum of ISTS connectivity sought by renewable developers	68
Figure 60: Virtual PPA arrangement	69
Figure 61: Open access/captive sales in key states for FY23 (penetration as % of total C&I sales)	70
Figure 62: Share of RE open access capacity across states as of June 2025	71
Figure 63: Historical open access RE capacity addition in C&I space (in MW)	71
Figure 64: Utility vs open access solar landed tariff for Industrial consumer for FY 2025	77
Figure 65: Utility vs open access wind landed tariff for Industrial consumer for FY 2025	78
Figure 66: Utility vs open access wind solar hybrid landed tariff for Industrial consumer for FY 2025	78
Figure 67: Share of different sources of power consumption among C&I consumers in FY 2023, TWh	82
Figure 68: Year wise expected solar capacity addition	90
Figure 69: Expected annual wind power capacity additions	91
Figure 70: Expected installed RE capacity outlook in C&I market (solar, wind and rooftop)	92
Figure 71: Projected rooftop solar capacity additions over fiscals 2027-2031	95
Figure 72: Total equity and total debt investment	100

Figure 73: Solar and wind energy generation trends	105
Figure 74: Process flow for setting up an RE plant	106
Figure 75: Total RE EPC services Market India fiscal 2019-fiscal 2025	107
Figure 76: Checklist of an EPC model	108
Figure 77: Key Determinants for selecting EPC contractor.....	110
Figure 78: Total RE EPC services Market India (FY2024-FY2031)	114
Figure 79: O&M services demand across RE (solar and wind), fiscal 2019 to 2025	115
Figure 80: Value chain for renewable energy	117
Figure 81: India- RE O&M services demand forecast (solar and wind) Fiscal 2026 to 2031	119
Figure 82: Overview of products on the power exchange	120
Figure 83: Short-term market volumes (FY12 - FY26).....	120
Figure 84: Process flow for I-RECs	121
Figure 85: Pictorial depiction of CfD	122
Figure 86: DAM trading process flow	122
Figure 87: Weighted average prices and volumes traded in DAM.....	122
Figure 88: RTM trading process flow	123
Figure 89: Weighted average prices and volumes traded in RTM	123
Figure 90: GDAM trading process flow	124
Figure 91: Weighted average prices and volumes traded in G-DAM.....	124
Figure 92: REC Trading.....	125
Figure 93: All India typical demand curve.....	125
Figure 94: A typical daily graph of GDAM market	126
Figure 95: Power exchange transactions volume FY25-FY30	127
Figure 96: Solar power price forecast (Rs./kWh)	128
Figure 97: Wind power price forecast (Rs./kWh).....	128
Figure 98: Conventional generation power price forecast (Rs./kWh)	129
Figure 99: Share of sources in power exchange	130

Figure 100 : Annual weighted average power exchange price forecast over FY26-30	130
Figure 101: Schematic of c-Si PV module supply chain	131
Figure 102: Existing vs upcoming technologies	133
Figure 103: Schematic diagram of solar cell manufacturing process	135
Figure 104: Solar module key components.....	135
Figure 105: Solar Module manufacturing process	137
Figure 106: Benchmarking of India's leading module manufacturers and IPPs	140
Figure 107: Module prices in US Cents/Wp	144
Figure 108: Only select players can afford full integration	146
Figure 109: Domestic production to increase 2 times by FY2030 and reliance on imports to reduce	148
Figure 110: Solar cell and module imports	148
Figure 111: Wafer and cell prices	149
Figure 112 : Module prices, USD/ Wp	150
Figure 113 : China's share in solar value chain.....	151
Figure 114: Module technology share	154
Figure 115: Annual solar capacity additions in major economies.....	157
Figure 116: Global solar PV installed capacity registered about 27% CAGR between 2016 and 2025	158
Figure 117: Projected cumulative solar PV capacity CY25-30.....	158
Figure 118: Export of modules and cells from India in value terms.....	159
Figure 119: US solar manufacturing benefits	161
Figure 120: Growth in cumulative Solar PV installed capacity in USA	165
Figure 121: Expected installed solar capacity in US	165
Figure 122: Total US module supply chain capacity by component and status	168
Figure 123: Growth in installed solar capacity in Africa.....	173
Figure 124: Expected installed solar capacity in Africa	173
Figure 125 : India-Current and projected manufacturing capacity, GWp	179

1 Overview of Indian macroeconomic landscape

1.1 Overview on global macro-economic landscape

1.1.1 Overview of global economy

The global economy encountered significant headwinds in 2022, including the Russia-Ukraine conflict, rising inflation, economic slowdowns in the US and Europe, and persistent supply chain disruptions. These factors moderated in 2023, resulting in a global real gross domestic product (GDP) growth rate of 3.3%. Further the escalating tensions between Israel and Iran have heightened concerns regarding energy security and global inflation. The conflict has triggered volatility in crude oil markets, with fears of disruptions to the Strait of Hormuz which is a critical global energy trade route through which nearly one-fifth of global oil supplies transit. Rising geopolitical risks in the Middle East have increased uncertainty around energy prices, logistics costs, and global supply chains, posing downside risks to economic growth and potentially reigniting inflationary pressures across major economies. The global economy is projected to grow at an estimated rate of 3.1% in 2026 and 3.2% in 2027 as per the International Monetary Fund (IMF) World Energy Outlook (WEO), April 2026. However, as per the WEO for July 2026, the global growth reduced by 0.1% to 3.0% for 2026 and increased by 0.2% to 3.4% for 2027.

During Fiscal 2025, the global inflation rate has eased marginally at an estimated rate of 4.3% as per the IMF WEO (October 2024).

The global inflation rate is expected to moderate from 4.1% for FY 2026 to an estimated rate of 4.7% for FY 2027 as per the IMF-WEO (July-2026), it is expected to stabilize at 3.9% in FY 2028. The forecast for FY 2027 is revised upward by 0.3% from April 2026 WEO, whereas that for FY 2028 is revised upward by 0.2%.

Table 1: Inflation rate across countries and global (in %)

Inflation rate	Brazil	Canada	China	France	Germany	India	Italy	Japan	United Kingdom	United States	World
CY 2015	10.7	1.3	1.7	0.3	0.3	5.3	0.1	0.2	0.2	0.7	2.8
CY 2016	6.3	1.4	1.9	0.8	1.6	3.5	0.6	0.3	1.6	2.2	3.0
CY 2017	2.9	1.8	1.8	1.3	1.6	4.6	1.0	0.5	3.0	2.2	3.3
CY 2018	3.7	2.1	1.9	1.9	1.8	2.5	1.1	0.9	2.1	1.9	3.6
CY 2019	4.3	2.1	4.4	1.7	1.5	6.7	0.5	0.5	1.3	2.1	3.9
CY 2020	4.5	0.8	0.3	0.0	-0.6	4.9	-0.2	-0.9	0.6	1.6	3.0
CY 2021	10.1	4.7	1.5	3.5	5.4	6.3	4.2	0.5	5.4	7.4	6.3
CY 2022	5.8	6.6	1.8	6.8	10.7	6.2	12.2	3.9	10.5	6.4	8.9
CY 2023	4.6	3.2	-0.2	4.1	2.9	5.0	0.6	2.9	4.0	3.2	6.1
CY 2024	4.8	1.9	0.0	1.6	2.5	3.7	1.3	2.9	2.5	2.7	5.0
CY 2025	4.3	2.2	0.9	0.8	2.3	3.3	1.2	2.7	3.4	2.9	4.1#
CY 2026(P)	4.3	2.5	1.3	2.6	2.6	4.7	3.6	2.7	3.5	2.8	4.7#
CY 2027(P)	3.0	2.0	1.6	1.3	2.2	4.0	2.4	2.0	2.0	2.4	3.9#
CY 2028(P)	3.0	2.0	1.9	2.1	2.0	4.0	2.3	2.0	2.0	2.2	3.3
CY 2029(P)	3.0	1.9	1.9	1.7	2.2	4.0	2.0	2.0	2.0	2.2	3.2
CY 2030(P)	3.0	2.0	2.0	2.1	2.2	4.0	2.0	2.0	2.0	2.2	3.2
CY 2031(P)	3.0	2.0	2.0	1.4	2.1	4.0	2.0	2.0	2.0	2.2	3.2

P: Projected; # as per World Economic Outlook July 2026.

Source: World Economic Outlook Database (Apr-26 and July-26) by IMF; Crisil Intelligence

Despite these projections, the outlook faces headwinds from higher interest rates implemented by central banks to combat inflation and reduced government spending due to accumulated debt. The global economy is stabilizing after several years of overlapping negative shocks.

According to the World Bank's Global Economic Prospects Report (June 2026), global growth is expected to slow to 2.5% in 2026 from 2.9% in 2025. However, this pace of growth is unlikely to be sufficient to fully recover from the cumulative impact of successive negative shocks that have affected the global economy in recent years, with the

most vulnerable economies being disproportionately affected. Growth in the emerging market and developing economies (EMDEs) is projected to ease to 3.6% this year. For all EMDE regions, the outlook for 2026 indicates weaker growth compared with 2025. In addition, EMDE per-capita income growth is expected to slow to its lowest rate since the pandemic period. The level of per-capita income in EMDEs excluding China and India relative to advanced economies is not anticipated to recover to pre-pandemic levels until after 2028, pointing to a prolonged period of diminished income convergence of nearly a decade.

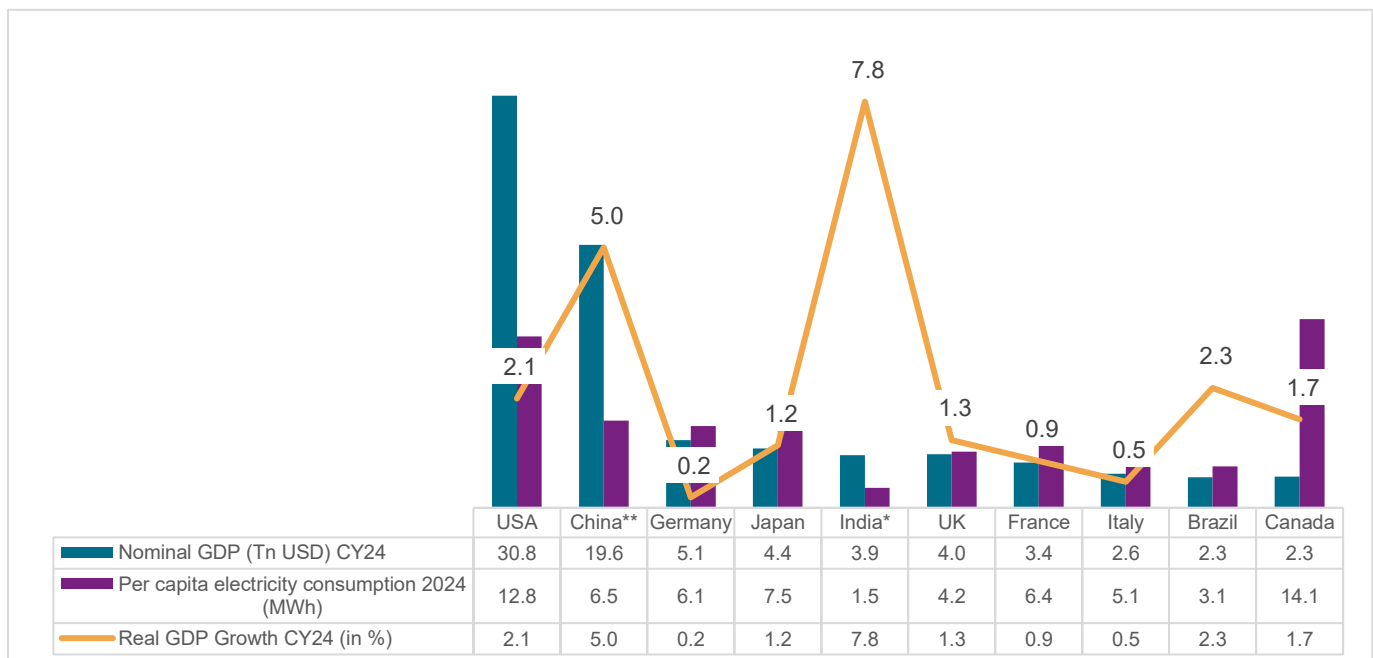
1.1.2 Economic indicators

India's economic performance over recent years has been marked by remarkable resilience, even as global headwinds such as trade disruptions, policy shifts in advanced economies, and volatile capital flows have challenged growth worldwide. In fiscal year 2025-26, India's real GDP is estimated to grow at 7.8%, outpacing most major economies and maintaining its status as the fastest-growing large economy.

On 27th February 2026, India's Ministry of Statistics and Programme Implementation (MoSPI) released the New Series of annual and quarterly national accounts estimates with base year 2022–23, which replaced the previous series with base year of 2011–12. Accordingly, India's GDP is estimated to rise to Rs. 324.70 trillion in fiscal 2026, up from Rs. 301.54 trillion for fiscal 2025 and Rs.280.90 trillion for fiscal 2024. This translates into a growth of 7.8% in fiscal 2026, accelerating from 7.2% in FY2025, a reflection of an economy still fundamentally powered by domestic consumption.

India's economy currently ranks sixth in the world and is projected to become the fourth largest economy in the world in fiscal 2027, according to the IMF's WEO (April 2026). As per IMF GDP Forecasts (July 2026), India's real GDP growth is estimated at 7.7% in fiscal 2026 and 6.4% in fiscal 2027, the highest amongst the top 10 economies. IMF has estimated that India will be the world's third-largest economy by fiscal 2031 surpassing both Japan and Germany. Additionally, World Bank has estimated India's GDP to grow at 6.6% in fiscal 2027.

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



* India GDP data as per NSO for Financial Year 2026 and per capita consumption as per CEA; **China per capita electricity consumption as of 2023.

Source: World Economic Outlook Database (April and July 2026) by IMF; IEA, CEA, Crisil Intelligence

Over the past decade, India has experienced steady and consistent GDP growth, except for the COVID-19 pandemic years. During this period, India's economic growth has outpaced that of other top economies, earning it recognition as an economic growth centre by international organizations and global rating agencies.

Table 2: Historical and projected growth of real GDP for major economies (figures in %)

Real GDP growth	Brazil	Canada	China	France	Germany	India*	Italy	Japan	United Kingdom	United States	World
2015	-3.5	0.6	7.0	1.0	1.7	8.0	0.9	1.8	2.1	2.9	3.4
2016	-3.3	1.0	6.8	0.7	2.2	8.3	1.2	0.7	2.2	1.8	3.2
2017	1.3	3.0	6.9	2.3	2.8	6.8	1.6	1.6	3.0	2.5	3.8
2018	1.8	2.7	6.8	1.6	1.1	6.5	0.8	0.8	1.6	3.0	3.6
2019	1.2	1.9	6.1	2.1	1.0	3.9	0.4	-0.3	1.3	2.6	3.0
2020	-3.3	-5.0	2.3	-7.6	-4.1	-5.8	-8.9	-4.3	-10.0	-2.1	-2.7
2021	4.8	6.0	8.6	6.8	3.9	9.7	8.9	3.6	8.5	6.2	6.7
2022	3.0	4.7	3.1	2.8	1.8	7.6	4.8	1.3	5.1	2.5	3.8
2023	3.2	2.0	5.4	1.6	-0.9	7.2	0.9	0.7	0.3	2.9	3.3
2024	3.4	2.0	5.0	1.1	-0.5	7.1	0.8	-0.2	1.0	2.8	3.5
2025	2.3	1.9	5.0	0.9	0.2	7.7	0.5	1.1	1.4	2.1	3.5
2026(E)#	2.4	1.1	4.6	0.6	0.7	6.4	0.5	0.6	1.0	2.3	3.0
2027(E)#	2.2	1.7	4.1	0.9	1.0	6.7	0.5	0.7	1.3	2.2	3.4
2028(E)	2.4	1.7	4.0	1.2	1.2	6.5	0.8	0.6	1.6	2.1	3.2
2029(E)	2.5	1.7	3.7	1.2	0.9	6.5	0.7	0.6	1.6	1.9	3.2
2030(E)	2.5	1.7	3.3	1.1	0.7	6.5	0.7	0.6	1.5	1.8	3.1
2031(E)	2.5	1.8	3.3	1.1	0.6	6.5	0.7	0.6	1.4	1.8	3.1
CAGR (CY15-25)	2.4	4.1	5.7	3.3	4.0	6.5	3.3	-0.2	3.1	5.3	4.5
CAGR (CY26-31)	5.1	4.6	5.7	2.7	3.1	10.3	2.7	3.2	4.8	3.8	4.6

* India GDP data as per NSO, *For India financial Year (April-March) CY 25 is Fiscal 2026; # As per WEO July 2026;

Source: World Economic Outlook Database (April 2026 and July 2026) by IMF; Crisil Intelligence

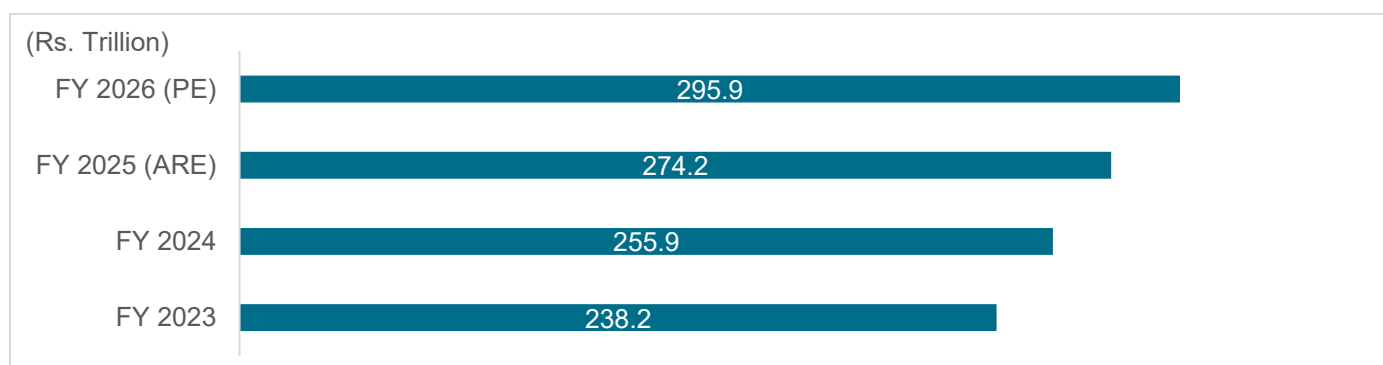
IMF projected global growth at 3.0% in 2026 and 3.4% in 2027, however, the growth in India is projected to remain strong at 6.4% in 2026 and 6.7% in 2027, with the robustness reflecting continuing strength in domestic demand and a rising working-age population.

Going forward, Crisil Intelligence forecast India's GDP growth to stand course at 6.6% in fiscal 2027.

1.2 India-GVA performance

The real Gross Value Added (GVA) indicator of economic performance, representing the value of goods and services produced within an economy, adjusted for inflationary effects. The real GVA is estimated to grow at 7.9% in fiscal 2025-26 from 7.1% in fiscal 2024-25.

Figure 2: GVA at basic prices



PE: Provisional estimates; ARE: Annual revised estimates.

Source: Ministry of Statistics and Programme Implementation, Crisil Intelligence

1.3 Outlook on other economic factors

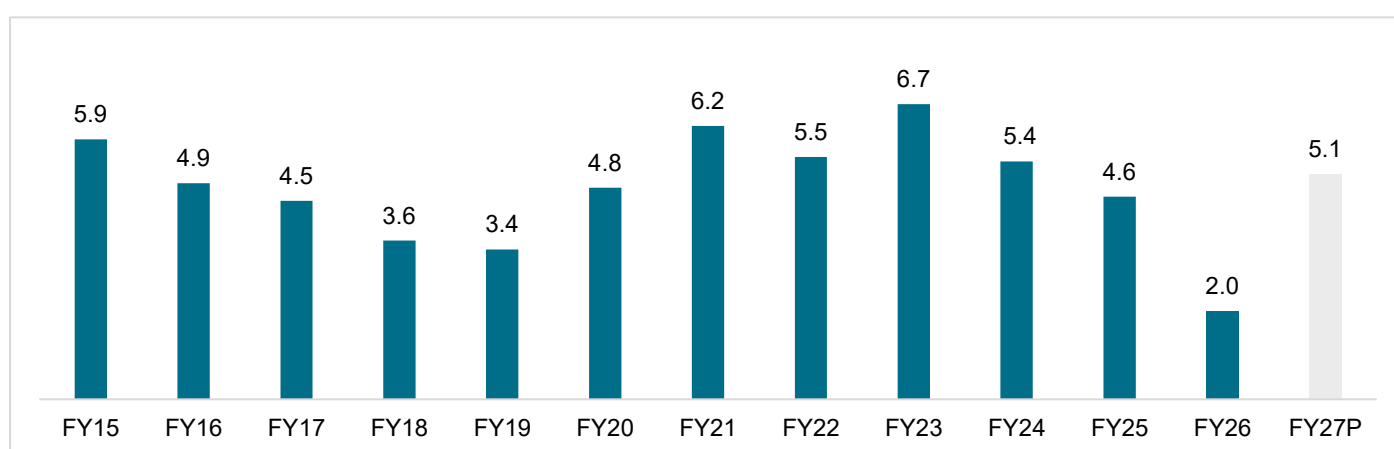
1.3.1 Consumer price index

Consumer Price Index (CPI) inflation rose mildly to 4.45% in July 2026 from 4.38% in June 2026 driven by an uptick in food inflation while core inflation was broadly unchanged. While the conflict in West Asia is still ongoing, food inflation saw limited rise. Food inflation picked up to 5.2% in July 2026 from 5.1% in June 2026.

Crisil Intelligence expects CPI inflation to average 5.1% fiscal 2027 against 2.0% in fiscal 2026, driven by a low-base effect and expectations of intensifying price pressures in major segments.

Crisil Intelligence expects the Monetary Policy Committee (MPC) of the RBI to keep rates remaining flexible with close monitoring of emerging inflation risk.

Figure 3: CPI inflation (% , y-o-y)

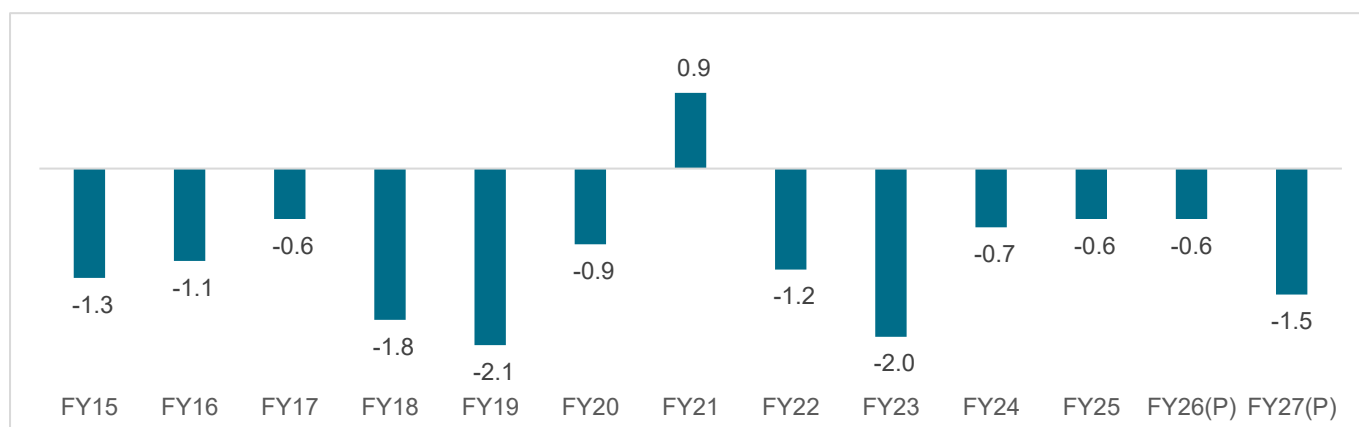


Source: NSO, CEIC, Crisil Intelligence

1.3.2 Current account deficit

India's current account deficit (CAD) widened to a modest \$25.2 billion (0.6% of gross domestic product or GDP) fiscal 2026 from \$22.9 billion in fiscal 2025. Crisil Intelligence expects the CAD to rise to 1.5% of GDP in fiscal 2027 from 0.6% in fiscal 2026. The impact of geopolitical issues will remain a monitorable.

Figure 4: Current account deficit (as a % of GDP)



Negative: current account deficit; Positive: current account surplus

P: Projected

Source: RBI, SBI, Crisil Intelligence

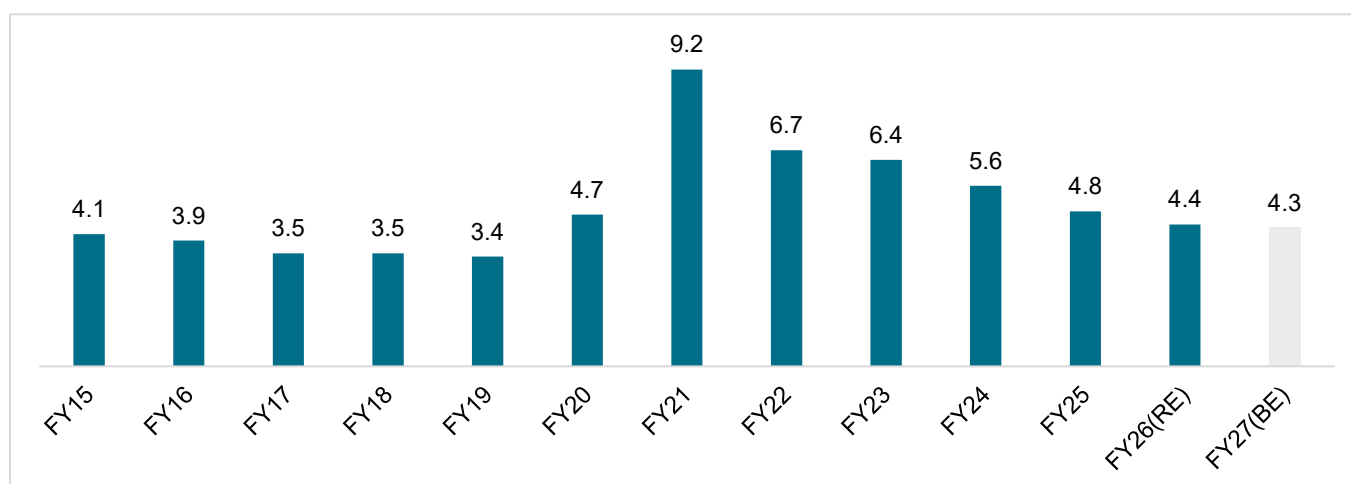
1.3.3 Fiscal deficit

India's fiscal deficit in 2020 reached a high of 9.2% of GDP during the pandemic. It has since decreased significantly. The fiscal deficit during fiscal 2025 stood at 4.8% of the GDP was better than previous year which stood at 5.6% on account of higher revenue realisation and lower expenditure according to data released by the Controller General of Accounts (CGA) in December 2025. In actual terms, the fiscal deficit--the gap between expenditure and revenue, was at Rs. 15.77 trillion.

The revised estimates for fiscal 2026 of the non-debt receipts are Rs. 34 trillion of which the Centre's net tax receipts are Rs. 26.7 trillion. The revised estimate of the total expenditure is Rs. 49.6 trillion, of which the capital expenditure is about Rs. 11 trillion.

For Fiscal 2027, the non-debt receipts and the total expenditure are estimated as Rs. 36.5 trillion and Rs. 53.5 trillion respectively. The Centre's net tax receipts are estimated at Rs. 28.7 trillion. To finance the fiscal deficit, the net market borrowings from dated securities are estimated at Rs. 11.7 trillion. The balanced financing is expected to come from small savings and other sources. The gross market borrowings are estimated at Rs. 17.2 trillion for fiscal 2027.

Figure 5: Fiscal Deficit as % of the GDP



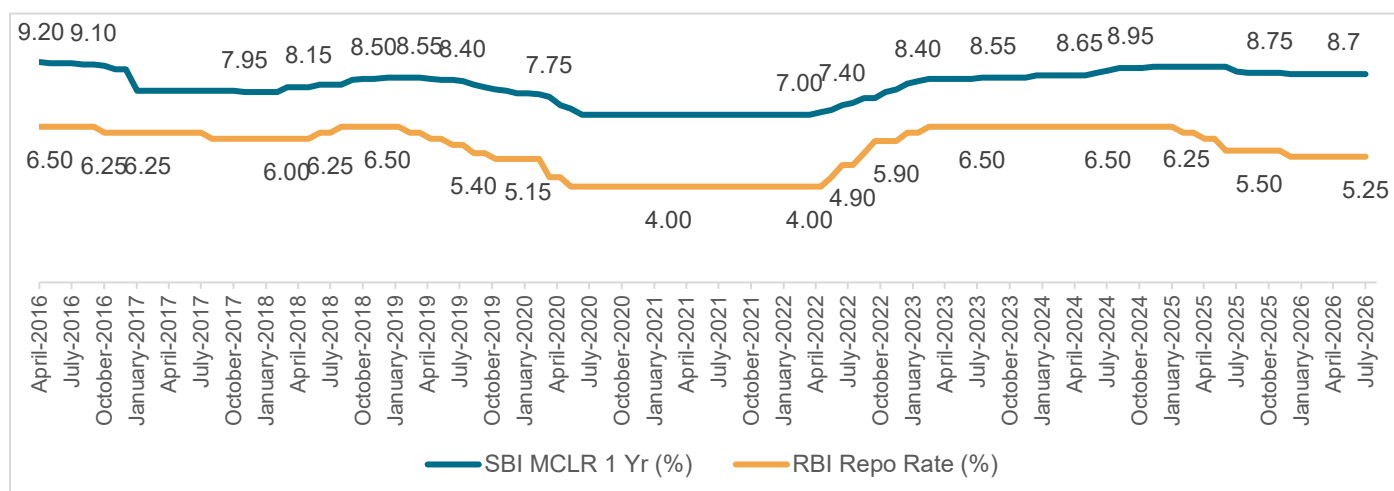
BE: Budgeted Estimates

Source: RBI, Controller General of Accounts; Crisil Intelligence

1.3.4 Interest Rates

The MPC did not change any key policy rates at its policy meeting in August 2026. A total cumulative reduction of 100 bps in fiscal 2026. The MPC also changed its stance to accommodative, signalling that rate cuts will continue.

Given easing inflation and a mild rise in growth, though, Crisil Intelligence expects rate cuts to continue in base case. The quantum rate cuts, however, are expected to be 75-100 bps in the current cycle vs the 225 bps cuts around the pandemic. A shallower Fed rate cut cycle and weather risks will have a bearing on the extent of rate cuts in India as well.

Figure 6: Interest rates increasing (%)


Source: RBI, SBI, Crisil Intelligence

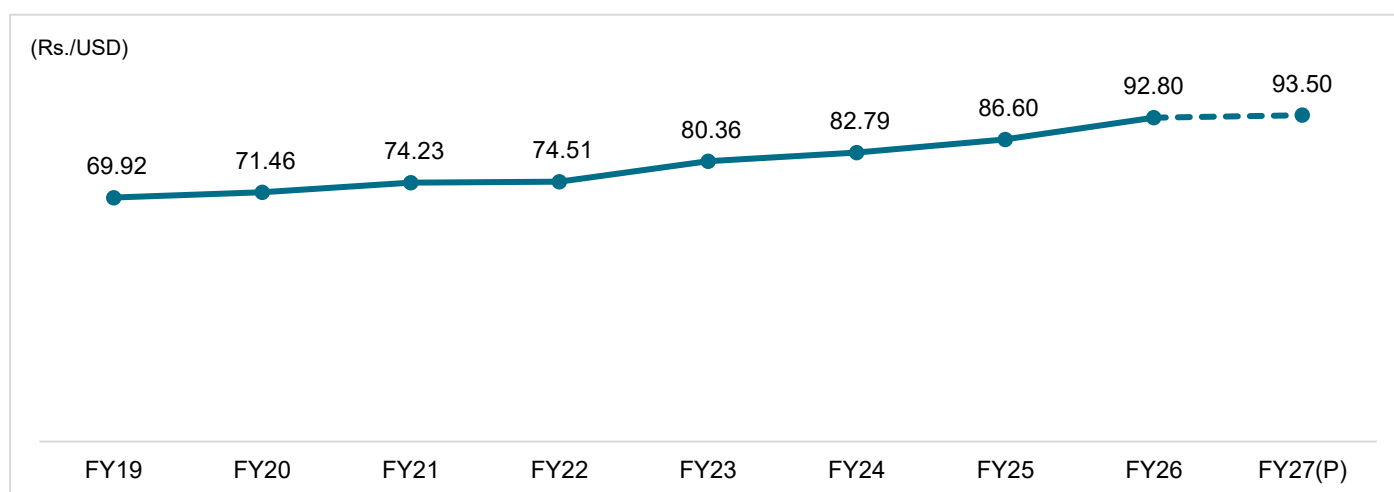
While money market rates have seen a sharp drop, bank lending rates have not eased to the same extent as the repo rate. This means the full effect of past rate cuts is still unfolding.

1.3.5 Currency

The rupee weakened to Rs. 95.8/USD in July 2026 on average compared with Rs. 95.0/USD in June 2026 and breached the Rs. 96/USD in May 2026, hitting record lows due to intense volatility from geopolitical tensions and rising energy prices.

Although the CAD in fiscal 2027 is estimated to stand at around 1.5% of GDP which rose from 0.6% of GDP in fiscal 2026, geopolitical uncertainties pose a significant risk.

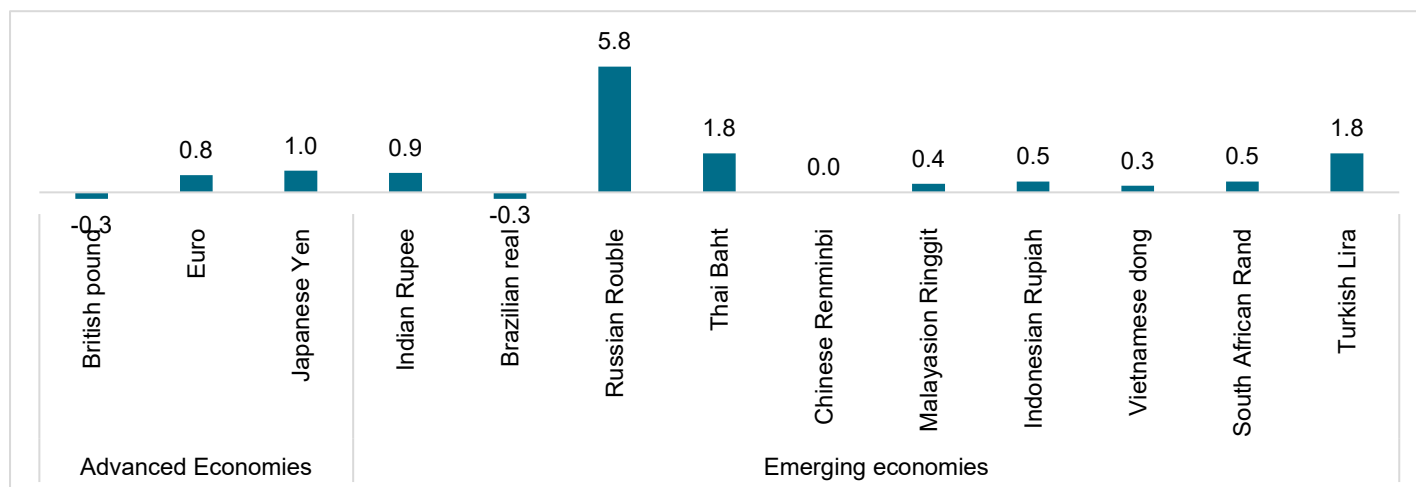
With the West Asia conflict extending beyond April, the risks to the previous forecasts have been materialised. Crisil Intelligence expects the rupee to average Rs. 93.5/USD in March 2027. The current account deficit should stay manageable, but risks from disruptions in global growth and geopolitical uncertainties remain. Crisil Intelligence expects the CAD to widen to 1.5% of GDP in fiscal 2027 as against a projected 0.6% of GDP in fiscal 2026 also healthy services trade surplus shall keep the CAD manageable.

Figure 7: Exchange rates USD and INR


Source: RBI, Financial Benchmarks India Pvt Ltd, CEIC, Crisil Intelligence

Most emerging market currencies appreciated against the dollar, barring the Russian rouble, Turkish lira, Thai baht, which weakened 5.8%, 1.8% and 1.4 % respectively.

Figure 8: Major currencies vs dollar % y-o-y (As of July 2026)



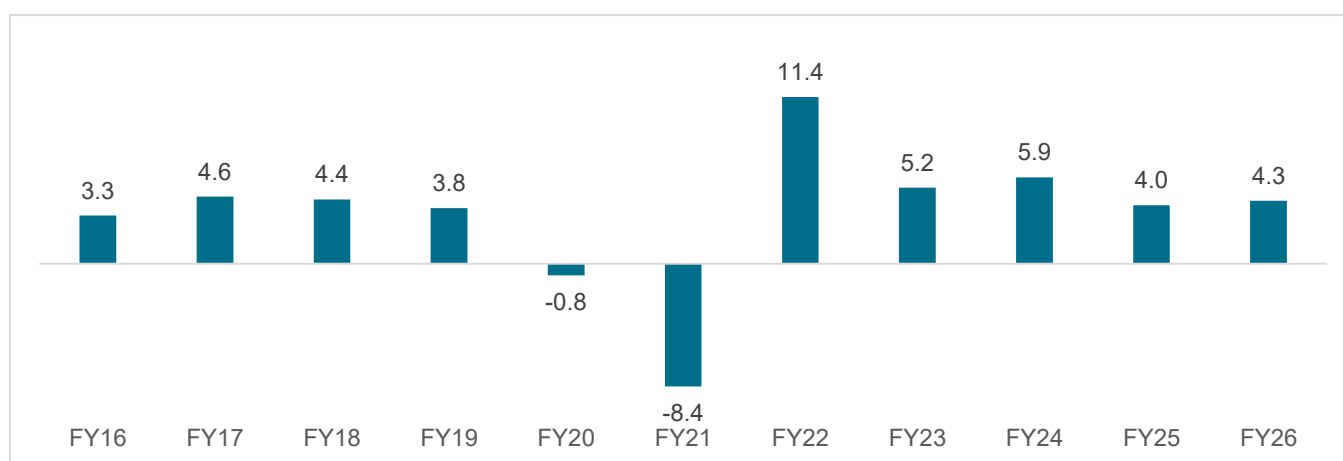
Note: Positive growth indicates depreciation, negative indicates appreciation

Source: CEIC, Crisil Intelligence

1.3.6 PMI and IIP Trend

The Index of Industrial Production (IIP) is an indicator that measures the changes in the volume of production of industrial products during a given period and The Purchasing Managers' Index (PMI) is an economic indicator that provides insights into the current and future conditions of a business. IIP growth rate for fiscal 2024 over fiscal 2023 stood at 5.9% which then changed to 4.0% in fiscal 2025 and then further to 4.1% in fiscal 2026. It slowed to 6.7% in July 2026 from 8.8% in June 2026, however it remained above last fiscal average of 4.3%.

Figure 9: Trend of Index of Industrial Production



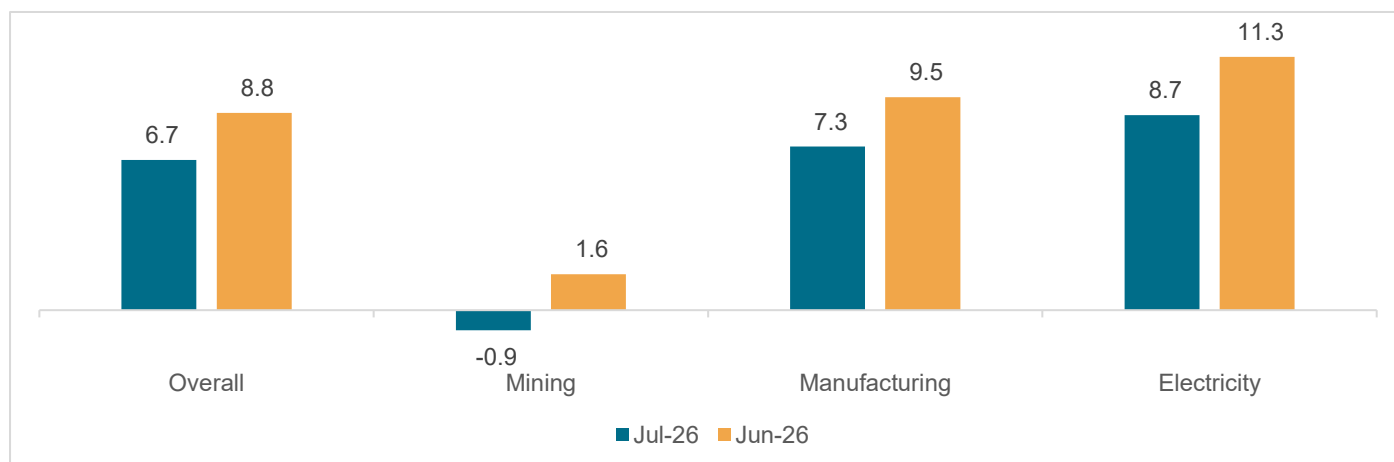
As per the base 2011-12; Source: NSO, MOSPI, Crisil Intelligence

The IIP slowed in July 2026 and was driven by manufacturing (7.3% July 2026 vs 9.5% June 2026) and electricity and gas (8.7% vs 11.3%) and mining declined (-0.9% vs 1.6%).

The moderation in IIP growth after fiscal 2022 is driven by stronger growth in manufacturing and electricity production. Domestic demand remained resilient, as evident in auto sales, retail credit, electricity demand and other indicators, despite headwinds from the West Asia conflict.

However, fiscal 2026 indicators (as of March 2026) point to a recovery versus the previous year, with stronger year-on-year performance in mining (5.5% vs 1.2% in March 2025), and manufacturing (4.3% vs 4.0%), however the electricity sector showed depletion (0.8% vs 7.5%).

Figure 10: The improvement in IIP growth was driven by manufacturing (in %, month on month)

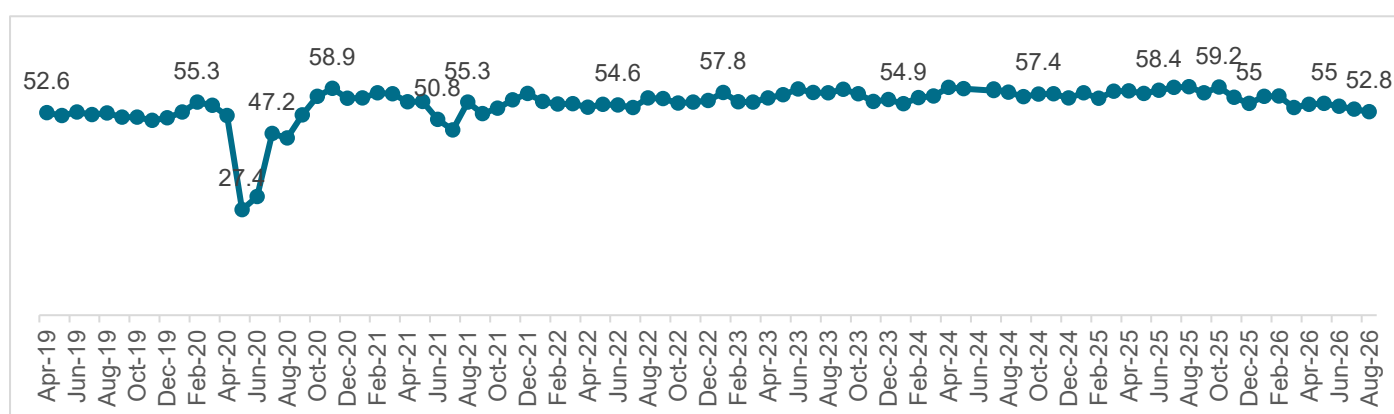


Source: MOSPI, CEIC, Crisil Intelligence

The Indian manufacturing sector's strong start to 2025 continued in fiscal 2026. Despite slowing to the weakest since December 2023, rates of expansion in output and sales remained elevated in the context of the survey's 20-year history. Favourable domestic and international demand prompted firms to increase purchasing activity and hire extra workers at above-trend rates. However, demand buoyancy kept charge inflation at an elevated level despite softer cost pressures. The Manufacturing PMI experienced significant declines during two distinct periods: March 2020 to June 2020 and June 2021 to July 2021. These downturns are due to the first and second waves of the COVID-19 pandemic, respectively.

The seasonally adjusted HSBC India Manufacturing Purchasing Managers' Index™ (PMI®) registered 52.8 in August 2026, down from 53.5 in July 2026. PMI above 50 indicates a robust growth and expansion of economic activity in the manufacturing and services sector.

Figure 11: Manufacturing PMI (in %)



Source: Industry, HSBC, S&P Global, Crisil Intelligence

Crisil Intelligence expects the economy to weaken its 6.6% GDP growth rate in fiscal 2027 with downside risks. Despite the slowdown in real GDP, the nominal GDP growth is set to be higher due to higher inflation based on both Wholesale Price Index and the Consumer Price Index.

1.3.7 Outlook on per capita GDP in India and Global economies

The per capita GDP of India (current prices), estimated at \$2,812.0 for 2026 is behind the global average, highlighting the country's ongoing efforts to bridge the economic gap with the rest of the World, however it is estimated to grow at a CAGR of ~ 10.6 % between 2025 and 2031, which is highest among the top 10 global economies followed by Brazil & China with 7.8% & 7.3% respectively. Since 2016 till 2025 the per capita GDP of India has grown at a CAGR of ~ 5.3%.

Table 3: Per capita GDP vs Global economies (in USD)

Countries	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026 (P)	2027 (P)	2028 (P)	2029 (P)	2030 (P)	2031(P)
Brazil	8,812.5	10,055.6	9,281.7	9,010.5	7,057.1	7,951.6	9,256.5	10,350.4	10,282.2	10,685.7	12,312.6	12,882.3	13,368.9	14,063.3	14,796.8	15,571.7
Canada	42,382.5	45,192.4	46,618.0	46,431.0	43,573.2	52,907.5	56,608.8	55,002.4	55,209.1	55,764.7	60,304.6	63,468.2	66,123.1	68,607.2	71,028.4	73,536.1
China	8,225.1	8,939.4	10,038.3	10,349.4	10,700.4	12,872.4	12,989.4	13,029.2	13,452.7	13,968.1	14,873.6	15,678.0	16,671.4	17,725.5	18,775.5	19,883.2
France	37,081.5	38,756.7	41,539.8	40,487.3	39,230.9	43,848.3	41,095.8	44,749.7	46,053.6	48,929.9	52,083.3	53,035.1	54,379.4	55,849.1	57,347.1	58,797.0
Germany	43,189.6	45,881.5	49,384.5	48,177.6	47,953.7	53,151.5	50,943.6	54,793.1	56,086.9	60,438.8	65,302.9	67,613.1	69,804.9	72,087.8	74,263.7	76,425.9
India	1,685.2	1,919.5	1,930.3	1,998.8	1,862.2	2,181.1	2,280.0	2,434.4	2,592.0	2,675.3	2,812.6	3,074.9	3,369.3	3,699.8	4,047.8	4,420.6
Italy	31,357.6	32,797.3	35,042.8	33,767.0	31,956.9	36,812.9	35,672.0	39,282.4	40,404.7	43,270.4	46,505.1	47,715.2	49,175.4	50,593.1	52,068.4	53,588.9
Japan	40,251.7	39,750.6	40,746.9	41,560.2	41,233.6	41,643.6	35,566.0	35,224.7	33,820.3	35,973.2	35,703.4	37,390.8	39,104.2	40,397.9	41,720.2	43,038.1
United Kingdom	41,411.6	40,952.2	43,760.4	43,185.9	40,844.3	47,707.1	47,206.4	49,938.3	53,338.7	57,608.2	61,056.1	63,704.1	66,419.1	69,288.3	72,501.3	75,760.8
United States	58,179.7	60,293.0	63,165.3	65,561.3	64,518.0	71,365.7	77,949.0	82,536.1	86,173.4	89,991.2	94,429.8	98,277.6	101,714.8	105,171.2	108,659.5	112,241.9

Source: IMF World Economic Outlook April 2026, Crisil Intelligence

1.4 Overview of other demographic factors

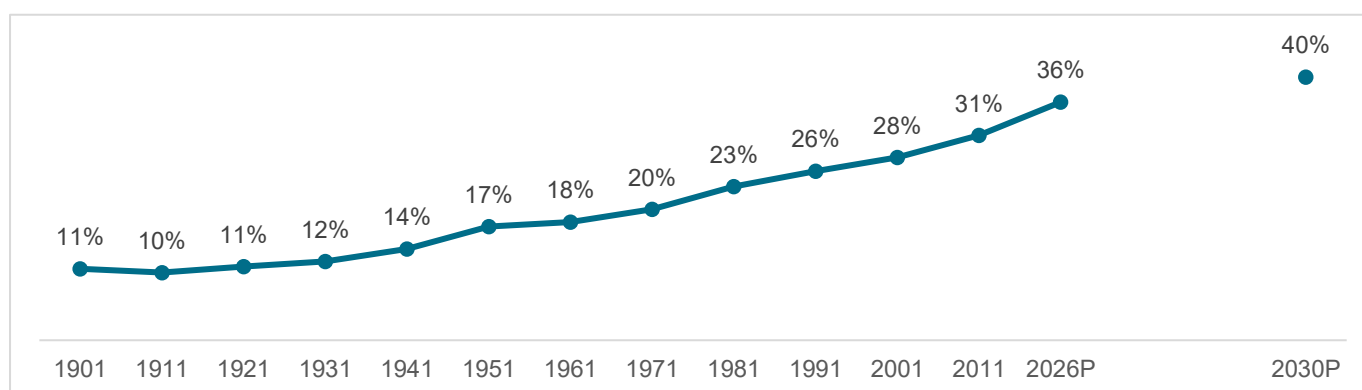
1.4.1 Urbanisation

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

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

Indeed, urban consumption in India has shown signs of improvement and given India's favourable demographics, along with rising disposable income, the trend is likely to continue and drive the country's economic growth.

Figure 12: Urban population as a % of total population of India



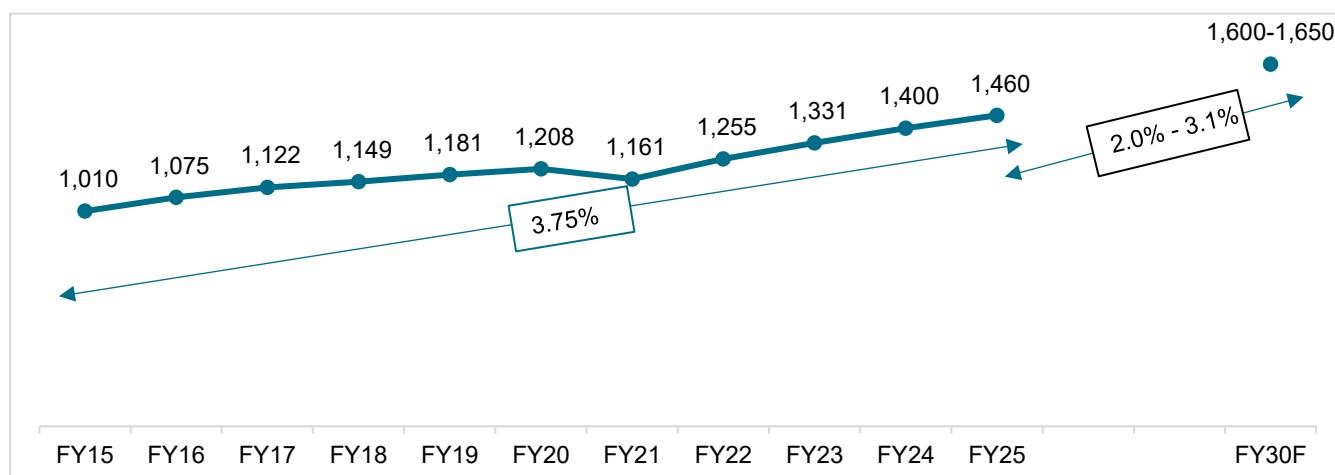
P: Projected

Source: Census 2011, Report of The Technical Group on Population Projections by Ministry of Health & Family Welfare (July 2020), Crisil Intelligence

1.4.2 Per capita electricity consumption

Electricity consumption per person rose to 1,460 kWh in fiscal 2025 (as per CEA's provisional data), from 1,010 kWh in fiscal 2015 at a CAGR of 3.75%, primarily led by increasing economic activities, rising domestic consumption, rural and household electrification. Post successive on-year growth in consumption, demand declined in fiscal 2021, particularly from high-consuming industrial and commercial categories on account of weak economic activity following the outbreak of the COVID-19 pandemic. In fiscal 2022, though, per capita consumption rebounded to 1,255 kWh on the back of a recovery in demand, with 1,400 kWh in fiscal 2024 and 1,460 kWh in fiscal 2025. Similarly, the energy requirement grew at 4.7% CAGR over fiscals 2015 to 2025 i.e. from 1,069 BUs to 1,694 BUs.

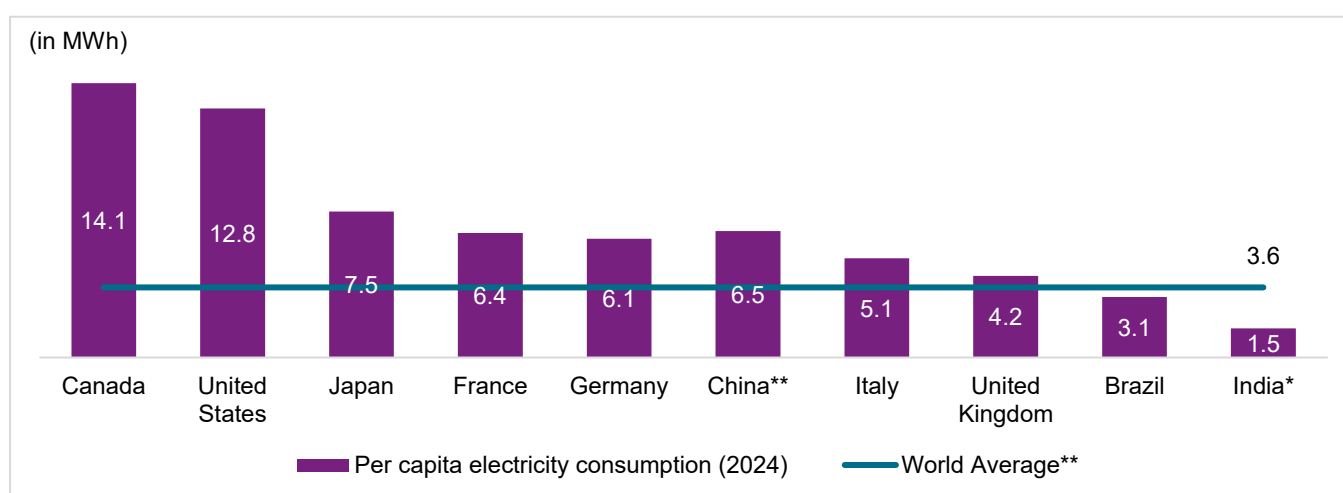
Between fiscals 2025 and 2030, India's per capita electricity consumption is expected to grow at ~2-3% CAGR. Per capita consumption is expected to gradually improve in the long term as well, as power demand picks up on the back of improvements in access to electricity, in terms of quality and reliability, rising per capital income, increasing EV penetration, railway electrification, intensive rural electrification, resulting in the realisation of latent demand from the residential segment, increased penetration of consumer durables. However, there are a few factors which could restrict growth, such as improved energy efficiency, focus on T&D loss reduction, sustainability targets, and increasing share of services in GDP. Consequently, Crisil Intelligence expects per capita electricity consumption to reach 1,600-1,650 kWh by fiscal 2030.

Figure 13: Per capita electricity consumption (in kWh)


F: Forecast

Source: Central Electricity Authority (CEA), Crisil Intelligence

Despite this healthy increase, the per-capita electricity consumption remains significantly lower than other major as well as developing economies. Developing countries, such as Brazil, Malaysia and China, have significantly higher per-capita electricity consumption than India.

Figure 14: Per capita electricity consumption 2024


*Latest available figure from CEA; ** As per World bank data 2023;

Source: World Bank, IMF, EIA, Crisil Intelligence

The global average per capita electricity consumption is 3.6 MWh, with India having a significantly lower per capita consumption compared to other large economies. Specifically, Canada, the USA, and Japan have per capita consumption that exceed India's by a factor of 9.4, 8.5, and 5.0, respectively.

1.5 Global renewable capacity addition

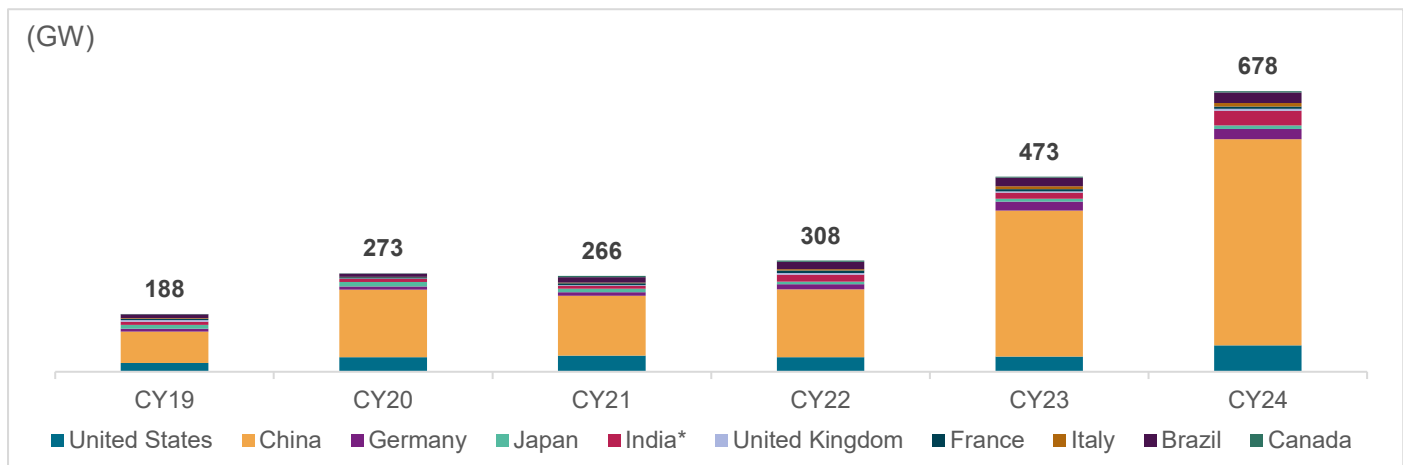
In the past five years, the top 10 global economies China, the US, India, Japan, Germany, the UK, France, Brazil, Italy, and Canada have significantly scaled up renewable energy capacity, collectively driving the global clean energy transition. The renewable energy capacity has more than tripled between 2019 - 2024 and has grown at CAGR of ~26%.

China has led globally, accounting for the largest share of new capacity additions, particularly in solar PV and onshore wind, under its Five-Year Plans and 2060 carbon neutrality target. The US saw strong growth in solar and wind, supported by federal tax incentives and the Inflation Reduction Act, with increased private sector participation.

India witnessed steady additions, primarily in solar, under national programs like PM-KUSUM and international collaborations such as the ISA, targeting 500 GW non-fossil capacity by 2030.

Germany, France, and the UK focused on scaling offshore wind and distributed solar to meet EU climate goals, while phasing out coal and nuclear. Japan expanded solar and offshore wind with enhanced grid integration strategies post-Fukushima. Brazil, Italy, and Canada have made modest addition, leveraged their existing energy infrastructure, and implemented new policies to promote renewable energy.

Figure 15: Global renewable annual capacity addition (in GW)



*India addition as per CEA; Source: IEA, Crisil Intelligence

The world has witnessed a significant shift towards renewable energy in recent years, driven by policy commitments and international agreements.

1.6 India's emergence as a global manufacturing hub

India is emerging as a major global manufacturing hub, supported by strategic policy reforms, infrastructure upgrades, and a rising focus on domestic value addition. India has improved its digital infrastructure, and ease of doing businesses, which has positioned them as a competitive alternative to traditional manufacturing centers in Asia. There has also been a significant improvement in logistics by development of projects such as dedicated freight corridors, new shipping terminals and expansion of highways & railways network. Currently India's manufacturing sector contributes around 17–18% to the GDP. In the coming years India aims to increase it to 23–25%, driven by robust demand, export orientation, and greater automation. Sectors such as electronics, automotive, pharmaceuticals, and clean energy are expected to lead this growth.

India remains one of the most popular FDI destinations in the world, with highest FDI inflow in South Asia, leading in greenfield projects particularly in digital services according to the World Investment Report 2026.

Equity inflows increased to USD 50.02 billion in fiscal 2025 (12.6% growth over fiscal 2024) due to lower infusion in sectors such as services, computer hardware and software, telecom, auto and pharma. During fiscal 2025, the total FDI (includes equity inflows, reinvested earnings, and other capital) increased by ~13.7% over fiscal 2024 to USD 81.04 billion during fiscal 2025 from USD 71.28 billion in fiscal 2024. It is pertinent to note that India received the highest ever FDI inflows of USD 84.83 billion in fiscal 2022. During fiscal year 2026, India received equity inflows of USD 58.84 billion and a total FDI inflow of USD 94.5 billion i.e. an increase of 18% in equity inflows and 17% in total FDI over previous fiscal year.

The growing manufacturing base has increased demand for reliable, cost-effective, and clean power prompting investments in renewables, energy storage, and grid modernization. India's push for domestic manufacturing of solar modules, batteries, power equipment, and hydrogen infrastructure is creating an industrial ecosystem that will reduce import dependence and enhance energy security. India has various advantages which makes it an attractive destination for global manufacturing investments. Some of these advantages are summarised below:

Government initiatives: The Central government has launched various initiatives such as Make in India, "Startup India", "Digital India" and Production-Linked Incentive (PLI) schemes across sectors that have accelerated industrial activity and attracted significant foreign direct investment (FDI). These initiatives aim to create a business-friendly environment, improve infrastructure, and provide incentives for manufacturers.

Economic growth: India is one of the key large economies which is showing encouraging economic indicators. India has become the fifth largest economy in the world in CY 2023 and India's real GDP is estimated to grow the highest amongst the top 10 economies.

Demographic dividend: India has an added advantage of young population. It has a large and young population, with more than 65% of its population below the age of 35. This can help in providing the significant workforce required for the manufacturing sector.

Infrastructure development: The Indian government is investing heavily in infrastructure development, including roads, ports, and airports, which can improve connectivity and reduce logistics costs for manufacturers.

Increasing domestic demand: India's growing middle class and increasing consumer spending power are driving demand for manufactured goods, creating opportunities for domestic manufacturers.

Sunrise sectors: Sunrise sectors such as mobiles, computers and information technology, telecommunication devices, consumer electronics, aerospace and defence industries, automobiles are pushing the investment in manufacturing. Technological advancements and increased consumer demand for new and innovative products are driving the investments.

Competitive labour cost: India has a competitive labor cost advantage compared to other countries (special western countries), making it an attractive destination for manufacturers looking to set up production facilities.

Digitalization and Industry 4.0: The adoption of digital technologies like artificial intelligence, robotics, and the Internet of Things (IoT) can improve manufacturing efficiency, productivity, and competitiveness, driving growth in the sector.

Skilled workforce: India has a large pool of skilled engineers and technicians, which can support the growth of the manufacturing sector. Indian Government also focusing on skill development through various initiatives such as National Policy on Skill Development & Entrepreneurship, Pradhan Mantri Kaushal Vikas Yojana, Craftsmen Training Scheme, National Apprenticeship Promotion Scheme, Entrepreneurship Training, Skill India Digital Hub platform etc.

Ease of doing business: The Central government has taken various steps to provide simpler regulatory environment, compliance requirements, single window clearance and improve the ease of doing business. This helps manufacturers to set up and operate in the country efficiently. Improved EoDB (from 132nd rank in 2013 to 63rd rank in 2020) make it a favourable destination for manufacturing.

Growing exports: According to recent data from the Commerce Ministry, India's export competitiveness has witnessed notable advancements over the last five years, particularly in petroleum, precious stones, agrochemicals, and sugar. This growth has been marked by a surge in the country's share in global trade across these sectors, alongside other segments like electrical goods, tyres, and semiconductor devices.

As a result of these, India's manufacturing sector has seen some the new investments in production facilities (both greenfield as well as brownfield) by leading MNCs like Siemens, GE, Philips, Samsung, PepsiCo, ABB etc.

- Siemens Limited has planned the expansion of two Indian factories, augmenting its manufacturing capabilities namely Power Transformer factory in Kalwa and Vacuum Interrupter factory in Goa. The total Capex investment is projected to surpass Rs 10 billion.
- GE Aerospace has set up Multi-Modal Facility (MMF) in Pune with an investment of USD 200 million.

- Philips India inaugurated its innovation campus in Yelahanka, Bengaluru; It also planned a new R&D centre to expand its Healthcare Innovation Centre (HIC) in Pune, Maharashtra.
- On June 7, 2017, Samsung announced an investment of INR 49.15 billion to add new capacity at the Noida plant in Uttar Pradesh.
- ABB India in February 2023, inaugurated its new state-of-the-art factory in Nashik, Maharashtra doubling its Gas Insulated Switchgear (GIS) production capacity.
- In April 2024, PepsiCo India, a leading global consumer packaged goods company, announced an investment of Rs. 12.66 billion in India to establish a state-of-the-art flavour manufacturing facility in Ujjain, Madhya Pradesh.
- Jaguar Land Rover, a subsidiary of Tata Motors has started production from Pune Plant
- Mercedes-Benz India's production facility in Chakan near Pune
- Rolls-Royce Engineering Centre (Aerospace) at Bangalore and Engineering Centre (Power Systems) at Pune

1.7 Increasing interest rate adding to borrowing costs for renewable IPPs

In September 2026, global interest rates are shifting toward a tightening trend as major central banks respond to persistent, above-target inflation pressures. Central banks in developed markets such as the United States, the Eurozone, and Japan have signaled a reversal in their interest rate pause and started to increase the interest rates. This increasing interest rate is expected to have significant ramifications for capital-intensive sectors, particularly renewable energy.

Global Monetary Policy Trends

United States (Federal Reserve): After a series of steep rate hikes since 2022 to combat inflation, the Federal Reserve has recently indicated a dovish tilt, with market consensus anticipating multiple rate cuts through 2025 as inflation moderates and economic activity cools. The US Federal Reserve raised its benchmark interest rate by 25 basis points at its September 15–16, 2026 meeting, bringing the federal funds rate to a target range of 3.75%–4.00%.

Eurozone (European Central Bank): The European Central Bank raised its three key interest rates by 25 basis points, effective September 16, 2026, to combat rising energy costs and inflation.

United Kingdom (Bank of England): The Bank of England kept its benchmark interest rate unchanged at 3.75% in September 2026 but warned that an increase is becoming more likely.

Canada (Bank of Canada): Canada held the lending rate at 2.25 % in September 2026 highlighting, that the conflict in the Middle East has been keeping the energy prices high and new US tariffs and announcement of Canadian counter measures following the breakdown of trade talks between Canada and the US. The Canadian economic activity strengthened in second quarter.

Japan (Bank of Japan): The Bank of Japan raised its benchmark short-term interest rate by 25 basis points to 1.25% from 1.0% on September 18, 2026, marking a 31-year high not seen since 1995.

Implications for Renewable IPPs

Rising interest rates generally pressure RE IPPs because RE projects require substantial upfront investment and recover that capital through cash flows extending over 25 years. Higher rates increase financing costs, reduce project values, and can require higher PPA rates.

Higher borrowing costs increase the weighted average cost of capital, reducing the overall return on investment. Many IPPs are forced to delay final investment decisions, scale back pipelines, or terminate unprofitable power purchase agreements particularly in capital-heavy sectors like offshore wind. Highly leveraged IPPs may face severe liquidity pressure and heightened default risks if their operational cash flows cannot cover escalating debt service obligations. Rising financing costs temporarily erode the cost advantage that wind and solar historically held over fossil-fuel alternatives.

However, IPPs are likely to be more resilient when they have predominantly fixed-rate, long-dated debt and limited near-term refinancing needs. Strong off-taker credit and diversified counterparties and projects with high-quality resources, secure interconnection, and manageable curtailment also help IPPs to manage the increased interest rates.

Overall, higher rates do not undermine the fundamental operating advantage of zero-fuel-cost generation, but they raise the hurdle rate for building and owning renewable assets.

1.8 Aatmanirbhar Bharat Abhiyan

Production Linked Incentives (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).

The five focus points of the *Aatmanirbhar Bharat Abhiyan* are economy, infrastructure, system, vibrant demography, and demand. Its five phases are:

- Phase I: Businesses including MSMEs
- Phase II: Poor, including migrants and farmers.
- Phase III: Agriculture
- Phase IV: New horizons of growth
- Phase V: Government reforms and enablers

Table 4: Sector-wise focus of Aatmanirbhar Bharat Vision

Sector	Government spends	Key schemes
Renewable energy	~Rs 1,300 billion	- Rs 45 billion Production Linked Incentive Scheme 'National Programme on High Efficiency Solar PV Modules'. This was further increased by Rs 195 billion in the budget for fiscal 2023, taking it to Rs 240 billion; in tranche I 8.7 GW and in tranche II 39.6 GW capacity were allocated for domestic solar module manufacturing capacity under the PLI scheme. - PM Surya Ghar Muft Bijli Yojna: This scheme has a proposed outlay of Rs. 750 billion and aims to light up 10 million households (rooftop solar) by providing up to 300 units of free electricity every month till fiscal 2027 - 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 Rs 344 billion. The scheme has been extended till March 31, 2027 - Pradhan Mantri Surya Sarovar Yojana (PM-SSY): Scheme for the development of Floating Solar Photovoltaic (FSPV) Projects with ESS with a total outlay of Rs 50.7 billion with a target of 5 GW of FSPV, projects will be sanctioned during fiscal 2027 to 2031, with disbursement of financial support continuing up to fiscal 2033. - Approved Models and Manufacturers of Solar PV Cells to be effective from 1st June 2026 (ALMM List-II)

Sector	Government spends	Key schemes
		- Proposed to issue List-III of wafers under ALMM, which shall be effective from 1st June 2028. - 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 20% on solar cells and 20% on solar modules, effective May 1, 2025. However, the Agricultural and Infrastructure Development Cess (AIDC) of 20% on modules and 7.5% on cells keep the effective BCD rate of solar modules at 40% and for cells 27.50%. Further, antidumping duty of upto 30% on imported solar cells from China have been proposed by DGTR for three years
Power distribution companies (discoms)	~Rs.970 billion	- Rs 1.35 trillion liquidity infusion for discoms via Power Finance Corporation/ Rural Electrification Corporation (PFC/ REC) against receivables - Rebate for payment to be received by generation companies (gencos) to be passed on to industrial customers - Revamped distribution sector scheme (RDSS) to help discoms improve their operational efficiencies and financial sustainability by providing result-linked financial assistance; outlay of Rs 3,037.58 billion over 5 years i.e., fiscals 2022 to 2026. The outlay includes an estimated government budgetary support (GBS) of Rs 976.31 billion.
New energy	~Rs. 388 billion	- Rs 181 billion under 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 Rs 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	Rs. 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

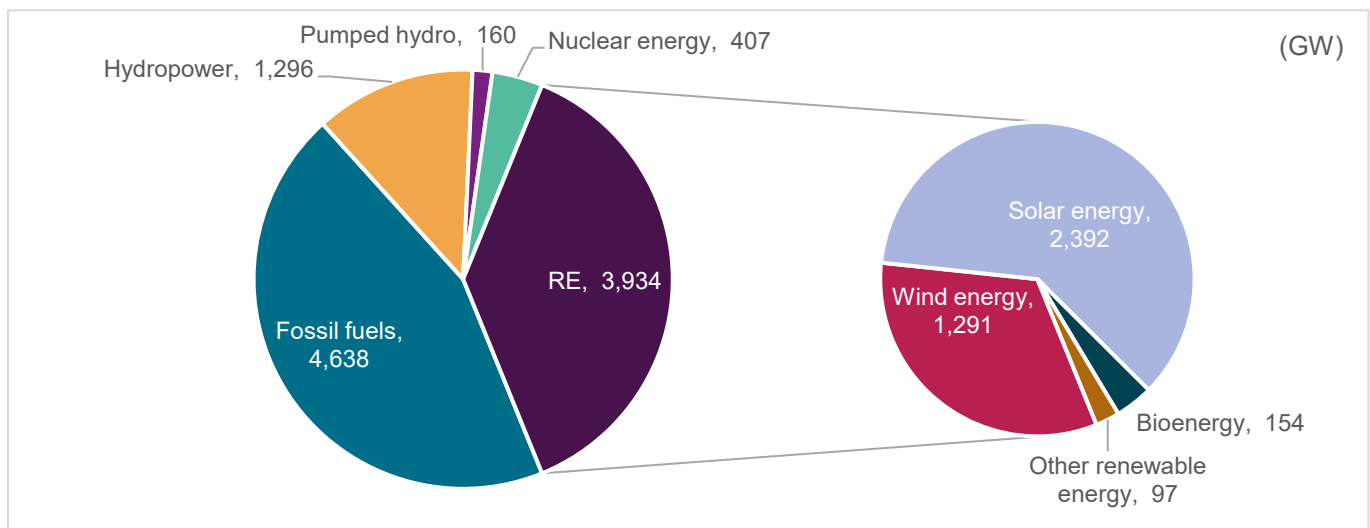
2 Overview and outlook of power sector in India

2.1 Overview of global power sector

2.1.1 Global installed capacity

As per the International Renewable Energy Agency (IRENA), global installed capacity stood at 10,4365 GW as of 2025. Fossil fuels lead the installed base with a 44% share, whereas carbon-free generation sources (nuclear, hydropower, and combined renewables) contribute ~55% and 1% from biomass and waste. Non-hydro renewables (Solar and Wind) lead to carbon-free generation with 35%, followed by hydro (including pumped storage) at 14% and nuclear with 4%. Within the non-hydro renewables, solar and wind leads with ~61% and ~33% share, respectively.

Figure 16: Global power mix- installed capacity as of 2025



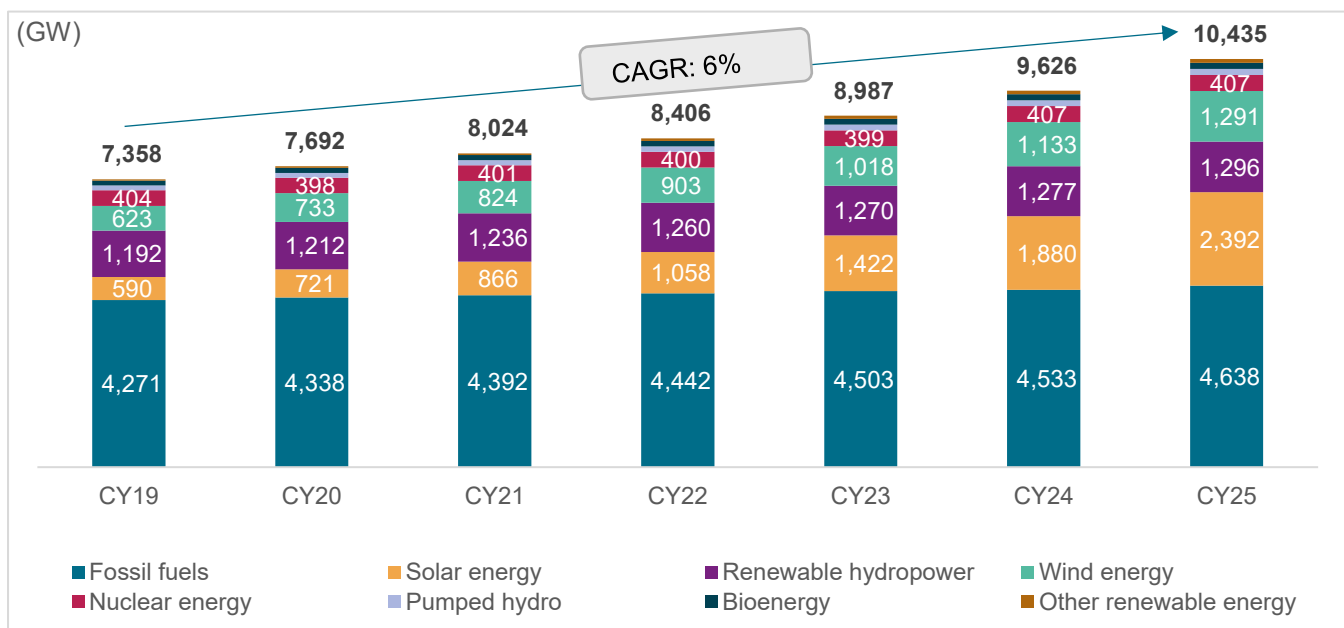
Other renewable energy includes geothermal and marine energy.

Source: IRENA, Crisil Intelligence

In 2025, the world saw a remarkable surge in renewable energy capacity, with an addition of approximately 676 GW - the highest growth rate in the past 20 years. As the growth in renewable energy sources in Europe, the United States, and Brazil reached record levels, China's progress was remarkable. In an astonishing surge, China's solar PV installations in 2025 were 314 GW.

The following chart summarises the installed capacity addition across various fuel sources. During the six-year period (2020-2025), ~ 2,229 GW solar and wind capacity was added against 299 GW of fossil fuels. During the same period, 121 GW hydro (incl. pumped storage) capacity was added. The total renewable energy capacity (incl. hydro and PSP) has grown at a CAGR of 12.7%, whereas solar capacity has grown at a CAGR of 27.1%.

Figure 17: Growth in cumulative global electricity installed capacity



Other renewable energy includes geothermal and marine energy; PSP, Bioenergy and Other RE has lower figures, hence not shown

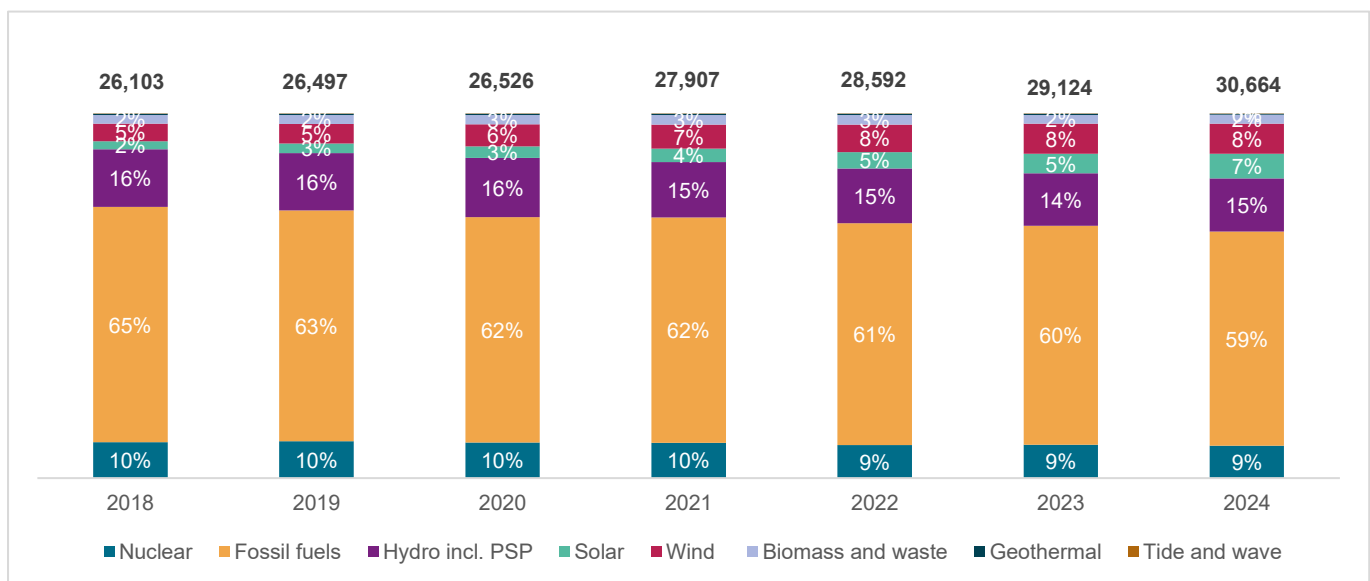
Source: IRENA, Crisil Intelligence

2.1.2 Share of renewable energy in global electricity generation

Renewable energy sources (incl. hydro and PSP) accounted for 32% of electricity generated globally in 2024, totaling 9,905 TWh. The other 68% (20,759 TWh) corresponded to fossil fuels, nuclear energy, and other non-renewables, bringing global electricity generation from all sources to 30,664 TWh in 2024.

The energy industry is driven by increasing adoption of renewable energy, rising demand in emerging countries with minimum environmental impact, the expansion of distributed power sources such as electric vehicles and storage batteries, deregulation of the electric power sector in countries and regions, and advances in electric power system reform. Digitalization in power assets, systems and processes is creating the environment of energy internet with real-time integrated grid control system and asset performance management with predictive maintenance technologies.

Figure 18: Share of solar and wind increasing whereas fossil fuel decreasing in energy generation



Note: EIA provided latest data till 2024 only.

Source: US EIA, Crisil Intelligence

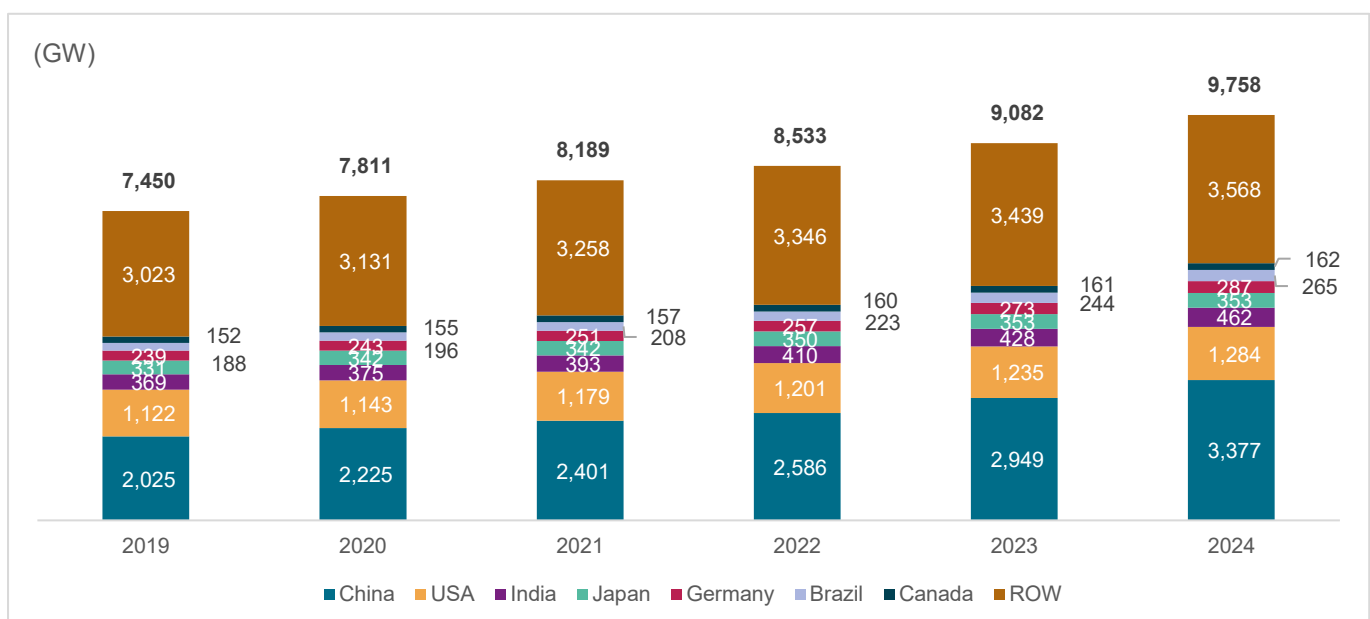
The increasing power requirements arising from AI, cloud computing, hyperscale data centers and digital infrastructure expansion are expected to drive significant long-term renewable power demand globally, both in India and across key international markets.

2.1.3 India's position on power sector globally

In terms of total installed capacity, India stands at third position after China and USA. India added about 60 GW of capacity between 2019-23 which is ~3.6% of total capacity addition globally.

India stands 4th globally in renewable energy installed capacity (including large hydro), 4th in wind power capacity, and 4th in Solar power capacity.

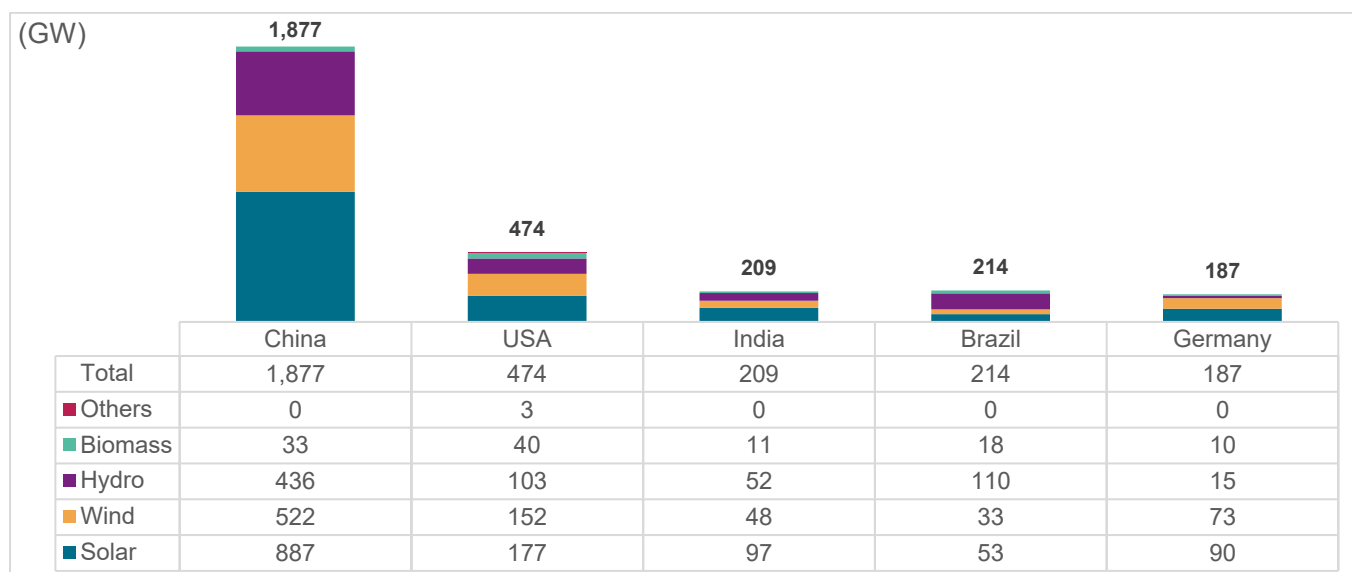
Figure 19: Installed capacity of major countries



Note: EIA provided latest data till 2024 only.

Source: US EIA, Crisil Intelligence

Figure 20: Top 5 countries installed base in total renewable (incl. Hydro) CY2024



Note: Hydro includes pumped storage also, Others include tidal and wave as well as geothermal energy

Source: EIA, Crisil Intelligence

2.2 Overview of Indian power sector

2.2.1 Evolution of power sector and its structure

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

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

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

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

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

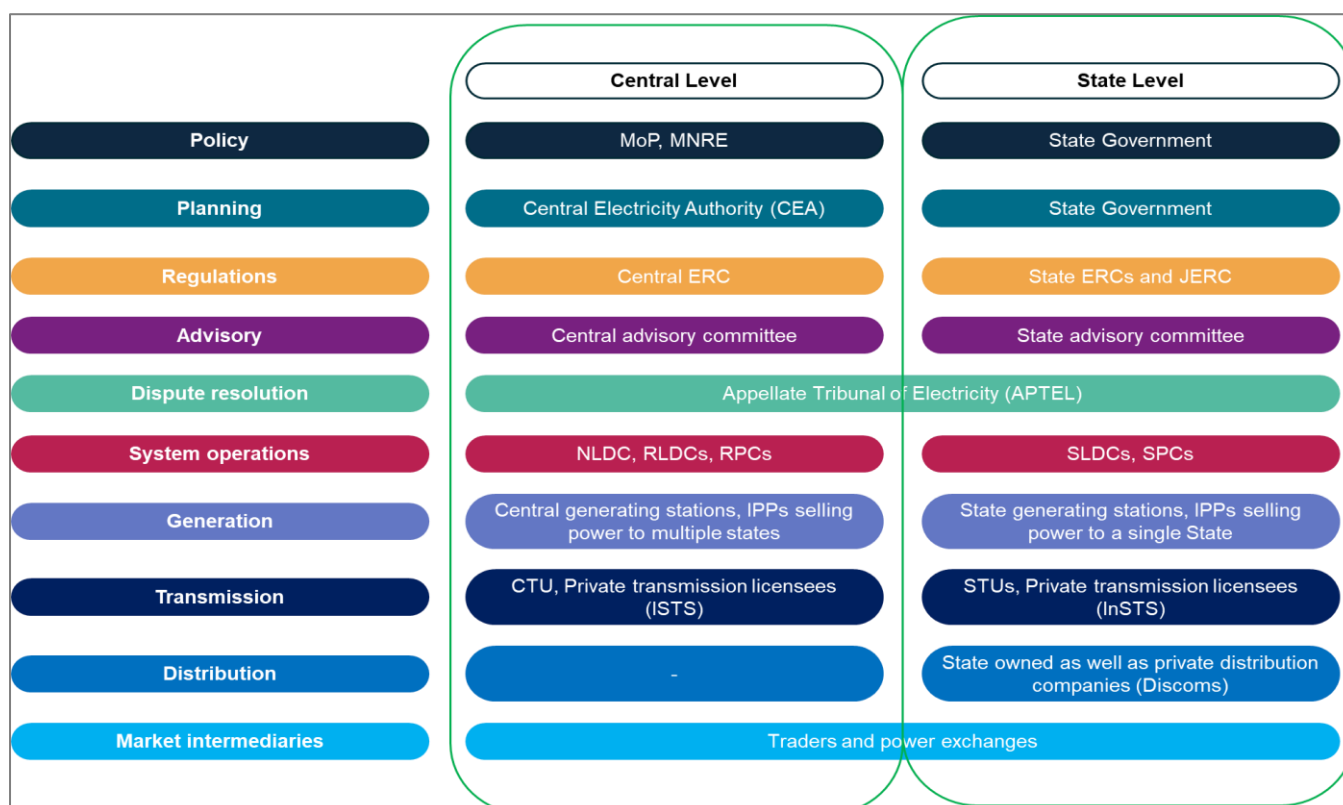
The power distribution system is the last leg of the electricity value chain. The main function of the power distribution system is to provide power to the premises of individual consumers. Responsibility for distribution and supply of power to end-consumers rests with the states. The power distribution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

2.2.2 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 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 CERC, the CEA, and the SERCs.

Figure 21: Institutional and structural framework



Note: MoP: Ministry of Power, MNRE: Ministry of New and Renewable Energy; ERC: Electricity Regulatory Commission, JERC: Joint Electricity Regulatory Commission, NLDC: National Load Despatch Centre, RLDC- Regional Load Despatch Centre, RPC: Regional Power Committee, SLDC- State Load Despatch Centre, SPC: State Power Committee, IPP: Independent Power Producer, CTU- Central Transmission Utility; ISTS: Inter State Transmission System, STU- State Transmission Utility, InSTS: Intra State Transmission System

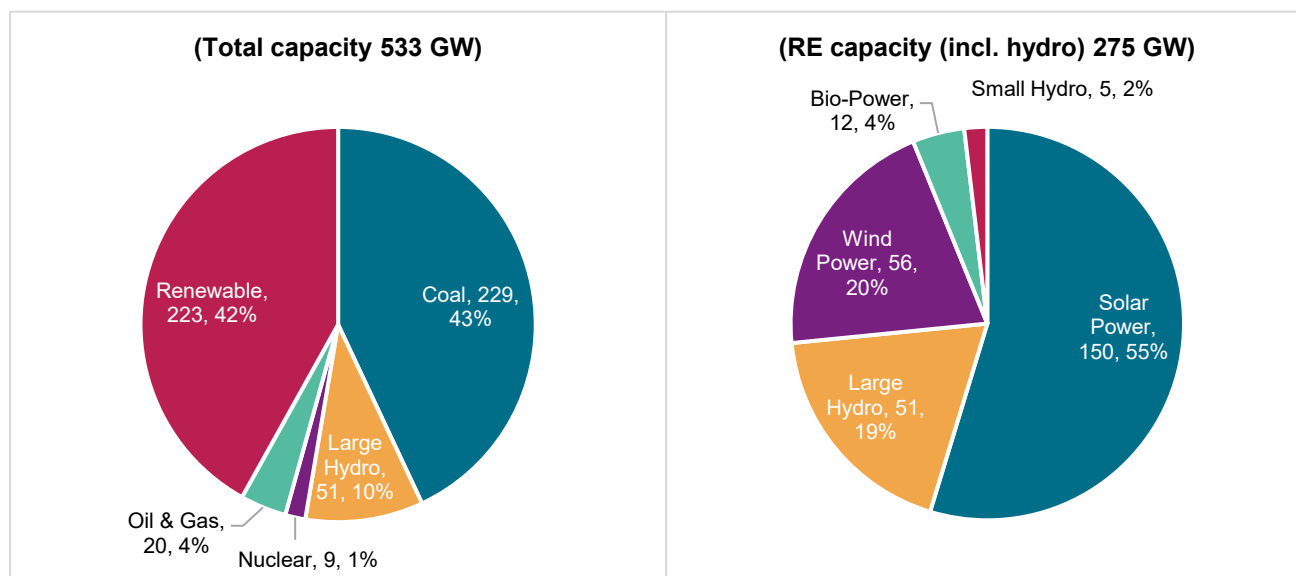
Source: Crisil Intelligence

2.3 Review of power demand-supply in India

2.3.1 Installed capacity and fuel mix

The total installed generation capacity as of March 2026 was 533 GW. Coal and Lignite-based installed power generation capacity has maintained its dominant position over the years and accounts for ~43% as of March 2026. However, RE installations (including large hydroelectric projects) have reached ~275 GW capacity as of March 2026, constituting ~52% of total installed generation capacity. This growth has been led by solar power, which rapidly rose to ~150 GW in a decade.

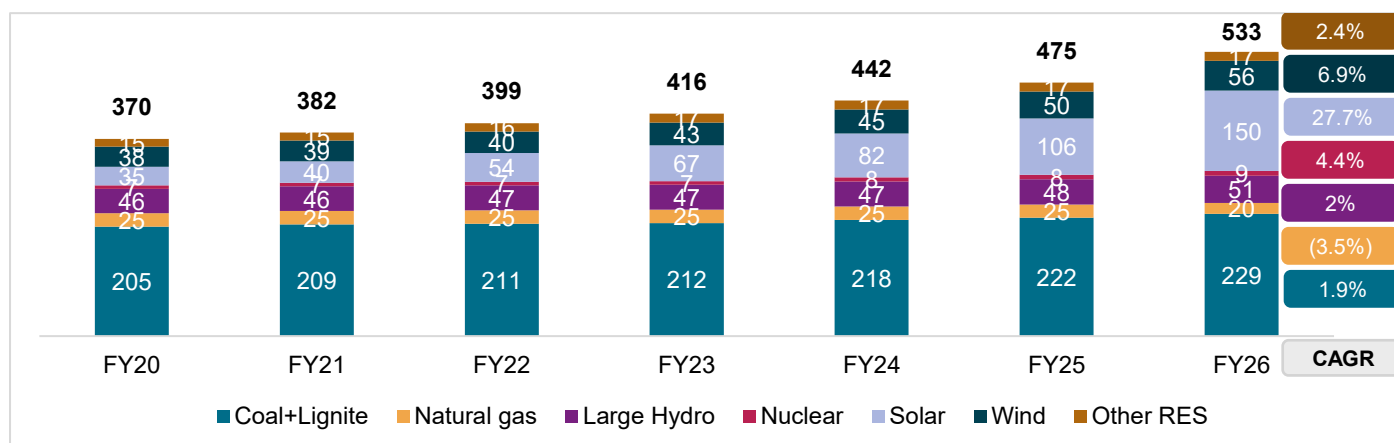
Figure 22: Installed capacity as of March 2026 (GW, %)



Source: CEA, Crisil Intelligence

Over the past few years, the installed capacity has exhibited a CAGR of 6.3% between fiscal years 2020 and 2026. Notably, the capacity addition of RE sources (incl. large hydro) has demonstrated a more pronounced growth trajectory, achieving a CAGR of 12.9% 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 27.7%. Additionally, wind energy has also contributed to this growth, albeit at a relatively modest pace, with a CAGR of 6.9%.

Figure 23: Growth in India's electricity installed capacity (in GW)

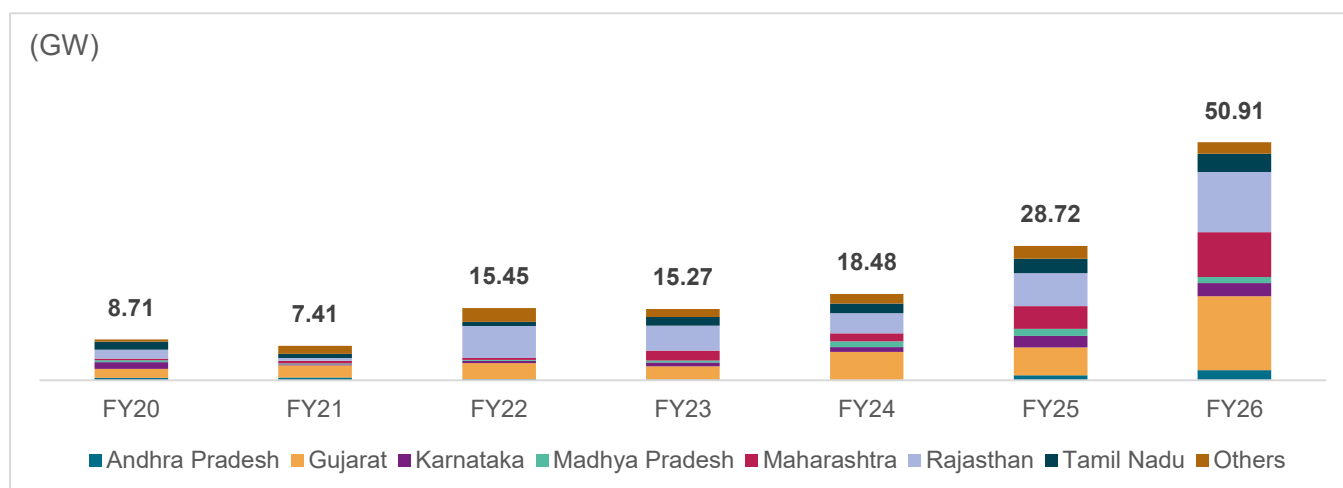


Source: CEA, Crisil Intelligence

2.3.2 RE capacity addition by key states

During fiscal 2020-2026, total RE capacity of ~136 GW (excl. large hydro) has been added, of which ~115.6 GW of solar capacity and ~18.4 GW of wind capacity has been commissioned. Rajasthan and Gujarat cumulatively added ~62.8 GW followed by Maharashtra and Tamil Nadu at 17.2 GW and 10.4 GW of solar capacity respectively. Wind power capacities have remained concentrated in certain states. About 15.8 GW of wind capacity has been added in Gujarat, Karnataka, and Tamil Nadu. During fiscal 2026, the total capacity of ~50.1 GW has been added, of which about 28.7 GW was added by Gujarat and Rajasthan.

Figure 24: Annual RE capacity addition trend by key states (in GW)

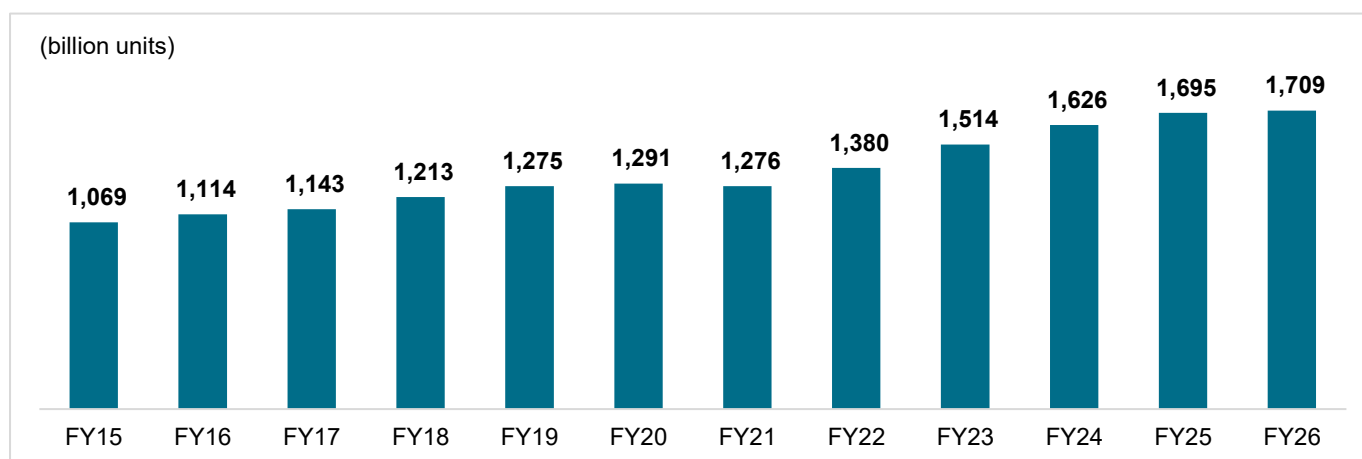


Source: MNRE, Crisil Intelligence

2.3.3 Energy requirement

Over the past decade (fiscals 2015-2026), India's energy requirements have experienced a steady growth rate of 4.4% CAGR and 6.0% CAGR in the last five years, driven by increased power availability, improved electricity access, rapid urbanization, and the implementation of 24x7 power supply. Additionally, government initiatives such as the "Make in India" program, PLI schemes, and railway electrification have contributed to this growth, along with rising per-capita income and continued government support.

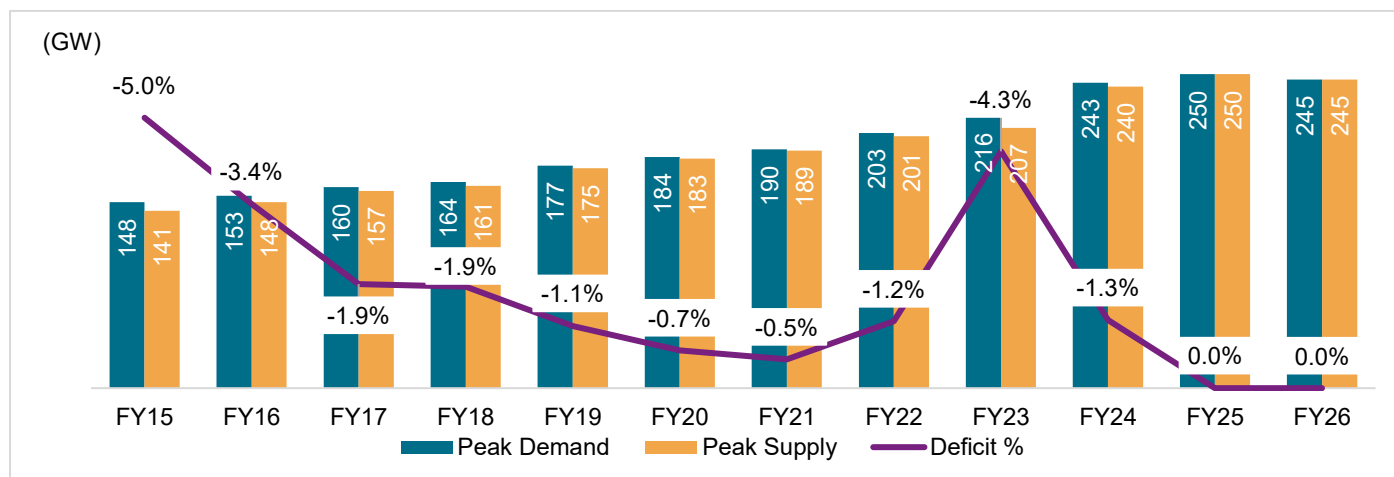
Although the COVID-19 pandemic led to a temporary slowdown in energy requirement growth, due to economic contraction and the financial strain on power distribution companies, the sector has since rebounded. In fiscals 2023 and 2024, energy requirements surged by 9.7% and 7.4% year-over-year, respectively, driven by a resurgence in economic activity, a pickup in manufacturing and agricultural production, and increased infrastructure spending by the government. However, in fiscal 2025 and 2026 the energy requirement increased with a slower pace at 4.2% and 0.8% due to erratic weather patterns resulting from climate change have also played a role in driving up energy demand. While long-term factors like sustained industrial activity, rapid urbanization, rising incomes, and the expansion of digital and transport infrastructure continue to drive India's overall structural power demand upward, the extremely muted 0.8% annual growth rate (which marked a six-year low) was primarily shaped by distinct weather anomalies (early monsoon arrival, unseasonal rains up until February) and market variables across the fiscal year.

Figure 25: Historical trend of Energy requirement in India


Source: CEA, Crisil Intelligence

2.3.4 Peak demand

Despite the COVID-19 pandemic, which led to a decline in base demand, peak demand has consistently increased over the years. Between fiscal 2015 and 2024, peak demand increased from 148 GW to 243 GW, and further to 250 GW in May 2024, representing a CAGR of 5.4%. However, during fiscal 2026 it dipped to 245 GW. Also, in May 2026 it reached all time high of ~271 GW. This steady growth can be attributed to factors such as economic expansion, seasonal fluctuations, and rising temperatures in India. However, during the same period, peak supply increased at a CAGR of 5.9% to meet the rising demand and in fiscal 2025, the peak demand-supply deficit became zero.

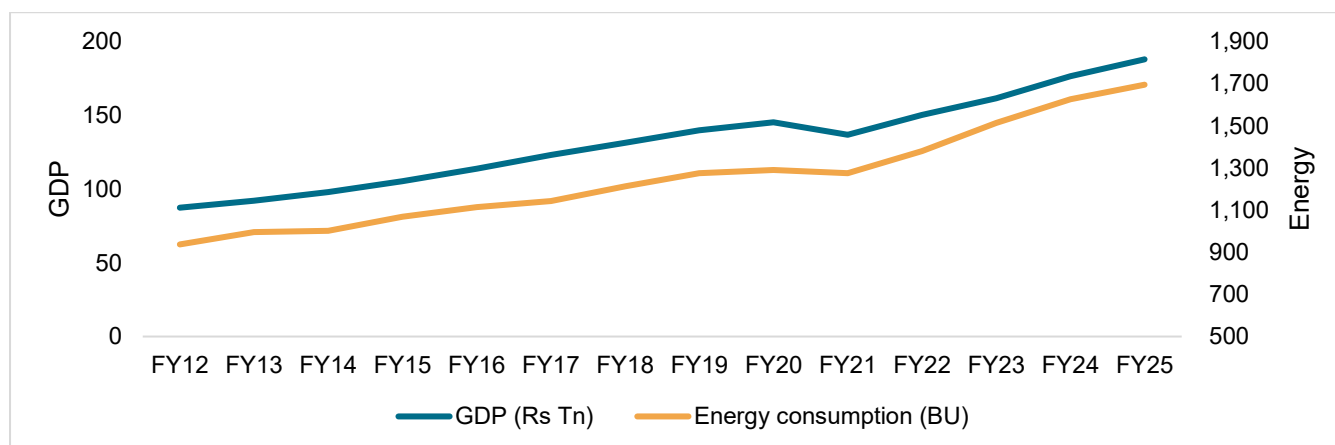
Figure 26: Historical trend of Peak demand and supply in India


Source: CEA, Crisil Intelligence

2.3.5 Correlation between GDP and electricity consumption

Historically, power demand in India has shown strong correlation with GDP driven by factors such as industrialization, urbanisation, and economic expansion. In fiscal 2025, the energy deficit across states and union territories stood at 0.03%. GDP in India has grown at a CAGR of 6.14% since fiscal 1985 and stood at Rs. 188 Tn in fiscal 2025. Over the same period, power demand rose at a CAGR of 6.1% to reach 1,695 billion units in fiscal 2025. The correlation of coefficient ("Multiple R") of national power demand with GDP (fiscal 2012 onwards) showed strong relation.

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

Figure 27: Correlation between GDP and energy consumption


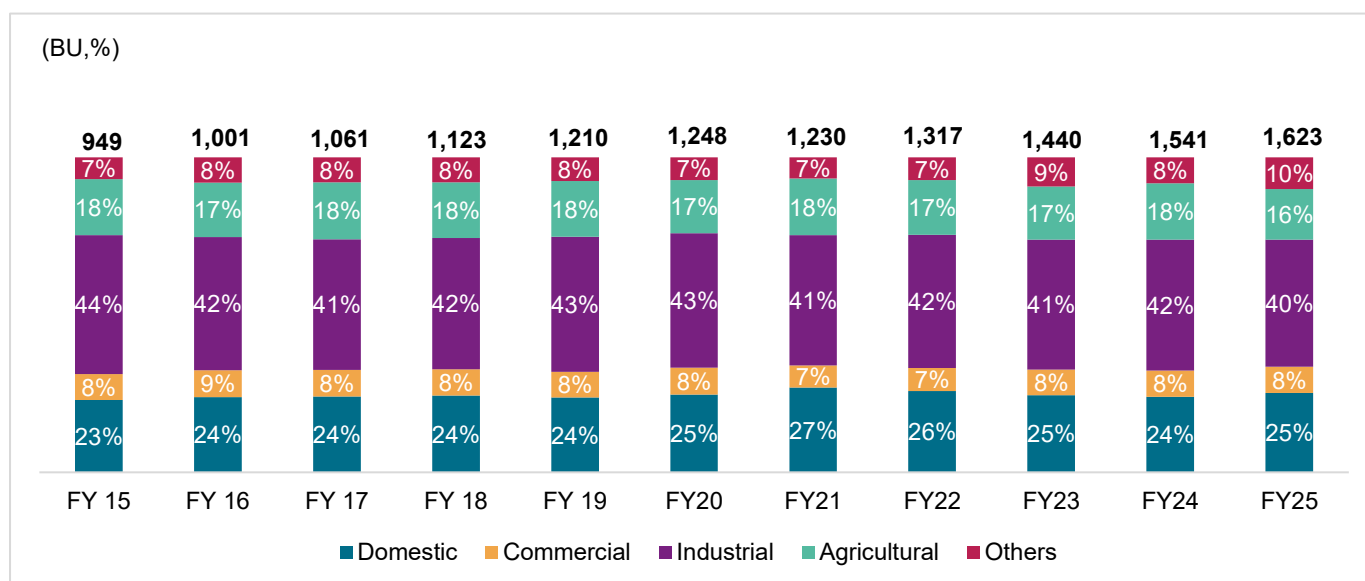
Source: MoSPI, CEA, Crisil Intelligence

2.3.6 Consumer category wise sales

The growth in energy demand can be attributed to the significant growth in domestic and industrial consumption. Over the period of fiscal 2015 to 2025, domestic electricity consumption grew at a CAGR of 6.5%, from 217 BUs to 409 BUs, while industrial consumption increased at a CAGR of 4.6%, from 418 BUs to 656 BUs. This upward trend can be linked to factors such as a growing population, expanding economy, urbanization, and industrialization, Make in India and the PLI scheme. The establishment of special economic zones and industrial parks, along with increased access to grid-based electricity in rural areas, has also contributed to the rise in energy consumption. The demand in fiscal 2025 has grown by 7.1% from fiscal 2022 driven by increased industrial production, mining activity, and infrastructure development.

The domestic sector's share of total energy demand has increased from 23% in fiscal 2015 to 25% in fiscal 2025, driven by rising urbanization, improving living standards, and growing demand for air conditioning to mitigate soaring temperatures and offering free units upto a certain level to some category/regions of India. Pradhan Mantri Sahaj Bijli Har Ghar Yojana (SAUBHAGYA), launched in 2017, has played a crucial role in achieving universal household electrification, with 28.6 million households electrified under the program. This, in turn, has driven up electricity demand. Furthermore, the scheme aims to provide 24x7 power supply to rural areas, separating agricultural and non-agricultural feeders, and strengthening sub-transmission and distribution infrastructure.

These schemes have helped in increasing the average availability of electricity in rural areas from 12.5 hours in 2014 to 22.6 hours in January 2026, while urban areas now enjoy up to 23.4 hours of power supply, reflecting substantial improvements in the reliability and reach of electricity services.

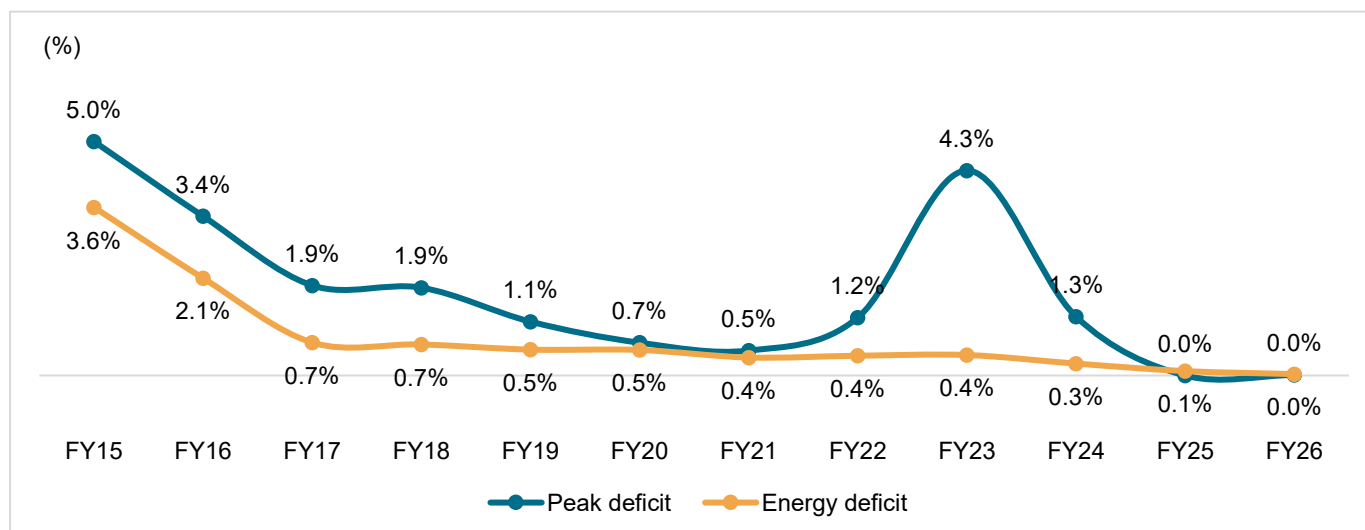
Figure 28: Consumer segment-wise energy sales in India


E: Estimated

Source: NITI Aayog, Crisil Intelligence

2.3.7 Power deficit-surplus

On the back of strong growth in installed capacity, growth in energy availability outpaced demand growth. As a result, the gap between demand and supply narrowed, both in terms of energy as well as peak demand in the country. Peak demand shortage fell sharply to 1.4% in fiscal 2024 and 0% in fiscal 2025 and fiscal 2026, from 5.0% in fiscal 2015, whereas the energy shortage fell to 0.03% in fiscal 2026 from 3.6% during the same period. In fiscal 2026.

Figure 29: Energy and peak demand shortage trends during the past 10 years


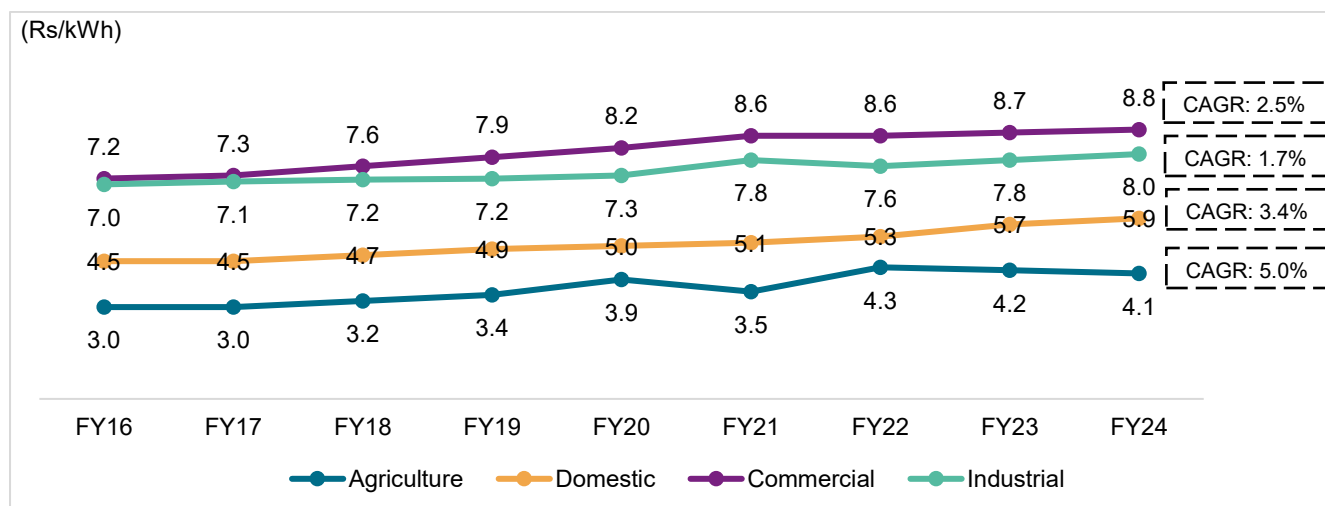
Source: CEA; Crisil Intelligence

2.3.8 Consumer tariff trend

The tariffs across categories have increased at a CAGR of ~3.0%- between fiscal 2016 and 2024, with domestic tariffs increased at a rate of 3.4% followed by commercial and industrial tariffs at ~2.5% and 1.7%, respectively. However, this tariff increase has been accompanied by a significant cross-subsidization of agricultural tariffs by commercial and industrial (C&I) consumers. In fiscal 2024, the average cross-subsidization level for C&I consumers was around 116%.

A review of the average billing rates across different consumer categories at the national level reveals that agricultural tariffs have seen negligible growth over the years due to heavy subsidization. In contrast, domestic tariffs remained steady at around Rs 4.5-5.0/kWh until fiscal 2021. However, with the introduction of the Revamped Distribution Sector Scheme (RDSS) in fiscal 2022, which aims to eliminate the gap between the average cost of supply (ACoS) and average revenue realization (ARR) by fiscal 2025, domestic tariffs have started to increase. The National Tariff Policy 2016 also emphasizes the need to reflect power supply costs in tariffs and limits cross-subsidies to within 20% of the average cost of supply.

Figure 30: Category wise historical average billing rate at national level

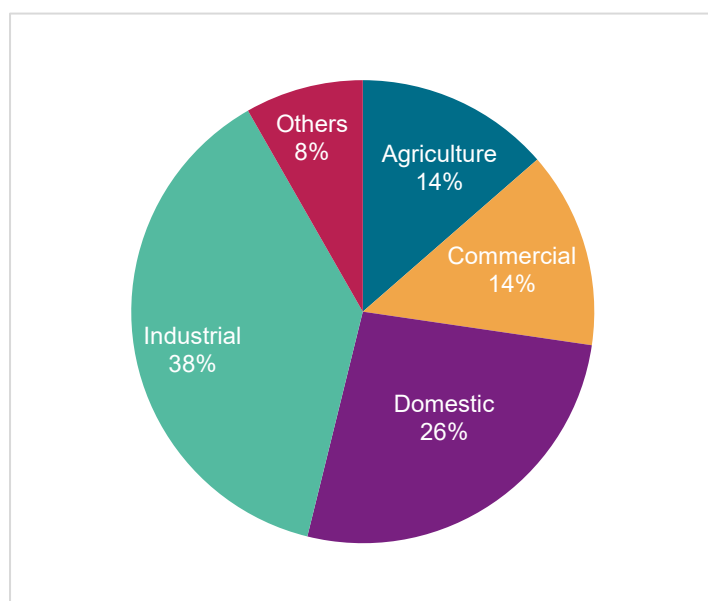


Source: NITI Aayog, Crisil Intelligence

2.3.9 Discom's revenue share from various consumer categories

The industrial sector dominates the C&I segment, accounting for over 80% of the electricity consumption within this category. Furthermore, the C&I segment as a whole constitutes around 50% of India's total electricity consumption. In terms of revenue also C&I consumers have consistently contributed over 50% of the total revenue, with certain states such as Gujarat, Maharashtra, Andhra Pradesh, Tamil Nadu standing out with an even higher share of over 60%. This highlights the significant role that industrial consumers play in the Indian power sector, both in terms of energy consumption and revenue generation for discoms. During fiscal 2025, as per NITI Aayog, the discom's cumulative revenue from sale of power was reported as Rs. 9.46 trillion. The breakup of the same is given in the chart below:

Figure 31: Share of revenue from sale of power in FY2025



Source: NITI Aayog, Crisil Intelligence

2.4 Distribution sector reforms

The distribution sector is a critical component of the power sector value chain, and the sustainability of discoms is essential for the overall health of the industry. To address this, the government has introduced various schemes and initiatives to support state discoms, including capital investments through the Integrated Power Development Scheme (IPDS) and Deendayal Upadhyaya Gram Jyoti Yojana (DDUGJY) for providing basic electricity infrastructure in villages by strengthening and augmentation of the existing infrastructure and metering of existing feeders/distribution transformers, as well as financial sustainability measures through the Ujwal DISCOM Assurance Yojana (UDAY). In July 2021, the GoI launched the RDSS to enhance the quality and reliability of power supply to consumers while ensuring the financial sustainability and operational efficiency of the distribution sector.

As per Power Finance Corporation's (PFC) 14th Annual Integrated Rating report for fiscal 2025, the AT&C losses stood at 15.04%, billing efficiency improved to 87.59% and collection efficiency at 97%. The days payable reduced from 169 days in fiscal 2022 to 113 days in fiscal 2025 and days receivable improved to 112 days in fiscal 2025 from 141 days in fiscal 2022. Overall, the trend in financial performance improvement seen over the years is due to a lot of initiatives undertaken by the utilities and the reforms taken by centra and state governments.

2.4.1 Integrated Power Development Scheme (IPDS)

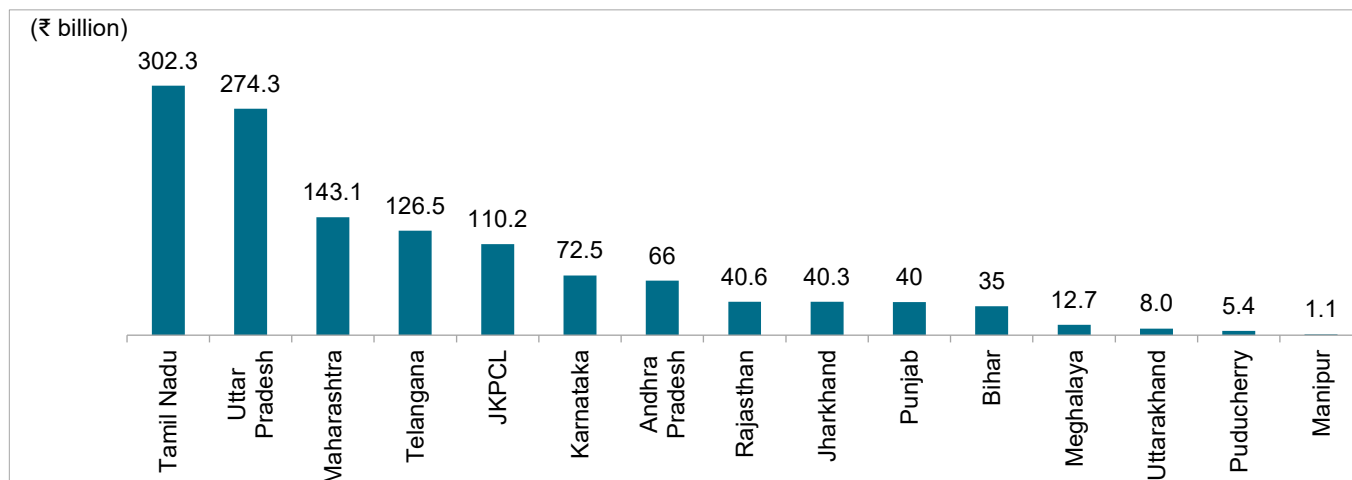
IPDS was launched with the objectives of strengthening the sub-transmission and distribution network in urban areas, metering of distribution transformers/ feeders / consumers in urban areas and IT enablement of the distribution sector. The component of IT enablement of the distribution sector and strengthening of the distribution network, approved by Cabinet Committee on Economic Affairs (CCEA) in June 2013 in the form of R-APDRP for 12th and 13th plans, have been subsumed under this scheme. The total cost of projects envisaged under this scheme during the 12th and 13th plans was ~Rs 700 billion.

2.4.2 Liquidity infusion scheme for discoms under Aatmanirbhar Bharat Abhiyaan

To address the problems faced by discoms due to the COVID-19 related lockdown, the GoI announced a liquidity package of Rs 900 billion for discoms to clear their pending dues towards power generators. Later, this amount was enhanced further to Rs 1,350 billion. Disbursal of the liquidity infusion package is linked to reform measures such as the states' undertaking to liquidate outstanding payments to discoms, installation of smart prepaid or prepaid meters in government departments, digital payment of electricity bills, timely payment of subsidies, and an action plan to be

provided by states to bring down losses over the next 3-4 years. Against the sanctioned amount of Rs 1,355 billion worth of loans, Rs 1,037 billion has already been disbursed till January 2022.

Figure 32: Central government support to states under discom relief package



Source: Ministry of Power, PFC/REC

2.4.3 Revamped distribution sector scheme (RDSS)

RDSS is a reform-based and result-linked scheme for improving the quality and reliability of power supply to consumers through a financially sustainable and operationally efficient distribution sector.

In Union Budget 2022, the Gol announced the RDSS with an outlay of Rs 3.04 trillion, partly funded by the Gol to the tune of Rs 976 billion, aimed at improving the operational and more importantly financial parameters like ACoS-ARR gap of discoms. The schemes of IPDS, DDUGJY have been subsumed in RDSS. As has been the case with the Aatmanirbhar Bharat discom liquidity package, PFC and REC will be the key nodal lenders for disbursement of funds to discoms. The Gol has laid down the guidelines and criteria for availing funding under the scheme, which aims to improve operational efficiency, distribution infrastructure, and governance and compliance standards of state discoms. The scheme's primary objective is to reduce AT&C losses to 12-15% at pan-India levels and reduction of ACoS-ARR gap to zero by fiscal 2025. As per the MoP's guidelines, the tariff revision is one of the pre-conditions for the release of funds under RDSS and no new Regulatory Assets have been created in the latest tariff determination cycle. As per the revised timelines, the scheme has been extended by two years up to March 2028.

As of December 2024, out of the 52 discoms that submitted DPR for approval, the Gol have approved DPRs worth Rs 2.52 trillion, out of which Rs 1.30 trillion is sanctioned for smart meters and Rs 1.22 trillion for loss reduction.

Figure 33: Key objectives under RDSS

S. No.	Parameters	Target/objective under RDSS
1.	ACS-ARR	To bring ACS-ARR gap to zero by fiscal 2025
2.	AT&C losses	National target of 12-15% by fiscal 2025
3.	Tariff reforms	Cost reflective tariff to ensure profitability
4.	Direct benefit transfer	Direct transfer of the subsidy to the end consumer
5.	Working capital rationalisation	Payable days to creditors for the year under evaluation to be equal to or less than the projected trajectory
6.	Hours of supply	Govt aiming for 24*7 power for all under a parallel programme
7.	DT metering and smart metering	Non-agriculture and agriculture DT metering to be completed by June 2023 and March 2025, respectively. Smart metering to be completed by March 2025

S. No.	Parameters	Target/objective under RDSS
8.	Corporate governance and compliance	Discom to publish audited annual accounts by December-end of following fiscal for the first 2 years of the scheme and by September-end from 3 rd year onwards. Tariff Orders to be issued by SERCs by April 1 of new fiscal

Source: MoP, Crisil Intelligence

2.4.4 Lending by PFC and REC to discoms

The MoP has directed PFC and REC to extend lending only after assessing the ability of the discoms to pay their loans. The assessment should be based on actual receipts rather than on an accrual basis. As per MoP's directives the computation of income should not include any subsidy due but not paid, any regulatory income (unless it is passed through in tariff and recovered) and UDAY grants. Any power purchase dues to be deducted from the profits while determining the debt repayment ability. All such parameters need to be considered to formulate a ratio for evaluation of discoms' capability to pay their immediate liabilities against the loans before fresh loan proposals are processed.

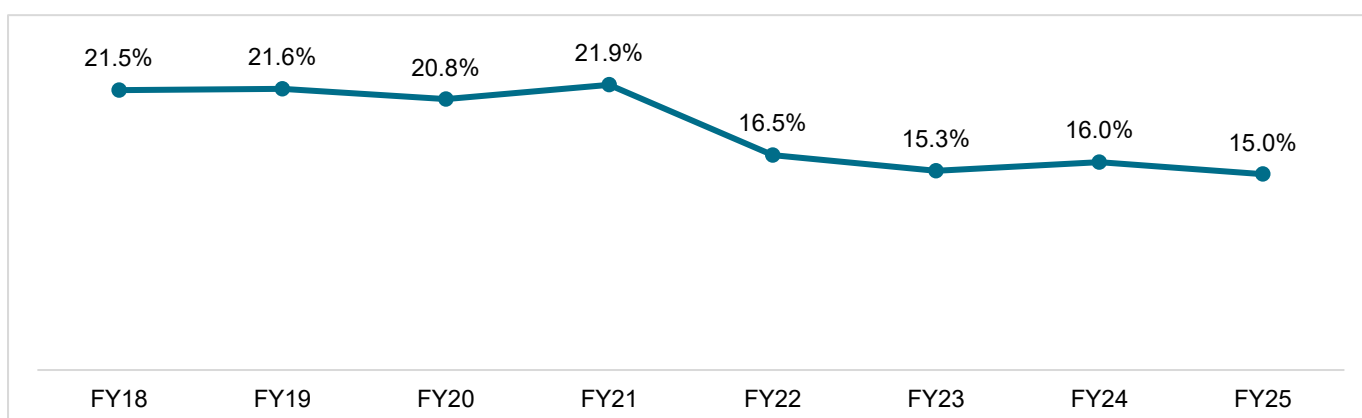
In order to recover regulatory assets by discoms, the PFC and REC have developed a policy for funding against regulatory assets of discoms. The funding would be available only 50% against the regulatory assets recognized by the respective SERCs in previous three years' tariff orders and recovery schedule included in the tariff order. It must include a time bound recovery plan of the regulatory asset by SERC and plan for recovery of carrying cost of the regulatory assets by SERC.

2.4.5 Discom's financial health

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

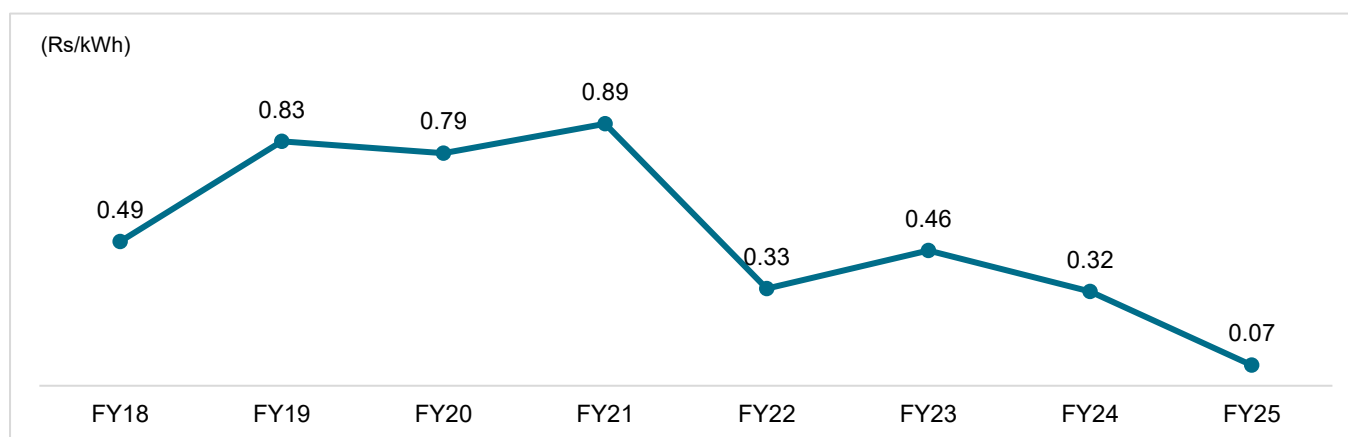
The AT&C losses for distribution utilities improved significantly from 21.9% in fiscal 2021 to 16.5% in fiscal 2022 due to an increase in collection efficiency from 92.5% to 97.2%. Collection efficiency increased due to improvement in subsidy disbursement by the state governments. The aggregate subsidy 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 now increased by 0.40% to 97.0% in fiscal 2025. This led to an increase in AT&C loss in fiscal 2024 to 16.0% which has now decreased to 15.0% in fiscal 2025.

Figure 34: AT&C loss trajectory (%)



Source: PFC, Crisil Intelligence

The cash adjusted ACS and ARR gap narrowed to Rs. 0.33/kWh as of March 2022 driven by higher subsidies disbursement by state governments and better cash collections. In fiscal 2024, the gap decreased by Rs. 0.20/kWh to Rs. 0.39/kWh. In fiscal 2025, the ACS and ARR gap stands at Rs. 0.07/kWh.

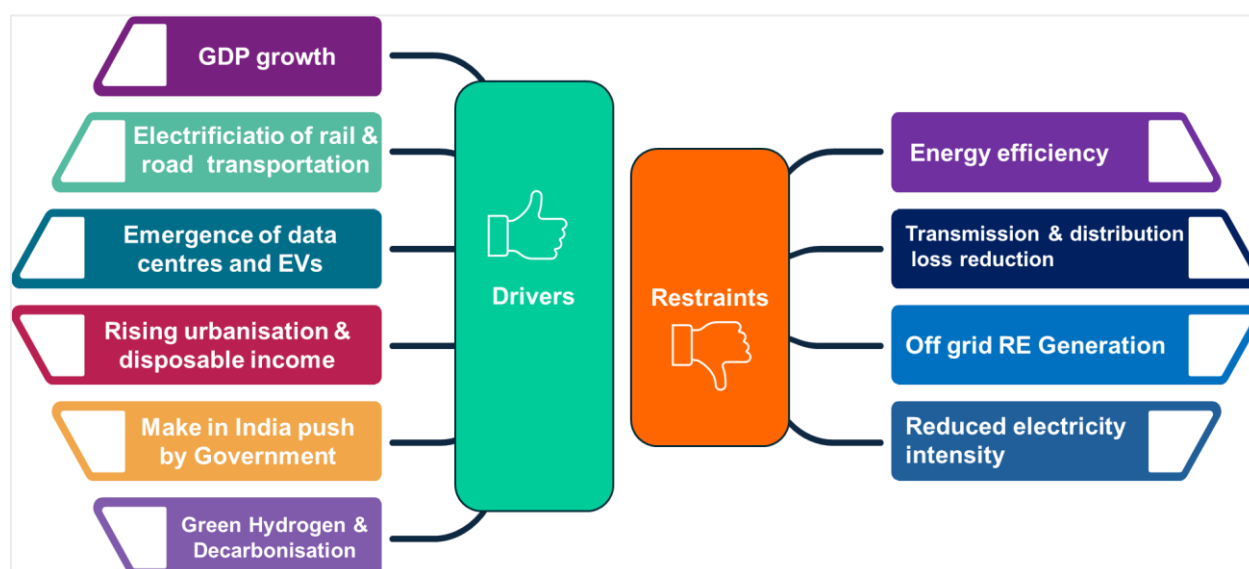
Figure 35: ACS-ARR gap


Source: PFC, 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 36: Factors influencing power demand


Source: Crisil Intelligence

Apart from macroeconomic factors, power demand would be further fueled by railway electrification where the government targeted to achieve 100% electrification by fiscal 2026 (99.6% of India's 70,001 RKM Broad Gauge network already electrified as of March 2026) and under-construction metro rail projects of over 1,018 km are

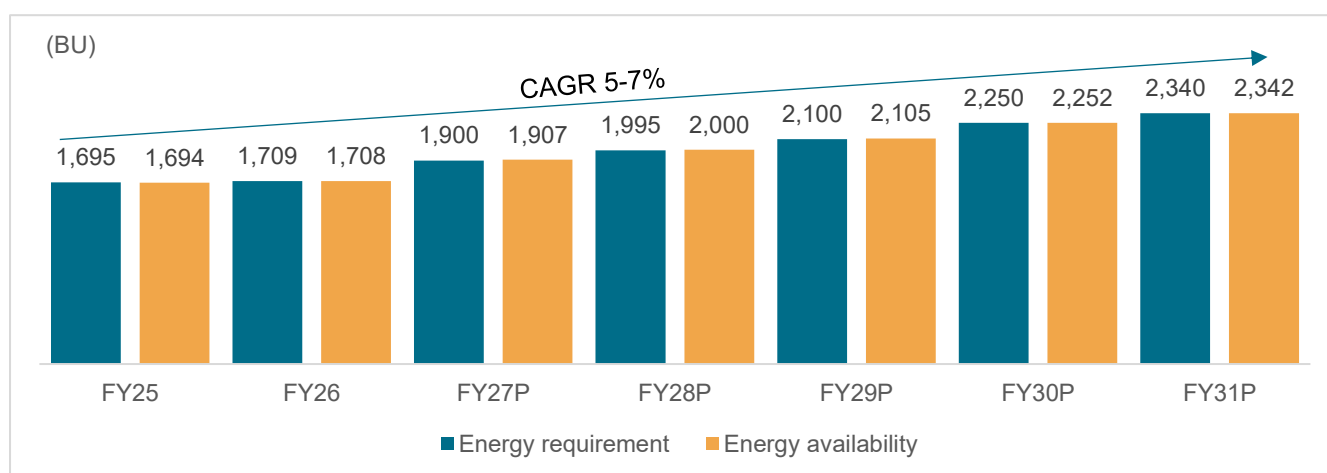
expected to add about 120-125 BU of demand by fiscal 2030. Further, growing demand for charging infrastructure due to increased adoption of electric vehicles would add 40-50 BU. Electrification of industrial processes, establishment of data centers which would require 2-3 GW of power by fiscal 2027 and 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.

Global supply chains are realigning. India is emerging as an alternative supply source given its raw materials, low labour costs, growing manufacturing knowhow, and entrepreneurial ability. With Make in India and various other initiatives, the government has targeted to increase the share of manufacturing in GDP to 25% which has been in the range of 17-18% over the past 10 years. Further, China+1 Strategy would help companies diversify their businesses away from China and India is seen as a potential beneficiary of this shift, with its large population, skilled workforce, and competitive costs. This can lead to increased power demand in India as companies relocate operations, boosting manufacturing, and potentially other sectors, thus requiring more electricity.

2.5.2 Outlook on energy requirements

Despite the high base of preceding three years, Crisil Intelligence expects power demand to grow by 5.0-7.0% between fiscal 2027-2031 driven by increasing electrification, industrialisation, data centres, green hydrogen and electric vehicle adoption. It will also be supported by infrastructure-linked capex, strong economic fundamentals along with expansion of the power footprint via strengthening of T&D infrastructure, coupled with major reforms initiated by the GoI for improving the overall health of the power sector, particularly that of state distribution utilities, are expected to improve the quality of power supply, thereby propelling power demand.

Figure 37: Energy demand outlook (fiscals 2027-31)



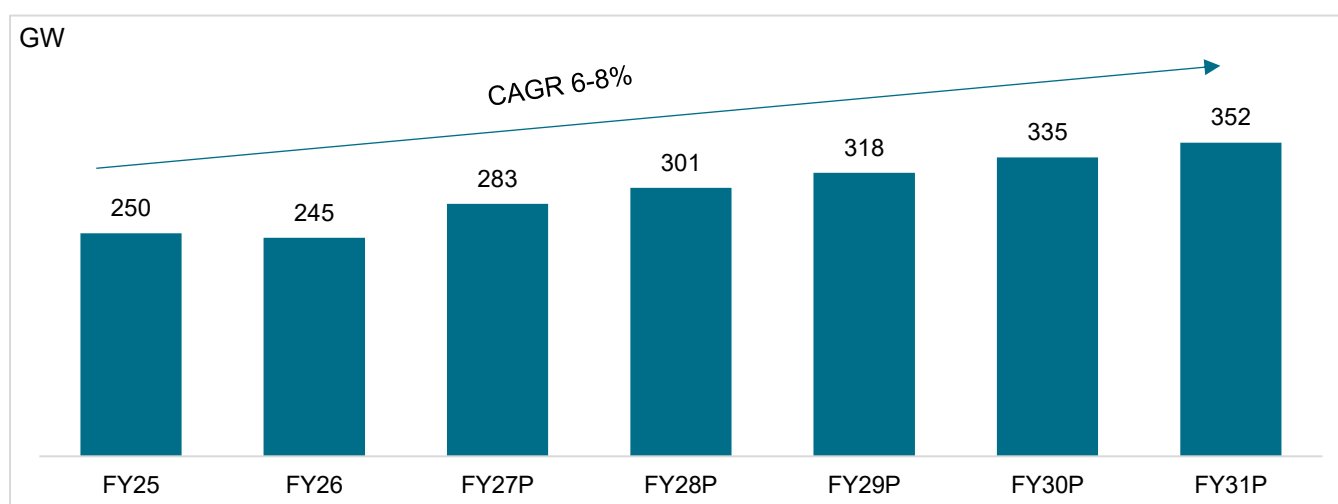
P: Projected, Source: CEA, Crisil Intelligence

According to the 20th Electric Power Survey (EPS) released by the CEA, India's electricity energy requirement is projected to reach 3,776 (BU) by the year 2041-42.

2.5.3 Outlook on peak demand growth

Peak demand is expected to grow at an annual average of 6-8% over fiscal 2027-31 to reach nearly 350 GW by fiscal 2031 with an expected persistent high temperature, rising urbanization, economic growth and infrastructure push leading to higher power consumption.

Figure 38: Peak demand to increase by around 100 GW between fiscals 2027 and 2031 to cross 300 GW



P: Projected, Source: CEA, Crisil Intelligence

2.5.4 Outlook on capacity addition

2.5.4.1 Government's key policy initiatives to boost capacity addition

i. Renewable energy

Renewable purchase obligations (RPO) to support RE capacity additions

To promote the installation of solar power systems across various Indian states, the government amended the National Tariff Policy in fiscal 2016, proposing an increase in RPO target to 21.0% by fiscal 2022. In July 2022, the MoP declared hydro power obligation (HPO) and energy storage obligation (ESO) trajectory till fiscal 2030 in addition to RPO. The total RPO target of 29.9% was set for fiscal 2025 which is rising up to 43.3% by fiscal 2030.

Annual RE bidding trajectory

Bids for 50 GW per annum RE capacity, with at least 10 GW per annum Wind power capacity, are to be issued each year from Fiscal 2024 to 2028 by Renewable Energy Implementation Agencies (REIAs).

RE zones and green energy corridors

To facilitate integration of RE projects and transmission of RE from RE-rich states to other parts of the country, India launched the Green Energy Corridor (GEC) project in 2013. In January 2022, the government approved GEC Phase-II with a total target of 10,750 ckm which is further revised to 7,574 ckm. The scheme will facilitate grid integration and power evacuation of 20 GW of RE power projects.

Solar parks and ultra mega renewable energy power parks (UMREPPs)

In 2014, the government planned to prepare land banks for 20 GW of solar projects across 25 states. The capacity of the scheme was doubled from 20 GW to 40 GW on March 2017, to set up at least 50 solar parks by fiscal 2022. As per the CEA report, as of March 2026, Solar Parks/UMREPPs with an aggregate capacity of 41.23 GW have been envisaged and an aggregate capacity of 21.30 GW of solar projects have been commissioned. Apart from this, 7.06 GW is under construction, and the remaining 12.30 GW is under award/tendering.

Waiver of ISTS charges for solar, wind, hydro, ESS projects

ISTS charges waiver for inter-state sale of solar and wind power for projects to be commissioned by June 30, 2025. Waiver for new Hydro/pumped hydro power projects would be applicable, for which construction work is awarded and Power Purchase Agreement (PPA) is signed on or before 30 June 2025.

Standard bidding guidelines

Tariff based competitive bidding guidelines for procurement of Power from Grid Connected Solar, Wind and Wind-Solar hybrid and firm RE projects have been issued.

Offshore wind projects

Viability Gap Funding (VGF) scheme for offshore wind energy projects for installation and commissioning of 1 GW of offshore wind energy projects (500 MW each off the coast of Gujarat and Tamil Nadu). The Offshore Wind Energy Lease Rules, 2023 have been notified in December 2023, to regulate the grant of lease of offshore areas for development of offshore wind energy projects.

Renewable energy is poised to become the preferred choice for future power capacity addition. The declining costs of solar and wind energy have made them competitive with fossil fuels even considering hybrid and complex RE projects, rendering them an attractive option for power generation. Moreover, the environmental benefits of renewable energy, including reduced greenhouse gas emissions and minimal water usage, are becoming increasingly important considerations for investors and policymakers. As a result, the market is naturally shifting towards renewable energy, driven by consumer demand and economic imperatives, rather than solely relying on government subsidies or incentives.

ii. Large hydro/pumped hydro projects

Budgetary support towards cost of enabling infrastructure, i.e. roads, bridges, ropeways, railway siding, communication infrastructure, and transmission line from powerhouse to the nearest pooling substation. Budgetary support for Flood Moderation/Storage hydroelectric projects.

iii. Thermal projects

CEA has envisaged 97 GW of coal-based capacity addition to meeting the base load requirement of the country in 2035. Installation of efficient Supercritical /Ultra Supercritical units over Subcritical Thermal Units is being promoted. The MoP has also issued a policy on utilization of Biomass for power generation through co-firing in coal-based power plants. The policy mandates 5-7% co-firing of Biomass primarily of agro residue with coal.

iv. Battery energy storage system

In August 2023, MoP published the National Framework for promoting Energy Storage Systems. The framework reaffirms various policies and provisions that have encouraged the planning and installation of ESS in the country. Additionally, it proposes various incentives to further encourage the development of ESS. The government expanded the VGF scheme from 4 GWh to 30 GWh in June 2025 with a budgetary allocation of Rs. 54 billion and a VGF amount of Rs. 1.8 million/MWh.

v. Nuclear power projects

The government has initiated steps to increase nuclear power capacity from the current 8.18 GW to 22.4 GW by fiscal 2032. This expansion includes the construction and commissioning of ten reactors, totaling 8 GW. Further, in the Budget 2025-26, government has set an ambitious target of 100 GW nuclear power capacity by 2047 by enhancing domestic nuclear capabilities, promoting private sector participation, and accelerating the deployment of advanced nuclear technologies such as Small Modular Reactors (SMRs).

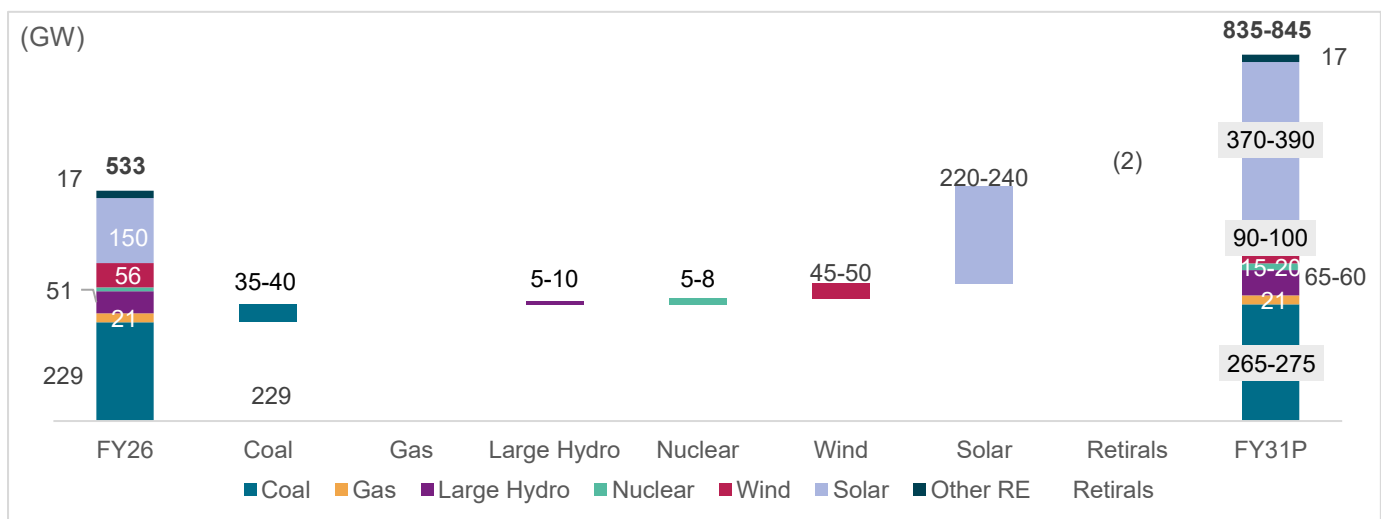
2.5.4.2 Capacity addition outlook (FY2026-2030)

As per CEA India's installed power capacity is expected to reach 609.6 GW by fiscal 2027 and increase to 900 GW by fiscal 2032, from its current capacity of 533 GW in March 2026. However, as per Crisil Intelligence estimates, the capacity additions in the conventional power generation segment are projected to be around 35-40 GW cumulatively between fiscals 2027 to 2031, supported by planned projects to meet peak demand and replace ageing coal plants. Nuclear power capacity additions of 4-6 GW are expected during the period.

The government's energy storage initiatives are likely to drive significant demand for value-added hybrid solutions. Crisil expects 5-10 GW of hydro power installations and energy storage systems is expected to further drive the capacity additions of PSP and BESS over the next 5 years and is expected to reach 50-55 GW by fiscal 2031.

By fiscal 2031, RE capacity (excl. large hydro) of ~264-274 GW is expected to be driven by various government initiatives, favourable policies, competitive tariffs, innovative tenders, development of solar parks and green energy corridors, etc. RE capacity is estimated to account for about 52-57% of the installed capacity of ~835-845 GW by fiscal 2031. RE is expected to account for over 80% of the additional capacity between fiscal 2027 and 2031.

Figure 39: All India installed estimated capacity addition by fiscal 2031 (in GW)



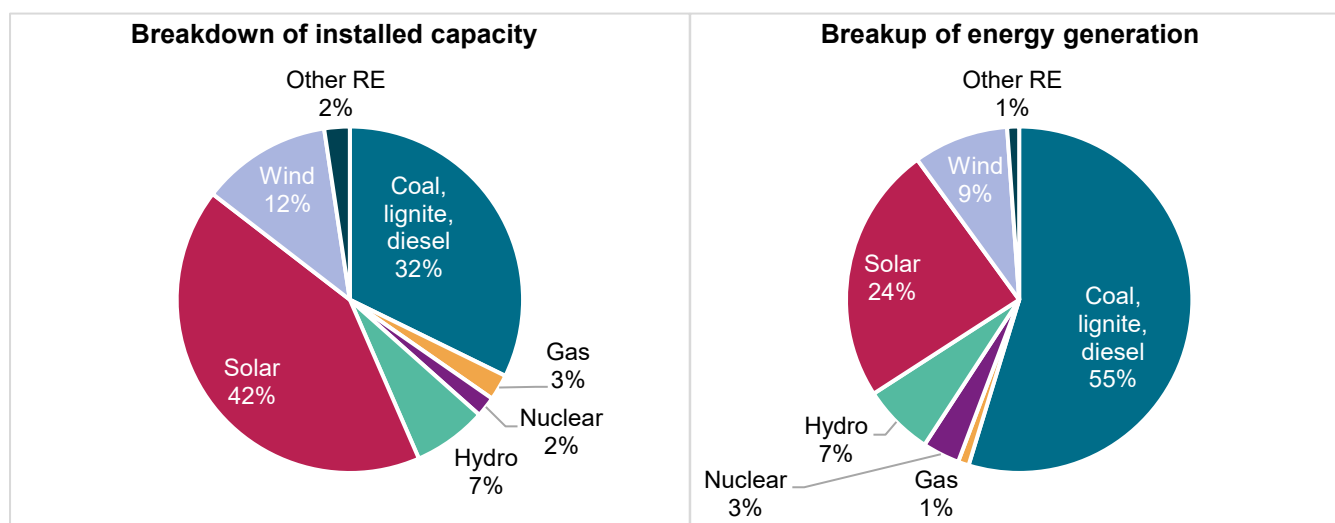
RE includes solar, wind, small hydro, and other renewable sources

Source: CEA, Crisil Intelligence

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 and ~54 GW in fiscal 2026.

The share of renewable energy in terms of installed capacity is expected to reach above 55% (including large hydro), however, the share of RE in terms of energy supply is expected to be about 35-40% by fiscal 2031 (incl. hydro). The share of solar energy supply is expected to be about 20-21% of the total RE supplied in fiscal 2031. The difference between installed vs generation breakup of thermal and RE is driving the need for more complex projects vs vanilla solar and wind and hence the companies with capabilities in both solar and wind are better suited for growth driven by ability to deliver round-the-clock / firm RE power.

Figure 40: Estimated capacity and generation breakup as of FY2031



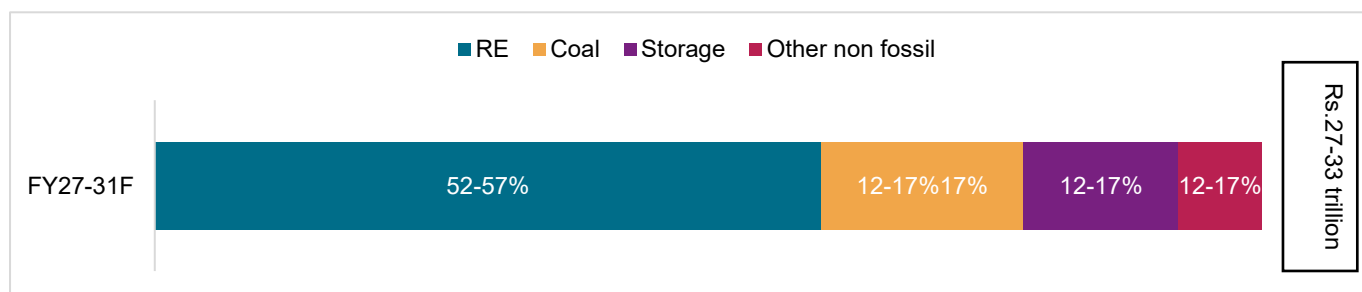
Source: Crisil Intelligence

From a supply perspective, there are uncertainties associated with the timing of decommissioning of older thermal power projects in part driven by environmental regulations and with the scale, pace and structure of replacement capacity, again reflecting a complex interaction of economic and political pressures and environmental preferences. The decommissioning of such power projects will cause a reduction in power supply while commissioning of new conventional energy and nuclear power projects pursuant to recent plans announced by GoI, such as the target of 100.00 GW of nuclear power capability by 2047 set by the GoI in Budget 2025-26, could result in increased supply of electricity.

2.5.5 Power generation investment outlook

Investments in power generation are expected to increase ~2.5 times from Rs. 12.0 trillion between fiscals 2022-2026 to Rs. 27-33 trillion between fiscals 2027-2031. Over the next five years, investments in generation will be led by renewable energy (excluding hydro and storage) capacity additions, followed by investments in conventional generation and FGD installations, indicating a shift in investment flow towards enhancing clean energy supply. Capacity addition from RE sources is expected to be 260-270 GW over fiscals 2027 to 2031, and 35-40 GW from coal-based plants sources over the same period. Investments in RE capacity will constitute ~52-57% of overall generation investments.

Figure 41: Breakup of investments in power generation sector expected between FY2027-FY2031



Source: CEA, Crisil Intelligence

2.6 Government's initiative for clean energy growth

2.6.1 United Nations Climate Change Conference

COP 26

The 2021 United Nations Climate Change Conference (COP 26) was a landmark event, as it saw several important decisions including:

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

Some of the key outcomes of COP26:

- Glasgow Climate Pact: It includes several commitments, including a commitment to phase down coal power and to accelerate the transition to clean energy.
- Global Methane Pledge: Countries committed to work collectively to reduce methane emissions by at least 30% below 2020 levels by 2030.
- Adaptation Action Framework: New financial pledges were made to support developing countries in achieving goals
- Santiago Declaration on Forests and Land Use: The declaration committed to prevent and reverse forest loss and land degradation by 2030.

India has submitted its updated first nationally determined contributions (NDCs), working towards climate justice after COP26. Some of the key NDCs are

- To reduce Emissions Intensity of its GDP by 45% by 2030, from the 2005 level.
- To achieve about 50% cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030, with the help of the transfer of technology and low-cost international finance including from the Green Climate Fund (GCF)
- To create an additional carbon sink of 2.5 to 3 billion tonnes of CO₂ equivalent through additional forest and tree cover by 2030.

COP 28

The 28th Session of the UN Climate Change Conference (COP 28) was held in Dubai, United Arab Emirates from 30th November 2023 to 13th December 2023.

The major outcome from COP 28 included the decision on the Outcome of the First Global Stocktake, ratcheting up global climate ambition before the end of the decade. These global efforts will be made by the countries in a nationally determined manner, considering the Paris Agreement and their different national circumstances. Another major outcome of COP 28 is the agreement on the operationalization of the Loss and Damage Fund and its funding arrangements. The decision was adopted by consensus by all Parties including India. Since the adoption of the decision, an amount of around USD 700 million has been pledged by several countries.

COP 29

The 29th Session of the annual climate summit under the UNFCCC was held in Baku, Azerbaijan in November 2024. It primarily focused on climate finance, positioned as the "Finance COP", it aimed to establish a new global climate finance target (NCQG) beyond the earlier \$100 billion annual commitment, while advancing the operationalisation of the Loss and Damage Fund to support vulnerable nations. It continued efforts on emissions reduction aligned with the 1.5°C pathway, expansion of renewable energy, mobilization of private and multilateral capital, and refinement of global carbon market mechanisms under Article 6.8.

COP 30

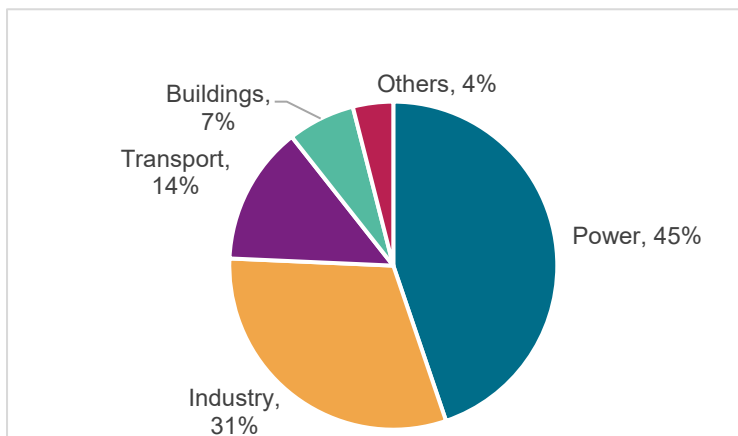
The 30th Session was the 30th Conference of the Parties under the UNFCCC, was held in Belém, Brazil, in 2025. It delivered a major push on climate finance and implementation of the Paris Agreement, with countries agreeing to mobilize \$1.3 trillion annually by 2035, significantly scale up adaptation funding, and fully operationalize the Loss and

Damage Fund. The summit launched key initiatives such as the Global Implementation Accelerator and the “Belém Mission to 1.5°C,” while also addressing climate disinformation and reinforcing global cooperation. Despite the strong expectations, the final agreement did not include a clear commitment to phasing out fossil fuels, instead only referencing earlier commitments from COP28, which remained a key gap.

2.6.2 Themes for Energy transition

India is the third-largest CO₂ emitter globally, with 2.8 gigatonnes (GT) of emissions, despite low per capita emissions. The power sector, heavily reliant on coal, has a high carbon intensity of 725 gCO₂/kWh, exceeding the global average. The industrial and transport sectors also significantly contribute to emissions, at 31% and 14%, respectively. To meet growing energy demands, these sectors require urgent decarbonization efforts.

Figure 42: CO₂ emissions from the Indian energy sector, 2019



Source: World Energy Outlook 2021 of IEA, Crisil Intelligence

A) Grid Decarbonisation

Decarbonizing India's grid requires a significant shift towards clean power sources, particularly RE integration. Despite progress, coal still dominates power generation, accounting for nearly 46% of installed capacity and resulting in high CO₂ emissions. To address this, the government aims to achieve 500 GW of non-fossil fuel capacity by 2030. To accelerate this transition, the government has introduced various initiatives, including 100% FDI, waived transmission charges till June 2025, RPO trajectory by 2030, VGF, PLI scheme, RE/solar parks, Green Hydrogen Mission among others. As a result, India has added 15-20 GW of RE capacity annually. However, to meet the 500 GW target, the government plans to add 50 GW of RE capacity annually for the next 5 years. By 2030, non-fossil fuels are expected to account for over 50-55% of India's installed capacity, with solar, wind, nuclear, and hydro power playing key roles. To achieve this, capacity additions in nuclear and hydro power will be necessary, in addition to wind and solar.

B) Industrial decarbonisation

Industrial decarbonisation implies reducing carbon intensity from energy-intensive and hard-to-abate industries with the help of efficient modern technologies and best practices. Using combination of various techniques such as energy efficiency, clean energy, carbon capture and usage, low carbon hydrogen, industrial decarbonisation can be targeted. Industrial decarbonisation can address 31% of CO₂ emissions.

- i. **Steel:** India's steel and iron sector accounts for ~40% of industrial emissions and ~12% of total emissions, with a high reliance on coal-based production. As the world's 2nd largest crude steel producer, the sector is poised for growth, but its energy and carbon intensity are exacerbated by small production facilities, poor coal quality, and dependence on coal-based DRI furnaces. To decarbonize, the Ministry of Steel has set targets to reduce CO₂ emissions to 2.2-2.7 T/TCS (tonnes per ton of crude steel) by 2030, down from 3.1 T/TCS in 2005. The ministry's strategy focuses on short-term reductions through energy efficiency and

renewable energy, medium-term adoption of green hydrogen and carbon capture, and long-term innovative technologies to achieve net-zero emissions by 2070.

- ii. **Cement:** India's cement sector is the second-largest emitter, accounting for ~28% of industrial emissions and ~8% of total emissions. Cement production is a highly emission-intensive process, with 60% of CO₂ emissions coming from the chemical calcination process. As the world's second-largest cement producer, India's growing economy and infrastructure demands are driving steady growth in the industry. To decarbonize, the sector can explore technologies such as renewable energy and alternative fuels, energy efficiency through waste heat recovery, carbon capture and utilization, and clinker substitution. These solutions can help reduce emissions from the cement industry, which is critical given its significant contribution to India's overall emissions.
- iii. **Aluminium:** India's aluminium production accounts for 3% of global capacity, with primary production involving energy-intensive smelting that consumes 85-90% of electrical energy. The sector has a high GHG intensity of 20-22 tCO₂/t, largely due to reliance on coal-based power. To decarbonize, the aluminium sector can adopt renewable energy, control direct emissions through technologies like inert anode smelters, and improve scrap recovery. Leading domestic manufacturers, including Vedanta, Hindalco, and NALCO, have set targets to reduce GHG emissions, such as Vedanta's 25% reduction by 2030 and Hindalco's 25% reduction by 2025. NALCO aims to increase non-fossil power sources to 40% by 2030, aligning with India's national goals.
- iv. **Fertilizers and ammonia:** Fertilizer production is energy-intensive, relying heavily on fossil fuels, particularly natural gas, and resulting in significant GHG emissions. Decarbonization options include renewable energy, hydrogen blending, and switching to green hydrogen. The Indian government has launched the National Green Hydrogen Mission with an outlay of Rs. 19,744 crores to promote green hydrogen production, aiming to make India a global hub for green hydrogen and its derivatives. The mission targets 5 MMTPA of green hydrogen production, reducing dependence on fossil fuel imports. Initiatives under the mission include the Strategic Interventions for Green Hydrogen Transition (SIGHT) scheme, which has issued a Request for Selection for 450,000 tons of green hydrogen production. Additionally, companies like GAIL and NTPC are piloting hydrogen blending in city gas distribution grids, with NTPC blending up to 8% green hydrogen in its PNG network. Other initiatives, such as hydrogen-based fuel-cell electric vehicles, are also being implemented by various CPSUs.

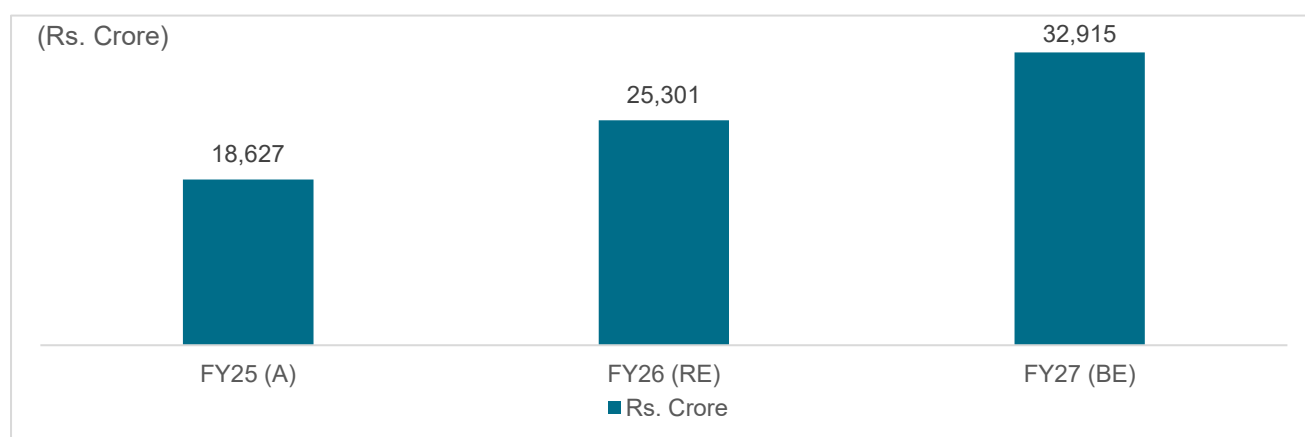
C) Transport decarbonisation

Decarbonizing India's transport sector is crucial to reduce GHG emissions and achieve net-zero emissions by 2070. The sector's heavy dependence on oil and growing demand for vehicles due to urbanization and industrialization make it a challenging task. To address this, the government has launched initiatives to promote electric mobility, such as the Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India (FAME India) Scheme, which aims to reduce fossil fuel dependence and vehicular emissions. The scheme's Phase-II, implemented from 2019 with a budget of Rs. 10,000 crores, focuses on electrifying public and shared transportation. Other measures include exempting battery-operated vehicles from permit requirements, promoting hybrid electric systems, and encouraging alternative fueling options. Additionally, improving fuel efficiency, promoting public transportation, and building infrastructure for electric vehicle charging and hydrogen refueling are essential to support the transition to cleaner energy sources.

2.6.3 Increased budget allocation

In 2026-27, the MNRE has been allocated Rs 32,915 crore, an increase of 30% from the revised estimate of 2025-26.

Figure 43: Government of India allocation towards MNRE



Note: A: Actual. BE: Budget Estimates; RE: Revised Estimates.

Source: Union Budget, Crisil Intelligence

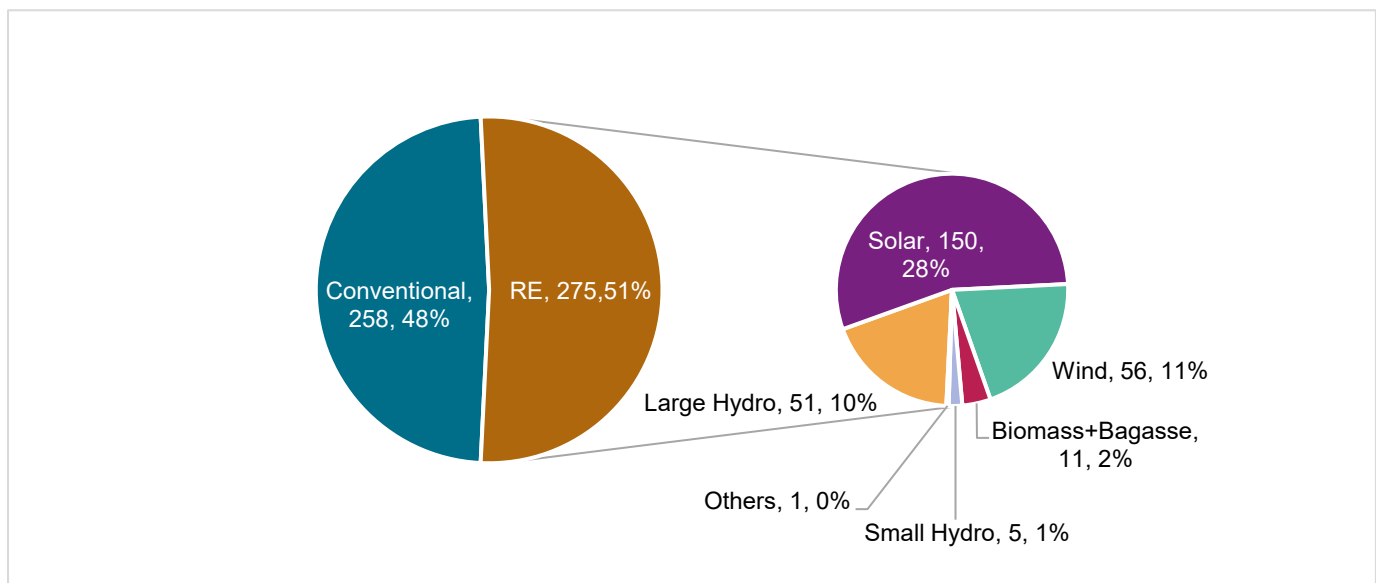
3 Assessment of the Renewable IPP Business in India

The Renewable Energy IPP business in India has witnessed significant growth, driven by ambitious government targets, policy support, and increasing investor interest. India has set a goal of achieving 500 GW of non-fossil fuel capacity by 2030, creating vast opportunities for IPPs in solar, wind, hybrid, battery storage, and emerging technologies like green hydrogen. The sector has seen participation from both domestic and global players, backed by long-term PPAs with central agencies like SECI, NTPC, and state distribution companies. However, challenges such as payment risks from DISCOMs, regulatory uncertainties, land acquisition hurdles, and transmission constraints persist. To mitigate risks, IPPs are increasingly exploring C&I consumers, corporate PPAs, and merchant markets. With falling technology costs, evolving financing models, and growing interest from institutional investors, the renewable IPP business in India is poised for sustained expansion, playing a crucial role in the country's clean energy transition.

3.1 Overview of RE capacity addition in India

Renewable energy installations (incl. large hydro) in India have increased to ~275 GW as of March 2026, as compared with ~63 GW as of March 2012 (source: MNRE), led by various central and state-level incentives. As of March 2026, installed grid connected RE generation capacity (incl. large hydro) in India constituted ~51% of the total installed generation base in India. This growth has been led by solar power, which has grown to ~150 GW from merely ~0.9 GW over the discussed time period (i.e., from March 2012).

Figure 44: India's RE (incl. large hydro) capacity was 51% at the end of March 2026

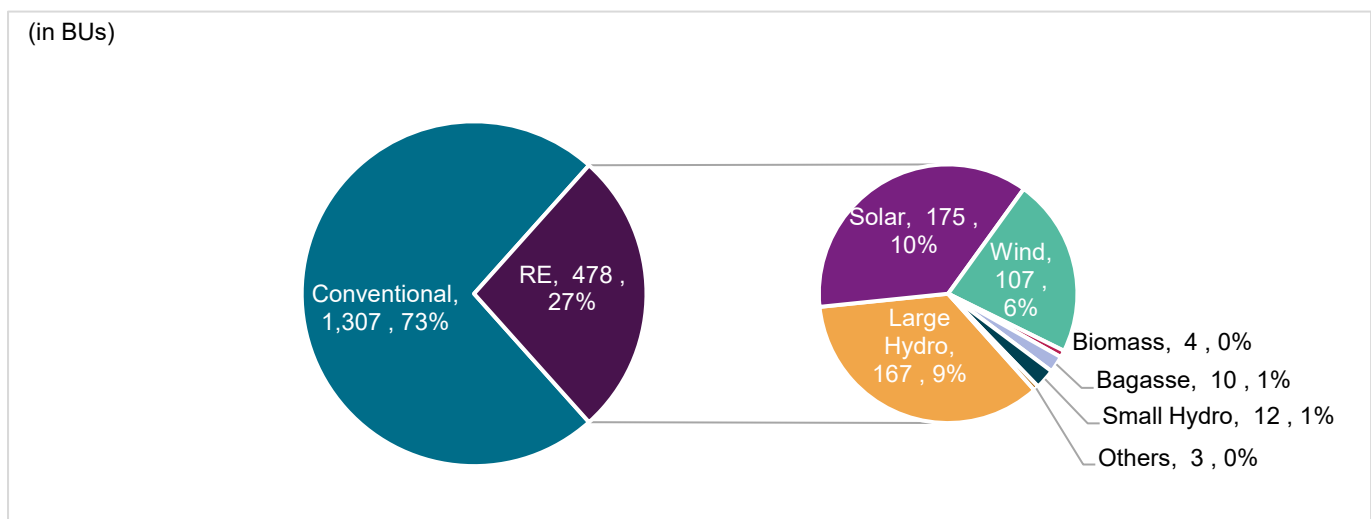


Conventional: Coal, Gas, Lignite, and Nuclear

Source: MNRE; CEA, Crisil Intelligence

However, owing to lower capacity utilisation factors (CUF), the RE penetration (incl. large hydro) in terms of energy generation was at 27% for fiscal 2026.

Figure 45: India's RE (incl. large hydro) penetration was about 27% at end of March 2026



Conventional: Coal, Gas, Lignite and Nuclear, Excl. Bhutan imports

Source: CEA, Crisil Intelligence

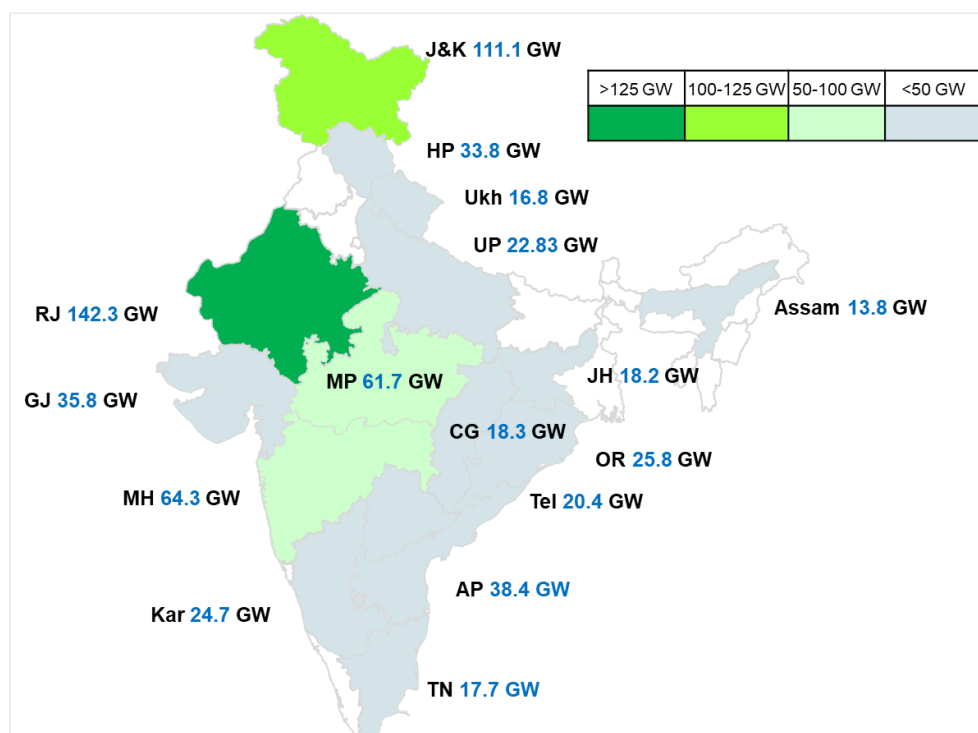
3.2 Solar potential across states

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

An important determinant of a solar power project's potential output is the amount of solar irradiation the site receives. Generally, higher irradiation levels lead to greater energy generation per MW of installed capacity. The daily average Global Horizontal Irradiance (GHI) measures the total solar radiation received on a horizontal surface. GHI levels naturally vary due to changing sunlight intensity, cloud cover, atmospheric dust, and the sun's activity cycle.

GHI in India is around 5 kWh/m² in north-eastern and hilly areas to about 7 kWh/m² in western region and cold desert areas. The annual GHI varies from 1600 – 2200 kWh/m². States like Gujarat, Rajasthan, Madhya Pradesh, Andhra Pradesh, Karnataka, and Tamil Nadu offer more solar irradiance as compared to other parts of India, which makes them desirable for installing solar projects.

While solar irradiation plays a key role in power generation, other weather factors also play a crucial role. The efficiency of solar modules is sensitive to temperature; high ambient temperatures can slightly reduce the power output compared to performance under standardized test conditions. Other weather events, such as heavy monsoon rains or dust storms, can also temporarily affect generation by increasing the soiling on modules or obscuring sunlight.

Figure 46: State wise solar potential


Others: ~83 GW; Source: NISE: MNRE, Crisil Intelligence

Table 5: State wise solar energy potential and installed capacity for key states (as of March 2026)

Sr. No.	State	Potential (GW)	Installed capacity (GW)	Untapped Potential (100%-(Installed/Potential))
1.	Rajasthan	142.31	41.13	71.10%
2.	Jammu & Kashmir	111.05	0.08	99.93%
3.	Maharashtra	64.32	19.62	69.50%
4.	Madhya Pradesh	61.66	5.99	90.29%
5.	Andhra Pradesh	38.44	7.49	80.52%
6.	Gujarat	35.77	29.30	18.09%
7.	Himachal Pradesh	33.84	0.36	98.94%
8.	Odisha	25.78	0.88	96.59%
9.	Karnataka	24.7	11.10	55.06%
10.	Uttar Pradesh	22.83	4.12	81.95%
11.	Telangana	20.41	5.07	75.16%
12.	Chhattisgarh	18.27	1.81	90.09%
13.	Jharkhand	18.18	0.26	98.57%
14.	Tamil Nadu	17.67	13.58	23.15%
15.	Others	113.76	9.47	91.68%

Source: MNRE, NISE, Crisil Intelligence

3.2.1 Renewable energy consumption in key states

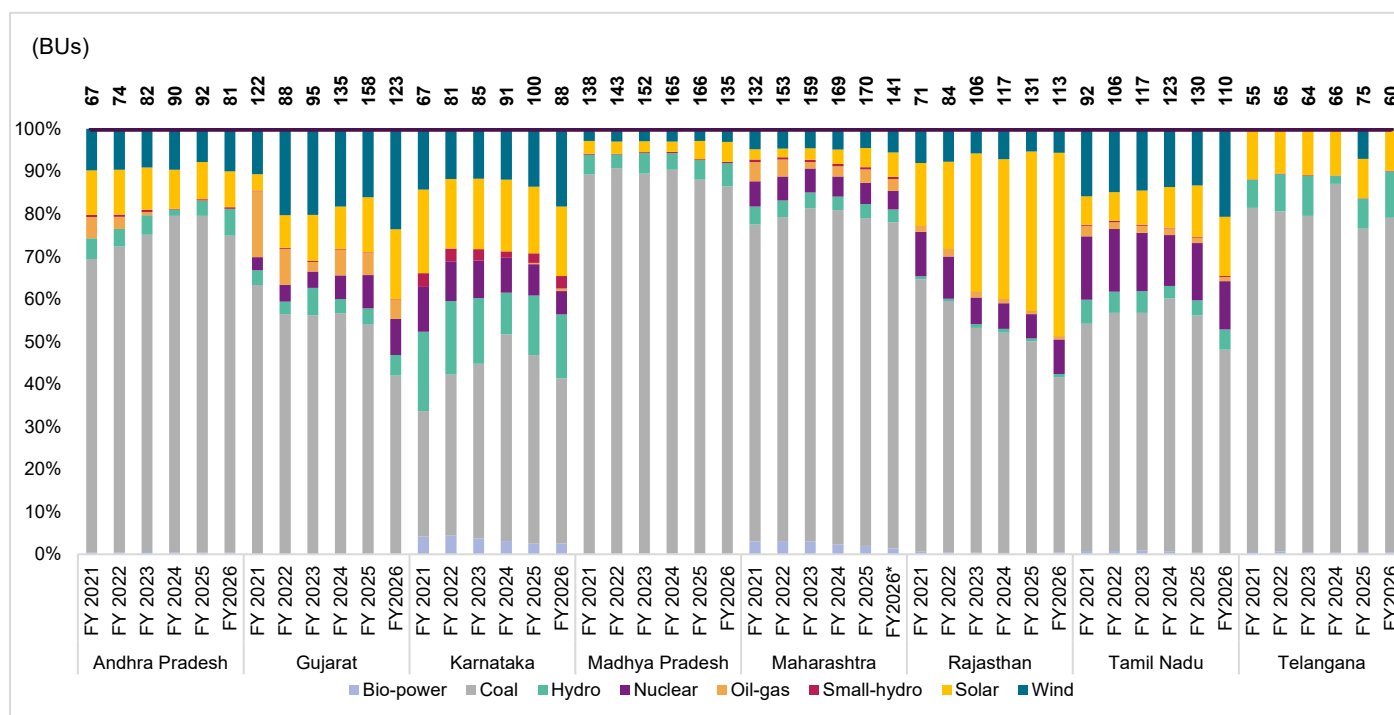
The rapid economic development, urbanisation and rising temperatures have exponentially increased the power demand in India. Overall generation in the country hit 1,848 BUs in fiscal 2026 which is a ~35% increase from 1,373 BUs in fiscal 2021. To meet the increased demand, coal has been the preferred source due to the economic advantage and to maintain grid stability.

In most states, the share of coal has increased to meet the demand, except in Rajasthan where the overall generation increased by 68% between fiscal year 2021 and 2025 but the share of coal declined from ~64% in FY 2021 to ~50% in fiscal 2025 owing to the rapid increase in solar power generation from 10 BUs to 49 BUs. In Gujarat, the share of

solar and wind increased steadily over the last 5 years, but the share of coal dropped in fiscal 2022 and 2023 from fiscal 2021 levels to bounce back again in fiscal 2024 and 2025.

Solar and wind generation in Andhra Pradesh, Karnataka, Madhya Pradesh, Maharashtra, Tamil Nadu and Telangana are increasing but coal still dominates in these states.

Figure 44: Trend of renewable energy penetration in key states



Source: ICED Niti Aayog, Crisil Intelligence

Note- FY 2026 data for coal, oil-gas, nuclear, hydro, wind and solar is till January 2026.

3.3 Assessment of key policies and regulations impacting RE IPP business in India

3.3.1 Key policies and regulations by the central government

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 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 mandate DISCOMs and industries to procure a minimum share of their electricity from renewables, driving demand for PPAs and open access projects. New tenders such as Round-the-Clock (RTC), Hybrid, and Firm & Dispatchable Renewable Energy (FDRE) are reshaping the market by requiring integration of battery storage and hybrid energy sources. Regulations like the General Network Access (GNA) and Deviation Settlement Mechanism (DSM) ensure smoother grid integration of renewables, while the evolving Green Hydrogen and Carbon Trading Frameworks are opening new revenue opportunities for IPPs. However, challenges such as DISCOM payment delays, land acquisition hurdles, and evolving open access charges continue to impact business models. As policies evolve, IPPs must navigate regulatory shifts strategically to remain competitive in India's fast-growing renewable energy sector.

The table below provides snapshot of key polies and how they impact the RE IPP business in India.

Table 6: Summary of key policy and regulations implemented by Gol and their impact

Sr. No.	Policy	Brief about the Policy & Key mandates	Impact on RE IPPs	Key monitorables
1	Renewable Purchase Obligations (RPOs)	Mandates that DISCOMs, captive power plants, and open access consumers procure a minimum percentage of power from renewables. The revised RPO trajectory sets a target of 43.33% by 2030 , including specific obligations for solar, wind, and energy storage (4.33%) . In 2024, the government brought the RPO trajectory under the ambit of the Energy Conservation Act to give it statutory status and make it binding and impose stiffer penalties provisions for non-compliance.	Increases demand for RE projects; encourages hybrid and storage-integrated solutions; enhances long-term PPA opportunities and sector growth.	RPO compliance level, penalties for non-compliance.
2	Renewable Energy Certificates (REC) Policy	Market-based mechanism enabling obligated entities to meet RPOs through the purchase of RECs instead of direct RE procurement. Recent changes include perpetual validity of RECs , removal of floor and forbearance prices, and quarterly trading sessions.	Enhances financial viability for RE projects without PPAs; provides flexibility in monetization of green attributes; increases liquidity in REC markets.	REC trading volume, price stability , participation of DISCOMs, industries, and open access consumers.
3	Must-Run Status for RE Plants	Ensures priority grid dispatch for renewable energy plants, meaning RE power cannot be curtailed except for grid security reasons. However, enforcement remains a challenge, with some states curtailing RE power despite the policy.	Ensures stable revenue and grid priority, but enforcement gaps can lead to occasional curtailment risks, impacting project returns.	Curtailment trends , enforcement by regulatory commissions, state-wise adherence.
4	Pooling of Renewable Tariff Mechanism	The Ministry of Power revised the Electricity Rules, 2002 , to introduce a pooling mechanism for renewable energy projects connected to the inter-state substations (ISTS). The objective was to harmonise power tariffs across a pool of projects, ensuring a more stable and predictable pricing environment. The government has created separate pools for different technologies/project types, including solar, wind, solar-wind hybrid, hydro, RTC power, peak power, and firm power. A weighted average tariff is calculated for each pool, based on the tariffs of individual projects within that pool.	The change is positive for the developers as it diversifies their offtake risk and significantly reduces the risk of tariff renegotiation and project cancellation.	Implementation timeline , DISCOM adoption, tariff competitiveness with conventional sources.

Sr. No.	Policy	Brief about the Policy & Key mandates	Impact on RE IPPs	Key monitorables
5	Green Energy Corridors (GEC)	Government-backed initiative aimed at developing transmission infrastructure for large-scale RE integration. Phase II targets 20 GW RE evacuation capacity across key renewable-rich states, with funding support from the Central Government and KfW (Germany) .	Reduces curtailment risk; improves transmission infrastructure; supports large-scale RE projects by addressing grid bottlenecks and evacuation challenges.	Project execution status , fund disbursement, transmission network readiness, capacity commissioned.
6	Renewable Energy Zones (REZs)	Identifies high-potential areas for solar and wind energy development with dedicated transmission planning and infrastructure to facilitate faster project execution. MNRE and CEA have mapped 66.5 GW of REZ potential , with phase-wise development planned.	Eases land and transmission constraints; facilitates large-scale project clustering; attracts investors by reducing development risks and ensuring grid connectivity.	Land acquisition progress , transmission evacuation planning, RE capacity addition in identified zones.

Source: Policy documents, Regulations by MoP, MNRE etc. Crisil Intelligence

RPO to support RE capacity additions; strict enforcement - a key monitorable

As per the Electricity Act, 2003, SERCs are required to fix the purchase of a minimum percentage of electricity from renewable energy sources out of total electricity consumption (excluding hydro) for obligated entities – discoms, open access consumers and captive power users – in the state. The RPO could be met by purchase of renewable energy or through purchase of renewable energy certificates (RECs). In the event of default by an obligated entity in any fiscal, SERCs may direct the obligated entity to pay a penalty or to deposit an amount determined by the relevant SERC, into a fund to be utilised for, among others, the purchase of RECs.

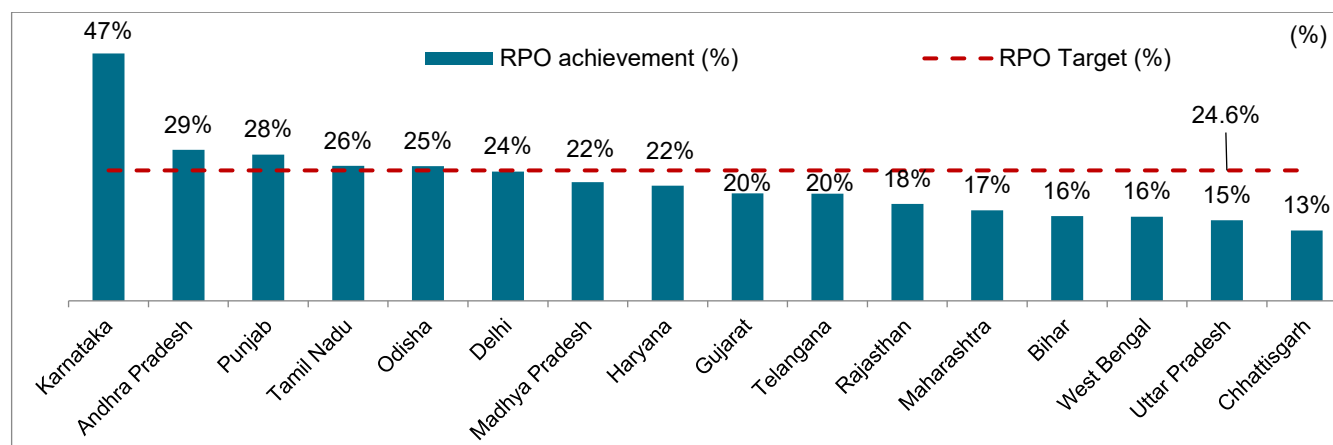
In October 2023, the MoP revised its RPO target from fiscal 2025 to 2030 and omitted ESO from the RPO category. In this RPO notification, MoP added a category for distributed renewable energy which would be met only from the projects that are less than 10 MW. Wind RPO component is for the new wind projects commissioned after 31st March 2024 and hydro component shall be met only by energy produced from Hydro Power Projects (including Pump Storage and Small Hydro Projects), commissioned after 31st March 2024. The older wind projects, all solar projects and other RE projects would come under “Other RPO” component.

Table 7: RPO targets by MoP notified in October 2023

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

Source: Ministry of Power, Crisil Intelligence

While RPOs have helped drive RE capacity additions, lack of strict enforcement has resulted in non-uniform RPO compliance across states. Going forward, it is critical that strict enforcement across states is ensured by the respective SERCs.

Figure 47: RPO compliance status across states for FY2023


Source: CEA, State discom tariff orders, Crisil Intelligence

To fulfil state RPO targets, as per respective trajectories, there has been increased tendering by states like Maharashtra, Gujarat, Uttar Pradesh, Madhya Pradesh, Punjab under their state schemes allocated over fiscals 2018-2023. In addition, any excess unit generated by the obligated entity, i.e., over and above its obligations, would be utilised by discoms to meet their solar RPO targets.

The overall RPO compliance in majority of the states has been more than 70% in fiscal 2023. This is mostly on account of the over-achievement of existing RPO targets by a few states such as Karnataka, Andhra Pradesh, Tamil Nadu, Punjab which have seen significant RE consumption. The hydro rich states such as Sikkim, Himachal Pradesh, Uttarakhand have registered over two times of the RPO target set by MoP for fiscal 2023.

In 2024, the government brought the RPO trajectory under the ambit of the Energy Conservation Act to give it statutory status and make it binding and impose stiffer penalties provisions for non-compliance.

(i) REC Mechanism

REC is a market-based instruments that facilitates RPO compliance by obligated entities which include discoms, captive power plants & open access consumers. The REC mechanism facilitates RPO compliance by obligated entities which include discoms, captive power plants & open access consumers. It is one of the simplest ways for small, obligated entities, such as captive power plants / open access consumers to comply with RPO regulations and to those C&I consumers who are committed to 100% energy consumption from green sources.

As of October 2023, a revised trading framework has been introduced, featuring two key changes. Firstly, the trading frequency has been increased to twice a month, allowing for more frequent buying and selling of RECs. Secondly, RECs have been made technology-agnostic, meaning there is a single trading process and price discovery for all RECs irrespective of technology.

Over the last 2 years, about ~68 million RECs have been issued, of which over 36 million RECs remained unsold. The total unsold RECs are about 43 million since inception. The average prices have fallen from Rs. 1,000 per REC in April 2023 to below Rs 354 per REC in March 2025. However, the price of RECs fell to its lowest ever Rs 110/ REC (Rs 0.11/ kWh) in October 2024 due to supply overhang. Strict implementation of RPOs and stiffer penalties are expected to provide the required nudge to RECs market.

A combination of factors including ambitious targets, strict implementation, and imposition of stiffer penalties for non-compliance is anticipated to provide the necessary growth impetus to the RECs market.

(ii) Must-run status for RE generation partly offsets operational risk

Power is scheduled on a day-ahead basis and the same is then dispatched by load dispatch centres under the merit order dispatch mechanism by prioritising the lowest-cost sources. Given the infirm nature of RE coupled with high RE tariffs, scheduling and dispatching RE would have been a challenge.

To address this issue, the Indian Electricity Grid Code, 2010, exempted RE from the merit order dispatch mechanism and scheduling regulations and provide (except biomass power plants with installed capacity of 10 MW and above) must-run status. This ensures offtake of RE sources and does not allow its curtailment unless it causes any grid stability issue. However, the Grid Code does not provide for any remedy for the failure of a procurer to schedule power from must-run power plants apart from grid safety/technical constraints.

Hence to resolve such issues the MoP notified Electricity (Promotion of Generation of Electricity from Must-Run Power Plant) Rules, 2021 which are applicable to all RE projects. RE projects including but not limited to wind, solar, wind-solar hybrid, hydropower sources, must be considered a must-run project as per the rules and the power from these projects must not be curtailed. The Rule provides monetary relief for any curtailment of the generation of must-run power plants by the procurer, regardless of whether it arises out of grid safety or technical constraints.

The must-run status has played a crucial role in partly offsetting operational risk and facilitating growth of the RE sector in India.

(iii) Pooling of renewable tariffs

The Ministry of Power revised the Electricity Rules, 2002, to introduce a pooling mechanism for renewable energy projects connected to the ISTS. The objective was to harmonise power tariffs across a pool of projects, ensuring a more stable and predictable pricing environment. The government has created separate pools for different technologies/ project types, including solar, wind, solar-wind hybrid, hydro, RTC power, peak power, and firm power. A weighted average tariff is calculated for each pool, based on the tariffs of individual projects within that pool.

The pooling mechanism will be dynamic, with projects being added to each pool over a three-year period, as new auctions are completed. After five years, the pool gets frozen, and a new pool is created for future auctions. DISCOMs are required to specify the amount of power they wish to purchase from a particular pool and commit to paying the weighted average tariff of that pool for the remaining PPA life of the respective projects. The introduction of the pooling mechanism is designed to address the issue of DISCOMs "cherry-picking" projects with low tariffs, which has led to auction cancellations and slowed sector progress in the past. By introducing a dynamic pooling system, the government seeks to reduce tariff volatility, encourage stable demand, and foster a predictable market environment.

This will help to mitigate the impact of tariff fluctuations caused by changes in equipment costs, taxes, interest rates, or tender conditions. The change is positive for the developers as it diversifies their offtake risk and significantly reduces the risk of tariff renegotiation and project cancellation.

(iv) National Wind-Solar Hybrid Policy 2018

The Wind-Solar Hybrid Policy 2018, introduced by the MNRE, aims to promote the optimal utilization of transmission infrastructure and land by encouraging the co-location of wind and solar projects. The policy allows both new hybrid plants and the hybridization of existing projects to enhance capacity utilization. It provides for incentives such as concessional transmission charges, waiver of ISTS for a specified period, and priority grid access. The policy also defines CUF requirements, allowing wind and solar components to be integrated in different ratios based on site-specific resource availability.

For RE IPPs, the Wind-Solar Hybrid Policy creates new avenues for higher energy generation per unit of land and transmission infrastructure, improving project economics. The hybrid model enhances grid stability by reducing the intermittency of single source RE generation, making such projects more attractive for RTC and firm power tenders. However, challenges include resource assessment complexities, hybrid project financing, and policy alignment at the state level. Leading RE IPPs are increasingly integrating storage solutions (BESS) with hybrid plants to align with emerging tender requirements such as FDRE and RTC supply, which demand higher reliability and flexibility. ***The policy has thus played a crucial role in shaping the next phase of India's renewable energy transition by encouraging diversified and optimized generation portfolios.***

(v) Competitive bidding guidelines

The Competitive Bidding Guidelines for the Renewable Energy Sector, issued by the MoP and the MNRE, establish a transparent and standardized framework for the procurement of power from renewable energy sources through auctions. These guidelines apply to solar, wind, hybrid, and storage-based projects and outline key aspects such as bid structure, tariff determination, PPA tenure (typically 25 years), payment security mechanisms, force majeure provisions, and termination clauses. Recent amendments include stricter eligibility criteria, bidding timelines, bidding structure, more stringent technical requirements, penalty and compensation provisions, extension in SCOD for events that have been hampering commissioning, stipulate some form of state government guarantee, and ease liquidity in the sector by way of introducing alternative payment security mechanisms. Additionally, these guidelines emphasize risk allocation, performance guarantees, and financial closure timelines, ensuring that only serious and well-capitalized developers participate in tenders.

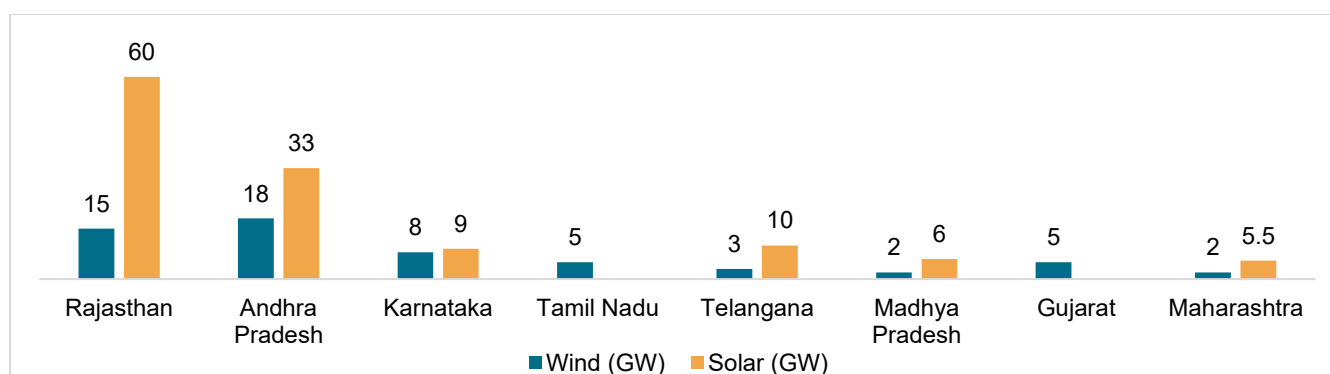
For RE IPPs, competitive bidding has led to increased market efficiency, lower tariffs, and improved investor confidence. The push towards hybrid and storage-based projects is reshaping the business strategies of leading RE IPPs, requiring them to integrate BESS and optimize CUF. **The guidelines have also improved PPA bankability and payment security, making the sector more attractive for institutional investors and long-term financiers. As the renewable energy market matures, these bidding norms continue to evolve towards ensuring a balance between affordability for DISCOMs and financial viability for developers, influencing how RE IPPs structure their portfolios and investment decisions.**

(vi) Green energy corridors and RE zones to enable smooth RE integration

The Green Energy Corridor (GEC) projects and Renewable Energy Zones (REZs) are critical infrastructure initiatives designed to facilitate the large-scale integration of renewable energy into the national grid. The GEC initiative, implemented in two phases, focuses on strengthening intra-state and inter-state transmission networks to evacuate power from renewable-rich states like Rajasthan, Gujarat, Tamil Nadu, Karnataka, and Madhya Pradesh. Phase I targeted 33 GW of RE evacuation, while Phase II aims to integrate an additional 20 GW by 2026 with funding support from the Government of India and international lenders like KfW (Germany). Under Phase-II, MNRE has also sanctioned implementation of 13 GW of RE Projects along with 12 GWh BESS in Ladakh in February 2024.

Complementing this, REZs identify high-resource potential areas for wind and solar development, ensuring dedicated transmission planning and streamlined land acquisition to accelerate RE deployment. MNRE/SECI have identified REZs totaling 181.5 GW for likely benefits by the year 2030. These REZ's are located in eight states as detailed below:

Figure 48: Potential RE zones identified by MNRE/SECI



Source: CEA: Transmission System for Integration of over 500 GW non fossil fuel-based Capacity by 2030

For RE IPPs, these initiatives mitigate curtailment risks, reduce grid bottlenecks, and enable large-scale project viability. The structured transmission planning under GEC ensures that developers can confidently bid for tenders without the risk of inadequate evacuation infrastructure. Additionally, the REZ framework simplifies site selection and project execution by pre-identifying feasible locations. However, challenges such as delays in transmission infrastructure execution, land acquisition hurdles, and coordination between central and state agencies remain key concerns. **Leading RE IPPs are aligning their expansion strategies with GEC and REZ development timelines,**

particularly in hybrid, RTC, and storage-integrated projects, ensuring their participation in complex tenders that require firm and dispatchable power. These initiatives are therefore foundational in scaling up India's renewable capacity and transitioning towards a more reliable and efficient clean energy ecosystem.

(vii) Amendments in the Electricity Act 2003 and Tariff Policy

The Electricity (Amendment) Rules, 2022, the **Late Payment Surcharge (LPS) Rules, 2022**, and the **Electricity (Amendment) Rules, 2024** are key regulatory reforms aimed at improving payment discipline, market efficiency, and investment security in India's power sector. The Electricity (Amendment) Rules 2022 introduced provisions for open access, enabling greater participation from C&I consumers in the renewable energy market, thereby expanding demand for IPP-led open-access projects. **The LPS Rules, 2022** mandated strict timelines and penalties for DISCOMs failing to make timely payments to power producers, reducing the risk of payment defaults and improving cash flow certainty for RE IPPs. The introduction of the LPS Rules in 2022 has led to a significant improvement in the payment landscape for generators. The outstanding payables to central government power generators have decreased substantially, dropping from a higher amount of INR 453 billion to INR 222 billion within a span of just 1.5 years. By December 2024, the payables had further reduced to a 6-year low of INR 181 billion, marking a notable achievement in improving the payment discipline of DISCOMs.

The **Electricity (Amendment) Rules, 2024** further strengthened contract enforcement, transmission access, and grid integration for renewable projects, ensuring smoother implementation of hybrid, storage, and RTC tenders. **These reforms collectively enhance the financial viability of RE IPPs, encourage investment in long-term projects, and reduce counterparty risk, making the sector more attractive for institutional investors and global players. However, effective implementation and strict enforcement at the state level remain critical to realizing their full impact.**

(viii) Other Rules notified by the government over the period

- **Electricity (Timely Recovery of Costs due to Change in Law) Rules, 2021-** The Rules would be applicable to gencos and transcos. The timely recovery of the costs due to a change in law is crucial for maintaining the financial viability of the project. At present the pass through under change of law takes a lot of time, forcing the drying of the investment in the power sector. In order to ensure timely recovery of recurring/ non-recurring costs arising due to change in law, the rule is expected to provide relief available to the affected party, irrespective of a specific change in law clause in the PPAs.
- **The Electricity (Rights of Consumers) amendment rules, 2021** give consumers of electricity right to set up renewable energy generation unit either by themselves or through third party service providers. The consumers can set up solar rooftop systems up to 500 kW under net-metering and gross-metering for loads above 500 kW. This is expected to boost open access transactions by corporate consumers.
- **The Electricity (Rights of Consumers) amendment rules, 2023** introduced Time of Day (ToD) Tariff mechanism wherein the tariff during solar hours of the day shall be 10%-20% less than the normal tariff, while the tariff during peak hours will be 10% - 20% higher. This would be applicable for C&I consumers having maximum demand of 10 kW and above, from 1st April 2024 and for all other consumers except agricultural consumers, latest from 1st April 2025.

3.3.2 State level policies impacting RE IPP business

Based on the MNRE's WSH policy, governments of RE-rich states have also introduced their own WSH policies. Gujarat was the first to come up with such a policy in 2018. Other states such as Rajasthan, Andhra Pradesh, and Karnataka followed. This has helped set up open access WSH projects and encouraged corporates to procure RTC power from such projects. These policies provide clarity in terms of various provisions, such as RPO, banking, settlement period, various waivers and incentives, applicability of transmission and wheeling charges and waiver in electricity duty etc.

Table 8: WSH policy comparison for select states

Parameter	MNRE	Gujarat*	Andhra Pradesh	Rajasthan	Karnataka
Policy name	National Wind Solar Hybrid Policy, 2018	Tariff Framework for Wind-Solar Hybrid Projects, 2024	Integrated Clean Energy policy, 2024	Integrated Clean Energy policy, 2024	Renewable Energy Policy 2022-2027
Issued in	May 2018	February 2024	October 2024	December 2024	April 2022
Capacity targets	No wind solar hybrid specific target	No wind solar hybrid specific target	No wind solar hybrid specific target	No wind solar hybrid specific target	No wind solar hybrid specific target
RPO	RPO can be fulfilled based on relative power procured from each source	No hybrid specific RPO	No hybrid specific RPO	No hybrid specific RPO	No hybrid specific RPO
Banking	As per MOP GOAR	Monthly banking- INR 1.50/kWh banking charges	Monthly banking- 8% banking charges	Annual banking- 8% banking charges	Monthly banking- 8% banking charges
Cross subsidy surcharge	As per MOP GOAR	25% CSS waiver if green attributes are surrendered by consumers	No exemption	No exemption	No exemption
Additional surcharge	As per MOP GOAR	25% AS waiver if green attributes are surrendered by consumers	No exemption	No exemption	No exemption
Transmission and wheeling charges	100% exemption from connectivity/ transmission for hybridization of existing plants	No waivers /concession	50% exemption in transmission and wheeling charges for new projects developed within the state	No exemption	No exemption
Electricity duty	-	No exemption	No exemption	No exemption	No exemption

*Gujarat has issued a new RE Policy in 2023 which includes hybrid projects. Thereafter a Tariff Order for procurement of WSH power was issued in March 2024. The aforementioned provisions are as per GERC's WSH Tariff Order

Source: MNRE, respective state policy documents, Crisil Intelligence

3.4 Business models adopted by Renewable IPPs

3.4.1 Overview of business models adopted by the leading RE IPPs

Leading Renewable Energy 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. The C&I offtake provides higher tariffs utility-scale offtake. 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 at 206 GW (solar and wind) as of March 2026. The installed solar capacity ~ 150 GW which is split in ground mounted, rooftop, hybrid component and off-grid by 77:17:2:4. Total wind capacity was ~ 56 GW.

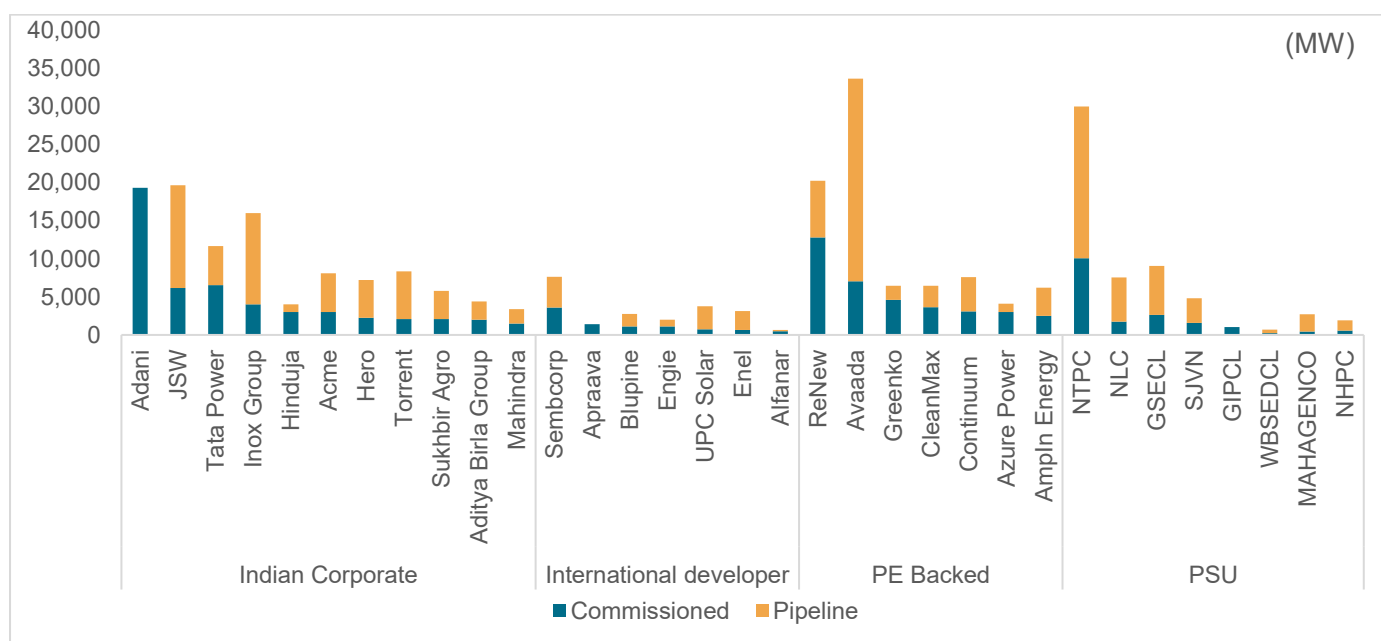
Rooftop systems can be installed using either CAPEX or OPEX models. In the OPEX model, the developer owns the rooftop solar system and installs it on the consumer's rooftop. It requires no upfront capital to be invested by the

consumer. Under this model any technological, operational and execution risk of the project is on the developer, and the consumer only pays for the power generated by the system, at a predetermined tariff. On the other hand, under the CAPEX model, the rooftop solar system is owned by the consumer, who bears the upfront cost of purchasing and installing the system. It is available to all consumers, irrespective of size and credit rating, subject to investment capability without having to sign any long-term PPAs. Within rooftop solar capacity addition, CAPEX model has become the preferred route with ~90% share in total capacity addition, while the share of the OPEX model falling to 7% in 2024 compared with 38% in 2019. Corporates prefer CAPEX projects due to easy access to financing and attractive loan options with low interest rates. The cost of power is also low in CAPEX model because of the incentives like GST credit and accelerated depreciation.

3.4.2 Key players in the Renewable IPP market

The renewable energy sector has witnessed a surge in new entrants over the past few years, driven by improving market fundamentals and a liberalized central government policy stance. This increased interest has been further fueled by higher corporate demand and high RPO targets. As a result, the project development business has become commoditized, with low entry barriers and easy access to capital, attracting a diverse range of players. Indian corporates, seeking to diversify from conventional power, have entered the renewable space, leveraging their strong financial and operational capacity, as well as their high-risk appetite, to navigate challenges such as state offtake, land acquisition, and policy uncertainty. Additionally, private equity-backed companies have emerged as highly active and aggressive bidders, driven by investor pressure and exit timelines. Meanwhile, PSUs have also shown strong interest in the renewable sector, motivated by pressure from the central government and a slowdown in their core businesses, such as thermal power and coal mining. In contrast, international developers have adopted a more cautious approach, carefully balancing risk, and rewarding in line with their experience in other countries.

Figure 49: Leading project developers (As of March 2026)



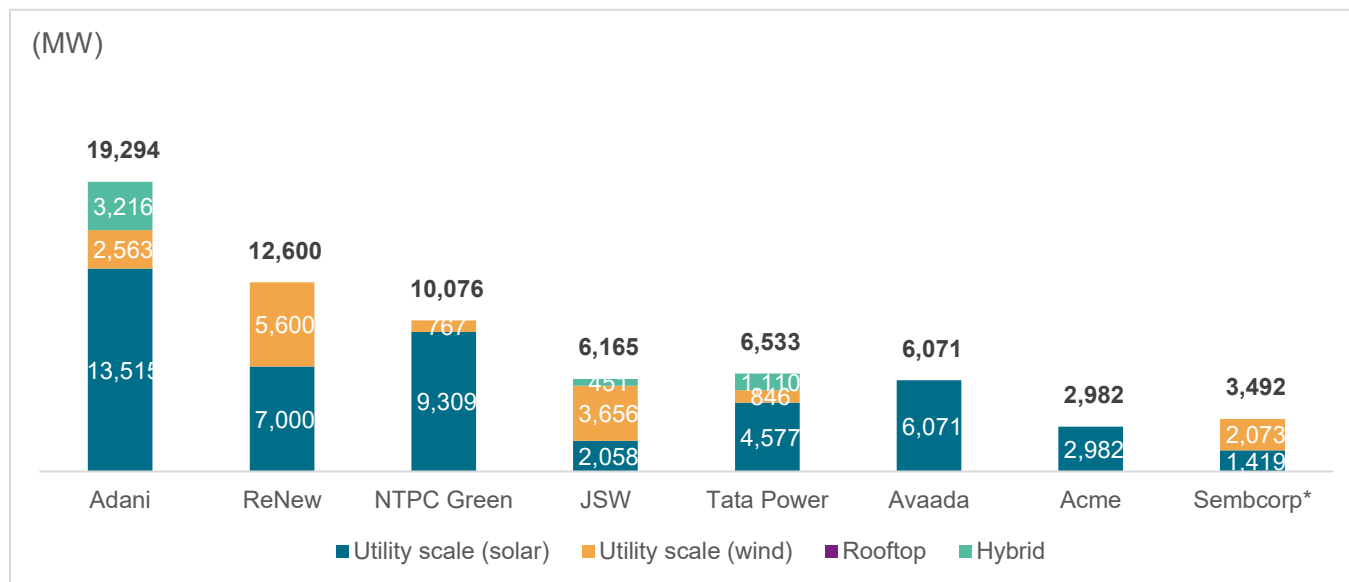
Source: Company websites, investor presentations, rating documents, Crisil Intelligence

3.4.3 Snapshot of business models adopted by leading RE IPPs

The top renewable energy players in India have demonstrated a strategic shift toward a diversified portfolio-based business model. The figure below highlights that while the utility scale projects remain as the key focus area for all leading renewable IPPs in India, investment in open-access and rooftop solar solutions is becoming more commonplace, signaling a move toward a more balanced and resilient business model. ReNew's substantial open-access capacity and Tata Power's diversified mix, including rooftop solar, indicate a strong emphasis on catering to C&I consumers seeking decentralized energy solutions. Companies like JSW have smaller but well-diversified

portfolios, ensuring market adaptability. The push toward portfolio diversification reflects the industry's response to evolving policy dynamics, corporate sustainability commitments, and growing demand for flexible renewable energy solutions beyond traditional utility-scale projects. This approach not only mitigates risks associated with single-segment exposure but also enhances long-term revenue stability.

Figure 50 : Top 10 renewable energy players operational capacity in India as of March 2026



*Sembcorp as of December 2025; Source: Crisil Intelligence

3.4.4 Emergence of new business models

In recent years, India's renewable energy sector has witnessed the emergence of complex tenders such as FDRE, RTC, and Hybrid tenders, aimed at addressing the intermittency challenges of renewables and ensuring grid reliability. These tenders require a mix of solar, wind, BESS and even pumped storage solutions to provide firm power supply as per predefined schedules.

WSH Projects: In May 2018, the Ministry of Power introduced the Wind-Solar Hybrid Policy to establish a framework for promoting large grid-connected wind-solar PV hybrid systems. The policy aims to enable optimal and efficient utilization of transmission infrastructure and land, reduce variability in renewable power generation and improve grid stability. It also seeks to foster the adoption of new technologies, methods, and innovative approaches for the combined operation of wind and solar PV plants.

Hybrid projects generally achieve a higher CUF compared to standalone wind or solar projects. This is because wind projects typically operate optimally during the morning and night, complementing solar projects, which achieve peak generation during the daytime. According to the revised bidding guidelines, the rated power capacity of either wind or solar in such hybrid projects must constitute at least 33% of the total contracted capacity. These guidelines also permit the solar and wind projects to be located either at the same site or at different locations. To meet energy commitments under PPAs, project developers often install renewable energy capacities exceeding the contracted capacity under the hybrid scheme.

FDRE Projects: In June 2023, the Ministry of Power issued guidelines for the procurement of firm and dispatchable power from grid-connected renewable energy projects that incorporate energy storage systems. These guidelines defined “firm and dispatchable power” as a specific power profile configuration outlined in the request for selection. This profile must be met by power generated from renewable energy sources and can include configurations such as reliable peak power, round-the-clock renewable energy with firm delivery of power at the rated capacity during any hour of the day based on demand, load-following power as specified by DISCOMs or renewable energy projects providing firm power delivery during fixed hours as required by discoms.

The guidelines also expanded the scope of renewable energy to include solar power generation systems, wind power generation systems, wind-solar hybrid systems or other renewable energy resource-based generating systems, either individually or in combination with energy storage systems.

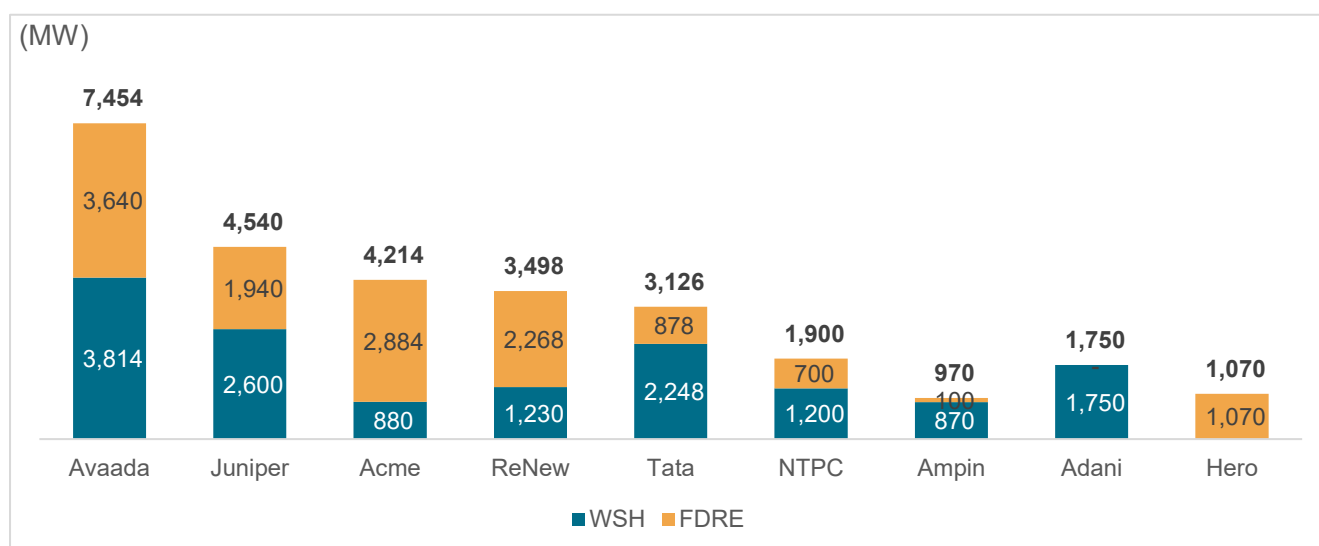
Energy generated from solar and wind projects is inherently intermittent and unreliable, resulting in lower capacity utilization. FDRE addresses these challenges through the following measures:

- supplying firm power as per demand specified by utilities; and
- achieving a higher CUF.

Under the FDRE model, project developers are required to ensure the delivery of renewable energy in a firm and dispatchable manner, aligned with the demand profile(s) specified by the purchasing entities. To provide firm power, developers must incorporate an energy storage system, such as a BESS or a pumped hydro storage system, which is charged using renewable energy and discharged as needed to match the power requirements of the buyers.

Additionally, to meet energy commitments under PPAs, developers typically install renewable energy capacities exceeding the contracted capacity to ensure the required level of firm power supply.

Figure 51: Hybrid and FDRE bids won by key players for period between Apr 2021 – March 2026



Note: FDRE bids including Peak power supply tenders

Source: Crisil Intelligence

Leading IPPs are adapting to this shift by integrating multi-technology portfolios, optimizing dispatch strategies, and leveraging energy storage and hybrid configurations to meet stringent tender conditions. Some of the key players such as Avaada, Acme, Juniper, ReNew, Adani, have been actively participating in the complex RE tenders. The transition to these complex models has driven IPPs to explore advanced forecasting, real-time energy management systems, and financial structuring with blended tariffs to ensure cost competitiveness. As policy frameworks evolve and the demand for reliable green power grows, IPPs are increasingly aligning their strategies to participate in these tenders, securing long-term PPAs with DISCOMs and corporate buyers, and positioning themselves as providers of stable and dispatchable renewable energy solutions. The declining cost of battery storage, with capital costs now ranging from INR 1.6-2 crore/ MWh, is further supporting development of hybrid projects. Battery prices have been coming down at a rapid pace in recent years due to increasing manufacturing capacity in China and exemption on custom duty for lithium carbonate, a key ingredient in manufacturing li-ion batteries.

A key factor in executing these complex projects is the supply chain for advanced energy storage, hybrid project components, and digital energy management systems. Unlike traditional solar or wind projects, RTC and FDRE tenders demand reliable access to battery storage solutions, long-duration energy storage (LDES), and sophisticated

forecasting technologies. This has prompted IPPs to forge long-term partnerships with global technology providers, battery manufacturers, and energy management software developers to ensure cost competitiveness and operational efficiency. Additionally, vertical integration strategies, including captive manufacturing for solar modules and in-house storage solutions, are being explored to reduce dependency on volatile global supply chains.

This shift signals a transformation in the traditional RE IPP business model, moving away from single-technology utility-scale projects toward integrated, multi-asset energy solutions that combine renewables, storage, and real-time energy management. As India progresses toward its 500 GW non-fossil fuel capacity target, IPPs that successfully adapt their business models, strengthen their supply chain strategies, and optimize their energy delivery mechanisms will be best positioned for long-term success in the evolving energy landscape.

3.5 Overview of utility scale market

The utility-scale renewable energy market in India is witnessing robust growth, driven by aggressive capacity additions and strong policy support. Central agencies such as SECI, NTPC, SJVN, NHPC and direct procurement by DISCOMs have played a pivotal role in streamlining long-term PPAs, ensuring revenue stability and enhancing project bankability. Over recent years, India has seen significant capacity additions particularly in solar and wind through competitive bidding processes that have led to lower tariffs and improved cost competitiveness. With competitive tariffs discovered through auctions and accelerating declines in the cost of storage technologies, renewable projects are becoming more cost-effective. Key factors fueling this market include declining technology costs, regulatory incentives like ISTS waivers and RPO mandates, and the availability of long-term PPAs that attract institutional investors. As these elements converge, the utility-scale market not only strengthens India's clean energy transition but also establishes a resilient framework for sustainable power procurement nationwide.

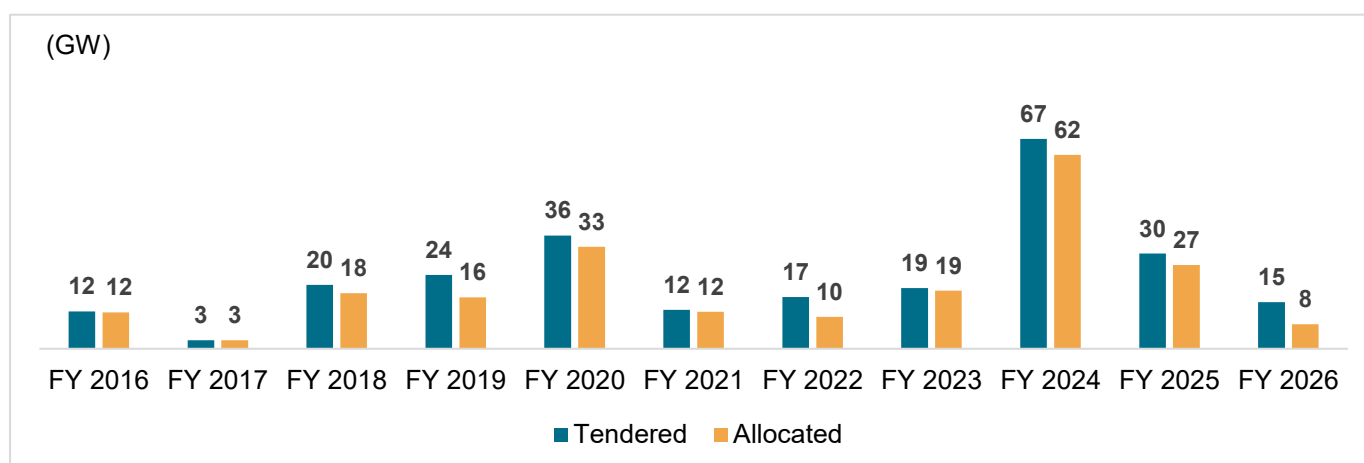
Recent trends in India's renewable energy market include a notable shift towards hybrid projects that combine solar, wind, and energy storage to provide round-the-clock power, reflecting the increasing demand for firm and dispatchable renewable energy. FDRE and RTC bids, aimed at mitigating intermittency and ensuring grid stability. Additionally, the sector is witnessing growing institutional investor participation, driven by enhanced policy support, improved financial instruments like green bonds and REITs, and stringent regulatory reforms to secure timely payments and reliable PPAs. Lastly, advancements in digital energy management and smart grid technologies are increasingly being integrated into projects to optimize operations and improve overall efficiency.

The utility-scale renewable energy market is crucial for RE IPPs as it provides stable, long-term revenue streams through secured PPAs, drives economies of scale, and reduces financing risks. This market attracts institutional investors by offering predictable cash flows and a favorable regulatory environment, which in turn facilitates technological advancements and cost reductions. With robust policy support and innovative financing models in place, the sector not only underpins India's ambitious renewable capacity targets but also strengthens the overall financial viability and competitiveness of RE IPPs, making it a cornerstone of the country's clean energy transition.

3.5.1 Review of competitive bidding mode as power procurement mode

The acquisition of new renewable power projects in India is typically determined through competitive bidding and tendering. Competitiveness in these auctions hinges on factors such as proposed pricing, technical and engineering proficiency, financial capacity, relevant experience and established track record. Utility scale has been the most preferred route for capacity addition. The tendering activity for utility scale RE projects had outpaced the government's target of 50 GW for fiscal 2024. Apart from this, over 100 GWh of standalone ESS tenders were also issued including pumped hydro storage. In FY 2025, 30 GW renewable capacity was tendered for utility scale projects, of which 27 GW was allocated. But, FY 2026 has witnessed a major slowdown in tendering and auction activity due to the lag in PPA signing of awarded projects. Of the 15 GW tendered, ~8 GW capacity has been allocated. Distribution companies have been delaying the signing of PPAs in anticipation of lower renewable energy tariffs in the future. The average allocation of tenders has been over 60% of the tendered capacity in the last four years but in the first half of FY 2026 allocation reduced to 53%.

Figure 49: Yearly tendered and allocated capacity up to March 2026



Source: Crisil Intelligence

India's renewable energy sector has primarily grown on the back of the utility-scale segment due to a combination of strong government policies, cost competitiveness, infrastructure readiness, and investor preference. The Indian government has consistently prioritized large-scale renewable projects through policy mechanisms such as solar park schemes, reverse auctions under SECI and state tenders, bidding calendar, and ISTS waivers.

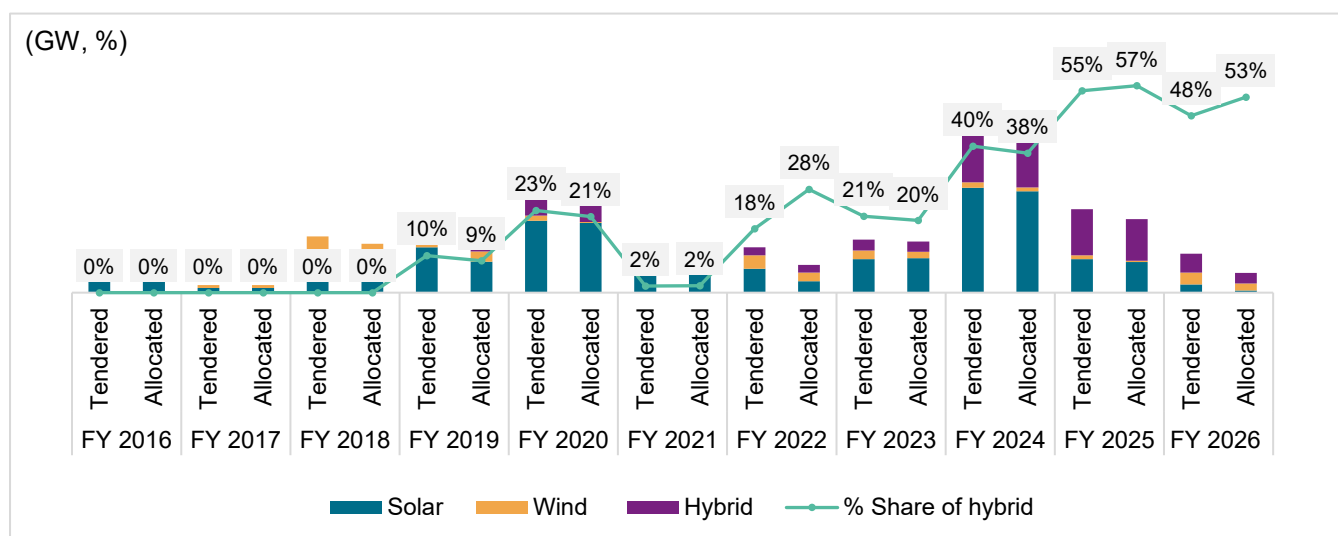
From 2016 to 2026, utility segment contributed between 65%-75% of the total renewable capacity addition. A key driver behind this growth has been the cost competitiveness of utility-scale solar and wind projects, which benefit from economies of scale. Large-scale renewable plants have consistently delivered some of the lowest power tariffs globally, with solar auction prices falling as low as Rs. 1.99/ kWh, making them highly competitive against fossil fuel-based power generation. The availability of low-cost financing from global investors, coupled with sovereign-backed PPAs, has further strengthened the bankability of these projects. Additionally, India has actively developed high-capacity transmission corridors, such as the Green Energy Corridors, to integrate large-scale renewable energy into the national grid, ensuring that utility-scale projects do not face curtailment issues.

Investor preference has also played a crucial role in the dominance of the utility-scale segment. Utility-scale projects have predictable cash flows, long-term PPAs, and scalability. In contrast, the distributed and rooftop solar segment has struggled to gain similar traction due to high upfront costs, policy uncertainties, resistance from DISCOMs, and financing hurdles. While open access segment is growing rapidly, the utility-scale model remains the dominant force behind India's renewable energy expansion. Given these structural advantages, large-scale renewable projects will continue to be the primary driver of capacity additions as India moves toward its clean energy targets.

3.5.2 Rising share of hybrid tenders

India issued over 144 GW of completed utility scale renewable energy tenders since fiscal 2022 across all technologies including complex hybrid tenders with storage. The tendering activity increased about three-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.

Wind-solar hybrid is gradually becoming the preferred renewable power source for DISCOMs as its power output is firmer and dispatchable (when complemented with storage). The share of hybrid has increased from merely 9% in FY 2019 to over 53% in allocated capacity in FY 2026. Share of vanilla solar has reduced in the total allocated capacity.

Figure 52: Increasing share of hybrid tenders in total tendered capacity


Source: Crisil Intelligence

Complexities in hybrid projects

• **Criticality of wind**

Wind-solar projects are particularly well-suited for a time-of-day tariff regime. During morning and evening peak hours, when additional tariffs are charged, wind power generation can capitalize on the higher rates. Conversely, during off-peak night hours, when tariffs are lower, wind power can still generate revenue, albeit at a reduced rate. The complementary generation patterns of wind and solar power, with wind power peaking after sunset and reaching its maximum generation late at night, allow wind projects to maximize revenue by selling power during evening peak hours when tariffs are 10-20% higher than normal.

The combined use of wind and solar technologies in hybrid systems has been shown to produce a more consistent power output, as the two resources often exhibit anti-correlated availability, thereby smoothing overall energy generation. Wind and solar energy exhibit both temporal and spatial complementarity, making them an ideal combination. Wind energy PLFs are generally higher during the high-wind season (April to September) and lower during the low-wind season (October to March). Solar energy PLFs are more stable year-round but can still be impacted by short-term conditions like cloud cover or pollution. Diurnally, wind power peaks at night and early morning, whereas solar power is highest during the day, enabling a stable and firm power supply. This complementary nature, combined with lower costs compared to storage, makes wind power a more viable option to address intermittency and complement solar power.

• **Optimal sizing**

In firm power tenders, project developers are presented with a complex array of design options, including component sizing, location, and timing, which come with associated risks. Since these tenders are technology-agnostic, developers have the flexibility to choose from multiple configurations. They can opt for a solar-heavy design with storage or a wind-heavy design with limited storage capacity to meet the tender requirements while taking considerable market exposure for surplus output. The wind-heavy designs with minimal storage are often more commercially competitive, depending on assumptions about market conditions and the potential for selling excess energy. Optimal sizing of storage is also critical. Overloading or oversizing may lead to under utilisation during the peak generation period (daytime in summer or night-time in monsoons) resulting in storage capacity remaining unutilised or idle. The size of the WSH plant differs from state to state depending on the resource availability.

Tariffs for firm power projects are intricately tied to the project design and sizing decisions made by developers. Achieving an optimal technology configuration that considers all relevant factors is a highly complex task. As a result, it is extremely challenging for developers to strike a balance between technical viability, financial sustainability, and tariff competitiveness.

- **Wind OEMs passed on risk to project developers**

Wind OEMs have sought to de-risk their business by abandoning the traditional lump-sum turnkey model, which included turbine supply, land acquisition, transmission connectivity, installation, commissioning, and O&M. Instead, OEMs are now focusing solely on manufacturing and selling turbines, leaving project developers to acquire remaining services from other contractors or perform them in-house. This shift in the value chain has led to significant market disruption, with the emergence of a new class of subcontractors and supply chains. The primary implication of this change is the transfer of execution and performance risk from OEMs to project developers. The new contractors, often small and with limited risk-bearing capacity, may not be equipped to handle the complexities and challenges associated with wind energy projects.

The consequences of this shift are far-reaching. Project developers are now caught between the pressure to maintain low tariffs and the mounting execution risks associated with managing multiple contractors and subcontractors. Any potential cost savings from this new arrangement are negligible compared to the increased risks and uncertainties. Several developers have started performing O&M activities in-house, while select developers are even seeking to make their own turbines with technology license from overseas companies to mitigate risks associated with wind supply chain

- **Lack of players in experience in both solar and wind**

Historically, RE developers have tended to specialise in either wind or solar projects, developing expertise in one area. However, the recent shift towards integrated hybrid systems has created a need for developers to expand their expertise to include both wind and solar technologies. Despite this, the wind sector has faced supply chain constraints, leading some developers to focus exclusively on solar projects. Currently, there is a limited number of players in the market that have the capability to cater to both wind and solar technologies which includes Adani, TATA Power, Inox GFL, Continuum, ReNew, CleanMax.

- **Lack of good sites**

The wind resource available at a site is fundamental to a wind power project's performance. Generally, higher average wind speeds result in greater energy generation. Hybrid projects require wind and solar plants to be co-located to inject power into the same pooling station. This means the ideal location should have good irradiation and experience high wind speeds. But such locations are hard to find, especially as major windy areas with strong grid evacuation facilities have been saturated. The preferred location for co-located solar and wind projects is usually Gujarat and Rajasthan for pan India tenders. Since wind projects can be installed at specific locations across a few RE rich states such as Gujarat, Rajasthan, Karnataka, Maharashtra, etc. and due to limited availability of high wind zones in these regions, IPPs are moving towards lower wind density sites (Type 2 and 3) in other states, that may not have adequate linked grid infrastructure, or may have a paucity of contiguous land parcels (~3 acre/MW for solar and ~1 acre/MW for wind) as required for the current scale of 200-300 MW of installations per project.

Hence, the industry demanded that wind and solar plants of a WSH project be allowed to operate from different locations. This has helped bring down tariffs owing to better plant optimization levels. The only advantage of co-location is better optimization of transmission infrastructure. However, Crisil Intelligence believes the advantage from reduced tariff (when wind and solar units are located separately) is much higher than the benefit of improved transmission capacity optimization (with co-location).

- **Grid balancing requirement poses implementation risks**

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

- **Delay in development of transmission evacuation infrastructure**

There is a limited margin available at existing/under implementation 220 kV and 400 kV bays of ISTS substations which creates bottlenecks for connecting new RE projects. The transmission projects face multiple challenges such as right of way issues, forest clearances, and supply chain constraints. Due to such challenges, the government has estimated that transmission connectivity for about 60 GW of RE capacity is expected by fiscal 2027.

- **Higher tariff**

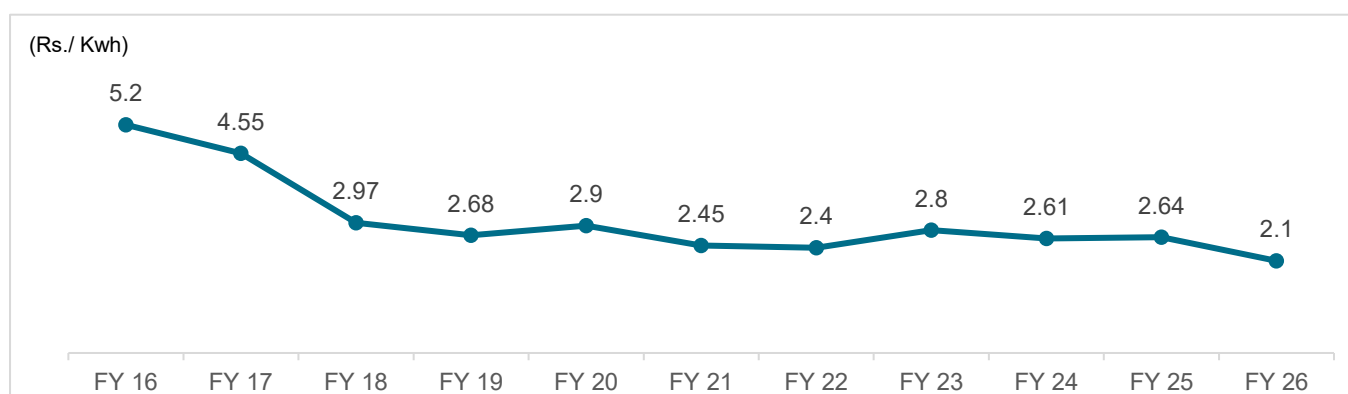
The weighted average tariff for WSH projects is Rs 3.41-3.45 per kWh higher than solar tariff, which has dropped to Rs 2.55-2.56 per kWh in recent bids, and lower than weighted average wind tariff, which has been higher at Rs 3.75 per kWh in recent bids. And although cross-subsidising costly wind power with low-cost solar power will provide some price cushion at the lower end, the pricing needs to be attractive to make WSH competitive.

3.5.3 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 ~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 Rs 2.4 - 2.6 per unit range even until fiscal 2022 when supply-side disruptions started to emerge. Weighted average tariff recorded a 16% uptick in fiscal 2023, when it rose to Rs 2.8 per unit before declining to Rs 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 ~47% in fiscal 2024. In fiscal 2025, the tariffs remained consistent with a weighted average tariff of Rs. 2.64 per unit. In fiscal 2026 the tariff dropped to Rs. 2.10 per unit.

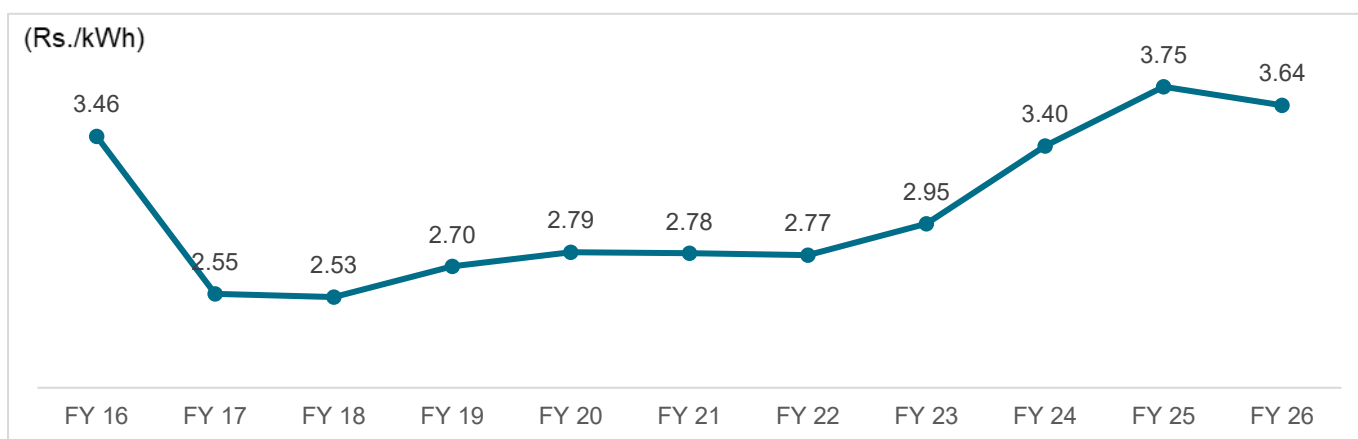
Figure 53: Weighted average solar tariff trend



Source: Crisil Intelligence

Previously, the discovered weighted average wind tariffs for competitively bid projects reached as low as at Rs 2.53-2.55 /kWh in FY 2017 and 2018 as against Rs. 3.6-3.9 per unit tariff required for earning 10-13% equity IRRs. Crisil Intelligence believes that previously projects were aggressively bid even when availability of developed land banks (availability of wind micro siting data and proximity to the transmission) with high wind density sites were not tied up prior or finalised before bidding. This has caused execution challenges for several projects in the sector, for e.g. the SECI ISTS III projects were previously not able to acquire required wind sites in the preferred region of Gujarat. This followed the cancellation or stagnation of some prominent tenders due to unviable tariffs. However, the tariff cap removal in March 2020, provided an opportunity to developers to factor in the added execution challenges along with concerns over project viability, leading to higher bid tariffs in successive auctions. Hence, wind sector power tariffs have risen steadily since 2022.

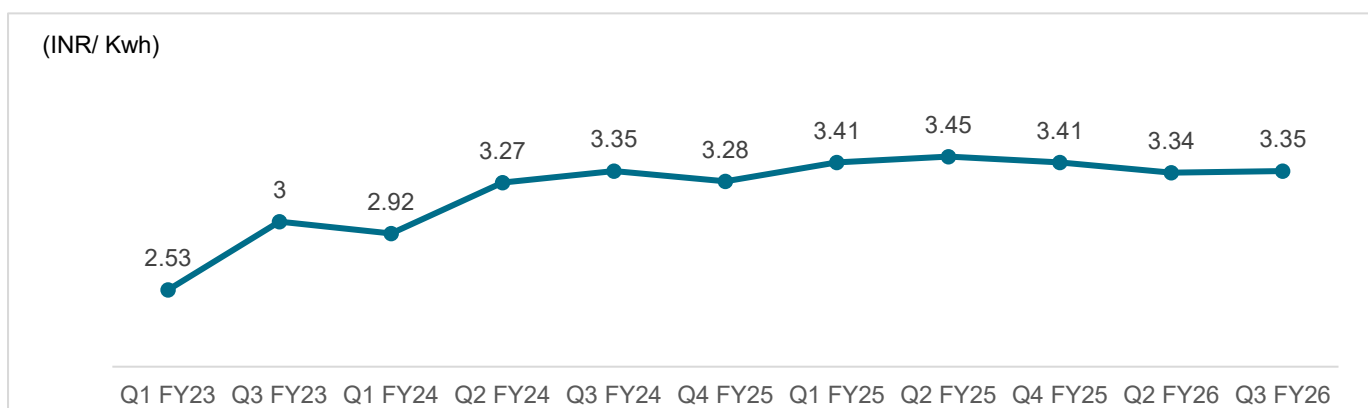
Figure 54: Weighted average wind tariff trend



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, Rs. 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 Rs. 3/kWh, lower than vanilla wind tariffs but competitive with vanilla solar tariffs.

Figure 55: Recent trend in competitively bid out wind-solar hybrid tariff (weighted average tariffs)



*No WSH tender allocated in Q1 FY26 and Q4 FY26; Source: Crisil Intelligence

3.5.4 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. Some key changes have been made

to tender structures concerning the quantum of generation available from RE sources and the ability to match peak demand.

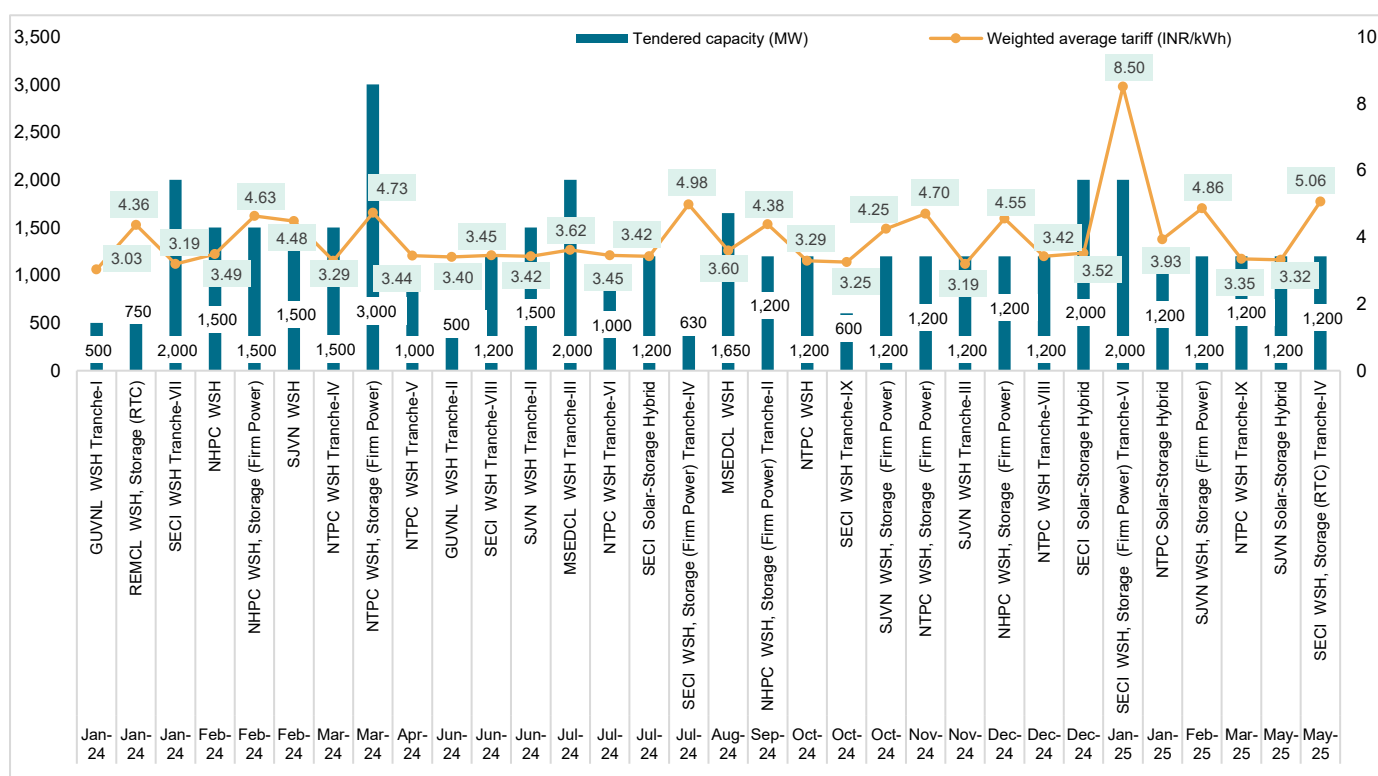
While there are multiple combinations now issued in the market some key distinctive features are as follows:

- 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.

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 Rs. 3.03/ kWh in a 500 MW wind-solar hybrid auction in January 2024, while the highest weighted average tariff recorded was 8.50/ kWh was seen in SECI's Tranche-VI 2,000 MW FDRE auction in January 2025. The weighted average tariffs for hybrid projects with storage or FDRE commitments ranged from Rs 3.42/ kWh to Rs 8.50/ 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 Rs. 7.47/ kWh, firm renewable power is cheaper, making it much more attractive for DISCOMs.

Figure 56: Tariff discovered in recent WSH tenders

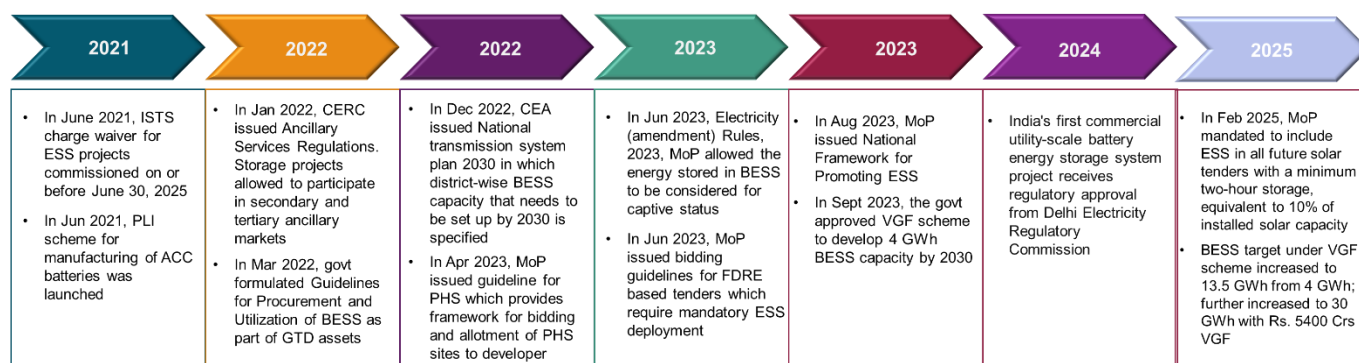


Source: Industry, Crisil Intelligence

3.5.5 Energy storage policies and regulatory landscape

Over the last 3-4 years, the government has taken several initiatives to promote energy storage through standardisation of the policy and regulatory framework by issuing guidelines, regulations, changes in bidding mechanisms, etc. The summary of key policy measures is listed below.

Figure 57: Key policy measures for storage projects



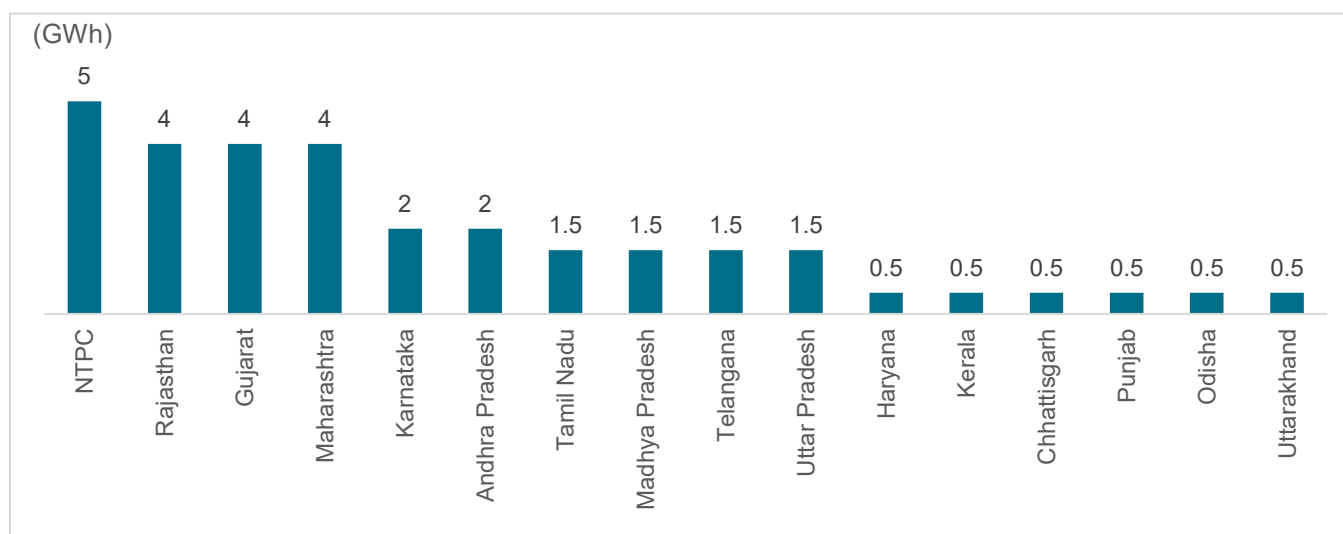
Source: MoP, MNRE, Crisil Intelligence

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

Battery energy storage projects

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

In September 2023, the government approved the VGF scheme for development of 4000 MWh of BESS capacity by fiscal 2031. In April 2025, due to a decline in battery prices, the capacity of the scheme increased to 13,200 MWh without any change in the budgetary allocation. The VGF support will be provided to the projects approved during 2023 – 2026. An initial outlay of INR 94 billion including budgetary support of INR 37.60 billion has been provided under the scheme. The VGF would be provided from fiscal 2024-26 and will be capped at 40% of the capital cost. Subsequently, in June 2025, the Central government approved addition VGF worth INR 54 billion for setting up 30 GWh of BESS. The scheme will provide financial support to 15 states and NTPC, allocating INR 1.8 million/MWh for each project. Of the total 30 GWh target, 25 GWh will be distributed among 15 states to meet their energy storage needs, while 5 GWh will be allocated to NTPC to optimize existing thermal generation and transmission infrastructure and supply electricity during non-solar hours reliably and cost-effectively.

Figure 58: State wise BESS capacity allocation


Source: Ministry of Power, Crisil Intelligence

Prior to VGF scheme, the Ministry of Heavy Industries in June 2021 launched a PLI scheme for Advance Chemistry Cell battery storage of 50 GWh capacity with an outlay of INR 181 billion, which includes more than 10 GWh grid-scale battery storage. The Scheme expects direct investment of around INR 450 billion in ACC Battery storage manufacturing projects. As of March, 2026, out of 50 GWh capacity, 40 GWh capacity has already been allotted through competitive bidding process and around 1 GWh is commissioned.

Usage of battery storage is expected to be strong across the generation, transmission, and distribution segments as well as at the consumer end. The National Renewable Energy Laboratory has also forecasted a fall in the price of storage solutions, especially lithium-ion technology. With the greater adoption of lithium-ion battery storage, improvement in battery efficiency, and large-scale manufacturing, Crisil Intelligence expects the four-hour utility-scale lithium-ion battery costs to decrease to \$90-100 per kWh in 2030 from the costs of \$100-105 per kWh in 2026.

3.5.6 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 ~ Rs 6.12/kWh) with pumped hydro storage and ReNew Power (300 MW at peak tariff of Rs 6.85/kWh) with BESS were awarded the project. The first FDRE tender of 1500 MW conducted by SJVN in November 2023 witnessed the lowest tariff of Rs 4.38/kWh.

Also, a few large-scale standalone ESS tenders were also issued by SECI, NTPC, GUVNL, MSEDCL in 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 March 2026, ~50 GWh of standalone grid-scale ESS capacity has been tendered, of which ~40 GWh has been awarded and are under different phases of execution.

A list of recently concluded storage tenders is mentioned below:

Table 9: Result of key standalone storage tenders

Sr. No.	Tender name	Capacity (MW/MWh)	Result date	Lowest bid	Winners
1.	SECI	125 MW/ 500 MWh	March 2026	Rs 3.04/ Lakh/MW/month	Coal India, Onward solar
2.	SJVN	250 MW/ 500 MWh	Feb 2026	Rs 1.97 Lakh/MW/month	Hardi Hydro
3.	NVVN	250 MW/ 500 MWh	Feb 2026	Rs 1.81/MW/month	Shreyas Sortex
4.	TNGECL	375 MW/ 1500 MWh	Feb 2026	Rs 3.15 Lak/MW/month	Eagle, OPF power, Onward solar
5.	GUVNL	335 MW/ 670 MWh	Feb 2026	Rs 2.1 Lakh/MW/month	Advait Infratech, Equentia, Sundrops
6.	RUVNL	500 MW/ 2000 MWh	Nov 2025	Rs 2.85 Lakh/MW/month	Patanjali, Ultravibrant, Rama Reflection, MEX Power, Bhagwati Lacto, Diwakar
7.	APTRANSCO	1000 MW/ 2000 MWh	Nov 2025	Rs 1.5 Lakh/MW/month	Ecoren Energy, Bondada Engineering, PGCIL, Bhagwati Group, Legion Energy, SBR Electro
8.	GUVNL	2000 MW/ 4000MWh	Nov 2025	Rs. 1.85 Lakh/MW/month	Sun Drops Energia, Engie Energy, MECPOWER Solutions, Samavist Energy, Stockwell Solar, Solar91 Cleantech, Viviana Power, Rajesh Power, Ultimate Flexipack
9.	RVUNL	1000 MW / 2000 MWh	Oct 2025	Rs. 0.18 Mn/MW/month	Stockwell, Oswal, Micromax, Patanjali, among others
10.	TNGECL	500 MW / 1000 MWh	Jun 2025	0.24 Mn/MW/month	Bondada Engg, Oriana, NLC
11.	KPTCL	500 MW / 1000 MWh	Apr 2025	Rs. 0.25 Mn/MW/month	Sarala, Oriana, Pace Digitek
12.	TGGENCO	250 MW / 500 MWh	Mar 2025	Rs. 0.24 Mn/MW/month	Bondada, Oriana, Pace Digitek
13.	GUVNL	500 MW / 1000 MWh	Apr 2025	Rs. 0.28 Mn/MW/month	Solarworld, HG Infra
14.	SECI Kerala	125 MW / 500 MWh	Feb 2025	Rs. 0.44 Mn/MW/month	JSW
15.	RRVUN Rajasthan Storage (VGF bases)	500 MW / 1000 MWh	Jan 2025	Rs. 0.21 Mn/MW/month	Solarworld, Rays Power, JSW, Oriana
16.	NVVN – Storage Tranche – I	500 MW / 1000 MWh	Oct 2024	Rs. 2.84 Mn/MW/year	Indigrid, Kintech, HG Infra
17.	SECI Rajasthan Tranche – II	1000 MW / 2000 MWh	Sept 2024	Rs 4.57 Mn/MW/year	JSW, Reliance

Sr. No.	Tender name	Capacity (MW/MWh)	Result date	Lowest bid	Winners
18.	MSEDCL	1000 MW / 8000 MWh	Aug 2024	Rs. 8.39 Mn/MW/year	Torrent, JSW
19.	GUVNL	250 MW/500 MWh	Mar 2024	Rs 0.448 Mn/MW/month	Gensol, Indigrid
20.	NTPC Storage	500MW/ 3000 MWh	Dec 2022	Rs 2.79 Mn/MWh/year	Greenko
21.	SECI Rajasthan	500MW/ 1000 MWh	Aug 2022	Rs 1.08 Mn/MWh/month	JSW

Source: SECI, Bidding agencies, Crisil Intelligence

There were other small scale solar-cum-storage tenders issued by SECI, NLC for regions such as Leh, Andaman and Nicobar Islands and Lakshadweep of capacities less than 50 MW, which have also been successfully awarded by the bidding agencies.

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

Renewable energy projects require large tracts of land to generate electricity, with approximately 3-4 acres of land needed for every 1 MWp installed capacity. The land must possess specific characteristics, including attractive renewable resources, suitable topography, contiguity, accessibility, proximity to transmission networks, and low cost. However, with the most desirable sites already utilized, project developers and government authorities are forced to seek out less-than-ideal parcels of land, often with uneven terrain, swampy or rocky conditions, and remote locations. The search for suitable land has led to the identification of sites located in ecologically or socially sensitive areas, such as wildlife habitats, forests, or indigenous communities. This has created conflicts between project developers, local communities, and environmental groups, resulting in delays, cost overruns, and even project cancellations. Key challenges in land acquisition include:

1. **Complex landownership patterns:** Land ownership patterns, particularly in rural areas, can be complex and fragmented, making it difficult to identify and acquire the necessary land.
2. **Regulatory hurdles:** The process of obtaining required permits and approvals can be time-consuming and costly, involving multiple government agencies and stakeholders.
3. **Environmental and social concerns:** The development of renewable energy projects can have significant environmental and social impacts, including habitat destruction, displacement of communities, and cultural heritage concerns.

The challenges facing wind energy projects are more significant. The availability of high-quality wind sites (Type I) in optimal locations is limited, raising concerns for developers. While alternative sites exist across various states, they often have lower wind density (Type 2 and 3 sites), lack adequate grid connectivity, or consist of fragmented land parcels. Due to the scarcity of Type I sites in preferred locations and congested transmission infrastructure, developers have increasingly shifted toward Type II wind sites. However, advancements in high-hub-height wind turbines have helped mitigate the impact of lower CUF.

The search for high-resource sites for renewable energy projects has resulted in a concentration of developments in a few states, putting immense pressure on transmission and grid connectivity in these regions. At the same time, states with significant renewable energy penetration continue to face challenges due to inadequate intra-state transmission infrastructure.

Furthermore, limited capacity remains in the existing and under-implementation 220 kV and 400 kV bays of ISTS substations, creating bottlenecks for connecting new renewable energy projects. Transmission projects also face

hurdles such as right-of-way issues, forest clearances, and supply chain constraints. In response, the government has estimated that approximately 60 GW of renewable energy capacity will have transmission connectivity by fiscal year 2027. The following table summarizes the connectivity margin available at ISTS substations.

Table 10: Tentative ISTS sub-station margin connectivity, as of December 2025

Region	Period	S/s Evacuation Capacity (MW)	Connectivity Granted/ Agreed (MW)	Connectivity Under Process (MW)	Margin for Connectivity (MW)	Additional Margin for Connectivity requiring ICT Augmentation / additional Tr. System (MW)
NR	Existing RE Pooling Stations	26,880	29,300	-	50	-
	COD Jul-25 to Dec-25	10,402	20,036	-	-	-
	COD Jan-26 to Mar-30	107,878	72,996	8,502	13,000	9,323
SR	Existing RE Pooling Stations	16,550	17,612	800	52	-
	COD Jul-25 to Dec-25	13,000	14,600	935	600	-
	COD beyond Dec'25	65,000	40,134	18,913	17,690	16,000
WR	Existing RE Pooling Stations	28,200	29,398	200	228	-
	COD Jul-25 to Dec-25	11,500	11,214	-	200	-
	COD beyond Dec-25	27,500	58,598	22,143	500	1,200
NER	COD Jul-25 to Dec-25	1,000	750	-	250	1,500
All India	Total	307,910	294,638	51,493	32,570	28,023
	Existing RE Pooling Stations	71,630	76,310	1,000	330	-
	Jul'25 to Dec'25	71,630	76,310	1,000	330	-
	Beyond Dec'25	26,880	29,300	-	50	-

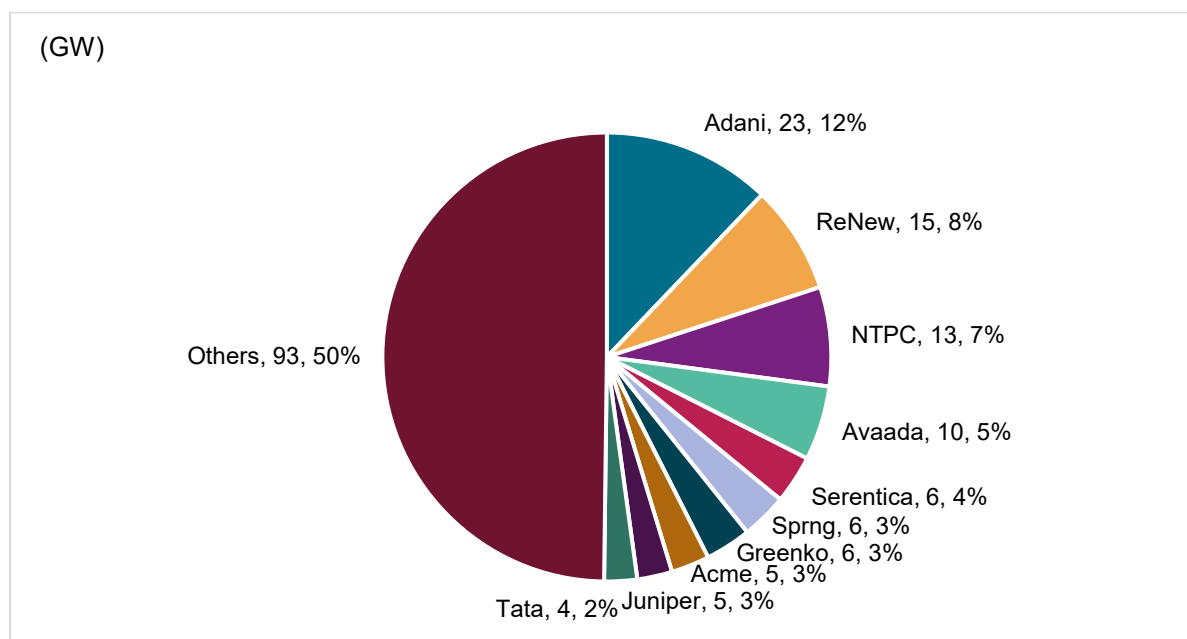
Source: CTUIL (As of 31.07.2025), Crisil Intelligence

As of July 2025, the total demand for connectivity stood at 186 GW. Notably, just five major players - Adani, ReNew, NTPC, Avaada, and Serentica - accounted for 36% of the total requested connectivity capacity. In terms of commissioning timelines, it is expected that 25% of the total connectivity will be operational by 2025, followed by 28% by 2026, 9% by 2027, 7% by 2028, 17% by 2029, and 14% by 2030.

Among C&I players, Serentica has sought the largest amount of connectivity, with a total of 6,485 MW, followed by Greenko, Mahindra, Sunsire, and Aditya Birla. This concentration of demand among a few large players highlights the significant role they are expected to play in driving the growth of the sector.

Due to the delayed development of substation and transmission infrastructure, utility-scale projects have been granted two six-month extensions to their scheduled commercial operation dates, and will still be eligible for the ISTS waiver, in recognition of the challenges posed by the slow buildout of necessary infrastructure.

Figure 59: Quantum of ISTS connectivity sought by renewable developers



Source: CTUIL (As of 31.12.2024), Crisil Intelligence

The competitive landscape for securing new C&I customers is increasingly challenging, with more renewable power providers entering the market and many off-takers demanding greater flexibility, shorter contract terms, and pricing concessions.

The utility-scale renewable energy market remains the dominant model for capacity addition in India, a trend expected to continue in the coming years. Historically, developers have adapted their strategies in response to evolving market conditions, regulatory shifts, and policy incentives.

Initially, most players focused on standalone solar projects, driven by falling module costs and favorable auction mechanisms. However, as the demand for round-the-clock renewable energy and hybrid solutions (solar + wind) increased, companies expanded their portfolios to include wind energy as well. This shift was fueled by government policies promoting hybrid projects and the increasing viability of wind-solar-storage combinations to address intermittency challenges. A critical aspect of competitive positioning in this space has been proactive land acquisition and securing grid connectivity well in advance.

Additionally, major renewable energy players have tactically participated in both central and state-level tenders to build a diversified and robust project pipeline. By carefully selecting auctions based on tariff trends, offtake security, and regulatory stability, these players have managed to scale their portfolios efficiently while mitigating market risks. As the Indian renewable energy landscape continues to evolve, these strategic pivots embracing hybrid solutions, securing early-mover advantages, and optimizing tender participation will define the success of utility-scale developers in the years ahead.

3.6 Overview of C&I/open access market

3.6.1 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 ~61 GW as of March 2026. 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**

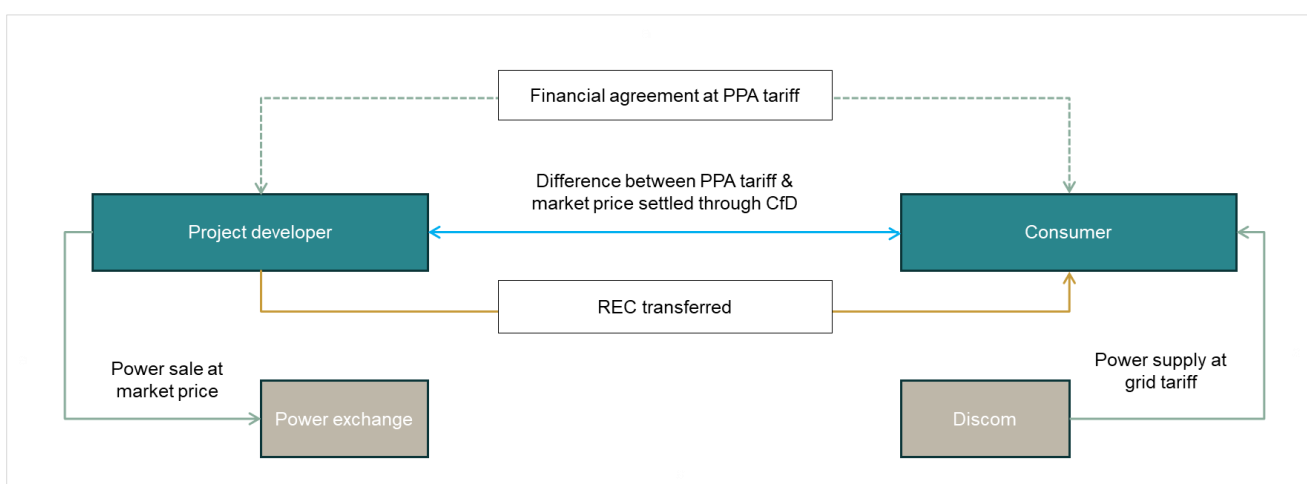
Third-party OA arrangements offer an attractive option for consumers who prefer not to make upfront investments and achieve substantial savings over grid-tariffs. Additionally, short-term, and medium-term third-party OA solutions are available, providing consumers with the flexibility to sign shorter-tenure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

- **Innovative products**

Virtual Power Purchase Agreement (VPPA) - VPPAs are more flexible in their structure than physical PPAs as the corporate buyer and power producer do not have to be connected to the same electricity network. It is a contract for difference. In this mechanism, RE developers sell their power in wholesale market while transferring the green attributes of power to VPPA consumers. In return, consumers guarantee a fixed price (strike price) with positive and negative adjustments based on difference of open market price vs. strike price. The entire transaction is financial and would not require actual physical transfer of power from generator to consumer.

October 2021, the Supreme Court passed the order wherein CERC was granted authority over all physical delivery-based forward contracts, while the regulation of financial derivatives was entrusted to SEBI. Consequently, any VPPA will be subject to joint regulation by both CERC and SEBI. As a result, investors, power producers, and consumers could now explore the benefits of such innovative power purchase mechanisms, leading to potential advancements in the adoption of RE sources, which is expected to further boost demand for corporate PPAs through the open access route.

Figure 60: Virtual PPA arrangement



Source: Industry, Crisil Intelligence

VPPAs allow consumers located in states with limited renewable potential or restrictive policy and regulatory framework or land and transmission challenges to meet their renewable purchase commitments. They are also a useful alternative procurement route for consumers with geographically distributed loads where it is not possible to directly procure renewable power. However, VPPAs in their true form are not being practiced in India due to lack of derivative products for electricity. Many developers and corporate consumers have entered deals that have elements of a VPPA.

3.6.2 Current status of RE based open access sale

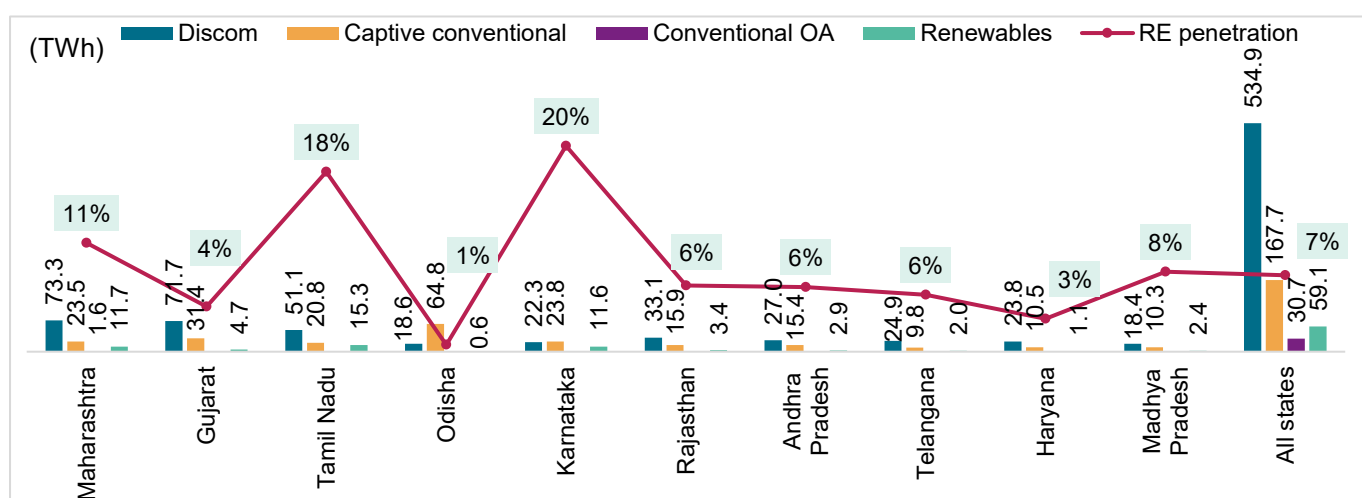
During FY23, the total C&I consumption in the country was 792 billion units, of which 68% was discom sales, captive conventional was 21%, conventional OA was 4% and renewables was 7%. The total C&I sales contribute over 42% of total discom consumption, industrial accounts for 78% and the rest are commercial consumers. As of fiscal 2023 the total installed capacity of captive based power plants was over 78 GW which generated 212 billion units. Of this, about 8.0 billion units were produced by RE based power plants. The majority of captive power plants are coal-based plants which contribute about 60% of the total captive based installed capacity. The share of RE capacity is about 7 GW which translates into 9% of the total captive based installed capacity.

Post fiscal 2017, there has been a notable shift in consumer behavior towards adopting RE based projects for captive consumption due to several factors such as RPO compliance, the escalating cost of conventional fuels, the decreasing trend of RE tariffs, and the attractive incentives offered under open access regulations in some of the states. The share of coal-based capacity has reduced by around 4.8 GW from 51.5 GW to 46.8 GW between fiscal 2020 and 2023. This trend indicates a growing recognition of the benefits and advantages associated with RE sources, as industries increasingly embrace sustainable practices and capitalize on the economic and environmental benefits of RE generation for their own consumption. There is still a significant portion of gas and diesel based captive plants of about 24 GW which could be replaced by RE projects in the medium term.

RE project installations under open access are independent of government tenders and targets. These projects allow C&I consumers to directly approach IPPs to procure RE enabling them to negotiate contracts, ensuring a more flexible and tailored approach to meet their energy needs.

The below graph shows the total C&I consumption at India level and for key states during fiscal 2023. It is evident from the graph that about 25% has been met through captive conventional and conventional open and projects and about 7% of the total C&I consumption has been met through RE based projects. Karnataka and Tamil Nadu are the leading states with over 18% of the C&I demand being met through renewable sources.

Figure 61: Open access/captive sales in key states for FY23 (penetration as % of total C&I sales)

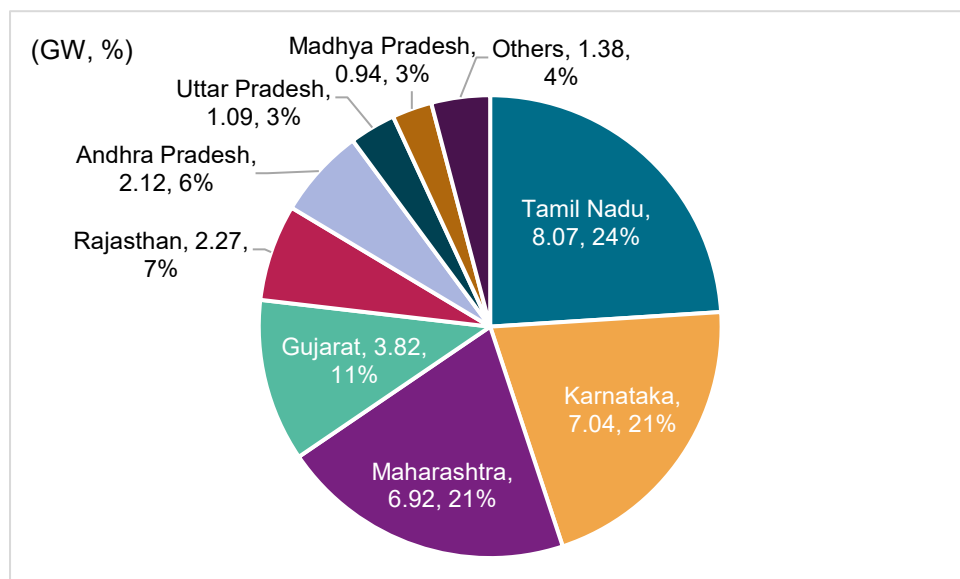


Source: CEA, Crisil Intelligence

A significant portion of OA capacity is concentrated in a few states such as Maharashtra, Tamil Nadu, Gujarat, and Karnataka, which together contribute about 77% of the total C&I RE open access capacity. These states are

recognized for their high industrialization levels and, consequently, account for a larger proportion of C&I power consumption compared to other states.

Figure 62: Share of RE open access capacity across states as of June 2025

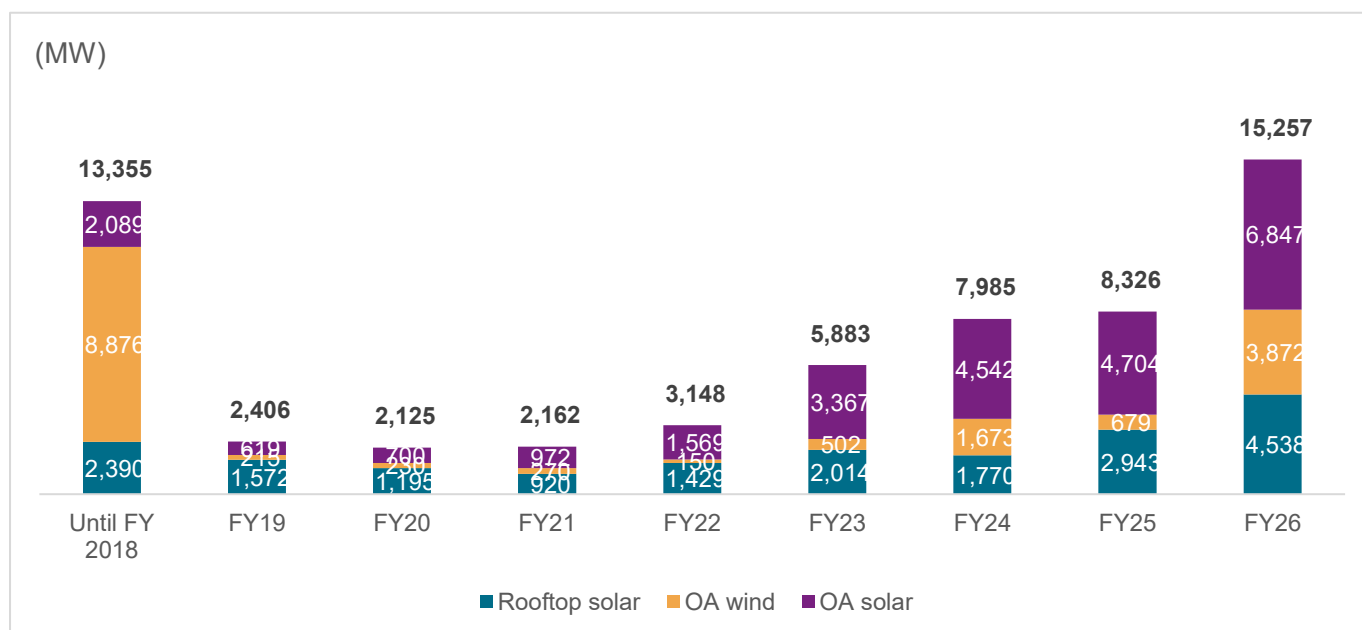


Source: Crisil Intelligence

3.6.3 RE based open access capacity addition in C&I space

The cumulative renewable C&I capacity including solar rooftop installation is ~61 GW as of March 2026, of which utility scale solar and wind OA project accounts for ~41.9 GW. The remaining ~18.8 GW is from rooftop solar. Among the renewable sources, solar holds the majority share above 73% (including rooftop solar). This dominance is attributed to its advantages, such as higher accessibility, wider availability of resources, shorter project gestation periods, and reduced construction and operational risks.

Figure 63: Historical open access RE capacity addition in C&I space (in MW)



Source: Crisil Intelligence

Note: Numbers have been rounded off

The C&I consumers are exhibiting a growing preference for transitioning wind-solar hybrid and RTC energy sources. This inclination is primarily driven by the advantages of wind power supplying energy during peak hours and diversified output profile of different sources helping corporates in achieving higher renewable penetration. Furthermore, with the recent introduction of Electricity Amendment Rule, 2023 wherein the ToD tariff regime has been specified and a specific provision has been made to set the tariffs for solar hours at 20% lower than the normal tariffs. As a result, C&I consumers may be reluctant in procuring standalone solar power at higher tariffs, as they would realize comparatively lesser revenue during the solar hours due to the lower tariffs imposed for solar energy consumption. Moreover, a noticeable trend is emerging as more states are shifting away from annual banking mechanisms towards monthly banking arrangements. In light of this, consumers are increasingly opting for the adoption of hybrid solutions, which offer distributed energy generation capabilities throughout the day.

The open-access segment also presents significant opportunities for IPPs. C&I consumers are increasingly driven towards India's corporate renewable market and this has resulted in strong growth drivers in the form of rising renewable purchase obligation targets. The open access market allows larger C&I consumers to optimize procurement costs through RE sources at tariffs that remain competitive when compared to grid power whose C&I tariffs have been increasing. Growth in this segment is further supported by favorable government policies, such as exemptions on cross-subsidy surcharges and group captive incentives in specific states.

3.6.4 Overview of regulatory framework for open access

3.6.4.1 Introduction of General network access

In October 2021, the MoP launched the GNA initiative, providing non-discriminatory access to the interstate transmission network nationwide for designated interstate customers. The Central Transmission Utility grants GNA for a specified period and maximum megawatt capacity, allowing for more flexible transmission planning and implementation. A key benefit of GNA is that it enables generators and drawees to plan their power requirements without needing to identify a specific source of purchase or sale, thereby streamlining the process for IPPs to access the transmission network without having to specify target beneficiaries.

3.6.4.2 Waiver of inter-state transmission charges for ISTS projects

The MoP, in August 2020, waived the ISTS charges and losses on all solar and wind projects commissioned before June 30, 2023. In June 2021, the waiver was extended up to June 30, 2025. However, this time, only the ISTS charges were waived, and losses remained applicable. Waivers are available for projects commissioned by June 30, 2025. However, post June 2025, an annual increase of 25% in the ISTS charges will be applicable for solar, wind, hydro PSP, and BESS sources, resulting in the applicability of 100% of ISTS charges from July 2028. Subsequently, in February 2023, it was clarified that green hydrogen and green ammonia projects would get a waiver of ISTS charges for 25 years if the projects are commissioned before June 30, 2025.

The MoP further decided to extend the waiver of ISTS charges on the transmission of power from new hydro power projects, for which, construction work is awarded and PPAs are signed on or before June 30, 2025. A significant relief has been given to renewable projects with two six-months SCOD extension beyond 30 June 2025 due to force majeure and unavailability of power evacuation infrastructure. These projects will be eligible for 100% ISTS charges waiver.

3.6.4.3 Introduction of green energy open access rules

The 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 and no limit for supply of power for captive consumers. Multiple consumers together with a total contract load of 100 kW are also eligible for open access, making access to OA easier for smaller consumers. As open access allows bulk procurement at low cost, open access has become one of the most popular routes among corporates.

Consumers who opt for open access to procure power from third-party suppliers are required to pay various charges to transmission and distribution utilities for using their network. These charges include cross-subsidy surcharge,

transmission and wheeling charges, losses, connectivity charges, and LDC charges, among others. The cross-subsidy surcharge is determined by respective state regulatory commissions to compensate distribution companies for loss of revenue on account of the shift of high-paying commercial and industrial consumers. However, the National Tariff Policy 2016 ensures that the cross-subsidy surcharge is not overly burdensome, allowing for competition through open access. Furthermore, the cross-subsidy surcharge is capped at 20% of the ACoS rate for industries and is not applicable to captive or group captive sales, only to third-party non-captive sales. The Electricity (Promoting Renewable Energy through Green Energy Open Access) Rules, 2022, provide

additional relief by limiting the increase in cross-subsidy surcharge to 50% for a period of 12 years from the date of project commissioning and waiving additional surcharges if fixed charges are paid by the consumer. This is a positive development, as cross-subsidy surcharge, and additional surcharge together account for approximately 50% of total grid charges, making open access a more viable option for consumers.

Banking is allowed on a monthly basis on payment of banking charges. The unutilised surplus banked energy would be lapsed at the end of each banking cycle and the RE generating station would get RECs to the extent of the lapsed banked energy. It also allows a consumer to purchase green energy by placing a requisition with their discom.

In addition, as per the rules, the electricity produced from offshore wind projects commissioned up to December 2032 will not attract additional surcharge for the energy supplied to open access consumers.

The rules provide long-term certainty of the open access charges for the stakeholders which will help in determining their returns from the project. Further, if an open access application is not approved within 15 days, it will be deemed approved. This will ensure timely execution of projects by minimizing any risk of cost escalations. The demand for green energy open access from C&I consumers is likely to increase after implementation of these rules. However, discom cooperation, regulatory proactiveness in timely tariff orders and green energy tariffs are key monitorable.

3.6.4.4 Evolving state RE open access regulations help in the adoption of green energy by C&I consumers

Consumers opting to procure power under open access are liable to pay various charges to transmission and distribution utilities to use their network to wheel power from the third-party supplier to the consumption point. These charges include cross-subsidy surcharge, transmission and wheeling charges and losses, connectivity charges, and LDC charges, among others. Further, cross-subsidy surcharge is determined by respective state regulatory commissions to compensate distribution companies for loss of revenue on account of the shift of high paying C&I consumers. However, as per the National Tariff Policy 2016, cross-subsidy surcharge should not be so onerous to eliminate competition through open access route. Moreover, CSS are not applicable to captive / Group Captive sales and are applicable only to third party non-captive sales. CSS is capped at 20% of the ACoS rate to industries. Further, as per Green Open Access Rules, 2022 provide that AS will not be applicable to renewable energy if fixed charges are being paid by such consumers. The Electricity (Promoting renewable energy through green energy open access) rules, 2022 state that cross-subsidy surcharge should not be increased by more than 50% for a period of 12 year from the date of project commissioning and full waiver on additional surcharge if fixed charges being paid by the consumer.

The expansion of the T&D networks, availability of more efficient systems to maintain grid stability, and increased operating efficiency of the utilities will free up network capacity to open access users. The increased operating efficiency and network availability would keep a rein on transmission and wheeling charges & losses.

Thus, the rationalization of cross-subsidy and efficiency in grid operations would make open access routes more attractive for bulk consumers.

SERCs of different states have either exempted or provided concessions to RE projects from payment of various open access charges from time to time to promote the use of renewable energy among C&I consumers. For instance, Tamil Nadu and Rajasthan have provided 50% concession in the wheeling and transmission charges for renewable

projects, Tamil Nadu has concessional cross-subsidy charges at 30% of conventional power. However, many states have reduced banking provisions for renewable energy projects from an annual energy banking settlement to monthly energy banking.

Despite the discontinuation of open access charges exemptions/incentives for new projects, it is important to note that these benefits will be applicable until their expiry for the old projects commissioned during the period when such benefits were introduced. However, the landed cost of open access projects without any exemptions/incentives could remain competitive as compared to utility tariff as the discom variable tariffs for C&I category are expected to continue to rise in future. There would be a sufficient margin between the levelized cost of RE and variable discom's C&I tariff to mitigate the risk of reducing/withdrawing the open access charges incentives. The savings will improve further if consumers opt for captive mode.

3.6.4.5 Deviation in Green energy open access regulations adopted by the States from MOP rules

Most of the large industrial and RE rich states have notified green energy open access regulations, largely in line with the original Rules. However, there are a few deviations observed which are listed in the table below. Tamil Nadu and Rajasthan have not notified green open access regulations however they have provisions under their respective state regulations for RE open access.

Table 11: Comparison of MoP's green open access rules with state notified RE open access regulations

	Eligibility	Banking	Cross subsidy surcharge for third party sale (waived for group captive)	Additional surcharge for third party sale (waived for group captive)	Standby charges	Compensation for unused banked power
MoP Rules	100 kW or above	Monthly; Banked quantum – 30% of monthly consumption for discom Banking charges at 8% of banked energy	Shall not increase by more than 50% in 12 years;	Not applicable if fixed charge being paid	Not applicable if notice is given 24 hrs. before the delivery of power; Should not exceed 25% of energy charges	Entitled to get REC for the lapsed banked energy
Andhra Pradesh	✓	✓	No cap on CSS	No AS exemption	✓ (20%)	Paid at 75% of the last discovered SECI tender for given RE source
Gujarat	✓	Banking charges of Rs. 1.5/kWh	✓	✓	✓ (10%)	✓

	Eligibility	Banking	Cross subsidy surcharge for third party sale (waived for group captive)	Additional surcharge for third party sale (waived for group captive)	Standby charges	Compensation for unused banked power
Karnataka	✓	Baking restricted to first 5 years of project operations; 2% additional banking charges for drawal of off-peak banked energy during peak hrs.	No cap on CSS	✓	✓	✓
Madhya Pradesh	✓	✓	✓	✓	✓	✓
Maharashtra	✓	No cap on banked quantum	No cap on CSS	✓	-	✓
Rajasthan	Minimum 1 MW contracted load	Banking on annual basis; Allowed only for CPPs; Banked energy – max. of 25% of RE injected or 30% of total monthly consumption from discom, whichever is higher Banking not applicable post FY2030	No cap on CSS	No AS exemption	-	✓
Telangana	✓	✓	✓	✓	-	✓

Source: MoP, Respective SERC Regulations, Crisil Intelligence

3.6.4.6 Summary of State RE policy

State	Provisions
Andhra Pradesh	50% exemption from transmission and wheeling charges for hybrid projects for 5 years 100% reimbursement of state GST for rooftop solar commissioned by residential or government buildings - Repowering wind turbines is allowed with an operational life of at least 10 years
Gujarat	- Net and gross metering allowed for rooftop solar projects [gross metering tariff- last 6 months average of utility scale auctions+ INR 0.20/kWh] - Wind solar hybrid projects to have at least 25% contracted solar or wind. - Floating solar projects to pay royalty to irrigation department
Madhya Pradesh	50% in wheeling charges for all RE projects (non-storage) for 5 years from COD 100% exemption from electricity duty and energy development cess for 10 years from COD 50% reimbursement of stamp duty on RE and captive projects; 15% reimbursement for storage projects 20% exemption on registration fees for storage projects - Availability of government land on concessional rates
Rajasthan	- RE park solar projects to be developed as JVs with 50% equity investment by developer - Rooftop solar project capacity is limited to 1 MW; Metering arrangements include net metering, gross metering, virtual net metering and group net metering - Capacity for grid connected decentralised solar project is 0.5-5MW - Repowering wind turbines is allowed with an operational life of at least 10 years 50% exemption on registration charges for new RE projects with minimum 50% BESS capacity; 100% exemption on pro rata basis for projects with over 50% BESS capacity

Source: State Policies, Industry, Crisil Intelligence

The States are slowly moving away from the benefits/waivers given to RE projects since the industry is now mature and new projects are not getting the concessions/waivers available to old projects commissioned before the implementation of new policies. This gives an added advantage to old projects with multiple-grandfathered benefits.

3.6.4.7 Captive/group captive policies

As per electricity Rules, 2005 a power plant could qualify as a captive generating plant (CGP) if the captive user holds at least 26% ownership. A group captive mode is where a developer develops a power plant for collective usage of many consumers. A power project is considered 'captive' if the consuming entity or entities consume at least 51% of the power generated and owns at least 26% of the equity.

As per the Rules, each captive user of a CGP has to consume electricity, on an annual basis, in proportion to its shareholding in the CGP entity, subject to a variation of +/-10%. As per Electricity (Amendment) Rules, 2023 notified in September 2023 has amended the provisions relating to CGPs. It has allowed power consumption by a subsidiary company, or the holding company of a captive user shall also be considered as captive consumption by the captive user. The amendment Rules also appointed CEA to verify the captive status of CGPs where the projects and their users are located across multiple states. Group captive is the most preferred route by corporate consumers due to minimal investment requirement and exemption from grid charges.

The Supreme Court judgement dated October 2023 also provided clarity relating to captive generation. It reaffirmed that the captive users must together hold 26% of ownership of the CGP and consume at least 51% of the aggregate electricity generated by CGP. It also mentioned that the minimum ownership requirement of 26% must be met and satisfied throughout the year and not at the end of the financial year. It also clarified the proportionality principle where the owner of every 1% shareholding in CGP should have minimum consumption of 1.96% with a variation of +/- 10%. The 51% Consumption requirement would be tested on a yearly basis.

As far as benefits for captive users are concerned, as per section 42(2) of the Electricity Act, 2003, captive power plants, set up by end-users for their consumption, are exempted from payment of cross-subsidy surcharge and the additional surcharges, otherwise would be applicable for open access consumers. Thus, the central government's policy support has played a role in promoting the captive/group captive model, especially for C&I consumers.

3.6.4.8 Rebate during solar hours

The MoP vide its notification dated 14 June 2023 has issued the Electricity (Rights of Consumers) Amendment Rules, 2023. In the said amendment, it was mandated Time of Day tariff for Commercial and Industrial consumers having maximum demand more than 10 kW to be made effective from 1st April 2024. The said amendment also mandated tariff for solar hours of the day (as may be specified by the State Commission) should be at least 20% less than the normal tariff. The status of implementation of rebate during solar hours is summarised in following table.

Table 12: Status of implementation of rebate during solar hours by various SERCs for fiscal 2026

State	Proposal for FY 2026	Solar Hours
Andhra Pradesh	50 to 100 paisa/kWh	10:00 Hrs to 15:00 Hrs
Gujarat	30 paisa / kWh	11:00 Hrs to 15:00 Hrs
Karnataka	Not implemented	No separate solar hours
Maharashtra	During April to September - 15% (FY26 & FY27), thereafter 20% and from October to March- 25% (FY26 & FY27), thereafter 30%	09:00 Hrs -17:00 Hrs
Madhya Pradesh	20% of normal rate of energy charges	09:00 Hrs -17:00 Hrs

NA: Not applicable; Source: tariff Petitions filed by State Discoms, Crisil Intelligence

3.6.4.9 Landed cost of RE open access vs grid tariff

The utility tariff for C&I consumers is significantly higher than other consumer categories and this trend is expected to continue in future. On the other hand, the landed RE tariff, which accounts for the levelized cost of RE projects and other open access charges to the consumers, has become increasingly competitive due to advancements in technology, higher CUF, lower cost of finance and supportive government policies and regulations for open access consumers. As demonstrated in the chart below, the difference becomes evident, offering businesses a compelling incentive to opt for sustainable and cost-effective RE solutions. In fact, it can be inferred from the chart below that the open access tariffs are still more competitive than variable utility tariffs even after removal/reduction of incentives for open access charges in majority of the states.

Figure 64: Utility vs open access solar landed tariff for Industrial consumer for FY 2025

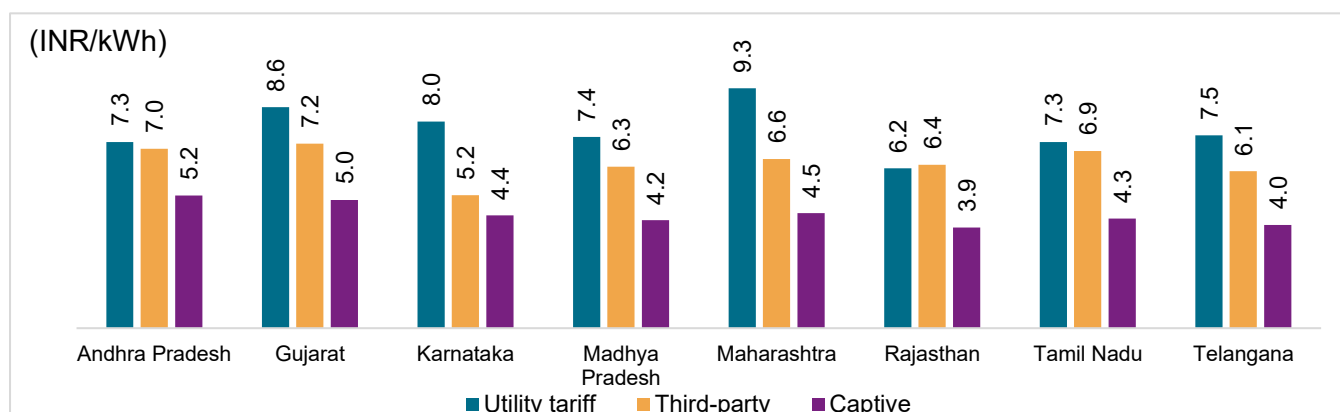
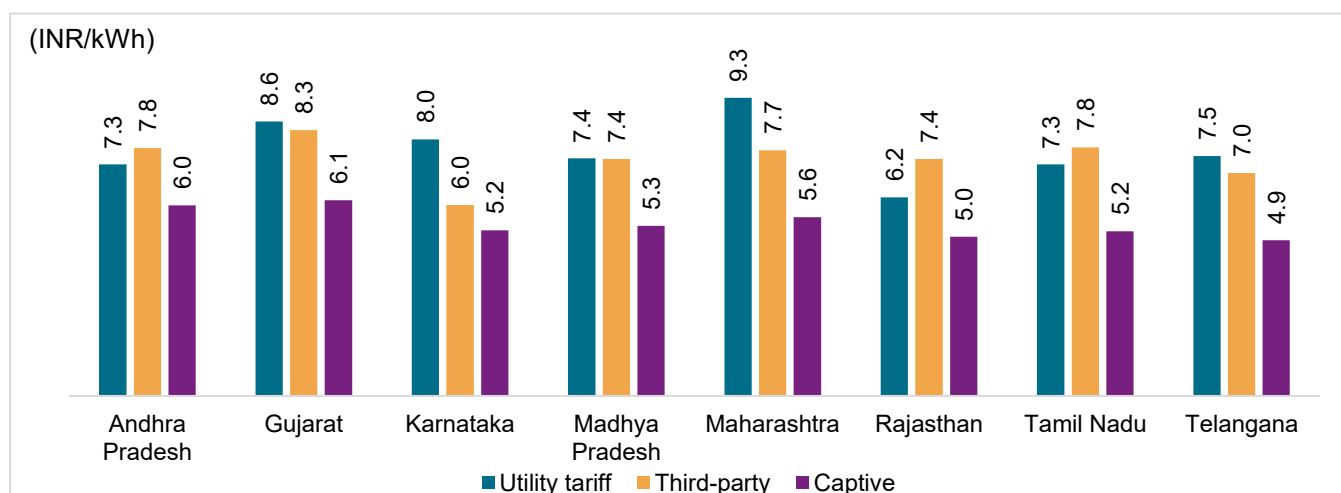
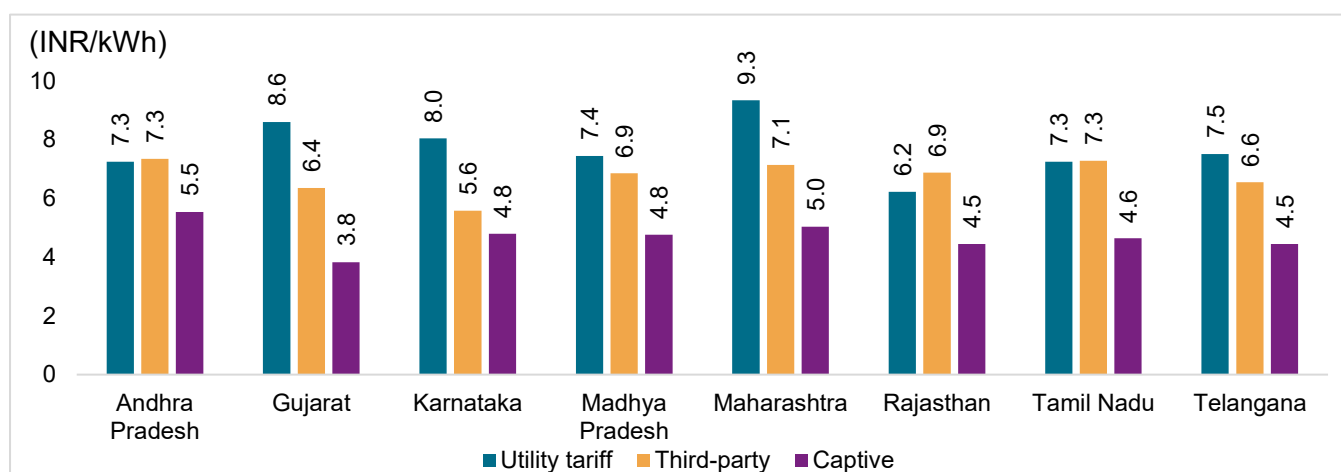


Figure 65: Utility vs open access wind landed tariff for Industrial consumer for FY 2025

Figure 66: Utility vs open access wind solar hybrid landed tariff for Industrial consumer for FY 2025


Note: The open access charges are as per Tariff Orders for FY 2025. The landed tariff includes prevailing exemptions/concessions applicable for OA charges.

Source: SERC Tariff Orders, Crisil Intelligence

Considering the various charges recovered from third party open access consumers, discoms certainly benefit for providing open access versus continuing supply to C&I consumers. Discoms are not required to pay transmission costs for units not supplied. The concerned open access consumer/developer as the case may be pays the transmission charges to Transco for consumed units. Discoms recover CSS and ASC for loss of cross subsidy and stranded assets due to open access. Further, due to the backing down of higher variable cost sources, Discoms save more than cheaper marginal sources. Also, being connected to the grid, the open access consumers continue to pay the fixed charges. Thus, there is net gain to Discoms in the case of third party RE open access.

3.6.4.10 Voluntary adoption of RE gaining rapid traction by corporates to meet sustainability goals

Several large electricity-intensive industries exist in sectors such as steel, cement, chemicals, textiles, automobiles, glass, and other industrial products. While several large corporations – utilising open access power or captive generation from conventional fuels – are mandated to meet RPO targets, their voluntary compliance is gradually rising.

On a broader scale, one of the main drivers behind the increase in Indian corporate PPAs in RE is the predominant reliance on coal in the country's electricity grid, resulting in high tariffs. Moreover, RE sources are now widely accessible and affordable in India, particularly solar energy due to significant advancements. Now many corporates are entering into wind-solar hybrid with and without storage to maximise the use of RE throughout the day.

Additionally, given the growing significance of sustainability and climate consciousness, there is a focus on robust Environment, Social, and Governance (ESG) standards and forthcoming green taxonomies, which may also extend to unlisted companies.

Furthermore, Gol's decisive shift toward renewable energy, driven by ambitious climate targets set under the Paris Agreement, has led to the implementation of various green policies and regulations. These include the recent modifications to the open access and REC regime in 2022, creating an environment that encourages and incentivizes the adoption of green practices.

Procuring electricity through open access using RE not only helps reduce costs but also cuts carbon footprint and aids in meeting sustainability goals. Several corporations are gradually setting out long-term goals for net zero carbon emissions for their own production and across their value chain, including suppliers, supply chain and distributors. In fact, the global list of RE 100 companies also features a few Indian companies.

Consequently, the number of corporate PPAs in the renewable energy sector has surged and is expected to continue with evolving policy, regulations, and business models.

3.6.4.11 Strong investor interest to support growth in the open access market

Several developers focused on the open access market have managed to attract marquee global investors. Investor interest has not only been from a specific investor class but has been witnessed across investor categories. Global IPPs, PE funds, Impact funds as well as multi-lateral agencies – have extended financing to such developers. This clearly indicates the potential of the open access market in India.

With rising awareness about climate change, several corporates in India are voluntarily procuring RE with an objective to operate sustainably. This provides a further impetus to RE.

3.6.4.12 Review of emerging business models for C&I players

Currently, different types of business models are being implemented by RE Project developers for open access. Different types of PPAs include:

Variable discount PPAs: As per the PPAs, the power is sold to customers at agreed PPA tariff computed by adjusting a customer benefit amount defined under the PPA from the variable tariff charged by Discoms of the customers' area. The PPAs also have a provision for periodic change in the customer benefit linked to corresponding change in variable tariff and open access charges. For example, in case of some of the PPAs, 50% of the increase or decrease in variable tariff is passed on to the customer through a corresponding increase or decrease in customer benefit on an annual revision basis. The variable tariffs and open access charges are approved by the SERCs through periodic tariff orders.

Fixed discount PPAs: In fixed discount arrangement, the customer benefit remains the same irrespective of the change in the variable tariffs as well as open access charges. The applicable PPA tariff is determined by deducting the agreed customer benefit from the prevailing variable tariff on monthly basis.

Bus bar tariff arrangement: In case of the bus bar tariff arrangement, the PPA tariff is at the delivery point, and all the open access charges are on account of the consumer.

3.6.5 Potential risks and challenges in open access projects

Contractual challenges:

- **Mismatch between PPA and loan tenure** – Typically the duration of long term PPA in C&I is of 10-15 years, while loan taken for the project might have a longer duration. The lenders may be hesitant to favourable loan terms if there is a significant tenor mismatch, potentially leading to higher interest rates. However, PPA tariff for supply of green power is generally at discount to Discom's tariff selling black power. Therefore, demand for green power should always be there.

- **Contract standardisation** – The government tenders usually have a standardized PPA which is a part of RfP document. However, in open access projects, PPAs are often customized based on mutually agreed terms between the parties after negotiation, leading to variety of terms and conditions. This can lead to inconsistencies in contractual terms and when any dispute arises, the lack of standardization can complicate the resolution process.
- **Contract enforcement** – It arises from the challenges associated with ensuring that all parties adhere to the terms of the PPA. However, inconsistent contractual terms, misinterpretation of any regulatory provision or ambiguity in policies and regulation can affect the enforcement of PPAs.

Operational challenges:

- **Performance risk** – RE sources are inherently variable. Unpredictable fluctuations in wind speed and solar irradiance due to extreme weather events lead to variations in power output which can affect the forecasted revenue for the period. Moreover, any unexpected breakdowns or faults can also lead to longer downtimes and reduced power generation.
- **Grid curtailment risk** – Integrating RE project into the grid in a RE rich state can pose challenges related to congestion, forcing grid operator to curtail power to avoid overloading the network. Moreover, intermittent supply of RE can also affect grid stability. Standalone solar is more prone to grid curtailment vis-à-vis wind or WSH since all solar projects peak at the same time which is not a case with wind.

Regulatory challenges:

- **Variable open access charges** – The open access charges are variable in nature; most of the state discoms are gradually increasing their open access charges which make it less attractive for the C&I consumer. Increase in open access charges can significantly increase the cost of RE power for a buyer. However, these charges being regulated cannot be increased on an ad hoc basis. The transmission and wheeling charges have remained consistent, albeit a few exemptions in most of the states. Cross subsidy surcharge is capped at 20% of the ACoS rate to industries and waived for group captive customers, full waiver of additional surcharge if fixed charges being paid by the consumer and not applicable for group captive customers. However, for projects offering fixed discount over discom tariff, any increase in CSS is advantageous. For a 20 paise per unit increase in CSS, an increase of Rs. 1.00 per unit in discom tariff would be required, which results in a clear advantage of 80%.
- **Addition of new open access charges** - There are various new charges other than the open access charges that have been introduced by many states on open access consumers. For example, in Gujarat, the hybrid policy of 2018 applied multiple wheeling charges of Re 0.05 per kWh on hybrid projects. In Madhya Pradesh, the Harit Urja Tax has been introduced in a new renewable energy policy at the rate of Re 0.10 per kWh. Some states have introduced grid support/parallel operation charges to captive power plants.
- **Captive project status** - Captive projects are more attractive than 3rd party open access projects. Most C&I consumers are opting for captive open access and due to this Discoms are incurring revenue losses. Group captive customers need to abide by group captive guidelines as per the Electricity Act 2005 and compliance is tested at the end of the year. The Supreme Court issued a judgement on 09 Oct 2023 clarifying multiple aspects of the Electricity Rules 2005 relating to captive/group captive plants and captive users.

3.6.6 Emerging business models and project financing

There are different types of emerging business models emerging in open access which are summarised below:

- **RTC power including storage** – RE-RTC supply has gained momentum in recent years due to benefits such as reliable supply of power, optimisation of solar and wind with complimentary profile. The RE RTC can be customized for the industries depending upon their load pattern. With Reduction in cost of storage technologies, it is expected that RE-RTC will become cost competitive with other standalone renewable technologies.
- **Green power trading** - In a bid to help obligated entities meet RPO targets and offer an alternative to IPPs to sell green power, the CERC approved the GTAM. This was supported by stabilisation in RE technology, falling price and availability of sophisticated tools for forecasting and scheduling RE. The GTAM platform would also enable

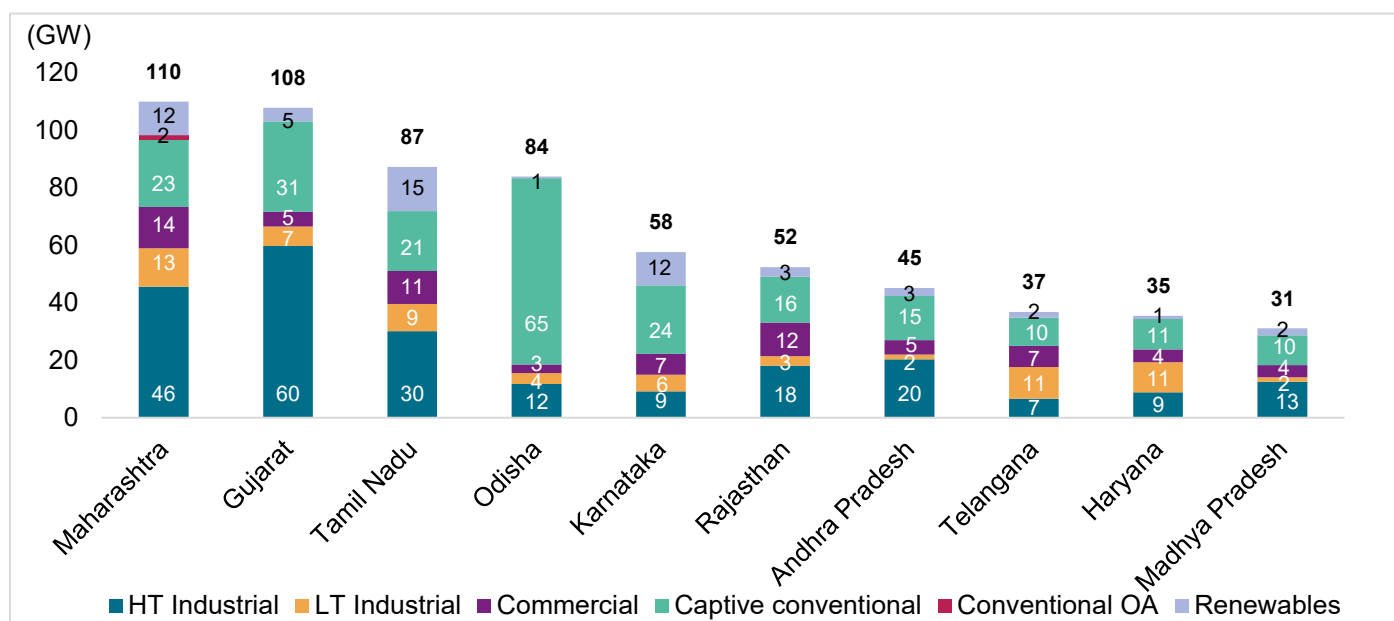
IPPs to sell 'surplus' RE and avoid any potential back-down or curtailment by discoms. Further, after the success of GTAM, the government has recently launched GDAM. These market segments will create additional sale avenues to the existing IPPs and encourage other merchant power plants to set up more RE capacity.

- **ISTS connected OA projects** - This market is growing strongly on the back of multiple drivers including a waiver from ISTS charges coupled with streamlined transmission connectivity approval process. The route offers scale and cost benefits particularly for larger consumers and those with distributed operations across multiple states. Exemption from ISTS charges is worth savings of about Rs 1.00-1.50/ kWh. The ability to set up larger projects at a single location with lower land cost and higher radiation results in further cost savings of about Rs 0.30-0.50/ kWh over intra-state projects. While consumers must bear incremental ISTS losses of about Rs 0.15/ kWh, the ISTS route is financially attractive across all states but only for projects commissioned by June 2026 (at least 75% ISTS charge waiver).
- Since notification of CERC Connectivity and GNA Regulations in October 2022, there has been a surge in ISTS connectivity applications from project developers – as of December 2024, over 10 corporate-focused developers including AM Green, Amplus, CleanMax, Serentica and Aditya Birla have applied for ISTS connectivity for total 22 GW renewable capacity.
- **Virtual Power Purchase Agreement (VPPA)** - The market is experimenting with variants of VPPAs. A variant to the typical VPPA framework includes an agreement for the RECs which will be sold directly to the consumer at a mutually agreed price and brown power will be sold on power exchange without CfD. In September 2023, Cleantech Solar started commercial operation of its VPPA. The solar project has been registered under the International REC (I-REC) mechanism, and the renewable attributes (I-RECs) from this project are being purchased by a leading FMCG company under a virtual PPA.
- **Energy storage as a service** - ESS is swiftly gaining prominence as one of the major components in RE projects. BESS is often coupled with solar rooftop by C&I consumers. This may provide several benefits. "Solar rooftop + BESS" systems in C&I segment are usually in behind-the-meter (BTM) configuration. During the day, whenever the solar generation is more than the required load demand, the excess energy is stored in the BESS system. With states having ToD tariff structure, BESS can be utilized such that consumer uptake energy from BESS during peak tariff hours. BESS during peak load periods will reduce the peak load, ultimately helping in the reduction of energy charges.
- **Carbon offsets** – By adopting RE, the industries can reduce their carbon footprint. Any reduction in carbon footprint can be traded by receiving carbon credits. This can be sold in the voluntary carbon market. Buyers of these credits are typically companies looking to compensate for their own emissions which they cannot reduce directly. This provides a revenue stream for C&I players.
- **Fund raising:** In January 2024, Sustainable Energy Infra Trust (SEIT), an infrastructure investment trust (InvIT) co-sponsored by the Mahindra Group and Ontario Teachers' Pension Plan Board (OTPP), raised Rs 2,262 crore through an initial offer of its units, with Rs 1,365 crore coming from global and Indian investors, including the Asian Infrastructure Investment Bank (AIIB). In May 2024, Jakson Green received a significant boost to its renewable energy business with a Rs. 600 million Sustainable Trade Facility from HSBC India. This funding will be utilized to support the company's working capital requirements, facilitating the expansion of its renewable energy operations in India and international markets.

3.6.7 Market expansion opportunities in underserved regions basis the RPO target

The RPO target of 43.33% of its power from renewable energy sources by 2030 applies to all conventional captive and open access consumers. However, corporate consumers are only required to meet overall renewable energy targets, without being obligated to meet specific technology-based targets. State regulators have been strict in enforcing RPO compliance among C&I consumers, showing no leniency.

Figure 67: Share of different sources of power consumption among C&I consumers in FY 2023, TWh



Several states, including Maharashtra, Tamil Nadu, Odisha, Rajasthan, Gujarat, and Karnataka, are prime markets for corporate renewable energy adoption due to their large consumer base dependent on conventional power sources (RPO obligated consumers), high grid tariffs, and favorable wind and solar resources. Odisha presents a significant untapped opportunity for open access renewables as there is no renewable penetration. The state has a substantial industrial base, primarily comprising metal and mineral operations, which currently rely on conventional captive power. Driven by RPO requirements and net-zero mandates, this consumer segment is poised to transition towards renewable energy sources, offering a considerable opportunity for growth in the open access renewable energy market.

PPAs with C&I players with good credit ratings; and the development of hybrid, RTC and FDRE projects are expected to provide good returns. These projects offer better internal rates of return than standalone solar and wind projects.

3.7 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.

3.7.1 Plans of leading renewable IPPs to be fully integrated company

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.

Table 13: RE players' presence across renewable supply chain

Player	Ancillary component manufacturing	Module manufacturing	Wind turbine manufacturing	BESS manufacturing	Transmission connectivity	EPC and O&M services	IPP business	Captive demand
Inox GFL group	NA	Gujarat facility 3.0 GW operational module manufacturing facility in Gujarat Odisha facility 5.0 GW integrated solar module and cell manufacturing facility Phase 1 (2.4 GW) by Q1 of FY28 FY2 (2.6 GW) by Q2 of FY28	Wind capacity – 2.5 GW of WTG manufacturing at Gujarat and MP	Chemicals, cathodes and other materials	Evacuation infrastructure capabilities	Relies on in-house EPC and O&M team having assets of 5.1 GW of renewable O&M capacity	Around 3.5 GW of operational capacity from solar, wind and hybrid projects	Large captive demand across Inox GFL group companies
Adani	Recently announced plans to enter cable and wires businesses to cater to the large captive requirements of the power, renewable energy, and ports sectors.	4 GW operational cells and module capacity 10 GW cell and module capacity in pipeline	2.25 GW wind turbine manufacturing capacity	-	22.6 GW	Relies on in-house EPC and O&M team	19.3 GW of operational capacity from solar, wind and hybrid projects	Large captive demand across Adani group companies Won PLI for electrolyser manufacturing

Player	Ancillary component manufacturing	Module manufacturing	Wind turbine manufacturing	BESS manufacturing	Transmission connectivity	EPC and O&M services	IPP business	Captive demand
	Adani Solar in December 2022 introduced a large-sized monocrystalline silicon ingot in its Mundra facility.							
ReNew	NA	6.4 GW module manufacturing capacity and 2.5 GW cell capacity	-	-	14.6 GW	Relies on in-house EPC and O&M team	13 GW of solar, wind and hybrid capacity 7.4 GW of pipeline capacity	None
AMP	NA	Setting up 1.3 GW cell and module facility with Jupiter	-	-	1.6 GW	Relies on third-party EPC and O&M services (L&T, Jakson, Sterling & Wilson, Rays Infra)	1 GW operational capacity 1.58 GW pipeline capacity	Nil
ACME	NA	1.2 GW solar PV module facility in Jaipur Planned solar cells	-		9.6 GW	Relies on in-house EPC and O&M team	2.9 GW operational solar capacity 5 GW pipeline capacity	None

Player	Ancillary component manufacturing	Module manufacturing	Wind turbine manufacturing	BESS manufacturing	Transmission connectivity	EPC and O&M services	IPP business	Captive demand
		manufacturing in Rajasthan						
Waaree	6 GW Ingot-Wafer capacity in pipeline	25.8 GW of operational module manufacturing and 5.4 GW cell capacity 2.6 GW module and 10 GW cell manufacturing capacity in pipeline	-	Plans to establish a 20 GWh BESS Plant (Battery Pack + Cells)	8 GW	Separate EPC business, 1.82 GW projects commissioned for other IPPs	40 MW of operational assets. PPA signed for 713MW/1044MWp	Won PLI for both electrolyser and green hydrogen production
TATA Power	NA	4.3 GW module and cell manufacturing capacity	-	Plans to build a 20 GWh gigafactory in Gujarat	4.4 GW	Separate EPC business: 6.4 GW commissioned capacity for other IPPs Relies on third-party O&M	6.5 GW operational capacity 5.1 GW pipeline capacity	Large captive demand across group companies
Avaada	NA	8.5 GW module capacity commissioned 12 GW cell and 5 GW module	-	-	10 GW	Relies on in-house EPC and O&M team	7.2 GW operational capacity 15 GW pipeline	Won PLI for electrolyser manufacturing

Player	Ancillary component manufacturing	Module manufacturing	Wind turbine manufacturing	BESS manufacturing	Transmission connectivity	EPC and O&M services	IPP business	Captive demand
		manufacturing capacity in pipeline						
JSW	NA	Postponed plans for module manufacturing	Has obtained license to establish a wind turbine blade manufacturing facility in Karnataka	To establish 50 GWh capacity target starting with 10 GWh capacity by 2026	3.6 GW	Relies on both third-party and in-house services	~6 GW operational and ~14 GW pipeline capacity	Large captive demand across JSW group companies Won PLI for green hydrogen production
Reliance New Energy	NA	targets 20 GW per annum of fully integrated solar module manufacturing capacity	-	targets 120 GWh of annual BESS and cell manufacturing capacity	NA	acquired a 40% stake in Sterling & Wilson Solar,	-	-

Source: Industry, Company websites, Crisil Intelligence

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.

Moreover, with 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 will 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 a captive demand or those with established export partnerships will be able to maintain their market presence and achieve long-term sustainability.

3.7.2 Importance of being an integrated player in RE space

Through the implementation of the Electricity Act, 2003 power generation was delicensed allowing any company to set up power plants. With low entry barrier scores of companies initially entered the thermal power generation and, subsequently, the renewable power generation sector. However, with growing regulatory, commercial, and technological complexities, especially in the renewable energy sector, companies with integrated operations across the value chain command a significant strategic advantage over others.

Greater control over timelines

Having an integrated value chain across manufacturing equipment, project design, engineering, and construction allows companies to ensure shorter delivery timelines to offtakers giving them an added advantage against their competitors. This also increases the attractiveness of such a company's offerings. For offtakers, especially commercial and industrial consumers, power procurement and decarbonisation are often not the core operations. The prospect of dealing with a counterparty for all activities across the value chain is very appealing against scouting for individual counterparties for each activity.

Greater control over quality

With an integrated operation spanning manufacturing to development and operation of power projects, a company has greater control over quality of equipment produced as well as operations. Solar modules and wind turbines generally account for a significant share of overall project development costs in solar and wind energy projects respectively and must last for at least 25 years. Deep technical knowledge and control over manufacturing processes provide greater certainty and visibility to companies while committing to operational performance over long periods. Further, a fully integrated company has better visibility on equipment availability and is better positioned to prioritise delivery to critical ventures, an advantage unavailable to developers' sourcing equipment from external suppliers. Availability of spare parts in the wind power sector has emerged as a major challenge for new and operational projects. With the exit of many manufacturers, developers have been unable to source equipment in a timely manner leading to liquidated damages amounting from failure to meet performance guarantees. An integrated manufacturer-developer is immune to such challenges resulting in better, and more certain, performance and revenue outlook.

Better margins and financial performance

Outsourcing project development activities can significantly hamper profit margins and project returns. Developers often outsource project design, engineering, equipment procurement and construction to external agencies resulting in margin leakage. While this is less pronounced in the case of solar power projects (entire EPC and O&M is typically assigned to a single external entity), it is much more significant in the case of wind power projects. Over the last few years, wind project development value chain has undergone significant decentralisation with small regional and largely inexperienced companies offering standalone services. This has substantially increased implementation, financial and operational risk for developers as it can lead to poor quality construction, delay in project commissioning and, eventually, demand for liquidated damages from offtakers.

3.7.3 Importance of having large plug & play infrastructure for upcoming projects

Plug-and-play model in renewable energy project development refers to having a common infrastructure from multiple small projects located with close vicinity of each other. Renewable energy parks have been developed across multiple states that offer common infrastructure facilities like road network, power evacuation equipment, cleaning, and other maintenance infrastructure, etc. These parks may be developed by government-owned agencies, through joint ventures between private and public sector companies or by developers themselves. In the first two cases, park facilities are typically available for all developers while in the third case, park facilities are exclusive to the entity and its subsidiaries that have set up the park. The importance of having a plug-and-play or park model has gained importance over the last few years due to increasing competition, dearth of resource-rich project sites, slow build-out of transmission infrastructure and escalating land prices. Such market conditions provide developers with renewable power parks a significant strategic and financial advantage over others.

Shorter project gestation period

When developers have transmission connectivity, land, and common infrastructure facility ready the actual project construction time reduces significantly. High degree of project readiness gives developers a competitive edge over other bidders as it means early scheduled commissioning date, potentially higher possibility of early offtake and favourable financing terms vis-à-vis other project developers. In tenders issued by corporate consumers, developers' ability to commission a project in the shortest time is one of the most important deciding factors for success.

Better market appeal

For most corporate consumers power procurement is not a core business, and they rely on external guidance – often from the project developer. In such a scenario, a company with high degree of readiness – land ready for construction, approved transmission connectivity, support infrastructure needed for project construction in place – will have a definite and significant edge over its competitors. While most developers may have project sites identified, construction readiness of the site is typically uncommon. Transmission connectivity approval for individual projects can take several months. However, once transmission connectivity is approved for a renewable energy park, getting the same for individual projects housed within the park is easier and swifter.

Reduced risk of penalties

With a plug-and-play model in place developers can avoid the risk of financial penalties and being blacklisted by tendering agencies and offtakers. Over the last few years, there have been multiple cases where project developers have failed to commission projects in time citing delays in land acquisition and/ or getting transmission connectivity in time. In many cases, such delays have resulted in partial or full encashment of bank guarantees by the tendering agencies or offtakers. Such developers also run the risk of being blacklisted from future tenders.

Criticality of land and transmission acquisition

Land acquisition is one of the most complex and time-consuming aspects of renewable energy development, often involving negotiations with multiple stakeholders, legal disputes, and bureaucratic delays. Access to pre-allocated land removes these obstacles, allowing developers to focus on project execution rather than legal battles. Pre-secured land and transmission infrastructure significantly shorten the project development cycle, enabling developers to achieve financial closure and commence operations more quickly.

Transmission constraints are one of the biggest risks for renewable energy projects delays in securing evacuation infrastructure can result in financial penalties or loss of revenue. With assured transmission access, projects can meet commissioning deadlines and avoid cost overruns. Investors and lenders prioritize projects with secured land and transmission access, as these factors directly impact project feasibility and revenue stability.

Securing these essential project elements enables developers to fast-track their projects, reducing the commissioning timeframe to just 4-6 months for solar projects and 6-9 months for wind projects, contingent upon timely procurement of modules and wind turbines.

3.8 Outlook on renewable capacity addition

The share of coal in the country's energy mix is estimated to decline to ~35% by fiscal 2031, due to limited thermal plant capacity additions. Hydropower capacity additions, including PSP (pumped storage) expected to be commissioned from fiscal 2026 - 2030, resulting in 7-9% share. The renewable energy market in India is supported by the Government's target of achieving 500.00 GW of non-fossil fuel-based installed capacity by 2030, implying renewable energy capacity additions of approximately 50 GW annually, in addition to C&I and captive power plant capacity additions. Renewable energy would account for the largest capacity addition of a total of ~260-275 GW till fiscal 2031. The share of total RE to reach 52-57% of total installed capacity in fiscal 2031.

3.8.1 Outlook on solar capacity additions in India

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

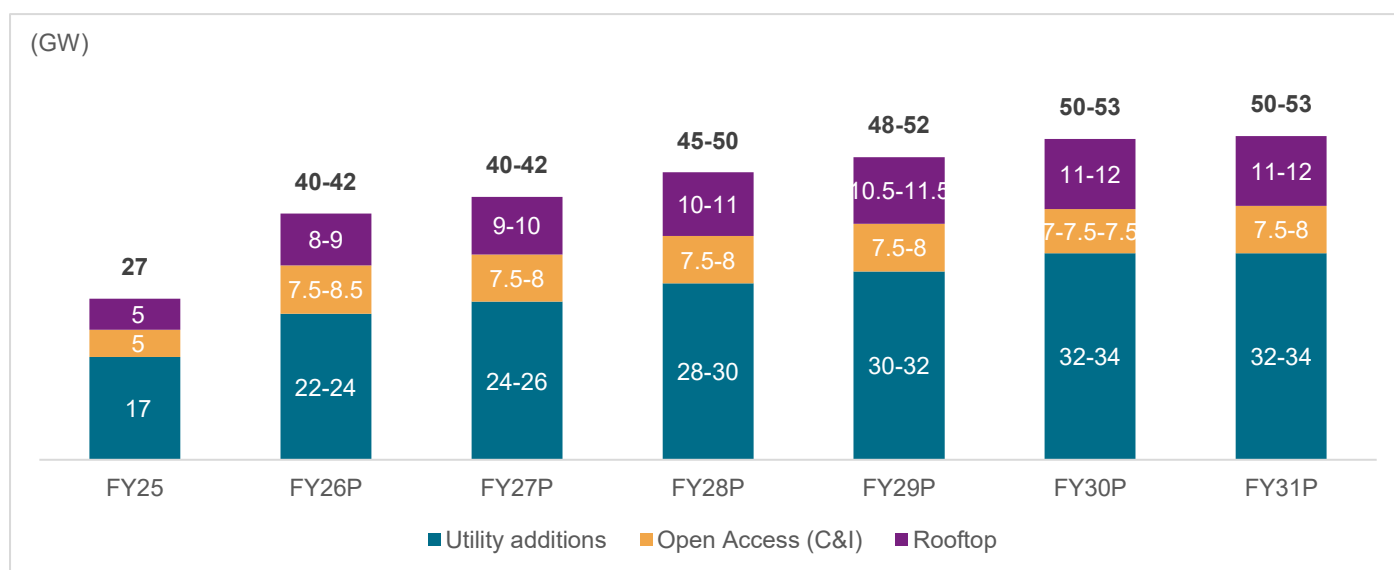
Crisil Intelligence expects 210-250 GW of solar capacity additions over fiscal 2027-2031. This will be driven by the additions under:

- **Other central schemes:** SECI has also started tendering projects outside the JNNSM Batch programme. It has initiated the ISTS scheme, wherein projects are planned for connection with the ISTS grid directly. Under this, SECI has already tendered and allocated ~38 GW (including hybrid).
- **State solar policies:** ~27 GW of projects are under construction and are expected to be commissioned over the fiscal 2027-2031 based on tendered capacities by states.
- **PSUs:** The CPSU programme under JNNSM has been extended to 12 GW in February 2019. The government is also encouraging cash-rich PSUs to set up renewable energy projects. NTPC has already commissioned a total of over ~3.7 GW of capacities in fiscal 2025. It has a target of installing ~60 GW of renewable energy

capacities by fiscal 2032. Similarly, NHPC has an installed capacity of 262 MW and a pipeline of 1,290 MW, while the Indian Railways has committed to 20 GW of solar power by 2030. Other PSUs such as NLC, defence organizations, and governmental establishments are also expected to contribute to this addition.

- **Rooftop solar projects:** Crisil Intelligence expects 50-60 GW of rooftop solar projects (under the capex and opex mode) to be commissioned by fiscal 2031, led by PM Surya Ghar Yojana and industrial and commercial consumers under net/gross metering schemes of various states.
- **Open-access solar projects:** Crisil Intelligence expects 35-45 GW of open-access solar projects (under the capex and opex mode) to be commissioned by fiscal 2031, led by green energy open access rules 2022, sustainability initiatives/RE 100 targets of the corporate consumers, better tariff structures and policies of states such as Uttar Pradesh and Karnataka, which are more long term in nature.

Figure 68: Year wise expected solar capacity addition



Source: Crisil Intelligence

Also, global conglomerates such as Amazon, and Microsoft have set their sustainability goals and procured more and more renewable energy in India to set off their global GHG emission. This also provides a lucrative opportunity for IPPs to sign PPAs for RE capacity. A 100 MW solar plant enables a reduction of 1,77,100 tCO_{2e} (with 22% CUF and a combined margin of 0.919) which is equivalent to planting approximately 0.71 million trees (with an average carbon sequestration of 25 kg per tree).

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

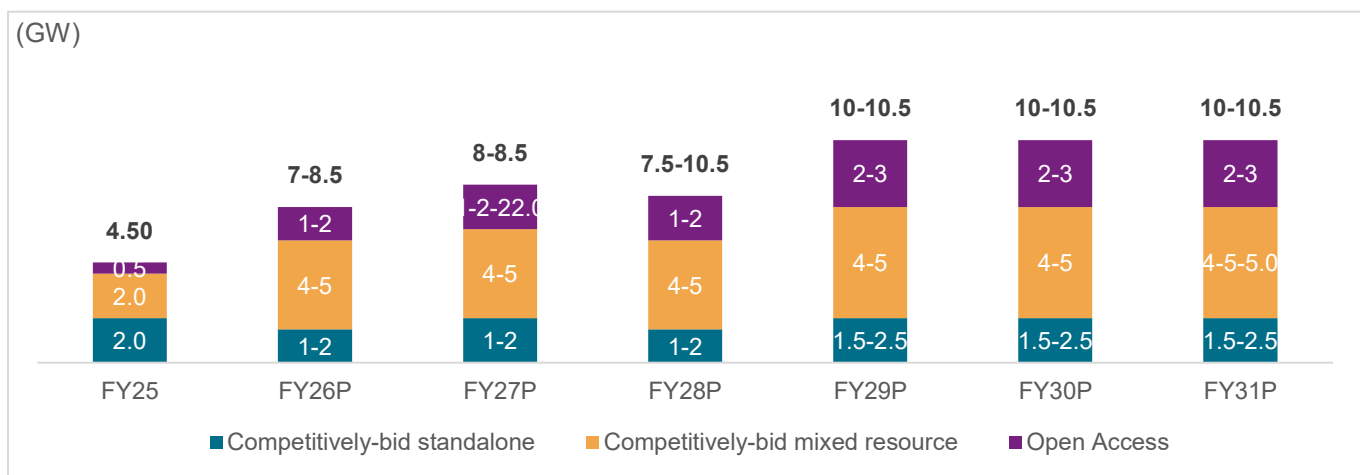
3.8.2 Outlook for wind capacity additions

Crisil Intelligence expects capacity additions to grow over the next five years led by pipeline build-up under existing schemes and new tendering schemes, improvement in technology, thrust on green hydrogen, renewable generation obligation and mixed resource models (RTC, hybrid, FDRE etc.). However, incremental challenges pertaining to wind-site/land availability, grid connectivity, and viability at low tariffs due to elevated capital cost pose challenges for the sector.

Led by India's ambitious clean energy targets declared under NDCs, focus on clean segments such as wind is expected to continue coupled with a healthy pipeline existing in the segment. The government policy to tender 10 GW wind capacity annually till fiscal 2028 will further boost the capacity additions. Central government allocations under relatively strong off-takers such as SECI and PTC, reduce risk and support developer interest. State allocation, on the other hand, has slowed as several states have instead signed power sale agreements (PSAs) with PTC and SECI for procurement of wind power to help fulfil their non-renewable purchase obligation targets.

Crisil Intelligence expects capacity additions of 45-50 GW over fiscals 2027-2031. Crisil Intelligence expects additions of 30-31 GW to come from competitively bid wind projects, while remaining 14-15 GW is expected from the open access segment. Mixed resource segment is estimated to see 68% of total additions in competitively bid wind segment adding 21.5-22 GW over fiscal 2027-31.

Figure 69: Expected annual wind power capacity additions



Source: Crisil Intelligence

Key factors to drive wind energy capacity additions

- New tender opportunities**

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

- Improved technology**

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

- Large-scale central allocations**

Post competitive bidding of 1 GW by SECI in February 2017, SECI further actively signed PPA tied capacity of ~16.4 GW over March 2017-January 2026 through standalone wind only schemes. This bodes well as central sector PPAs have lower counterparty risk compared with PPAs directly with discoms. The latter are known to delay payments to developers and have poor financial ratings, while SECI and PTC are better rated and provide various payment security mechanisms (LCs, payment security fund and SECI being party to the tripartite agreement).

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

- **Upward revision in RPO targets**

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

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

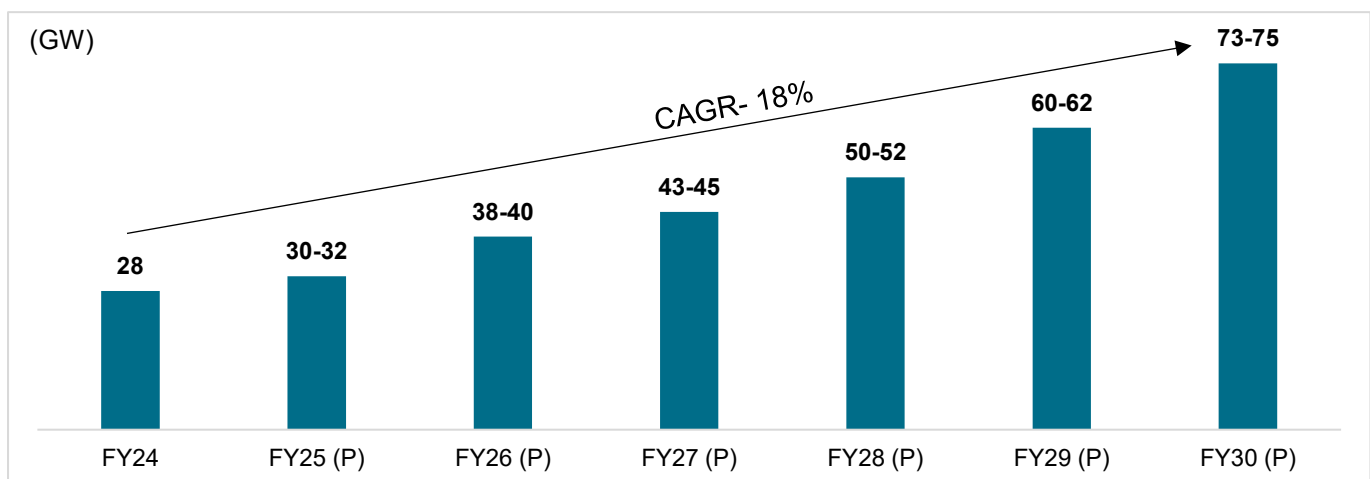
- **Accelerated depreciation**

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

3.8.3 C&I RE capacity addition outlook

Crisil Intelligence expects an installed capacity of about 75 GW of C&I driven RE capacity by fiscal 2030. About 45-50 GW is expected to be added between fiscal 2026-30. The capacity addition of 13-14 GW of open access capacity is expected from wind projects to deliver RTC power. About 18-20 GW from solar projects (large scale projects), led by green energy open access rules 2022, sustainability initiatives/RE 100 targets of the corporate consumers, better tariff structures and policies of states such as Uttar Pradesh and Karnataka, which are more long term in nature. Further, 12-14 GW of rooftop solar projects (under the capex and opex mode) is expected to be commissioned by fiscal 2030, led by industrial and commercial consumers under net/gross metering schemes of various states. Moreover, are also expected to be commissioned for C&I projects.

Figure 70: Expected installed RE capacity outlook in C&I market (solar, wind and rooftop)



P: Projected; Source: Crisil Intelligence

3.8.4 Benefits and challenges in open access market

Benefits

- **Bulk power at cheaper costs:** One of the main advantages and driving forces behind open access is the significant reduction in energy costs. Open access solar power offers a more economical alternative to purchasing electricity from DISCOMs, making it an attractive option for industrial consumers. The cost of industrial tariffs from DISCOMs can be substantial, ranging from Rs 6-8 per kWh, whereas open access solar power can be generated at a significantly lower cost of Rs 3-4 per kWh, excluding grid charges. This provides industrial consumers with the benefit of bulk energy consumption at affordable rates, making open access solar power a highly cost-effective solution.
- **Key decarbonisation lever:** For corporations, especially those dedicated to decarbonization, reducing emissions is a top priority, and renewable energy has emerged as a readily available and effective solution. As a commercially and technologically mature option, renewable energy offers a straightforward way for companies to significantly decrease their Scope 1 and 2 emissions, making it an attractive lever for those seeking to minimize their environmental footprint. By adopting renewable energy, corporates can achieve substantial emissions reductions, bringing them closer to their decarbonization goals.
- **Concessional benefits on open access charge:** Some states provide concessions on grid charges and captive consumers can avail benefit of exemption from cross-subsidy surcharge and additional surcharge and third-party consumers can also avail benefit of additional surcharge waiver, making it attractive for industries to shift to open access solar. These benefits reduce the overall cost of electricity procurement compared to purchasing from DISCOMs.
- **GOEA policy provides clear methodology for open access charge determination:** The GOEA policy aims to streamline the calculation of charges for open access consumers, ensuring predictability and transparency. This helps industries and commercial establishments make informed financial decisions while transitioning to renewable energy.
- **C&I segment benefits from diverse customers and flexible pricing** - Unlike the utility-scale segment, where energy is sold to a single off-taker, open access projects can have multiple industrial and commercial customers. This diversifies revenue streams and reduces financial risks for developers. C&I players also have the option to choose between different pricing models, such as short-term PPAs (3-5 years) or tariffs linked to industrial rates, rather than being locked into fixed long-term rates.
- **Technological flexibility:** Open access solar projects can incorporate battery storage or hybrid solutions (e.g., solar + wind) to enhance power reliability. Industries can optimize their power consumption by storing excess energy for later use, reducing dependence on the grid during peak hours. Waste heat recovery systems (WSH projects) can be integrated with solar for additional efficiency gains.

Challenges

- **Varying and rising open access charges:** While open access solar is cost-effective, state regulations frequently change, leading to uncertainty in charges. Grid charges are revised annually which can reduce potential savings and impact project viability.
- **Limited banking facility for excess renewable generation:** In most states, there is a limitation on storing excess solar power generated during the day in the grid for later use, with restrictions on the duration for which it can be stored or total quantum of power that can be stored. This constraint compels consumers to either utilize excess power immediately or relinquish it, resulting in inefficiencies and potential losses. Furthermore, some states that previously offered banking facilities, which allowed excess energy to be stored and used later, have either modified, or withdrawn these provisions. This change has retroactive implications,

affecting older projects that were established with the assumption of longer banking periods, thereby disrupting their operations and financial viability.

- **Grid infrastructure constraints:** Availability of transmission corridors is a major barrier, as open access projects need to use the existing grid to transport power. Congestion in T&D networks, particularly in states with high renewable penetration, can lead to curtailment of power generation.
- **Administrative difficulties created by DISCOMs:** State DISCOMs, fearing revenue loss from high-paying industrial customers, often create bureaucratic hurdles. These include delays in granting open access approvals, refusal to sign necessary agreements, and imposing restrictive policies.
- **Dependence on industrial tariffs:** Open access solar pricing is often linked to industrial electricity tariffs, which are volatile. If industrial tariffs fall due to government interventions, open access projects may become less competitive.

3.8.5 Benefits and challenges in utility scale market

Benefits

- **Payment Assurance:** The utility-scale market offers a high degree of payment assurance, which is a significant advantage for developers and investors. PPAs signed with government-backed agencies, DISCOMs, provide a guarantee of payment. This reduces the risk of payment defaults, as the offtaker is a credible entity with a strong credit history. Utility PPAs are 25-year long agreements ensuring a stable and predictable revenue stream. The segment has faced challenges due to delayed payments to generators, which has put the sustainability of the industry at risk. However, timely interventions by the government have helped DISCOMs to improve their financial stability, and the introduction of stricter penalties has ensured more prompt payments, thereby mitigating the risk of delayed payments.
- **Strong push from government:** The government has been actively promoting the growth of the utility-scale market through various initiatives and policies like RPO, bidding trajectory, VGF to support projects that may not be financially viable. These initiatives have provided the necessary support for the market to mature and have made the transition to renewables more financially attractive for DISCOMs.
- **Protection against policy changes:** The utility-scale tenders provide developers with a degree of flexibility in case of changes in policy or law. If there is a change in law that affects the project, developers can seek relief under the "Change in Law" provision. This provision allows developers to renegotiate the terms of the PPA or seek compensation for any losses incurred due to the change in law. This flexibility reduces the risk associated with policy changes and provides developers with a degree of certainty and stability.
- **Land and other infrastructure:** In some cases, the offtaker provides land for the project, making it easier for developers to acquire the necessary infrastructure. This can be a significant advantage, as land acquisition can be a major challenge for large scale projects.
- **Long-Term Revenue Stability:** The typical 25-year duration of PPAs ensures a stable and predictable revenue stream.

Challenges

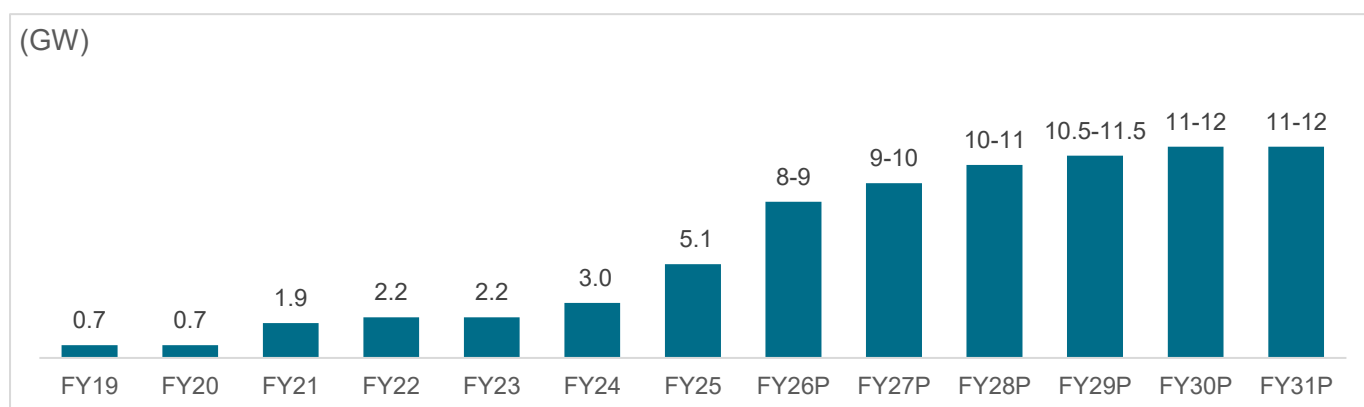
- **Growth dependent on auction wins:** Unlike open access, where developers can sell directly to industries, utility-scale renewable projects must win government auctions to secure business. The growth of these projects is therefore limited by the frequency and size of government tenders.

- **Fixed capacity allocation through long-term PPAs:** Utility-scale projects sign long-term PPAs with DISCOMs (typically 20-25 years). While this provides revenue stability, it also restricts flexibility, as developers cannot take advantage of rising market prices.
- **Bid-based fixed tariff structure:** Utility-scale projects are awarded based on competitive bidding, where developers must offer the lowest tariff to win contracts. This leads to price pressure and thinner profit margins, making it difficult for developers to absorb unforeseen cost increases.
- **Limited customer diversification:** Unlike open access, where multiple buyers can be engaged, utility-scale projects are locked into agreements with a single off-taker (usually a DISCOM). If the off-taker delays payments or defaults, the entire project's revenue stream is at risk.

3.8.6 Outlook for rooftop solar capacity additions

Crisil Intelligence expects 50-60 GW of projects to be commissioned between fiscal 2027-2031, led by the commissioning of capacities by SECI; capacities allocated by state governments, commissioning of capacities by government institutions; and capacities to be added by industrial and commercial consumers under net/gross metering schemes of various states. Residential rooftop consumers will also contribute to the growth. The Prime Minister's household scheme if effectively implemented can boost the residential segment offtake substantially.

Figure 71: Projected rooftop solar capacity additions over fiscals 2027-2031



Source: MNRE; Crisil Intelligence

3.8.7 Benefits and challenges in rooftop solar market

Rooftop solar is one of the simplest procurement option available to all consumers, irrespective of their size and credit rating, owning suitable rooftop space. Its other advantages include low cost due to exemption from grid charges in most states, minimal technology and construction risk, and no requirement of land and transmission infrastructure. However, consumers can typically achieve renewable power penetration of only about 10-20% depending on rooftop space availability.

Despite the Indian government's ambitious targets and initiatives to promote solar rooftop installations, several technical issues and factors may hinder the growth of rooftop solar capacity additions in India. Some of the bottlenecks which could hinder the growth of rooftop solar is the availability of affordable finance to residential consumers and small-scale industries due to their weak credit profile and ability to provide collateral. Further, discom's unwillingness to provide connections to high paying consumers in industrial and commercial segments. Discoms prefer to buy power from ground-mounted solar projects instead of rooftop projects due to lower tariffs in the segment. Moreover, there is a lack of long-term agreement for rooftop occupancy and issues related to enforceability of contracts. The RESCO mode of operation is currently successful only for government agencies and public infrastructure, such as rooftops of metro stations, railway platforms, and other government buildings, where the lending institution has surety for long-term roof availability.

Apart from the above, there are a few technical reasons which also affect the rooftop solar capacity addition:

- Households in high-rise buildings lack exclusive access to rooftops
- Inadequate roof space, irregular roof shapes and shading issues due to inappropriate orientation
- A large proportion of people live in rented properties in tier 1 and tier 2 cities and, thus, do not control the decision to adopt rooftop solar
- Developers face a significant challenge of aggregating small-scale customers in order to offer them a cost-effective solar rooftop system
- Limited awareness and education about the government policies, benefits, and technical aspects of rooftop solar
- Difficulties in selecting a reliable vendor for EPC and O&M

Indian renewable sector presents a vast and promising opportunity, with growth prospects that are extremely encouraging. Being an integrated renewable energy player will be critical in the coming times, as it will enable developers to gain a competitive edge in the market. An integrated player with control over the entire value chain, from manufacturing and supply of equipment to development, construction, and operation of renewable energy projects shall provide developers with a unique advantage, allowing them to optimize costs, improve efficiency, and enhance their overall project viability.

With the government's ambitious targets for renewable energy capacity addition, the demand for equipment, services, and expertise is expected to surge. Integrated players will be better positioned to capitalise on this demand, as they will have greater control over the supply chain and be able to respond more quickly to changing market conditions. Moreover, an integrated approach will also enable developers to mitigate risks associated with supply chain disruptions, equipment shortages, and other external factors that can impact project timelines and costs.

3.9 Competitive landscape

3.9.1 Peer comparison

India's renewable IPP business landscape is becoming increasingly competitive, and only those IPPs that have built structural advantages have been able to successfully scale and retain sizeable market share. The market is already separating players who have strategically diversified offtake, secured supply chain control, and locked in critical infrastructure from those who remain exposed to external risks.

Winning IPPs have balanced their portfolios by tactically bidding for utility-scale projects while also securing long-term C&I PPAs to reduce exposure to auction-driven tariffs. Players with large captive demand either from their own group companies or through strategic partnerships have ensured a stable revenue base, giving them an edge over those relying solely on central or state tenders.

At the same time, IPPs that have integrated their supply chains by building in-house EPC teams and investing in module and cell manufacturing are now better positioned against global trade volatility and policy shifts favoring domestic production. Additionally, those who have proactively secured land and ISTS connectivity well in advance have ensured faster project execution and reduced development risks.

There are fully integrated companies those have built a complete renewable energy value chain, from IPP operations to in-house EPC, O&M, and manufacturing of solar modules and cells. These companies are best positioned to sustain and scale as they control both supply and project development.

Another key trend shaping the sector is the transition from vanilla solar and wind projects to hybrid renewable energy solutions. With utilities, commercial buyers, and government agencies increasingly demanding RTC power, IPPs that were previously focused solely on solar or wind have now pivoted toward hybrid projects that combine solar, wind, and battery storage to provide more stable and predictable energy supply. As corporate buyers and Discoms increasingly seek reliable green power, and with the support of the National WSH Policy and similar initiatives in Gujarat, Andhra Pradesh, and Rajasthan, demand for integrated hybrid energy solutions is accelerating.

Several IPPs have been actively bidding in hybrid and RTC tenders and securing large-scale hybrid project pipelines as they recognize that standalone solar or wind projects will no longer be sufficient in a market that prioritizes grid stability and high availability power supply.

To gain a competitive edge, companies are now offering a range of services to C&I consumers, including green credits. They are also expanding into adjacent segments, such as green hydrogen. In this market, players typically compete by making strategic investments in land acquisition, securing transmission connectivity approvals, and developing other essential infrastructure, which accounts for around 8-10% of the project's total cost. The ability to quickly commission a project within 6-12 months of signing a PPA is a significant selling point for attracting consumers.

Table 14: Key players in RE IPP business

Parameter	Inox Clean	NTPC GEL	Adani Green Energy	Renew	Avaada	JSW Neo	TATA Power REL
Promoter/ Group	Inox Clean Energy	NTPC	Adani Group	Renew Group	Avaada	JSW	TATA Power
Operational capacity (GW) as on 30/06/2026	Solar: 0.91 Wind: 0.72 Hybrid: 0.66	Solar:9.9 Wind:0.8 (Incl. group companies)	Solar:14.20 Wind:2.67 WSH:3.27	Solar:6.45 Wind: 4.43 FDRE:1.86	Solar: 7.04	Solar:2.28 Wind:3.13 WSH:1.70	Solar:5.43 Wind:1.3
Under construction/ Development capacity (GW) as on 30/06/2026	Solar: 3.15 Wind:1.12 Hybrid:0.57 FDRE/Solar+ BESS:2.17	Under-construction/ pipeline :16.32	NA	Solar:1.32 Wind:0.26 FDRE:5.36	Solar:9.2 Hybrid: 7.6 Wind: 0.2 FDRE:9.6	Under-construction /pipeline:9.77	Solar:0.52 Hybrid: 1.44 Wind: 0.83 FDRE:2.44
Solutions offered	IPP EPC, O&M Wind and Solar PV manufacturing	IPP Hybrid Corporates RTC/ Storage	IPP Corporates RTC/ Storage Solar Park development	IPP Corporates Green credits Energy management RTC/Storage Solar PV manufacturing	Renewable IPP, RTC Storage Hybrid, FDRE, green hydrogen, solar PV manufacturing	IPP Corporates RTC/ Storage	IPP Corporates RTC/Storage Rooftop solar Solar PV manufacturing
Manufacturing capabilities	Solar Gujarat facility 3.0 GW operational module manufacturing facility in Gujarat Odisha facility 5.0 GW integrated solar module and cell manufacturing facility Phase 1 (2.4 GW) by Q1 of FY28 FY2 (2.6 GW) by Q2 of FY28. Wind 2.5 GW of wind turbine generator manufacturing	None	Solar 4 GW operational cells and module capacity 10 GW cell and module capacity in pipeline Wind 2.25 GW wind turbine manufacturing capacity	6.4 GW module manufacturing capacity and 2.5 GW cell capacity	8.5 GW module and 3 GW Cell capacity commissioned 5.1 GW module and 9 GW cell manufacturing capacity in pipeline	None	4.9 GW module and cell manufacturing capacity

Parameter	Inox Clean	NTPC GEL	Adani Green Energy	Renew	Avaada	JSW Neo	TATA Power REL
	at Gujarat and MP						
Captive demand by group companies	Gujarat Fluorochemicals, GFCL EV, Inox Solar		Adani ports, ACC Limited, Ambuja Cement, Adani Airports	None	None	JSW steel, JSW cement, JSW MG Motor India, JSW Paints	TATA Motors, TATA Steel, TATA Consultancy Services, TATA Chemicals, The Indian Hotels Company, TATA Consumer Products
In-house EPC and O&M capabilities	Relies on in-house EPC and O&M team	Relies on only third-party services	Relies on only in-house team	Relies on only in-house team	Relies on only in-house team	Relies on both in-house and third-party services	Relies on only in-house team
Portfolio structuring	Leading player of wind and solar	Leading player in utility segment, plans on entering C&I market	Top player in utility segment	Leading market player in utility and C&I segment	Presence in both utility and C&I segment	Presence in both utility and C&I segment	Leading rooftop solar EPC player, utility, and C&I project developer

WSH: Wind solar hybrid; RTC: Round the clock;

Source: Company websites, Crisil Intelligence Financing and Investment Trend

IPPs that have not taken strategic steps toward integration whether in supply chain, EPC, or diversified offtake models are now at a significant disadvantage. Those still operating under single-source generation models (solar-only or wind-only), without hybrid capabilities, face declining competitiveness in future tenders. Additionally, firms that have not secured their supply chains remain vulnerable to fluctuating module prices, supply chain disruptions, and the increasing cost of securing land and connectivity.

As competition intensifies and policy frameworks evolve to support domestic manufacturing and hybrid energy solutions, only players who have executed on these fronts will be able to sustain in the renewable energy business. The market is already making a distinction, and companies that fail to adapt will find it increasingly difficult to compete.

The IPPs in the C&I RE space in India offering clean energy solutions to diverse verticals including manufacturing, aerospace & defence, automotive, FMCG, pharma, food processing, retail chains, educational institutes, hospitals & healthcare, office buildings, shopping malls, etc. Some of the major companies are as follows:

Table 15: Key players in C&I open access

Players	Brief description
AMPIN Energy Transition	Headquartered in India, have presence across key C&I consumer segment such as automobiles, FMCG, heavy industries, cement & steel, pharma & healthcare, data centres and govt. institutions. It has a portfolio of over 3.8 GW including about 1.5 GW of C&I open access capacity. It offers solar, wind, WSH, BESS and Energy Management solutions.
Amplus Solar Power Pvt Ltd	It is part of PETRONAS group, Malaysia and is headquartered in India. It offers RE solutions to C&I customers by setting up on-site and off-site solar projects. It has a portfolio of over 2.3 GW.
Avaada Energy Pvt Ltd	Headquartered in India. It has implemented C&I projects over 1 GW and are engaged with domestic and multi-national entities for open access.
CleanMax Enviro Energy Solutions Pvt. Ltd.	Headquartered in India, have presence across automotive, education, pharmaceuticals, FMCG, and IT. It has a portfolio of over 5 GW. It is backed by investors like Augment Infrastructure, a US-based fund manager, Danish Investment Fund and UK Climate Investments.

Players	Brief description
Cleantech Solar Group	Headquartered in Singapore and operate across India and Southeast Asia focusing on long-term investments within the C&I customer segments. It has an overall capacity of over 750 MW under open access solar, wind, WSH and rooftop solar energy solutions.
Continuum Green Energy Ltd.	Headquartered in India, with a focus on C&I consumer segment offering utility-scale wind and WSH projects. It has a portfolio of over 4 GW. It is backed by North Haven Infrastructure Partners, a US \$4 bn Global Infrastructure Investment Fund managed by Morgan Stanley Infrastructure Partners.
Fourth Partner Energy Pvt. Ltd.	Headquartered in India and operates in Bangladesh, Indonesia, Vietnam and Sri Lanka. Have a portfolio of over 3.5 GW. Offers solar, wind, hybrid, RTC and BESS solutions to C&I consumers.
Hero Future Energies Pvt. Ltd.	Offers behind the meter ESS, distributed and utility scale solar solutions to C&I consumers.
ReNew Energy Global plc	ReNew Green Solutions is the B2B vertical of ReNew Power to provide customisable green energy solutions to C&I segment. It has a portfolio of over 2.2 GW
TATA Power Renewable Energy Ltd.	It offers utility scale as well as rooftop solar solutions to large corporates and small businesses

Source: Company websites, Industry reports, Crisil Intelligence

3.9.2 Source of funding

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

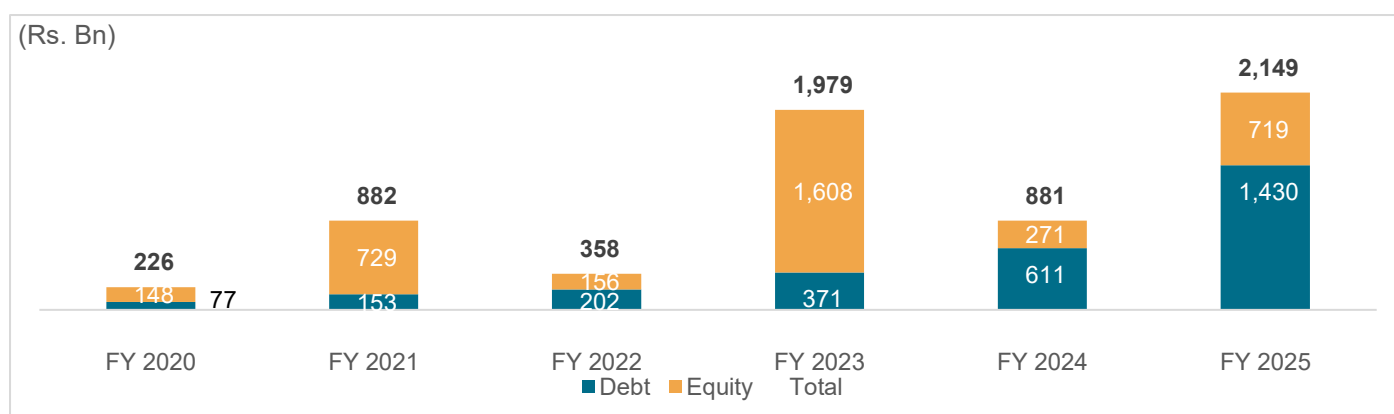
Funding from lending institutions such as PFC, IREDA, REC and PFS: Government financial institutions such as Power Finance Corporation (PFC), PTC India Financial Services Limited (PFS), Rural Electrification Corporation (REC) and IREDA are financing many solar projects. As of March 2026, loan asset book of PFC stood at Rs. 11.64 trillion as on March 2026. PFC continues to be the largest renewable sector financier in the country. REC's Loan Book has grown to Rs. 5,84 trillion as of March 2026.. Further, Loan sanctions by IREDA surged to Rs. 518.83 billion as of March 2026. The company's outstanding loan book stood at Rs. 930.07 billion as on March 2026.

- **Green bond / masala bonds market:** A green bond is like any other bond; however, it invests the proceeds to support green investments including renewable energy projects. The tenure of the bonds typically ranges from 18 months to 30 months. India is the second country after China to have national-level guidelines for green bonds; in India's case, they were published by SEBI. The green bonds may be issued by the national government; multilateral organisations such as Asian Development Bank, the World Bank or the Export-import (EXIM) bank of the country; financial institutions; and corporations. According to the Climate Bonds Initiative's latest update as of 2023, the Indian market has witnessed a significant surge in the issuance of green bonds, with a cumulative total of ~ \$38.3 billion. This substantial figure underscores the growing momentum and commitment of Indian entities towards embracing sustainable financing practices and contributing to the global efforts to mitigate climate change. Introduction of sovereign green bonds and green banking norms in India is creating improved access to funding for renewable developers.
 - In Q1 FY 2024, Renew Power raised \$ 400 million from a foreign investor as a high yield green bond for refinancing its SOFR linked loans due to inflated interest rates in the past year.
 - In Q4 FY 2023 RBI sold its first sovereign green bonds worth Rs. 80 billion.
- **Private Sector Participation:** Private banks and Non-Banking Financial Companies (NBFCs) contribute through syndicated loans and green bond investments.
- **Pension funds / endowment funds:** Pension / endowment funds are expected to play a key role in financing solar projects. Long-term 25-year PPAs with limited operational risk are very suitable to this investor category.
- **Funding from multilateral banks and International Solar Alliance (ISA):** The Central government channelises the funds available from multilateral banks and financing institutes such as World Bank and KfW. The Central government or its representative gets the funds, and it further gets allocated/allocated to various States/State

government schemes. Funds are also provided to various CPSUs/ Central non-banking financial companies (NBFCs) with Indian government backing under the Climate Investment Fund of the World Bank. For instance, State Bank of India (SBI) has also received ~US\$625 million of soft loans with a long tenure of 20 years from the World Bank at a concessional rate to support viable grid-connected rooftop solar PV projects. On the same lines, KfW Germany provided a 1-billion-euro loan through IREDA for funding solar projects. Further, European Investment Bank has signed a long-term loan of 150 million euros with IREDA to finance clean energy projects in India. The ISA, an association of solar-resource-rich countries, launched by the governments of India and France, aims at mobilising \$1,000 billion in funds by 2030.

The energy sector has continued to attract significant capital through both equity and debt channels, driven by the rising demand for cleaner technologies, infrastructure upgrades, and policy support. The period has seen diversified investment activity, reflecting a balanced approach toward financial sustainability and sectoral growth.

Figure 72: Total equity and total debt investment



Source: Crisil Intelligence

The FY 2025 witnessed a notable surge in investment activity, with debt financing emerging as the primary funding mechanism. Notably, this FY also recorded the highest level of financing, closely followed by FY 2023. A comparative analysis with the corresponding FY 2024 and FY 2025 reveals a significant uptick in investment trends, projecting a positive trajectory in the industry's financial landscape. Some of the major equity and debt investments, including:

Table 16: Recent equity and M&A investments

Sr. No.	Month	Target company	Deal Type	Investor	Portfolio /Deal Value (Rs bn)	Stake Acquired (%)	Remarks
1	Aug-2026	Vena Energy	M&A	Inox Group	0.627	100	To pursue growth opportunities across the energy transition landscape
2	July-2026	Sprng Energy	M&A	Aditya Birla Group	1.8	100	Accelerates RE growth ambitions by combining its strong presence in the C&I segment with Sprng Energy's complementary utility-scale platform.
3	Jan-2026	SunSource Energy	M&A	Inox Group	NA	NA	~ 300 MWp operating portfolio of SunSource Energy
4	Dec-205	Vibrant Energy	M&A	Inox Group	NA	NA	~1,337 MW diversified C&I platform.
5	Mar-25	Ayana	M&A	ONGPL	62.5	100	For supporting the expansion of Renewable portfolio.
6	Jan-25	ENEL Green Power India	M&A	Waaree	7.9	100	Expansion of project pipeline, strengthening wind project capabilities and renewable energy business.
7	Dec-25	O2 Power Pooling	M&A	JSW Neo Energy	125	100	Expansion of renewable 100portfolio by ~ 4.6 GW

Sr. No.	Month	Target company	Deal Type	Investor	Portfolio /Deal Value (Rs bn)	Stake Acquired (%)	Remarks
8	Sep-24	Total EREN	M&A	Total Energies	134	100	Increased the ownership by acquiring the remaining 70% stake.
9	Aug-24	Renom	M&A	Suzlon	51	4	Establishment of market leadership in the wind energy O&M service business.
10	Feb-24	Gensol	Equity	Multiple	9.0	NA	Rs 900 crore was raised via Equity capital through warrants convertible into equity shares on a preferential basis.

Source: Crisil Intelligence

3.9.3 Role of a strong balance sheet and parent support in driving scalable and sustainable business growth

In today's rapidly evolving business landscape, a robust balance sheet and reliable parental backing have become essential prerequisites for ensuring long-term sustainability, financial stability, and growth potential of businesses. This is particularly crucial for companies aiming to tap into capital markets, venture into new markets, or operate in sectors that require significant capital investment and regulatory compliance, such as infrastructure, energy, finance, manufacturing, and technology. A strong balance sheet and credible parental support are vital for these companies to navigate the complexities of the business environment and achieve strategic scalability. The role of parent companies extends beyond capital provisioning. It encompasses strategic oversight, operational expertise, governance frameworks, credit enhancement, and brand leverage. In the Indian context, where conglomerates often operate through a portfolio of subsidiaries and SPVs, the track record, financial health, and commitment of the parent group can significantly influence the investibility of the entity seeking public funds.

Strategic Relevance of a Strong Balance Sheet

A strong balance sheet is characterized by prudent leverage, optimal capital structure, adequate liquidity reserves, and high-quality assets which significantly enhance a company's operational flexibility and strategic optionality. enables them to undertake long-term projects, weather market fluctuations, and invest in research and development without being overly exposed to debt-related risks. A strong balance sheet provides companies with the necessary financial cushion to drive innovation, pursue growth initiatives, and create long-term value for stakeholders

Key Benefits of a Strong Balance Sheet:

1. **Access to Low-Cost Capital:** Companies with strong balance sheets typically enjoy superior credit ratings, enabling them to access debt at more favorable interest rates and from a broader pool of lenders, including international investors and development finance institutions.
2. **Operational Continuity and Risk Mitigation:** During periods of macroeconomic turbulence, characterized by commodity price volatility, geopolitical uncertainty, or declining demand, a robust balance sheet serves as a critical financial buffer, enabling companies to maintain business continuity and uphold stakeholder confidence. The presence of a sound balance sheet provides a degree of insulation against external shocks, allowing companies to navigate challenging economic conditions with greater resilience and stability. This, in turn, helps to mitigate the risk of operational disruptions, preserve stakeholder value, and ensure the long-term sustainability of the business.
3. **Growth Capital and Strategic M&A:** A company's ability to generate robust internal accruals and maintain low gearing is crucial in enhancing its capacity to pursue strategic growth initiatives, such as funding acquisitions, participating in auctions (including Public-Private Partnership (PPP) projects), or entering into joint ventures. By leveraging its internal cash flow and maintaining a prudent debt-to-equity ratio, a company can minimize its reliance on external financing, reduce the risk of diluting shareholder value, and avoid breaching debt covenants.

4. **Regulatory Compliance:** In highly regulated sectors such as energy and infrastructure, the regulatory bodies impose stringent capital adequacy requirements, leverage thresholds, and provisioning norms to ensure the stability and soundness of these industries. A strong balance sheet is essential for companies operating in these sectors, as it enables them to maintain continuous compliance with these regulatory requirements, thereby minimizing the risk of regulatory friction and potential penalties.

Additionally, Corporates having an integrated approach to renewable play - with wind/ solar manufacturing, EPC and O&M along with renewable energy generation via wind/solar and captive renewable consumption have an edge in terms of execution, costs, speed to market etc.

3.10 Challenges and Risk Assessment

The renewable energy sector in India is undergoing rapid transformation, driven by ambitious national targets such as achieving 500 GW of non-fossil fuel-based capacity by 2030. IPPs in the renewable energy domain play a pivotal role in achieving these targets. However, despite the robust growth prospects in the sector, the RE-IPP business is exposed to a complex array of risks that span across the policy, financial, operational, and market landscape.

3.10.1 Policy and regulatory uncertainties

The Renewable Energy Independent Power Producer (RE-IPP) business in India is inextricably linked with the country's policy and regulatory framework, which plays a crucial role in shaping the sector's growth trajectory. The RE-IPP business is highly sensitive to changes in government policies and regulations, whether at the central or state level, as these can have a profound impact on business continuity, revenue certainty, and overall investment attractiveness. Some of the key policy and regulatory factors that can affect the RE-IPP business in India include:

- **Regulatory Fluidity:** India's renewable energy policy is subject to frequent updates, such as modifications in the RPOs, Banking Policies, and the introduction or withdrawal of schemes like the ALMM.
- **Open Access Constraints:** Variations in open access regulations, banking provisions, and cross-subsidy charges across states impact scalability.
- **Curtailment without Compensation:** SLDC-imposed curtailments without financial recompense during high generation periods.
- **Regulatory Delays:** Tariff adoption, connectivity approvals, and policy notifications are often delayed.
- **Taxation and incentives:** Changes in taxation policies, such as the imposition of GST or the withdrawal of incentives like accelerated depreciation, can affect the financial viability of RE-IPP projects.
- **State-level policies:** Variations in state-level policies, such as differences in RPOs, or net metering policies, can create uncertainty and affect the investment attractiveness of RE-IPP projects.

3.10.2 Land acquisition and grid integration constraint

Access to land and timely grid connectivity are essential prerequisites for the development of RE projects, as they form the foundation upon which these projects are built. However, despite their critical importance, these two factors continue to pose significant challenges for RE project developers in India

- **Land Acquisition:** The process of acquiring land for RE projects is often complex, time-consuming, and prone to disputes, which can lead to delays and cost overruns. Others include legal title issues, zoning restrictions, and opposition from local stakeholders.
- **Land ownership and rights:** The lack of clear land ownership and rights can create uncertainty and disputes, making it challenging for RE project developers to secure the land needed for their projects.
- **Transmission Infrastructure:** The availability and accessibility of grid infrastructure can be a significant bottleneck for RE project development, as it requires careful planning, coordination, and execution to ensure timely and efficient connection to the grid.

- **Transmission and distribution infrastructure:** The condition and capacity of transmission and distribution infrastructure can also impact the ability of RE projects to evacuate power and sell it to consumers.
- **Right of Way (RoW):** One of the significant challenges facing the development of renewable energy projects in India is the resistance and bureaucratic inefficiencies encountered during the acquisition of Right of Way (RoW) for transmission lines. The process of obtaining RoW is a critical step in the development of RE projects, as it enables the transmission of power from the project site to the grid. However, the acquisition of RoW is often hindered by resistance from local communities, farmers, and other stakeholders, which can lead to delays, cost overruns, and even project abandonment.

3.10.3 Tariff volatility PPA risks

PPAs are a crucial component of the financial viability of Renewable Energy projects, as they provide a guaranteed revenue stream for the project developer. However, in recent times, PPAs have come under increasing stress, posing a significant challenge to the financial sustainability of RE projects.

- **PPA Renegotiation:** Some state governments and DISCOMs have attempted to renegotiate PPAs, citing high tariffs and seeking to reduce the burden on consumers. This has created uncertainty and risk for RE project developers.
- **DISCOM Payment Delays:** DISCOMs have been facing financial difficulties, leading to delays in payments to RE project developers. This has resulted in a significant increase in outstanding dues, affecting the cash flow and financial health of RE project developers.
- **Grid curtailment:** Grid curtailment, or the intentional reduction of power output from RE projects, has become a frequent occurrence. This not only affects the revenue of RE project developers but also undermines the viability of RE projects.
- **Auction Pressure:** Tariff compression in reverse auctions erodes project margins.
- **Counterparty risk:** The creditworthiness of DISCOMs and other off takers has become a concern, posing a significant counterparty risk to RE project developers.

3.10.4 Supply chain issues and dependency on imports

The RE-IPP sector in India is heavily reliant on imported equipment and raw materials, which exposes these businesses to significant global supply chain risks. The reliance on international suppliers for critical components, such as solar wafers, cells, wind turbines, and inverters, can lead to a range of challenges, including:

- **Trade tensions and tariffs:** Trade tensions and tariffs imposed by countries such as the United States and China can increase the cost of imported equipment and raw materials, affecting the viability of RE-IPP projects.
- **Supply chain disruptions:** Global events, such as natural disasters, pandemics, and geopolitical conflicts, can disrupt supply chains, leading to delays and shortages of critical components.
- **Currency fluctuations:** Fluctuations in currency exchange rates can impact on the cost of imported equipment and raw materials, affecting the profitability of RE-IPP projects.
- **Quality and reliability concerns:** Reliance on imported equipment and raw materials can also raise concerns about quality and reliability, which can impact the performance and lifespan of RE-IPP projects.
- **Dependence on a few suppliers:** The RE-IPP sector's reliance on a limited number of suppliers can create a concentration risk, making it vulnerable to supply chain disruptions and price volatility.

3.10.5 Financial and operational risks for IPPs

Given the capital-intensive nature of RE projects, financial and operational risks are intrinsic. The high upfront costs associated with RE project development, including the cost of land acquisition, equipment, and construction, can strain the financial resources of project developers and investors. Furthermore, the long-term nature of RE projects,

which can span several decades, exposes them to a range of operational risks that can impact their performance and profitability.

- **High upfront costs:** The high upfront costs of RE project development can make it challenging for project developers to secure financing and ensure the financial viability of their projects. Project financing structures involve high debt levels, subject to interest rate and refinancing risks
- **Financing risks:** The availability and cost of financing can be uncertain, and changes in interest rates, currency exchange rates, and other market conditions can impact the financial performance of RE projects.
- **Resource Underperformance:** One of the major impacts arises due to deviations in solar irradiation/wind speeds from projections.
- **Currency risks:** RE projects that rely on imported equipment or financing may be exposed to currency risks, including fluctuations in exchange rates and currency devaluation
- **ESG Compliance:** Increasing demand for transparent ESG disclosures and practices
- **Technology risks:** The performance and reliability of RE technologies, such as solar panels and wind turbines, can be uncertain, and technological failures can impact the operational performance of RE projects.
- **Maintenance and repair risks:** RE projects require regular maintenance and repair to ensure optimal performance, and the cost of these activities can be significant.

3.10.6 Other factors affecting RE adversely

The wind and solar power markets are developing at a fast pace in India. The wind and solar energy companies continue to experience improved efficiency and higher electricity output. However, trends in the renewable energy industries are based only on limited data and may not be reliable. Many factors may adversely affect the demand for wind and solar projects in India, including:

- Fluctuations in economic and market conditions that affect the viability of conventional and renewable energy sources;
- The cost and reliability of wind and solar projects compared to conventional and other renewable energy sources;
- The cost competitiveness as compared against tariffs for conventional energy sources and the preference of some state utilities for conventional energy sources;
- Public perceptions of the direct and indirect benefits of adopting renewable energy technology; and
- Regulations and policies governing the electric utility industry that may present technical, regulatory and economic barriers to the purchase and use of wind energy.

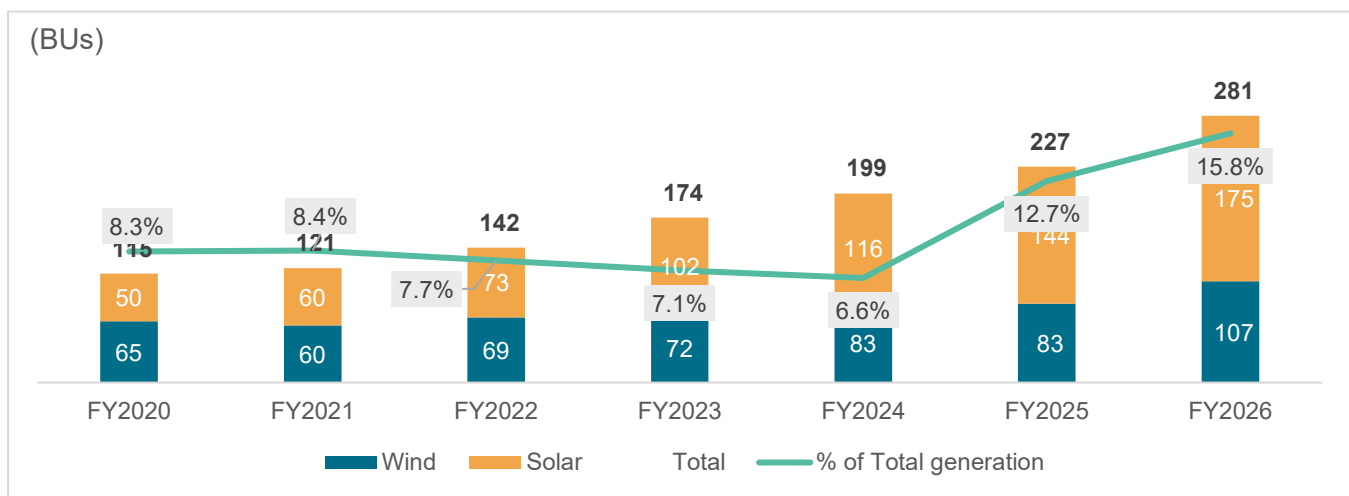
4 Assessment of RE (solar & wind) EPC and O&M market in India

4.1 RE (Solar and wind) EPC

4.1.1 Broad overview of RE market in India

India added ~ 116 GW of solar and ~ 18 GW wind capacity in the last 7 years (fiscal 2020 to fiscal 2026). As of March 2026, India has installed capacity of ~150 GW of solar and ~ 56 GW wind respectively. RE generation (from wind and solar) has increased from 115 BUs in fiscal 2020 to 281 BUs in fiscal 2026 at a CAGR of ~16.1%. Wind energy has witnessed a growth of 8.7% (CAGR) whereas solar generation seen a growth of 23.2% (CAGR) over the period fiscal 2020 to fiscal 2026.

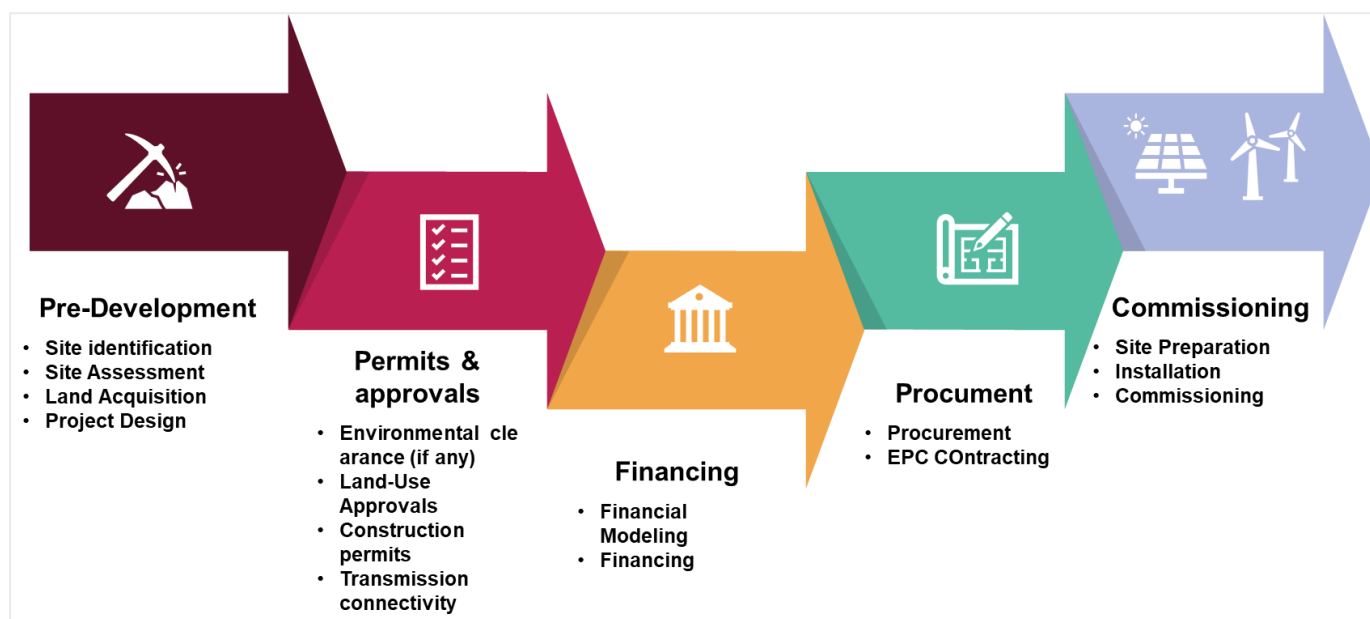
Figure 73: Solar and wind energy generation trends



Source: CEA; MNRE, Crisil Intelligence

Setting up large-scale renewable energy projects is a lengthy and intricate process that demands a high level of specialized knowledge and expertise. The planning of renewable energy projects requires a comprehensive approach, including meticulous site assessment, tailored system design, securing financing, and precise and timely installation to maximize the power output. A typical process flow for setting up a RE plant involves following steps.

Figure 74: Process flow for setting up an RE plant



Source: Industry, Crisil Intelligence

A typical EPC covers design, civil work, equipment purchases and installation, and commissioning. However, with constrained returns, the scope of an EPC project has evolved and now includes O&M services also. Most of the EPC players provide integrated and customised solutions as per the client requirements through a consultative approach. Favourable government initiatives, increased demand for clean and green energy, and rooftop installations by C&I Consumers have provided impetus to RE installations. The EPC services can be classified into various subcategories based on the scale and type of installations, i.e., Utility scale and rooftop solar installations.

Some of the key players in Solar EPC are Waaree Energies, Tata Power, Sterling & Wilson, Vikram Solar, BHEL, Solarworld, Prozeal Infra, KPI Green, L&T and Jakson Green etc. Most of these players are also present in rooftop solar installation's EPC. Similarly, Envision, Suzlon, Inox Wind, Vestas Wind Systems, Wind World are some of the key players in Wind EPC.

The development of RE projects in India requires a detailed and extensive process, from conceptualization to commissioning and regulatory approvals. The processes can be broadly divided into the following stages:

- **Conceptualization:** Identification of a project location, followed by a feasibility study and project proposal preparation.
- **Engineering:** Design and engineering of the RE plant, including layout, electrical infrastructure, and civil works.
- **Procurement:** Acquisition of equipment, materials, and services.
- **Construction:** Site preparation, installation of equipment, and construction of civil infrastructure.
- **Commissioning:** Pre-commissioning, commissioning, and performance testing to ensure the plant meets performance guarantees.
- **Regulatory Approvals:** Obtaining necessary permits and approvals during the construction and commissioning phase, including consent to establish, consent to operate, Fire NOC, Environment Clearance (if applicable), forest clearance, grid Connectivity approval, and registration with the State Nodal Agency etc.

The regulatory framework in India is administered by the MNRE, CERC, SERCs and State Nodal Agencies, with key regulations and policies including the Renewable Purchase Obligation, Open Access Policy, Grid Connectivity etc. The entire EPC process typically takes around 12-18 months for solar and 18-24 months for wind, with an additional 3-6 months for regulatory approvals. However, the process can be challenging, with common obstacles including land acquisition, grid connectivity, off takers, environmental and social impact, and financing.

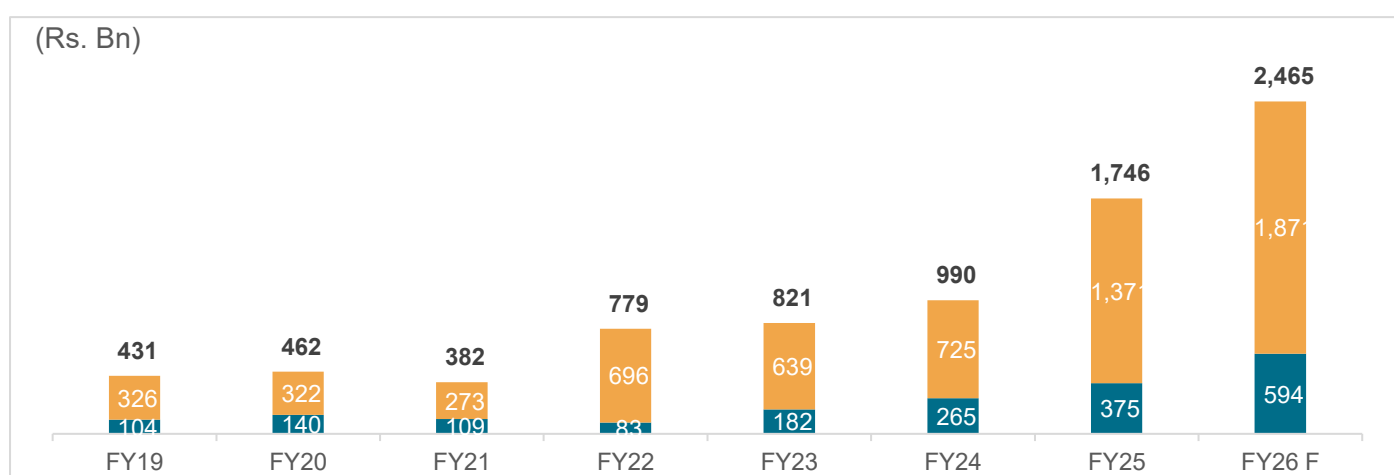
The overall project work is classified as supply (material) contracts and services contracts and are awarded to different entities instead of one single EPC contractor. The capital-intensive items, such as turbines/modules, transformers, inverters, and cables, covering around 75-80% of the project cost are being procured by developers. The developers enter into third-party contracts for services part, covering civil works, commissioning, erection and mounting of equipment, which forms around 20-25% of the project cost. However, some manufacturers insist on buying the entire package and not just turbines/modules, since they also provide EPC services.

4.2 Historical RE EPC Market in India

4.2.1 Solar and Wind EPC market size in India over the past years

India added ~ 116 GW of solar and wind capacity in the last 5 years (fiscal 2020 to fiscal 2026). As of March 2026, India has installed capacity of ~150 GW of solar and ~ 56 GW wind respectively. EPC services for RE are dominated by third-party service providers in the country. A solar EPC cost typically ranges from Rs. 25,000 -40,000/kW whereas wind EPC cost ranges from Rs.80,000-100,000/kW.

Figure 75: Total RE EPC services Market India fiscal 2019-fiscal 2025



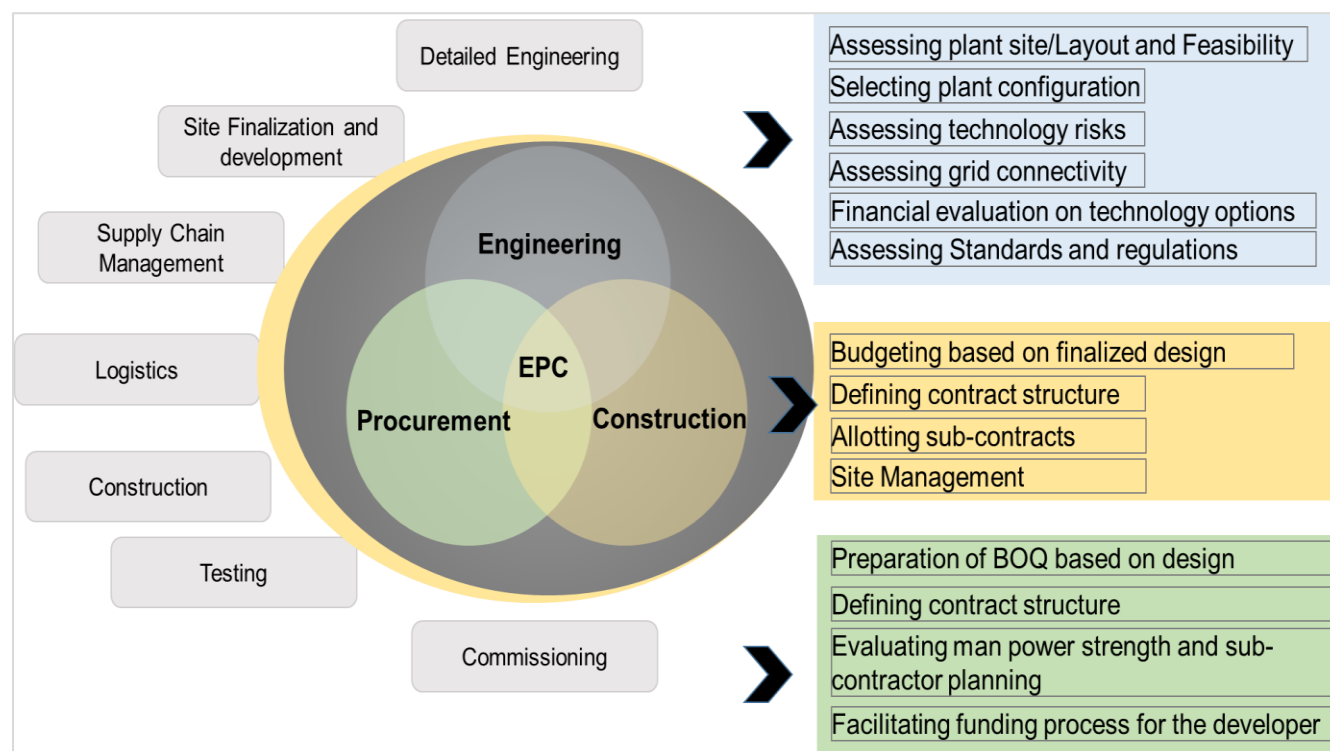
Source: Industry, Crisil Intelligence

4.3 Assessment of EPC Contract in solar and wind space

4.3.1 EPC Project: Turnkey vs. Balance of Plant

Nations, majorly developing ones, have been investing heavily on large infrastructure projects through public as well as private investments. To ensure efficient and timely construction, it is imperative to have an effective model which ensures timely project execution, minimise construction delays and improve transparency. The EPC model is primarily used in construction and O&M of RE plants.

Figure 76: Checklist of an EPC model



Source: Crisil Intelligence

Under turnkey project structure, the contractor holds full responsibility of design and execution of the works, including EPC. Therefore, the contractor makes the facility ready to be used at the turn of a key. The project must be delivered at a pre-determined time and pre-determined cost, and the contractor must adhere to project specifications. In case of deviations, the contractor is liable to pay monetary compensation.

In case of balance of plant (BoP) structure, the entire project is broken into multiple packages with a major chunk contracted through EPC route and the rest through BoP. For a solar plant, solar modules and inverters constitute the maximum cost and may be contracted singularly whereas the supporting components and systems (wiring, switches, battery banks, power conditioners, mounting structures) may be procured from various manufacturers. Additionally, for the BoP project structure, the owner would have to appoint an external consultant or anoint the principal contractor for holistic project management and act as an interface between subcontractors.

4.3.2 Key criteria for selection of an EPC contractor

Globally, the selection of an EPC contractor for any project is done in two stages:

- Initial selection: Using a checklist of qualification requirements and assessing the contractor on each of the points. The assessment may be done on a pass/fail basis against the criteria/ qualification requirements. Finally, the EPC contractor is selected if it surpasses the minimum pass/fail requirements.

1	2	3	4	5
Eligibility	Historical Non performance	Financial Situation	Experience	Past Performance
Nationality	History of Non Performing contracts	Financial Capabilities	General Experience	No. of similar contracts
Conflict of Interest	Pending Litigation	Average Annual Turnover	Specific Experience	Timeliness of delivery
Bank Eligibility	Litigation History			

Source: World Bank, Crisil Intelligence

- Once the bidder/ proposer is deemed qualified, submitted bids/proposals are evaluated. The final selection is based on the quality of the proposal and in some cases on the cost of services (as quoted).

Methods of selection of EPC contractors:

- A. **Quality and cost-based selection (QCBS):** This is the most commonly used method, which takes into account the quality of the proposal as well as the cost of services. The technical and financial proposals are submitted by the bidders at the same time in two separate sealed envelopes. Using pre-assigned weightages on technical and financial proposals (e.g., weight assigned to technical proposal: 75%, weight assigned to financial proposal: 25%), the final weighted scores are determined. The highest final score is deemed to be the winning submission.
- B. **Quality-based selection (QBS):** In this method, only the quality of technical proposals is evaluated to secure the most competent candidate. Once the best (highest ranked) technical proposal is determined, the corresponding financial proposal is opened, and the submitter is invited for subsequent negotiation of financial terms. After the conclusion of negotiations, the project is awarded to the contractor.
- C. **Least-cost selection (LCS):** The winning submission is determined based on lowest-priced financial proposal. The technical proposals are evaluated only to the extent of assessing the minimum technical score.

Using the two-step approach (as mentioned above), the EPC contractor is successfully selected.

The performance specification section of an EPC contract details the performance criteria that the contractor must meet. However, it does not dictate how they must be met and is left to the contractor to determine. Generally, a contract highlights technical and financial eligibility criteria for prospective bidders. It tests previous experience of contractors as well and checks for healthy balance sheets (minimum net worth/ average turnover/ average net gains).

In India, the qualification criteria also majorly consist of technical and financial requirements. The technical requirements for the contractor typically include all or some of the following:

- a. The bidder should have a minimum of xx MW (This value xx is a % or higher of total bid capacity) designed, supplied, erected, supervised, and commissioned of desired technology (for wind and/or solar) of which at least one plant should have been of xx MW capacity (a reference number in the multiples of 5 or 10 MW depending on total project size); the reference plant must have been in successful operation for at least 6 to 12 months prior to the date of techno-commercial bid opening.
- b. The bidder should be an Indian company registered in India and should be a group company / holding company / subsidiary company / JV company meeting the above requirements
- c. The bids of the JV company shall only be considered in certain conditions, such as the JV formed should be firmed prior to bid submission; JV with only two partners, submit role/scope of all individual partner in JV, LoI, PO and contract agreement shall be carried out with JV company etc.

Financial requirements typically include net worth and turnover requirements as stated below¹:

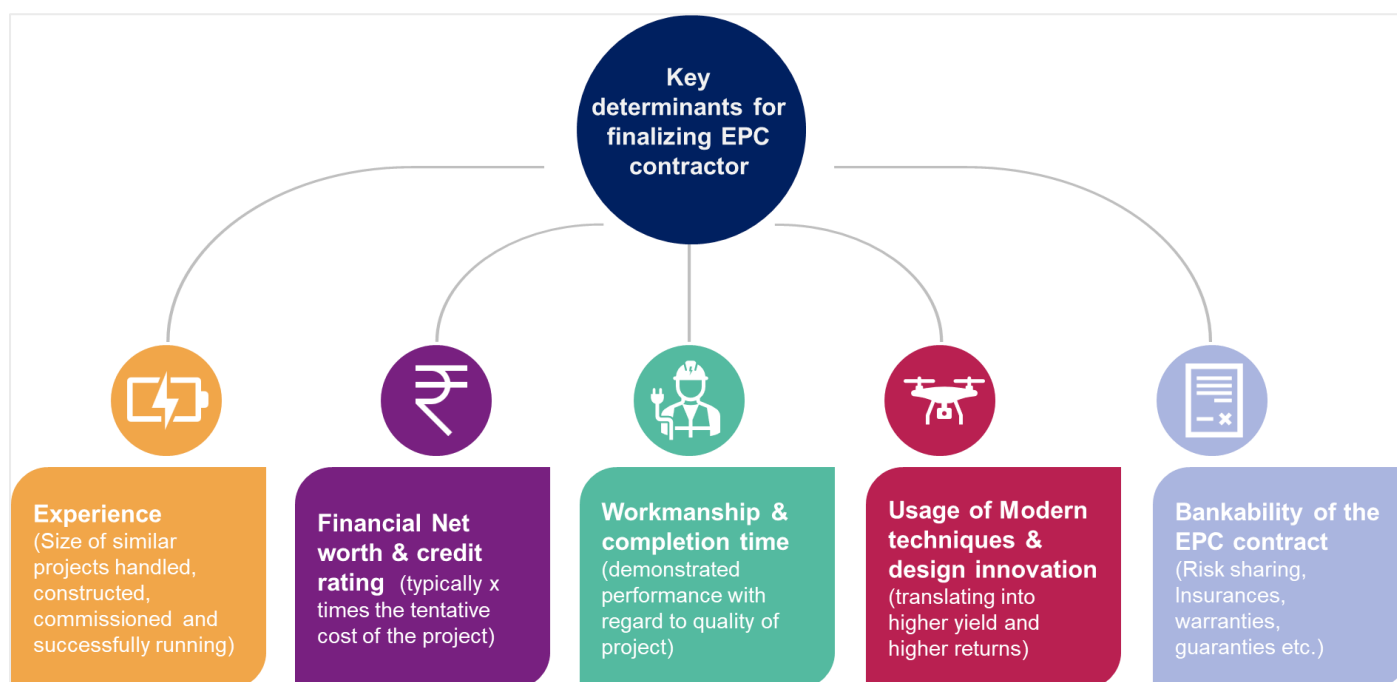
- a. The bidder should have a certain cumulative turnover for the past three financial years
- b. The net worth of the bidder during the last financial year shall be positive

¹ Taken from various tenders

- c. The bidder should have a certain minimum Working Capital as per the last audited financial statement. In case of inadequate working capital, Bidder to submit letter from Bank having net worth not less than a certain value, confirming availability of the line of credit for more than or equal to a certain minimum Working Capital.

The bidder may be required to submit a bank solvency certificate for an amount as mandated by the contract. Additionally, summarised sheets of turnover and/or financial statements for the past three years typically need to be furnished.

Figure 77: Key Determinants for selecting EPC contractor



Source: Crisil Intelligence

4.3.3 Key covenants of EPC contract

Construct of an EPC contract

A. Scope of the project: Defines the provisions, specifications, and standards of the project that the contractor has to adhere to. In case of a solar EPC project, the scope typically consists of the following specifications:

- Aggregate capacity of the solar plant
- Type of solar plant (rooftop/ground-mounted/floating)
- Usage of battery bank (Yes/No). If yes, capacity and specifications of battery bank including model and make of battery, type of battery management systems, power condition unit
- Operation and maintenance for given number of years

The scope also talks about suppliers' responsibilities for delivering equipment on site, insurance coverage covenants of materials, supervision of assembled and supplied goods, performance testing of the project, comprehensive maintenance tenure of the project (as specified), coverage of risk liability of all personnel engaged with the project, training to O&M personnel for acquaintance of operations of the plant.

- B. Obligations of the contractor:** Underlines the obligations which need to be fulfilled by the contractor, which may include all or few of the following: undertaking survey, investigation, design, engineering, procurement, construction, operation, maintenance of the RE plant. The contractor must also comply with applicable laws and applicable permits, as required, for the performance of its obligations. The section includes provisions and conditions for subcontracting works to other parties.
- C. Obligations of the authority:** Sets out the obligations of the authority, subject to receiving performance security, towards the project like providing right of way for land, environmental and forest clearances, work permits to contractors, security on project site, implementing and/or administering safety precautions etc. Obligations of the authority majorly consist of four heads:
- i. *Access and right to use of the site:* The authority grants the contractor right of access to, and make available the site to the contractor in accordance with the terms of property rights at the time of execution of the agreement
 - ii. *Notice to proceed:* The authority issues the notice to proceed to the contractor, and the commencement date initiates thereof
 - iii. *Permits and real estate rights:* The contractor obtains and maintains all applicable permits necessary
 - iv. *Utilities:* The authority provides the facilities, components, and services to be contractor, as required
 - v. *Safety precautions – protection of the project site:* The authority implements and administers a safety and health program for the contractor, other suppliers, and contractors.
- D. Representation and warranties:** Highlights that the contractor is duly organised and validly exists under the laws of India to execute and deliver the performance obligations under the agreement. Additionally, the section warrants absence of breach of contract, absence of violation or default, injunction, or decree of any court for the contractor and constitutes a legal, binding obligation, enforceable and valid in a court of law.
- E. Force Majeure and Termination Clauses:** The parties (authority and / or contractor) are excused from performing their obligations if a force majeure event occurs. Such an event is beyond the reasonable control of the affected party, and the affected party could not have prevented or overcome by exercise of due diligence and has material adverse effect on the affected party. Such events include non-political events (act of God, epidemic, extremely adverse weather conditions, lightning, earthquake), indirect political events (an act of war, invasion, armed conflict or act of foreign enemy, blockade, embargo, riot, insurrection, terrorist or military action, civil commotion etc.) and political events (change in law, revocation/ refusal to renew approval, consent or exemption required by the contractor). On the occurrence of a force majeure event, either party may issue termination notice or subsequently, termination payments will be payable after due assessment.
- F. Other provisions:** May include hypothecation of materials or plant provisions, liability and indemnity by the contractor, and dispute-resolution clauses

Features of an EPC contract

It is imperative to negotiate a well-defined contractual arrangement that sets out the rights and obligations of each party. In practice, lenders and investors are concerned not only about the written terms of the EPC contract, but also the ability of the EPC contractor to perform the terms of the EPC contract as per laid down norms. To shield the EPC contract from counterparty (contractor) risk, emanating from sub-par performance and/or non-adherence with contract obligations, it is standard for the contractor to include checkpoints.

- 1. Performance security/guarantee:** Irrevocable and unconditional guarantee for specified percentage of the contract price within ~21 to 30 days from the receipt of Letter of Award. Typically, performance guarantee is ~5 to 10% of the contract value. The performance security remains valid for a claim period after the expiry of the

Defects Liability Period (DLP); explained below). The authority releases performance security within the claim period of the expiry of the DLP or issuance of final acceptance certificate. The authority will not be obliged to release the security until all defects identified within the DLP are not rectified by the contractor. Additionally, if a project fails to generate any power continuously for a specified time any time (as stated in the contract) during the O&M period, it may be considered as “an event of default” and the entire bank guarantee will be encashed. Any time during the tenure of the project, the nodal agency/authority reserves the right to forfeit the Performance Guarantee of the bidder, to blacklist the bidders and may also cancel the contract if the bidder is found to provide false information regarding debarred / blacklisted or conceals the facts in this regard.

2. **Defect liability period (DLP):** The period of validity of the warranties given by the contractor commencing at operational acceptance of the facilities, during which the contractor is responsible for correcting all defects and deficiencies with respect to the operation of the facilities. A Defect Liability Period may be for a duration up to the end of the O&M period or for any duration extended by the mutual agreement of both the parties. The DLP may be extended upon repair/replacement of the facilities. At the end of the period, the contractor's liability ceases except for latent defects (plant and equipment warranties, spare warranties, etc.).

Delay liquidated damages (DLD): The contractor is mandated to complete the facilities/ project pursuant to the time of completion. Typically, the timeline for the project is clearly highlighted in the contract and indicative milestones are mentioned.

If the contractor is unable to achieve operational acceptance within the stipulated time, it is liable to pay liquidated damages for the delay as mentioned in the contract.

3. **Performance liquidated damage (PLD):** Performance guarantees are backed by the output, efficiency, and reliability of the project, as defined in the scope. Post operational acceptance and until the expiry of the O&M period, the bidder would be required to meet the specified conditions in the contract. This may include performance requirements, minimum generation requirements, etc. In case of non-compliance, the bidder is liable to pay compensation in the form of liquidated damages. PLD is generally calculated on the basis of loss in energy incidental due to deviance.
4. **Change of scope:** The authority may require the contractor to make modifications/alterations to the works before the issue of completion certificate. The contractor may be instructed or requested to make a change of scope involving additional costs or reduction in cost. After determining the time and money for the desired change, a change of scope notice will be issued to the contractor, highlighting modifications in design and/or construction, etc. However, both parties must mutually agree with the proposed changes.

4.3.4 Trend of developers in-house EPC teams vs. outsourcing to specialized EPC players

Complementary central and state government policies coupled with the increasing price competitiveness of RE have led to a surge in RE installations. However, declining module prices and aggressive competitive bidding on the part of players has led to lower RE tariffs. This has constrained margins for EPC players. To reduce costs, more developers are opting to carry out their own EPC rather than outsourcing to a contractor. Project developers are becoming system integrators, thereby providing holistic turnkey solutions. Standalone, large EPC firms are diversifying their portfolio towards building their own generation capacities to stay competitive. Smaller EPC firms without the financial prowess for project development are vertically integrating into captive projects and rooftop installations.

Following are some of the key considerations while making decisions.

- Size and complexity of the project
- Budget
- Timelines
- Own level of expertise

- Desired level of control over project

4.3.5 Pros and cons of different business models

Factor	In-house EPC	Outsourcing to large, specialised EPC contractors
Equipment costs	1. Players are likely to get bulk discounts on the prices of solar modules and inverters only if the project size of the developer is large enough (for the equipment supplier, typically >100 MW size). Hence, offering deep discounts is a challenge. 2. Availability of equipment financing possible only for large capacities and long-term relationship/tie-ups.	1. In the case of turnkey EPC contracts, players with large order books benefit from bulk buying/import of components such as modules and inverters. Hence, they can quote competitive rates, with minimal impact on margins. 2. Most large EPC players get the benefit of equipment financing from the module/inverter supplier.
Project management and timelines	1. Project development and meeting deadlines in the case of in-house EPC projects could be a challenge for relatively new and smaller players in the market. 2. In-house EPC players tend to sublet more of their work to smaller contractors resulting in elongation of project completion deadlines.	Led by varied experience across various geographies, project sizes and teams, project management is smoother. Likelihood of timely project completion is higher owing to better supply chain management.
Warranties, guaranties/ Spare part availability	The developer and O&M contractor bear the entire risk arising due to loss of generation led by multiple technical factors. However, it can be controlled by reducing the replacement time of faulty equipment. The problem is aggravated since major components such as solar modules and inverters are imported, resulting in higher lead time. Hence, in the case of in-house EPC projects, O&M contractors are appointed	As large EPC contractors also provide warranties and guarantees post commissioning, the lead time for spare parts to be available at the site is less. This reduces generation loss, especially in the peak power generation summer season.
Risk diversification	Although the solar industry is growing, it is still prone to volatility and uncertainty. Solar panels, the major component for a solar plant, are still majorly imported and susceptible to price fluctuations and local taxes (anti-dumping duty, safeguard duty). With capital costs as well as tariffs coming down due to maturing of the market and rise in competitors, solar project margins have also been coming down. In such a scenario, being vertically integrated across development and EPC contracting gives a company more scope to diversify risks and secure finance.	EPC players aim at playing with scale and cost to improve margins. However, with the top line for the companies falling on a per-project basis (developers not keen to raise EPC and O&M costs), stagnation tends to set in. Most EPC players have already reduced costs by taking strong efficiency measures and more breathing room is unlikely. This leads to risk aggregation and any untoward volatility in the market may distort margins.
Horizontal expansion	Horizontal expansion is restricted to the tune of business expansion.	In order to grab a larger market share in the business, large and established EPC players foray abroad. With the emergence of international markets in the solar sector such as Africa, Middle East, Southeast Asia, and South America, these players are building upon efficiency and low-cost capabilities to win tenders and augment portfolios.

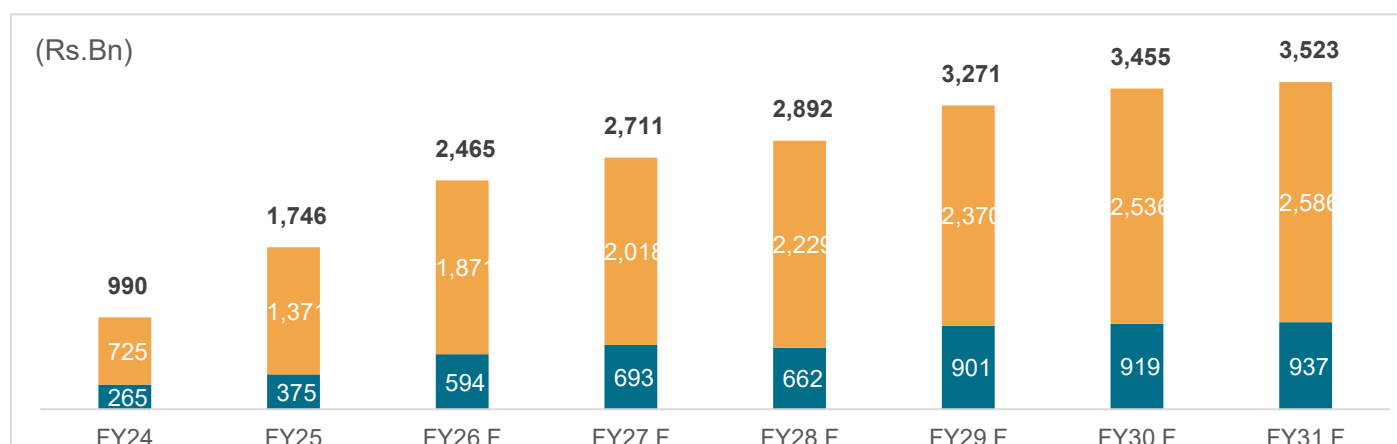
Factor	In-house EPC	Outsourcing to large, specialised EPC contractors
Firm sustenance and continuity	With solar development coming closer to EPC and concept-to-commissioning being offered in one suite, project developers will build on in-house solutions. However, merger deals for vertical integration are unlikely and companies would prefer investing in building in-house capabilities rather than buying specialised EPC firms	With the solar sector in India maturing, the sector may see consolidation and merger deals. With pricing pressures and thinning margins, only large and specialised EPC players are likely to remain in business. Bigger players like Sterling Wilson, Mahindra Susten, and Tata Power Solar will continue to have a strong market presence. However, small firms may not be able to sustain due to lower margins.

	Cons
	Pros
	Inconclusive

4.4 Outlook on RE (solar and wind) EPC Market fiscal 2025-2031

Crisil Intelligence foresees a surge in solar power capacity, adding 210-250 GW from fiscal years 2027 to 2031, significantly surpassing ~122 GW added between fiscal years 2019 and 2026. This growth is primarily spurred by robust government backing, demonstrated through an aggressive tendering strategy. Wind power to see capacity of 45-46 GW to be added over same period. Crisil Intelligence expects capacity additions to grow over the next five years led by strong pipeline build-up under existing schemes and new tendering schemes, improvement in technology and mixed resource models.

Figure 78: Total RE EPC services Market India (FY2024-FY2031)



Source: Crisil Intelligence

4.4.1 Key drivers and challenges for RE EPC Market

Growing demand for clean energy from industries, commercial establishments, and residential sectors is driving the growth of the RE EPC market. Declining costs of RE technologies, such as solar and wind, are making them more competitive with fossil fuels, and driving demand for RE EPC services. Increasing investment and funding from government and private sources are supporting the growth of the RE EPC market. Advances in RE technologies, such as bifacial solar panels and larger wind turbines, are improving efficiency and reducing costs, and driving demand for RE EPC services.

However, RE EPC services also face certain challenges. Intense competition in the RE EPC market is leading to pricing pressure, making it challenging for EPC players to maintain margins. Land acquisition and permitting issues can delay project timelines and increase costs, making it challenging for EPC players to deliver projects on time and within budget. Shortage of skilled labor can hinder project execution and quality. Ensuring grid integration and

connectivity for RE projects can be challenging, particularly in areas with limited grid infrastructure. Land acquisition and permitting issues can delay project timelines and increase costs, making it challenging for EPC players to deliver projects on time and within budget.

Overall, the RE EPC market in India is expected to grow significantly in the coming years, driven by government policies, declining costs, and increasing demand for clean energy.

4.5 RE (solar and wind) O&M Market in India

4.5.1 Overview of RE O&M market over the past five years

O&M services for solar energy projects are provided by various players including OEMs, specialised players, even some unorganized players. However, O&M services for wind energy are dominated by the equipment manufacturers (OEMs) in the country. A typical wind turbine O&M cost ranges from Rs.1,000-1,500/kW of capacity whereas for solar it ranges from Rs. 200 -300/kW. The type of services offered as a part of O&M contracts include:

Supply of equipment

- Large equipment supply
- Sundry or small equipment supply
- Consumables

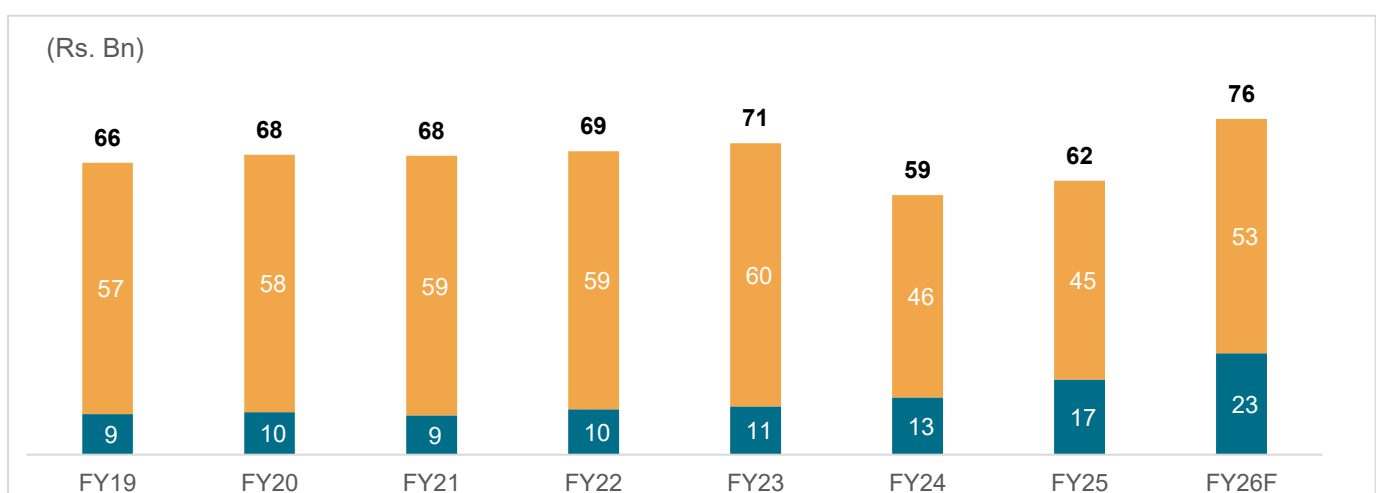
Repair services

- Regular repair and maintenance
- Major repair or overhaul
- Equipment replacement

Selecting appropriate WTGs involves careful technical evaluation, considering factors like turbine power curves, reliability and the performance guarantees offered by manufacturers. A higher CUF generally signifies greater electricity generation and operational efficiency, reflecting successful site selection, appropriate technology choice, and effective O&M.

The RE market grew at a healthy rate with capacity additions picking up pace in fiscal 2020 after low in 2019 on account of FiT regime change. This has also positively impacted the demand of O&M services, which grew from Rs. ~66 billion in 2019 to more than Rs. ~71 billion in 2023. Capacity additions declined in fiscal 2021 due to COVID-19 pandemic led lockdowns and mobility restrictions. However, this might have positively impacted on the remote monitoring capabilities and technological implementation across the RE energy sector.

Figure 79: O&M services demand across RE (solar and wind), fiscal 2019 to 2025



Source: Industry, Crisil Intelligence

4.6 Evolution of O&M services for solar and wind sector in India

Operations and maintenance cost form a critical component in the Levelized Cost of Electricity (LCOE) of solar, wind as well as hybrid energy projects. Therefore, renewable power producers adopt various strategies to lower this cost and improve the reliability of the services and to make the LCOE competitive with other producers and technologies. Typically, the O&M cost accounts for 20-25% of the LCOE involving 5 categories, namely, Insurance, regular maintenance, repair, spare parts, and administration. These costs generally rise with the years of operation, however, with more experience various approaches have been formulated that generators follow to keep a check on the O&M costs.

The industry started with reactive maintenance, mostly resulting in downtime and major service or overhaul. The major reason behind this was late detection of the fault or part failure. The cost of service due to this late detection increases compared to early detection and repair. Moreover, with an increase in the life of the plant's generation the cost of major repairs escalates. Currently, the O&M service providers offer solutions to minimise the major repairs and replacements while moving towards predictive maintenance. As a result of this, the cost of maintenance has decreased by more than 50% for onshore wind and by more than 50% for offshore wind generators in the past 10 years, as reported by IRENA.

4.6.1 Value chain for O&M services for solar, wind and hybrid energy

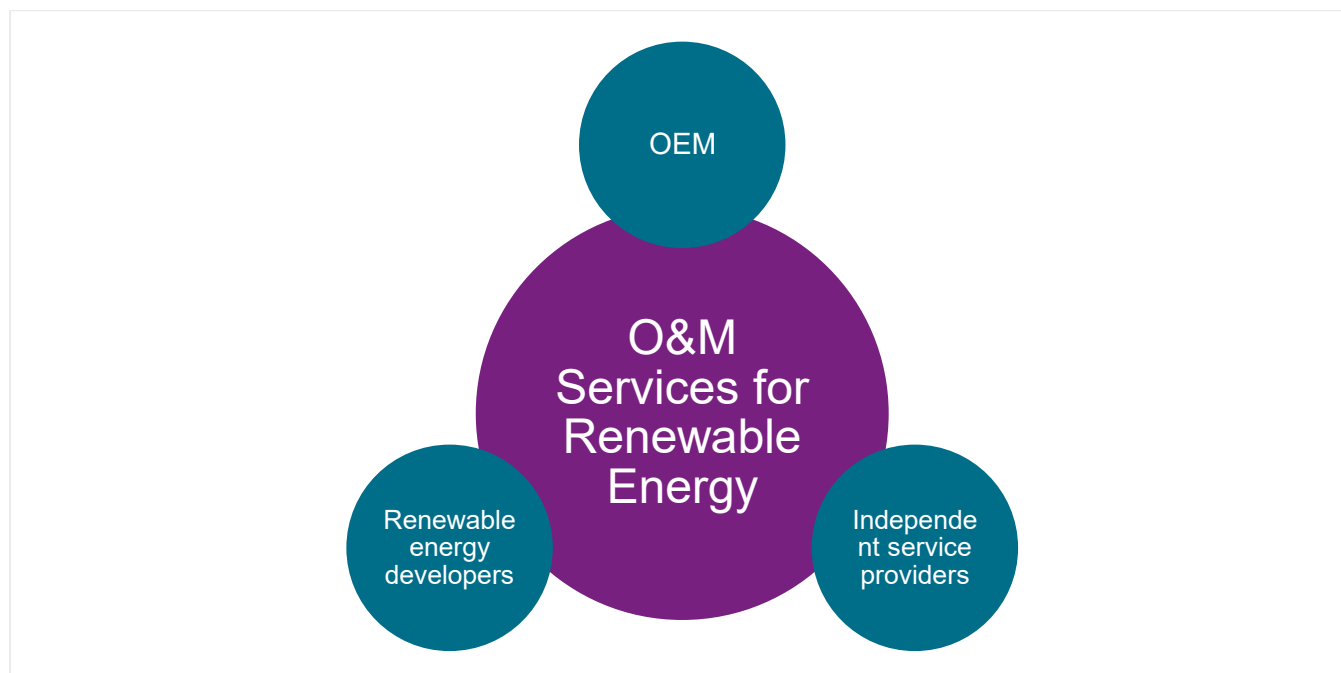
There are three channels to obtain the operation and maintenance for wind energy generators

Original Equipment manufacturers: Operation and maintenance services are usually acquired along with the components of the Solar Modules and Wind turbine generation (WTG) unit. These services are acquired for a time of 2 to 5 years as a part of annual maintenance packages. The key providers of these services are the OEM, which include guarantees and preventive and corrective maintenance that could be adopted after the expiry of the contract period. These are preferred globally due to the ease of procuring spare parts or replacement equipment from OEMs compared to other O&M service providers.

Renewable Energy Developers: Large renewable energy developers have also started to maintain their own capacity instead of traditionally OEM based O&M contracts. Currently, there is limited capacity from some of the key renewable energy developers being maintained in house. The major reason for this is to increase control over the operations of the generation and further reduce the dependence on the OEMs. This also reduces the risk of extended periods of shutdowns resulting in no drop in the availability of the plant. Moreover, due to financial hurdles for OEMs, IPPs have opted to carry out O&M activities in-house to avoid dependence on any external entity.

Third-party or Independent Service Providers: O&M services are also offered by third-party service providers. This is usually taken at the time of warranty expiration of the Annual Maintenance Contracts (AMC) with the OEM or when the OEMs are not preferred with the equipment acquisition due to financial constraints.

Figure 80: Value chain for renewable energy



Source: Industry, Crisil Intelligence

4.6.2 Asset management services

Effective asset management is a critical component of maintaining grid reliability and driving success in plant operations. Strategic asset management is critical for renewable energy assets like solar, wind, and hydroelectric power plants, as it enables owners and operators to optimize performance, reduce costs, and maximize returns. Renewable energy assets require expert management over their operational lifetime to ensure they continue to perform optimally and retain their value, but this expertise may not always be available or cost-effective to maintain in-house.

Third-party suppliers with a deep understanding of the industry and cutting-edge practices help renewable assets reach their full potential, delivering maximum returns on investment and optimal performance. Their operational management services for wind and solar renewables are designed to maximize energy production, reduce downtime, and minimize lifecycle costs, resulting in improved profitability and reduced risk.

Asset management services involve a multitude of activities, including performance monitoring, maintenance planning, and financial analysis, all aimed at optimizing asset performance, minimizing downtime, and maximizing returns on investment. To maximize energy production and minimize downtime, third party suppliers employ cutting-edge monitoring systems and data analytics tools to continuously track the performance of their renewable assets, detecting potential issues and optimizing output.

4.6.3 Key technological advancements/innovation and trends in O&M services

Predictive maintenance vs reactive maintenance:

Major components such as module, inverters, nacelle, turbine, generator, hydraulics, and electronics require constant monitoring to ensure smooth operability. Traditionally reactive maintenance was carried out when the equipment has shown severe operational faults or complete failure or during scheduled maintenance. The failure of reactive maintenance resulted in longer shutdowns and low availability of the generators.

On the contrary, predictive maintenance accurately forecasts the component failures before they occur based on historical data. This is a critical service in RE generation as it addresses the issues associated with reactive

maintenance. Furthermore, proactive maintenance reduces the operational cost by reducing the wear and tear of the equipment in the system. As a result of implementation of predictive maintenance techniques, replacements and major repairs in wind energy have declined considerably over the past years. Therefore, more and more developers are going for predictive maintenance as compared to reactive and scheduled maintenance.

The disadvantage of solely relying on historical data is that some of the assets will be flagged for maintenance despite being functionally sound and performing well. This drives the maintenance cost of the assets into good operational conditions. Hence it needs another layer of technological intervention that segregates, analyses and prioritizes the activities. Thus minimize the unwanted spending on maintenance of assets that are in healthy condition. AI and IoT enablement can solve this purpose and lead to cost savings, especially in the case of power plants having assets spread across large areas. For instance, in large solar parks predictive maintenance using AI can lead to significant savings of inspection and maintenance planning of the assets. Moreover, it also aids capacity planning and addition over the years. In the case of distribution networks, precision mapping of the assets leads to proper identification and location of the assets in the network for maintenance and addition of the consumers.

Condition monitoring

A key element of predictive maintenance suite, condition monitoring, is used to monitor the health of the module and turbine and related electrical systems. Its purpose is to predict maintenance issues so site operators can conduct repairs and replacements only when needed to avoid unnecessary and costly up-to-tower jobs. Although the intent is to cut time and cost from O&M tasks, condition monitoring system have become rather detailed in accumulating and analysing data and hence can become expensive. The system can supply the failure rate of the turbine and related equipment for up to 20 years along with simulations to predict future failures thereby reducing the cost of energy considerably by avoiding major replacements. In this context, drones with HD cameras and thermal sensors are becoming a popular solution globally to resolve a number of issues that module and wind equipment managers face by helping them inspect damage and thermal imaging to detect any internal abnormalities. This mode of airborne inspection is particularly more popular for solar and offshore wind turbine sites.

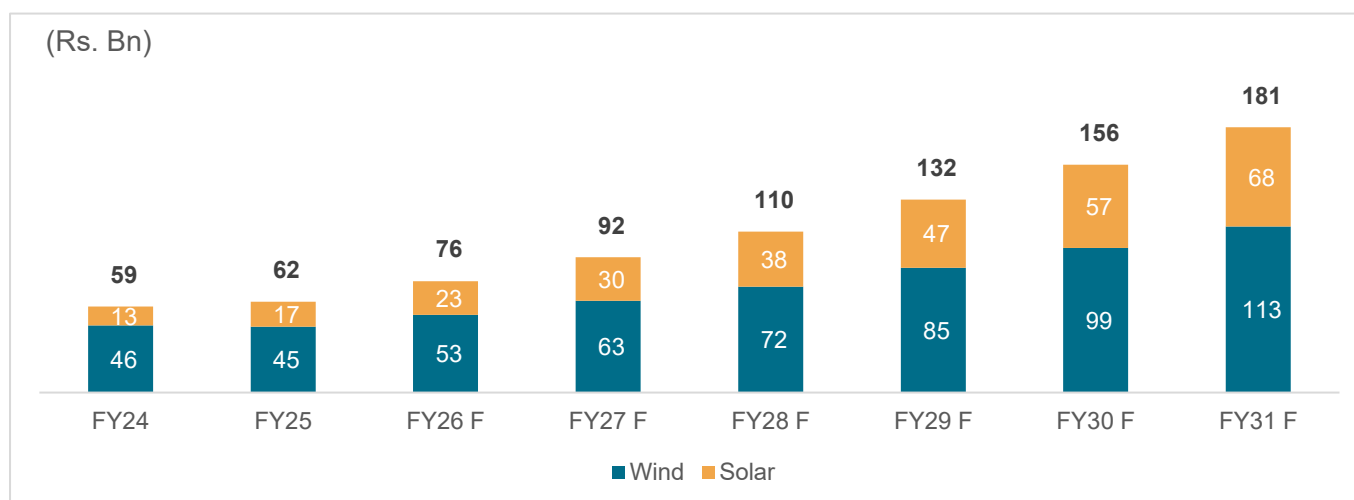
Impact of technology implementation on O&M services

Technology driven solutions are constantly evolving and are being deployed across the sector. For instance, the implementation of AI-based predictive analytics solutions can help analyse real-time operational data at scale, identify any underperformance, and recognize failures using machine learning. The most advanced implementation of technology across wind energy includes digital twin. Digital twin is a virtual representation of the actual asset for remote interaction by the trained professional. Digital twin minimises the need of human team diagnosing the faults, instead engineers can analyse and identify problems remotely. Thus, saving the efforts of personnel to specific instances. Applications such as demand response management, hybrid energy storage systems, vehicle-to-grid, virtual power plant etc are being tested across the clean energy sector involving implementation of new technologies. Machine learning (ML) and artificial intelligence (AI) can also be applied to recognize patterns, predict faults, and highlight important variables that could otherwise be missed.

4.7 Outlook on RE O&M services market in India fiscal 2027-2031

Crisil Intelligence foresees a surge in solar power capacity, reaching 210-250 GW from fiscal years 2027 to 2031, significantly surpassing ~122 GW added between fiscal years 2019 and 2026. This growth is primarily spurred by robust government backing, demonstrated through an aggressive tendering strategy. Wind power to see capacity of ~45-46 GW to be added over next five years. Crisil Intelligence expects capacity additions to grow over the next five years led by strong pipeline build-up under existing schemes and new tendering schemes, improvement in technology and mixed resource models. As a result of this, the demand for O&M services is expected to be in the range of Rs.175-185 billion by fiscal 2031.

Figure 81: India- RE O&M services demand forecast (solar and wind) Fiscal 2026 to 2031



Source: Industry, Crisil Intelligence

4.7.1 Drivers and challenges for O&M services in India

India's ambitious renewable energy targets, including 500 GW of non-fossil fuel capacity by 2030, are driving the demand for RE O&M services. Supportive government policies such as National Wind-Solar Hybrid Policy, RPO mechanism, green hydrogen/green ammonia initiatives, offshore wind energy, easy open access for C&I consumers, and the grid connected rooftop solar programme are driving the growth of the RE sector and creating opportunities for O&M service providers. As the RE sector matures, there is a growing focus on optimizing performance, reducing downtime, and improving overall efficiency, creating opportunities for O&M service providers. Advances in technologies such as IoT, AI, and data analytics are improving the efficiency and effectiveness of RE O&M services, making them more attractive. Increasing investment in renewable energy, including from foreign investors, is driving the demand for professional O&M services to ensure optimal performance and returns on investment.

However, the O&M services in India also face certain challenges. Most of the RE assets, such as wind farms and solar plants/parks, are located in remote areas, making it challenging to access and maintain them. The shortage of skilled labor in the RE O&M sector, particularly in areas such as turbine maintenance can hinder the growth of the industry. The lack of standardized data management practices and limited use of digital technologies can make it difficult to optimize RE O&M services and predict maintenance needs. RE sources, such as solar and wind, are subject to seasonal variations, which can impact performance and require specialized O&M strategies. The integration of RE sources into the grid can be challenging, requiring specialized expertise and equipment to ensure smooth and efficient operation.

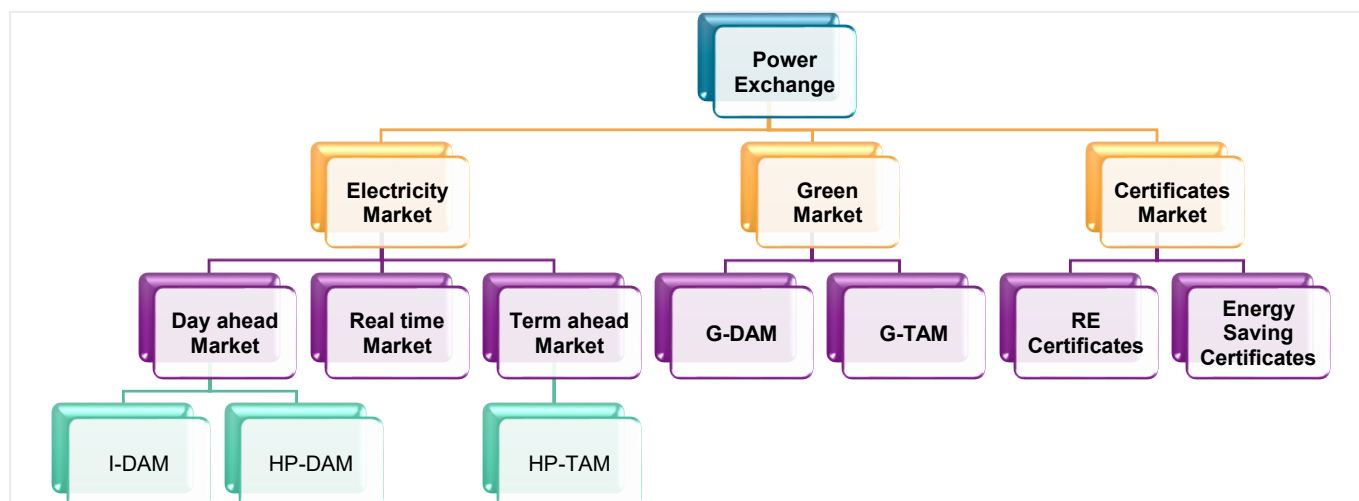
Overall, the RE O&M services market in India is expected to grow significantly in the coming years, driven by government initiatives, technological advancements, and increasing demand for efficient and effective maintenance services.

5 Overview and outlook on merchant power price

5.1 Overview of products/ options available on exchanges

The power exchange market can be broadly classified as under

Figure 82: Overview of products on the power exchange

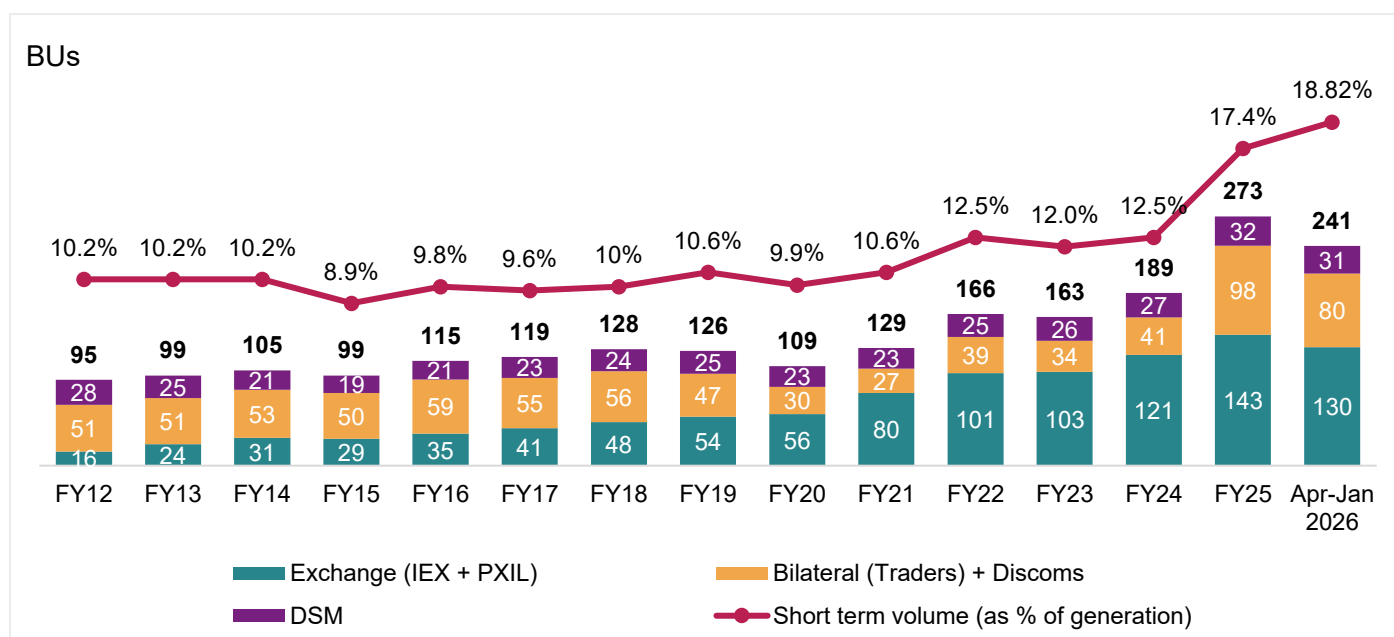


Source: CERC Market Monitoring Report, Crisil Intelligence

Cross-border electricity trade, which commenced in April 2021 at IEX, aimed at integrating the South Asian Power market, enabling countries like Nepal, Bhutan, and Bangladesh to participate in Day Ahead Market (DAM) and Term Ahead Market (TAM). Additionally, long-duration contracts of up to 3 months were launched in FY 2022.

In March 2023, IEX introduced the High Price Day Ahead Market (HP-DAM) for high variable cost generators who were unable to participate in DAM due to the price ceiling of Rs12/kWh. The bid price range initially was between Rs.0/kWh to Rs. 50/kWh in this segment, later revised to Rs. 20/kWh w.e.f. 11th April 2023.

Figure 83: Short-term market volumes (FY12 - FY26)



*Upto January 2026

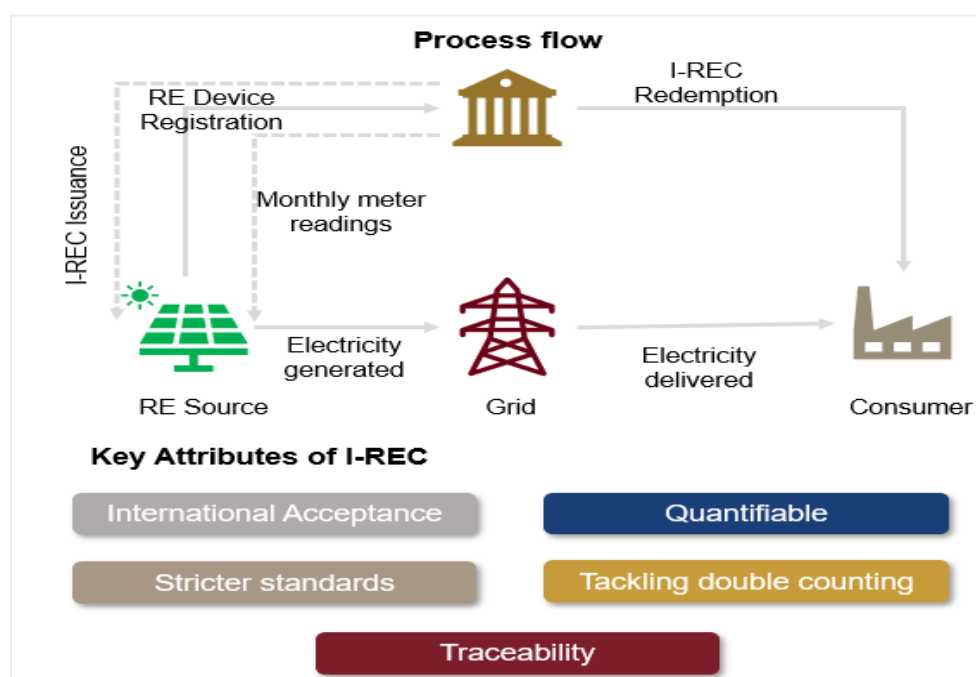
Note: Exchange volumes include TAM, GTAM, HPTAM, DAM, RTM, GDAM, and HPDAM

Source: CERC, Crisil Intelligence

The short-term market volume grew at a CAGR of ~8.5% from FY12 to FY25. However, power procurement through medium/long- term PPAs continue to be the preferred mode among power distribution companies. Share of short-term volume, as a percentage of power generation has stayed in the range of 10%-13% over the past 12 fiscals. With improvement in market liquidity, power transactions through exchanges increased from 16.5% in FY12 to ~52.5% of short-term transactions in FY25.

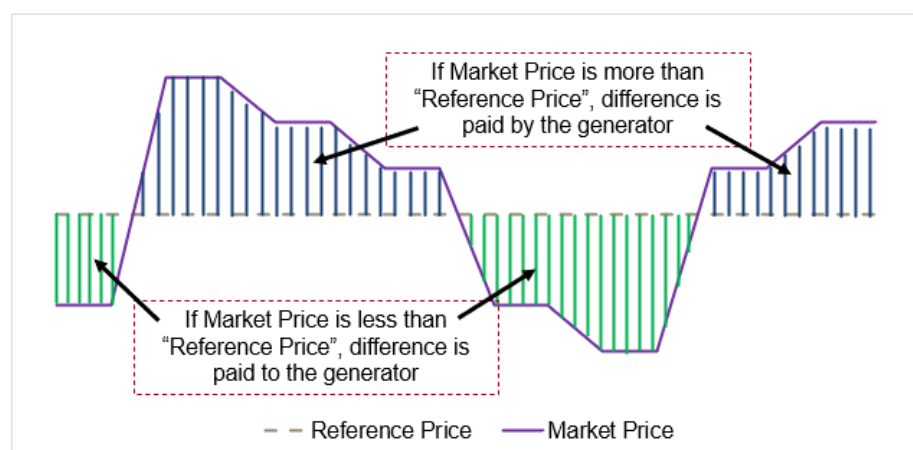
International Renewable Energy Certificate: International Renewable Energy Certificate (I-REC) is an unbundled Energy Attribute Certificate. I-RECs are administered by the (I-REC Standard. I-RECs are issued by specific agencies registered with the I-REC Standard for RE generation. Green Certificate Company (GCC) is the authorized issuer of I-RECs in India. I-RECs enable the purchaser to claim the environmental attributes of RE. Each I-REC represents 1 MWh of RE produced having a unique ID to prevent double counting, double issuing, and double claiming of underlying attributes.

Figure 84: Process flow for I-RECs



Source: Industry, Crisil Intelligence

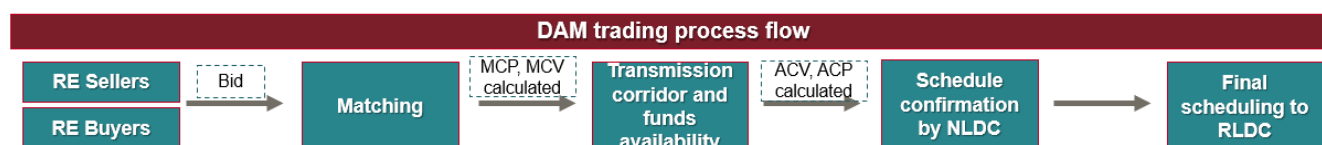
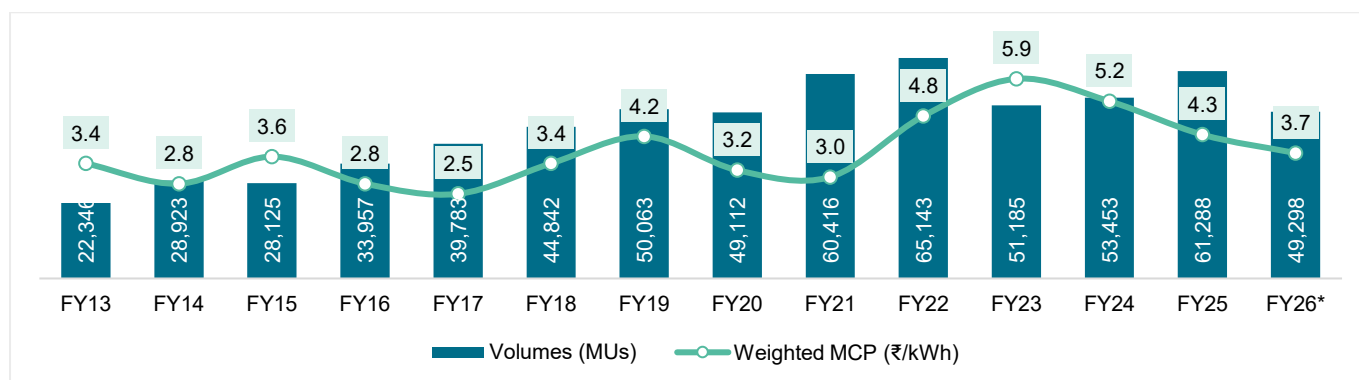
Contract for difference (CfD): Under CfD, power is traded and scheduled at Power Exchange at market prices. However, the generator gets assured revenue through a 'Contract for Difference' (CfD).

Figure 85: Pictorial depiction of CfD


Source: Industry, Crisil Intelligence

5.2 Price trend of different products

Day Ahead Market: Day Ahead Market (DAM) serves as a physical electricity trading market for trading 15-minute contracts in 24 hours of the next day. Prices and quantum of electricity to be traded are determined through an anonymous double-sided auction bidding process. Further, SLDC gives clearance to buyers and sellers subject to network availability and ABT (Availability Based Tariff) meters.

Figure 86: DAM trading process flow

Figure 87: Weighted average prices and volumes traded in DAM


*Upto January 2026

Source: CERC Market Monitoring Report, Crisil Intelligence

The weighted MCP for DAM was highest during FY23 at Rs.5.9/kWh due to a sharp rise in demand for electricity driven by economic recovery and extreme weather conditions. Additionally, high global coal and gas prices increased power generation costs, especially for thermal plants, tightening supply and pushing prices up. The volume of yearly DAM transactions grew by 174% from FY13 to FY25 to reach 61,288 MU. The overall share of DAM trades out of total exchange trade remained above 60%. However, it has decreased over FY21 and FY22 due to the introduction of new products like RTM, G-DAM and GTAM. The volumes and prices stabilized in FY25 to reach an average price of Rs. 4.3/kWh.

High Price Day Ahead Market: High Price Day Ahead Market (HP-DAM) is a recently launched segment of the Indian Energy Exchange (IEX) where power utilities (gencos and discoms) can trade expensive electricity generated from imported coal-based plants, gas-based plants, and renewable energy with battery storage. For the price below the ceiling tariff of Rs.10/unit, I-DAM market is available while for the power priced between Rs.10/unit and Rs.20/unit, HP-DAM has been introduced. HP-DAM has reduced the burden of earlier I-DAM ceiling tariff of Rs.12/unit on the generators which have high power generation cost.

Real Time Market: Real Time Market (RTM) is a newly launched market, commenced operations in FY21. In this product, every new auction session is of 30 minutes (48 times a day), and power is to be delivered after 4-time blocks (or 1 hour after gate closure of the auction). Price and quantum of electricity traded is determined via double-sided closed auction bidding. It is classified into two bids – Single and block. In Single bids, there are 15-minute bids for different price and quantity pairs, and partial execution of bids is possible. Under Block bids, there are any 15-min block or series of 15-min blocks during the same day where partial execution is not possible.

Figure 88: RTM trading process flow

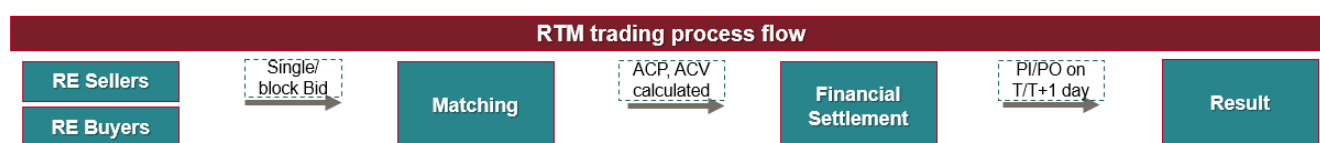
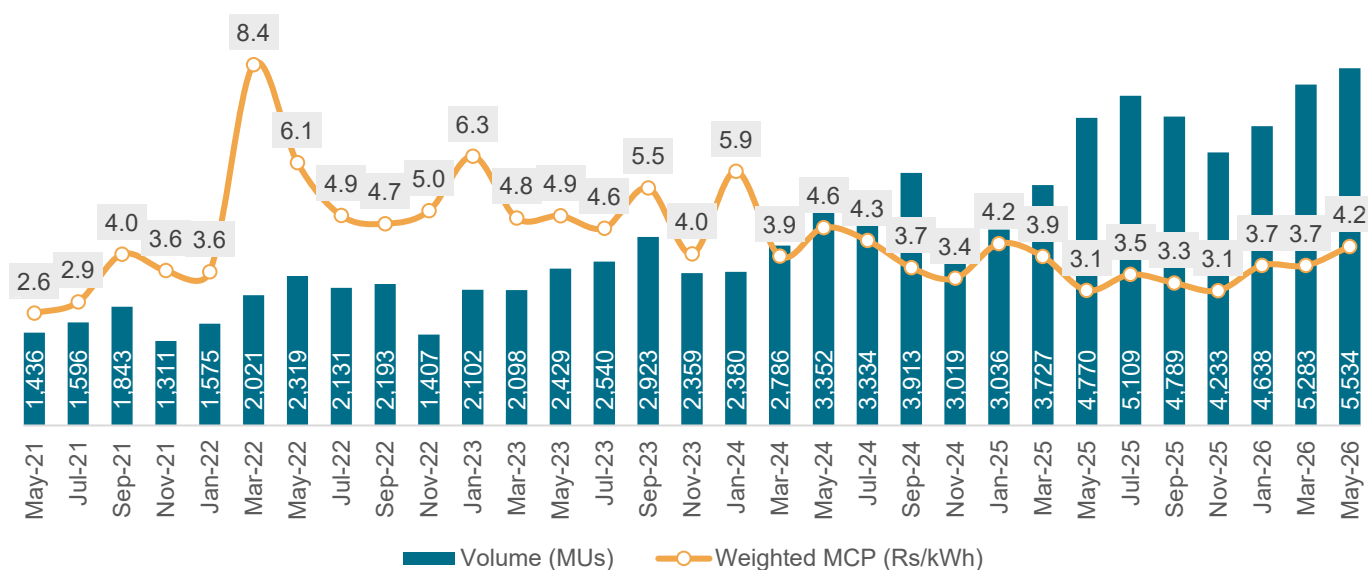


Figure 89: Weighted average prices and volumes traded in RTM



Source: IEX, CERC Market Monitoring Report, Crisil Intelligence

IEX Real Time Market commenced in June 2020. The weighted MCP for RTM varied from Rs. 2.6 to Rs. 9.1 per unit, peaking in April 2022. Over FY22 and FY23, higher volumes of trade were observed during monsoon months. RTM trades, which had 10-20% share for past months in FY21 and FY22, achieved over 30% market share in the ongoing fiscal.

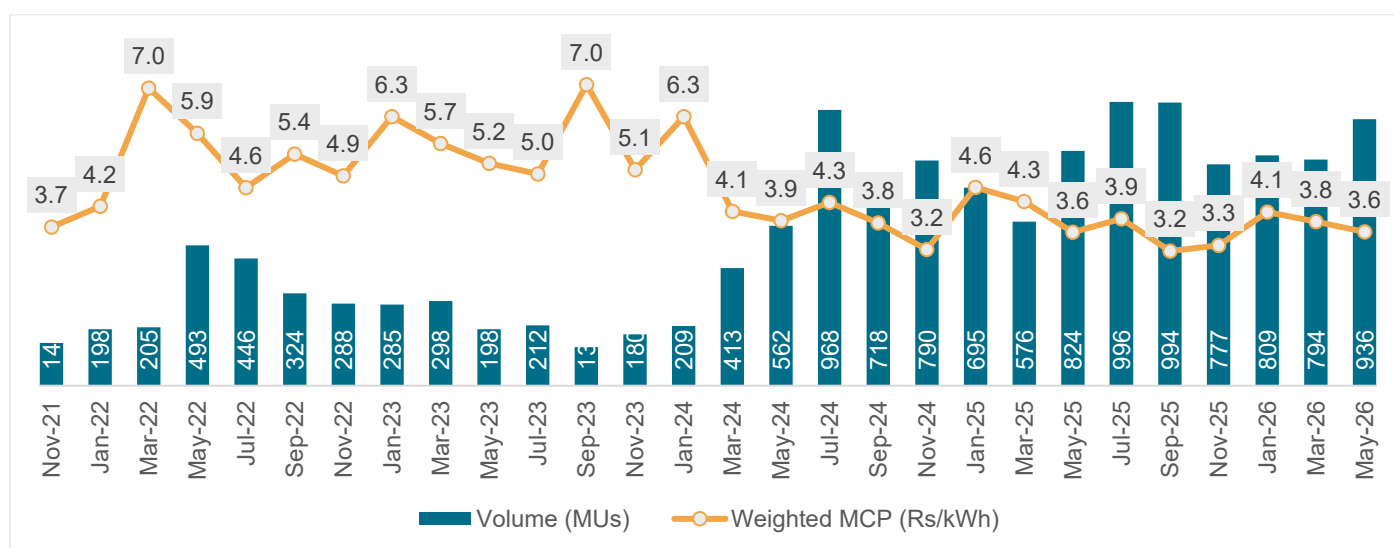
Green Day Ahead Market: Green Day Ahead market (G-DAM) is a marketplace for trading renewable power on a day-ahead basis. RE Generators, Discoms subject to issuance of NoC/Standing clearance by RLDC/SLDCs containing type of RE source along with other details viz maximum quantum in accordance with the applicable regulations are eligible to act as sellers. RE Generators registered under REC mechanism are not eligible to be sellers. Entities which are eligible to procure power through Open Access shall be eligible to participate in G-DAM as buyers.

This market involves double-sided anonymous auction bidding wherein there are separate quantity limits for sellers in each category, i.e. Solar, Non-Solar and Hydro. Participants at either premium or discount price can use 'Order Carry forward (OCF)' at the time of placing bid to carry forward uncleared bids to conventional DAM

Figure 90: GDAM trading process flow



Figure 91: Weighted average prices and volumes traded in G-DAM

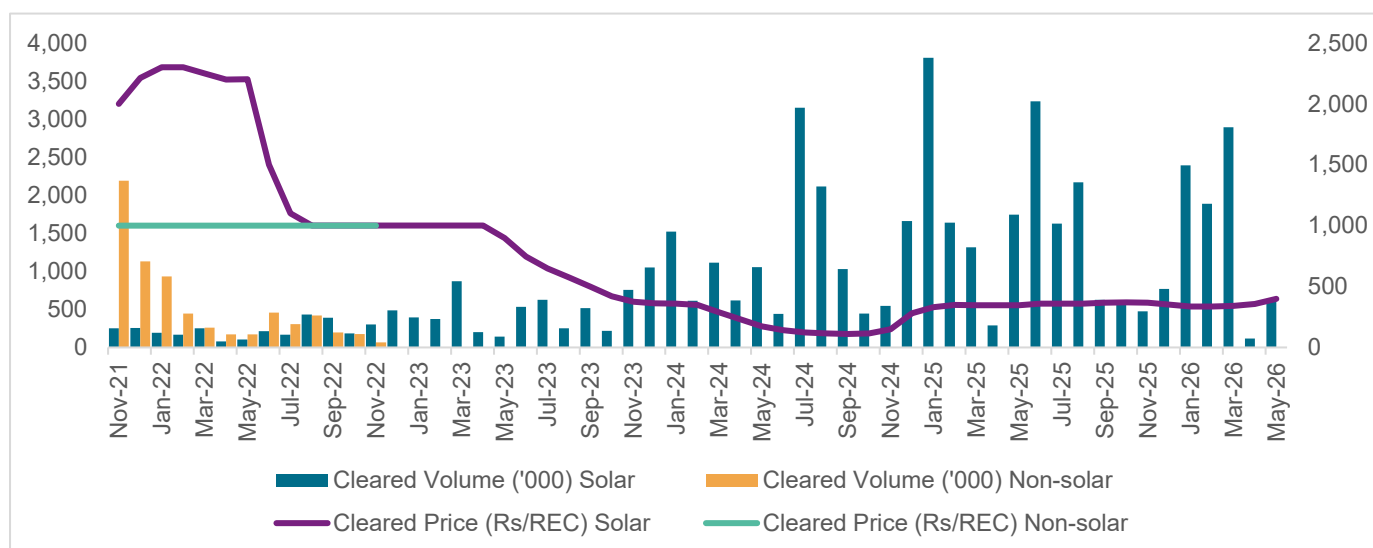


Source: IEX, CERC Market Monitoring Report, Crisil Intelligence

Renewable Energy Certificates: Renewable Energy Certificates (REC) enable buyers to meet RPO obligations without purchasing green power. 1 REC is equivalent to 1MWh energy generated from renewable energy sources. Trading is done through a closed double-sided auction on the last Wednesday of every month. Sellers include RE generators and distribution companies whereas buyers include discoms, OA consumers, Captive consumers, voluntary entities (NGOs, individuals, corporates).

Carbon credit trading system: Under this system, the Government allocates a fixed number of credits to each entity. Those that are within emission limits can sell their extra credits to excess emitters or back to the market. It also requires establishing a minimum share of non-fossil fuels to be consumed by various industries. The implementation of a carbon market will help regain traction for REC market as a mechanism for corporates to fulfill climate commitments.

Post the implementation of CERC Terms and Conditions for Renewable Energy Certificates for Renewable Energy Generation) Regulations, 2022 in May 2022, all renewable energy projects are eligible to receive RECs in case they are selling power through power exchanges in the day-ahead market.

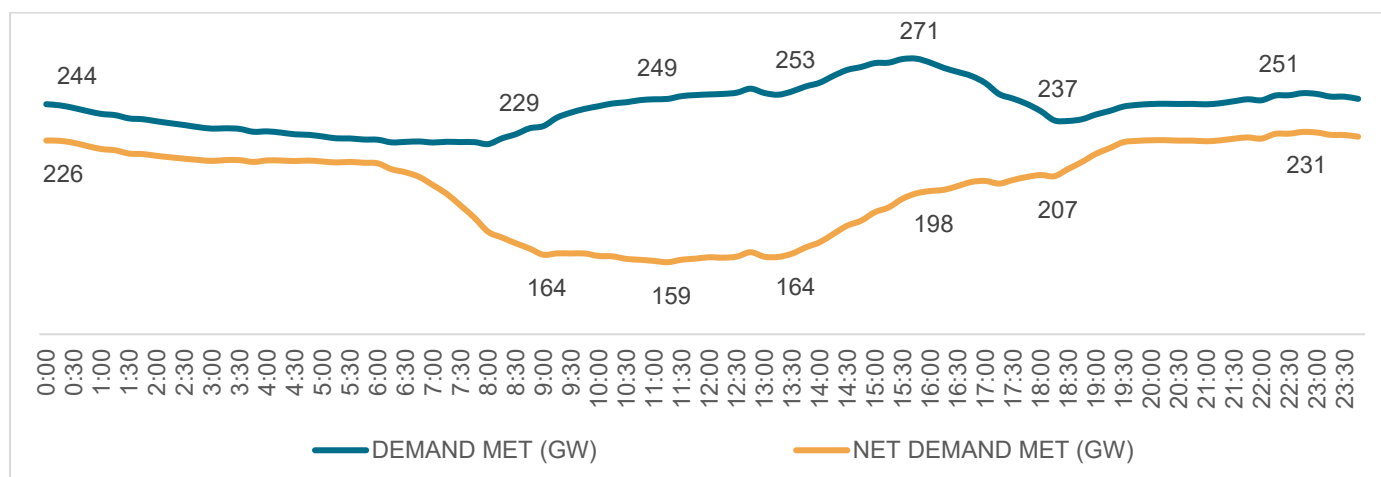
Figure 92: REC Trading


*Note: New "REC" contract introduced as per CERC's "REC Regulations 2022"

Source: IEX, CERC Market Monitoring Report, Crisil Intelligence

IEX resumed Renewable Energy Certificate trading in November 2021, after being paused in June 2020. Solar REC prices declined from Rs.2,000 to Rs.1,000 per unit, matching non-solar REC prices. Solar REC monthly trading volumes grew at a CAGR of 8% since November 2021. Solar and non-solar REC contract was deactivated from December 2022, and a new contract named "REC" was made available. Further, with the introduction of ToD tariff regime which comprises separate tariffs for peak hours, solar hours and normal hours is applicable from 1st April 2024, where the tariffs during the solar hours would be cheaper than normal hours. Solar generation creates a midday peak in supply, pushing down prices during those hours. The penetration of solar energy would be significantly higher than other RE sources during daytime leading to ramp down of net-load of non-RE generation as solar-energy generation fills in during the daylight hours as shown in below Figure. The issue arises when the solar generation drops to zero during evening, which is mostly a peak-demand time.

Therefore, there is a need for market-based fast ramping technologies to deal with the anticipated steeper duck curve (due to gradual increase of solar energy penetration into the grid) to serve the power demand and balance the system. Here wind energy can address the challenge to reduce evening ramp-up rate. The wind generation peaks in the evening and thus reduces the duck curve impact on the grid.

Figure 93: All India typical demand curve


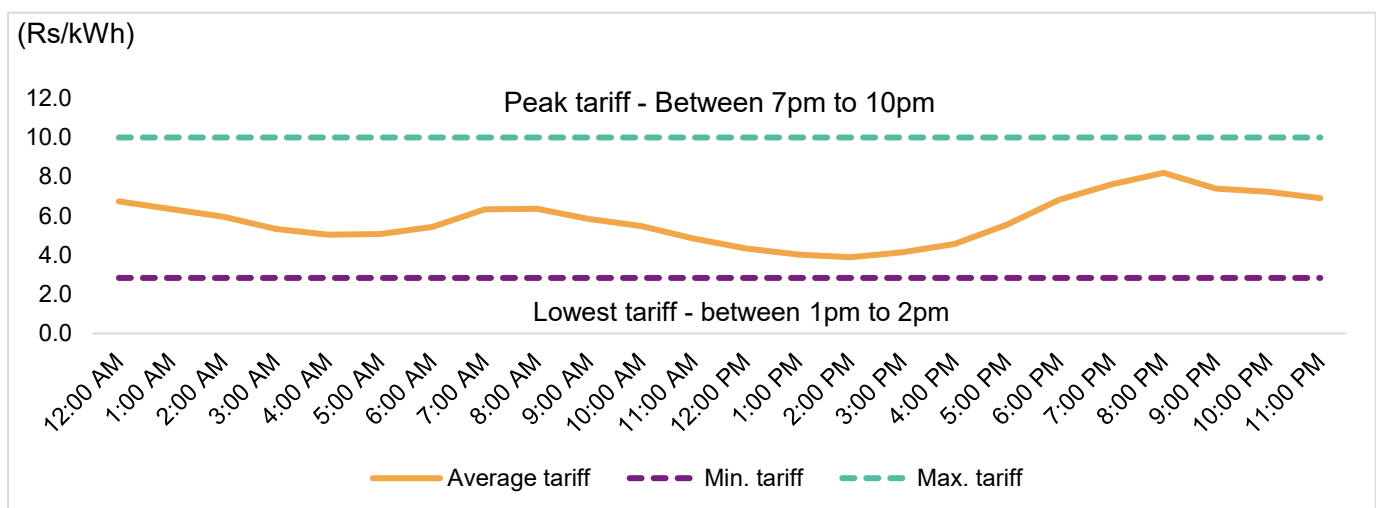
Demand met: Total electricity demand met during the period; Net Demand met total demand met less dispatched wind and solar PV capacity during the period

Source: Grid India (for 21st May 2026), Crisil Intelligence

In the chart shown below, it is evident that the electricity rates are at their peak during evening peak hours between 7pm to 10 pm and lowest during afternoon hours between 1pm to 2-m in most of the conditions when solar is at its peak generation. The wind energy generation coinciding with the demand peak in the evening can benefit as wind energy would become more valuable to meet the demand gap, potentially pushing up merchant prices during those hours resulting in high realisation thereby improving the financial viability of wind projects under ToD tariff regime. In the GDAM market, the prices during solar hours to witness a discount to average GDAM prices on account of increased supply and ToD requirements. However, it is expected that in the long-term when a significant volume of BESS would be deployed in the system, the surplus solar energy during peak daylight hours would be used to charge such energy storage systems which is expected to create a balance between availability of solar energy during solar hours in power exchanges and demand.

Solar generation typically peaks at the same time across the country. In contrast, wind generation is highly dependent on local wind conditions, which can vary significantly by region and time of day. This variability in wind patterns with sites spread across different parts of the country can benefit by selling power at different time of the day when wind is stronger in one region and weaker in another. This can allow the developer to capitalize on varying electricity prices throughout the day in the merchant market.

Figure 94: A typical daily graph of GDAM market



Source: IEX, Crisil Intelligence

5.3 Demand and supply curve projection

Demand for power exchange volumes is impacted by multiple factors such as:

Shift from long-term PPAs: Fresh PPA announcements by discoms have fallen sharply due to a decrease in deficit and poor financial health. Between FY 2013 to 2022, only 5 discoms have conducted case-I bids, aggregating ~9 GW, to enter new long-term PPAs. Discoms are shifting towards short-/medium-term PPAs to lower cost of procurement instead of engaging in long-term contracts, at least in the conventional generation segment. Presently, there is ~21 GW of capacity without long-term PPAs that has been already commissioned.

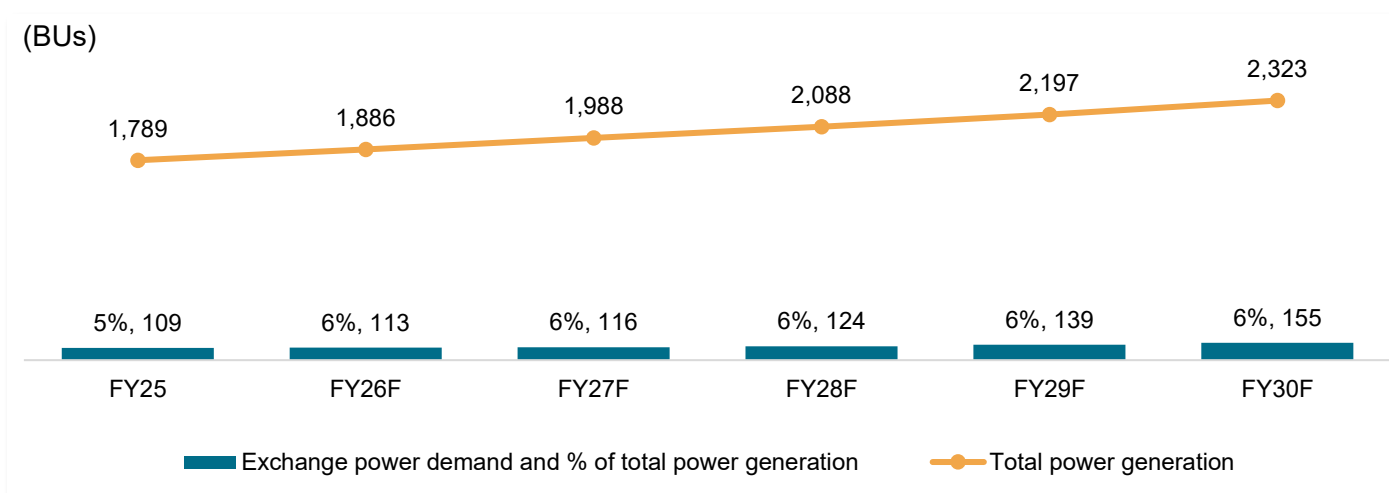
Rising Open Access consumption: There is an estimated rise in open access consumers transacting on power exchanges.

Transmission System Capacity Augmentation Plans: As of March 2024, India has 485,544 ckm of Transmission Lines with MVA: MW ratio of 2.8. As per the "Transmission System for Integration of over 500 GW non fossil fuel-based Capacity by 2030", the Ministry of Power envisages substation capacity addition of 433,575 MVA with transmission line addition of 50,890 ckm for integrating 537 GW renewable capacity. According to Crisil estimates, to further prevent RE curtailment, 47% loading of transmission lines is to be maintained for such high RE capacity addition.

Table 17: Key drivers of short-term power market in India

Factors	Short-to-medium term impact
Demand growth	Power demand to rebound over medium term led by infrastructure investment push by government
Seasonality factors	Seasonality in demand supply balance across states provides opportunity for short term trading
Supply growth	Constrained conventional capacity additions, especially coal will result in reduction in un-tied up capacity available in the short-term market
Phasing out of coal-based power plants	Phasing out of old, inefficient thermal capacities by state and central entities will result in rise in short term demand
Phasing of long-term contracts	Long term contracting is unlikely to resume owing to reluctance of utilities to enter into fixed cost obligations
Power procurement cost optimization by large consumers	Large C&I consumers would optimize their overall power procurement costs via short term power purchase on exchanges at lower cost
Coal production and supply	Domestic coal production is set to increase in the near future led by commercial coal mining & ramp by CIL. Thus, improving capacity utilization of power plants contracted by states
Transmission	Augmentation of ISTD network, rising TBCB investments in transmission to reduce network congestion to negligible levels
State open access policies	State-level procedural issues and high cross-subsidy surcharge are expected to remain, and restrict exchange volume
Open access registry	Initiatives such as this would provide a transparent mechanism for consumers to seek open access.
Other trading options	Exchange to play dominant role in day ahead, traders in term ahead. Tighter DSM regime can push discoms to move to day-ahead and intra-day markets
DEEP platform	Initiatives like DEEP to restrain some growth from which exchanges could have benefited
Financial health of discoms	With implementation of revamped distribution sector scheme, discoms financial health is expected to improve leading to increase in power procurement by discoms
Overall view	Exchange volume expected to maintain its share in short term and total power. But in absolute terms, volume is expected to witness slower growth

5.4 Potential demand to be met from PPAs and that from power exchanges

Figure 95: Power exchange transactions volume FY25-FY30


Note: Exchange includes DAM, GDAM, RTM volumes

F: Forecasted

Source: Crisil Intelligence

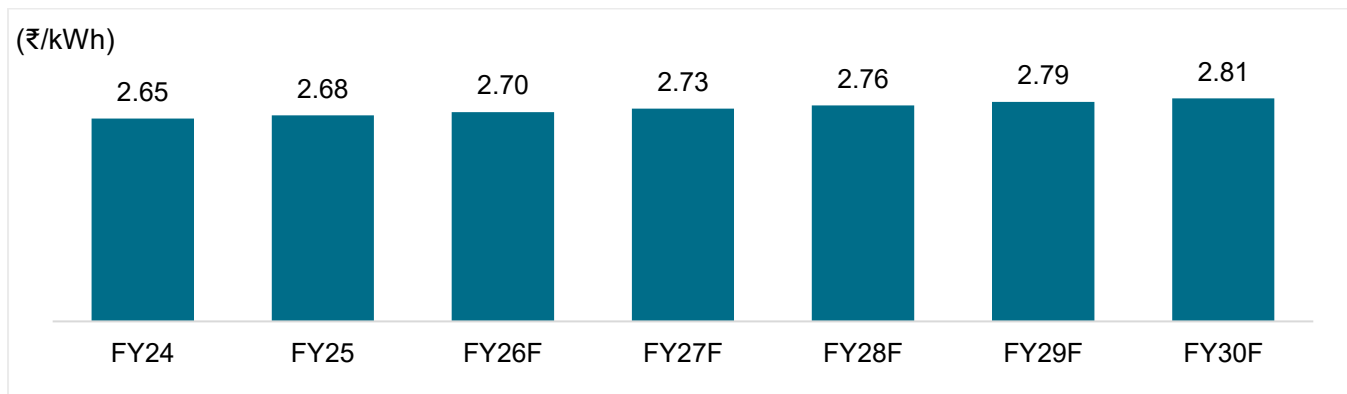
Exchange Volumes have been estimated considering regression with monthly power demand & supply volumes as there was high correlation in past. External market development expected in future will drive exchange transactions. Key developments relate to the proposal of MBED model, competition with new players filing for exchange license, introduction of new products in exchanges dedicated to RE players (GTAM, G-DAM, RTC), phasing out of long-term contracts (PPAs) to favour short-term exchange-based transactions.

Factoring the regression analysis and impact of external market developments, exchange volumes are expected to grow at a CAGR of ~7.4% between FY25 and FY30

As a result, transactions on exchanges are estimated to grow to ~155 BU in FY30, occupying a share of ~7-8% of total power generation, up from the present share of ~5 to 6% in FY25.

5.5 Assessment of source wise variable cost of generation

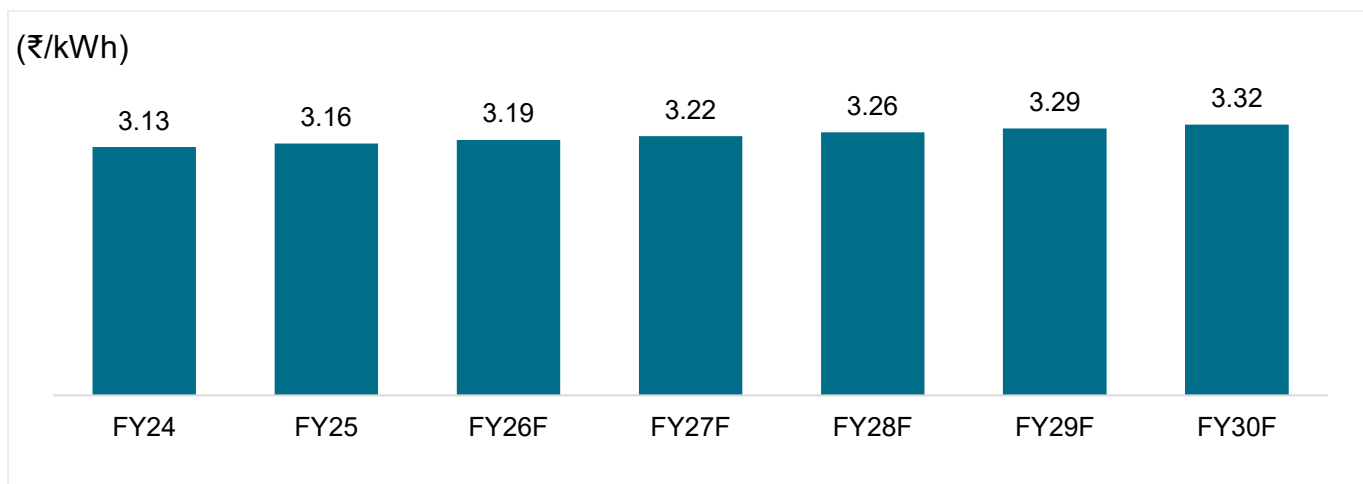
Figure 96: Solar power price forecast (Rs./kWh)



Source: Industry Reports, Crisil Intelligence

Polysilicon prices have increased from ~9 USD/kg to ~37 USD/kg from 2020 till date due to shortage of raw materials. In the long run, it is expected to witness a falling trend thereby bringing down the levelized tariffs. However, commodity prices are expected to showcase an increasing trend impacting the solar tariffs. Tariffs for new solar installations are expected to reach ~ Rs.2.8/kWh till FY30 based on the offsetting impact of commodity prices, and polysilicon prices.

Figure 97: Wind power price forecast (Rs./kWh)

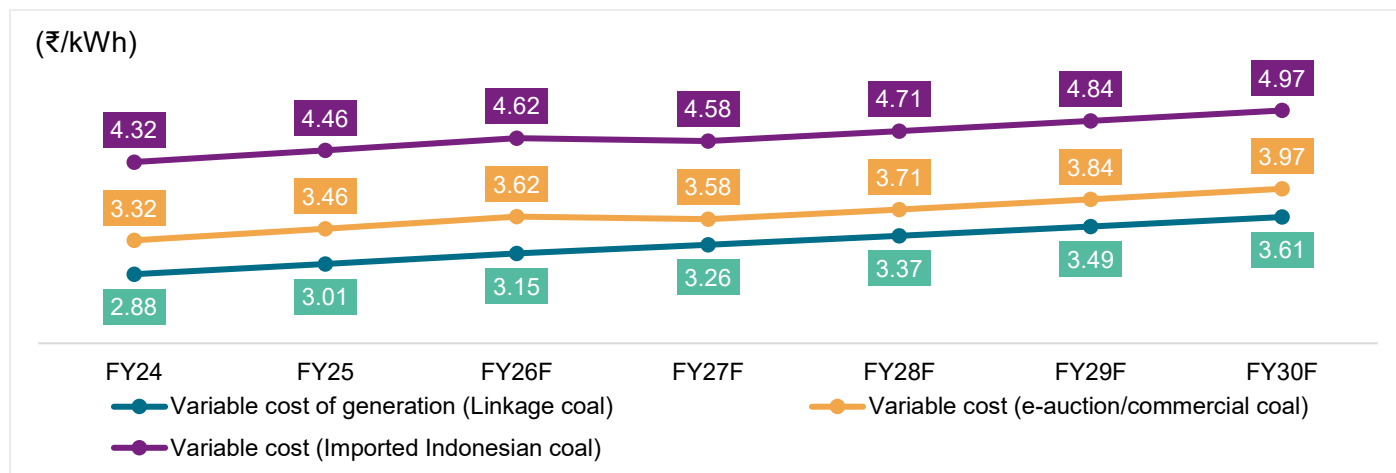


Source: Industry Reports, Crisil Intelligence

Wind tariff is largely driven by commodity prices which are expected to have an upward trajectory. Tariffs for new wind installations are expected to remain in the range of ~ Rs.3.2/kWh to ~ Rs.3.3/kWh till FY30 considering the compensating impact of technological advancement and rising commodity prices till FY30.

The sale of power in the merchant market, particularly wind power during evening peak hours when prices are highest, is expected to provide good returns.

Figure 98: Conventional generation power price forecast (Rs./kWh)



Source: Industry reports, Crisil Intelligence

Coal prices have increased drastically in fiscal 2022 and 2023 owing to the international coal price upsurge considering Russia-Ukraine conflict creating higher demand for coal from European countries. Similarly, coal imports to India increased on account of increased industrial activities in the country after COVID-19 affected previous fiscals. This resulted in higher prices for coal-based power in FY23. Furthermore, coal-based power is likely to witness an upward trajectory during the forecast period with increasing cost of transportation and mining. Non-coking coal prices (grade G11) are expected to be in the range of Rs. 1600-1700 per tonne by FY30. Hydro power generation is likely to have a high tariff towards the end of the forecast period. Gas based variable tariffs are likely to escalate at 2% considering the current economic and geopolitical conditions.

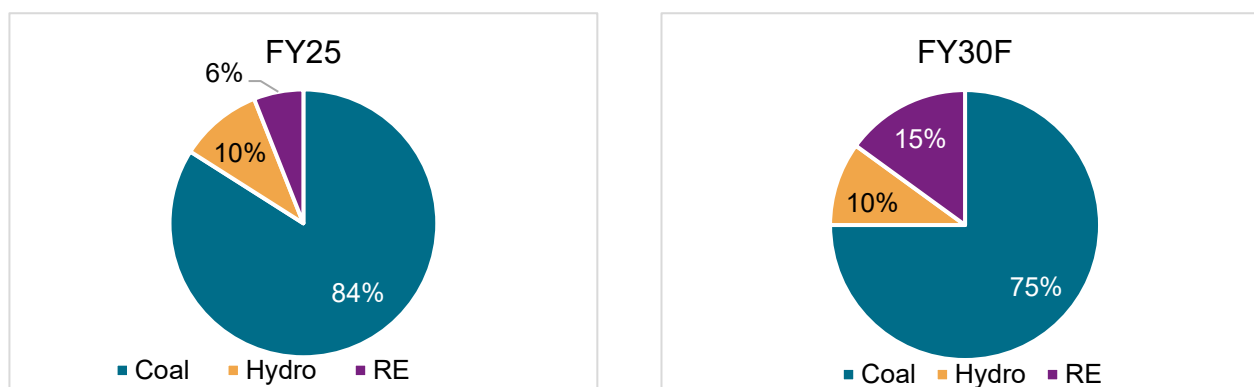
5.6 Potential transmission constraints

CERC (Sharing of Inter-state transmission and losses) Regulations, 2020 allows waiver off inter- state transmission charges (ISTS charges) for renewable energy capacities installed by 30 June 2025. However, renewable capacities commissioned after 30 June 2025 will be subject to ISTS charges which might put them in a disadvantageous position with regards their participation through open access route. However, the treatment of ISTS charges (INR 0.40-0.60 per kwh at present) to be levied on power purchased through exchanges from projects commissioned post June 30, 2025, is not clear and guidelines from CERC will be a key monitorable.

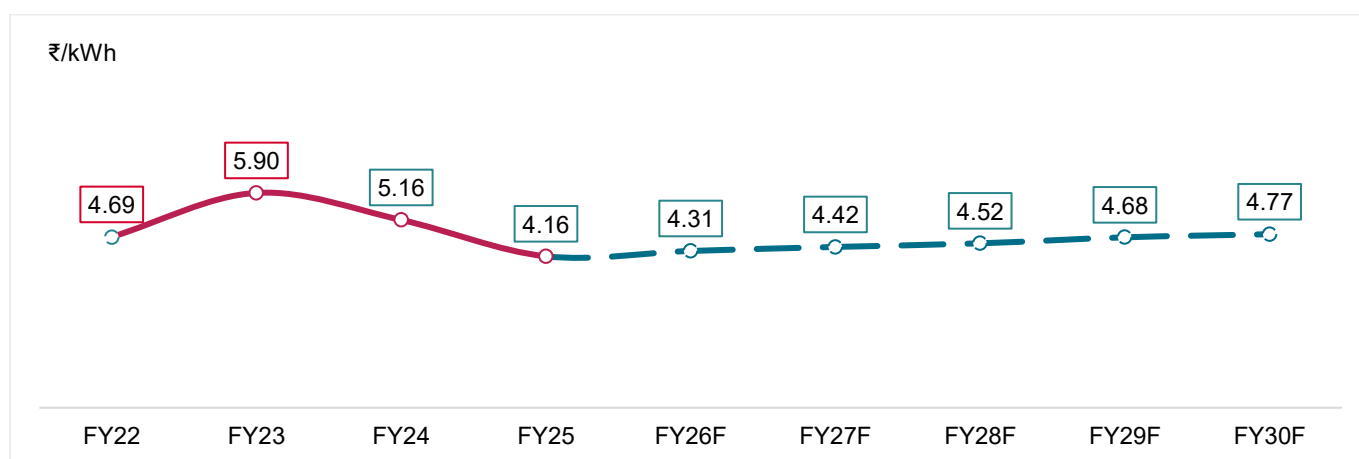
5.7 Estimation of average power exchange price forecast at a national level

The threshold price is estimated to be the price at which electricity is traded in the short-term market. In turn, it will govern the maximum price a discom or an OA consumer will be willing to pay for procuring electricity from the long-term market, subject to technical feasibility (transmission constraints, open access constraints, etc.).

Coal, which is responsible for the majority of power transacted on exchanges, is expected to continue to remain the top resource for electricity transactions even in FY30. However, RE sources like solar and wind, which constituted only 6% of transactions in FY25, are estimated to rise to 15% by FY30. This is attributed to the recent introduction of products like G-DAM, GTAM and RECs which promote RE-based transactions on the exchange. Hydropower based transactions are estimated to increase till FY30, however, its overall share in the power mix would marginally fall.

Figure 99: Share of sources in power exchange


Source: Industry reports, Crisil Intelligence

Figure 100 : Annual weighted average power exchange price forecast over FY26-30


Note: FY22 to FY25 are at actuals

Source: Crisil Intelligence

Coal based power generation dominated the power traded through exchanges with over 88% share of the total power traded in fiscal 2023 while the domestic coal supply was unable to meet the demand from the merchant power producers resulting in higher electricity power of the trade electricity. On the other hand, FY23 witnessed an elevated power exchange tariff. Imported coal-based power witnesses a huge rise in price due to soaring coal prices.

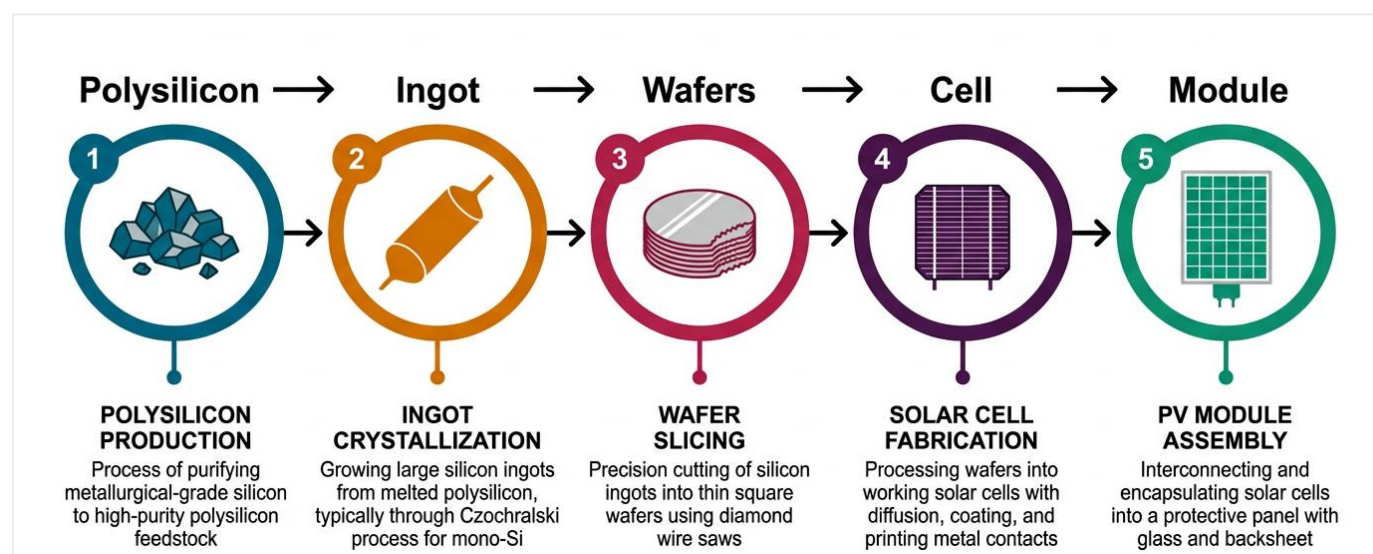
Overall, weighted average exchange tariff is likely to increase from Rs 4.69/kWh in FY22 to Rs 4.77/kWh in FY30, rising with a CAGR of 0.2%.

6 Overview of Indian Solar PV cell and module manufacturing sector

6.1 Overview of solar module manufacturing value chain in India

Crystalline silicon (c-Si) technology dominates the global and Indian solar PV markets and is expected to play a major role in India's goal of adding 280 GW of solar capacity by 2030. However, India's domestic manufacturing capacity is currently insufficient to meet demand, resulting in majority of solar modules being imported, with key components such as polysilicon ingots and wafers also being imported at high cost, highlighting the need for development of a domestic manufacturing base.

Figure 101: Schematic of c-Si PV module supply chain



Source: Crisil intelligence

Table 18: Overview of Solar 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		25-30 GW (as of September 25) Moderate	~116 GW (Expected as of October 2025) Significant
Key players in India as of March 2025	Operational: Adani Solar Planning: Reliance,	Operational: Adani Solar, Planning: Adani Solar, Reliance,	Operational: Waaree, Adani Solar, Premier, Tata Power, Renewsys, Renew, etc. Planning: Adani, Reliance,	Operational: Adani Solar, Tata, Premier, Renewsys, Saatvik, Vikram Solar, Waaree, etc. Planning:

		Waaree, Avaada, Renew, Shirdi Sai etc.	Waaree, Avaada, Renew Shirdi Sai, Vikram Solar, Inox Clean etc.	Adani, Reliance, Waaree, Avaada, Renew, Inox Clean etc.
Import dependence	High	High	High	Moderate

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.

6.2 Solar PV Module manufacturing process

Solar modules use sunlight as a source of energy to generate DC electricity. The primary raw materials and components used in the manufacture of solar modules are solar cells. A solar module is constructed using individual solar PV cells, and solar cells are made from layers of silicon semiconductor materials. Solar PV cells are connected electrically in series and/or parallel circuits to produce higher voltages, currents and power levels. Such a connection of modules in a series and/or parallel combination is known as solar PV array or PV module array. The number of solar cells in the module determines the output power. A standard PV module consists of many layers; glass, encapsulation sheet, the interconnected cells, a second layer of encapsulation sheet and plastic back sheet. These layers help to protect against environmental elements. Furthermore, a junction box, an interface of a solar module with the external world, is integrated with module to channel the power generated by the solar module to the external world.

Monofacial modules generate electricity using solar cells on only one side, which directly faces the sun. They do not rely on reflective surfaces or require specialized mounting equipment for installation, as long as the solar cells are positioned towards sunlight.

Bifacial solar modules are designed with dual surfaces that enable them to collect sunlight from both the front and rear sides of the module, which leads to a higher total energy output than conventional monofacial modules. In contrast to Monofacial modules, which only capture light on one side, bifacial modules leverage the light reflected off the ground or nearby surfaces which is then absorbed by the rear side of the module. This additional energy capture leads to a significant increase in the total energy output of the system.

To optimize their performance, bifacial modules are commonly installed using specialized mounting systems and are particularly effective in locations with high ground reflectivity, such as areas with white gravel or snow. They are especially advantageous in regions at higher latitudes, where the sun's path allows for better utilization of the dual-sided design, and in utility-scale power plants that employ solar trackers to adjust the module positioning dynamically.

Currently, the solar PV market is predominantly dominated by monocrystalline silicon technology. This is primarily due to its high efficiency levels and competitive pricing. However, ongoing technology innovation in manufacturing processes is crucial to reduce material intensity, especially for critical minerals like silver and copper. These efforts aim to minimize vulnerabilities in the supply chain.

In addition to process improvements, the development of new solar cell designs is essential for achieving further efficiency gains while simultaneously reducing material intensity and manufacturing costs. Multiple companies are actively working on tandem and perovskite technologies. These innovative designs have 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.

Figure 102: Existing vs upcoming technologies

Parameters	Mono PERC	TOPCon	HJT
Initial Capex	\$ 15-20 mn. /GW	\$ 23-30 mn. /GW	\$ 55-70 mn. /GW
Cell Efficiency	23.2% - 23.7%	24.5% - 25.2%	25.0% - 26.5%
Module Efficiency	20.0% – 21.5%	22.0% - 23.0%	22.5% - 24.0%
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: Industry, CRISIL MI&A Consulting

TOPCon technology, considered more cost-efficient than heterojunction technology for large-scale solar manufacturing, offers lower production costs and compatibility with existing PERC lines, enabling faster and more economical scaling. Additionally, TOPCon enhances performance levels by delivering higher power conversion efficiencies, which contribute to better PLFs in solar power generation.

TOPCon solar cell technology is a next-generation n-type crystalline silicon photovoltaic technology that offers higher conversion efficiency and better long-term performance characteristics compared to conventional PERC solar cell technology and is expected to become the mainstream solar cell technology globally over the medium term. Industrial TOPCon solar cells currently achieve conversion efficiencies of approximately 24.50-25.20%, or higher at the cell level, and TOPCon technology is being progressively adopted across major solar manufacturing markets, including India, the United States and China.

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.

6.2.1 Solar cells

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 a 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.

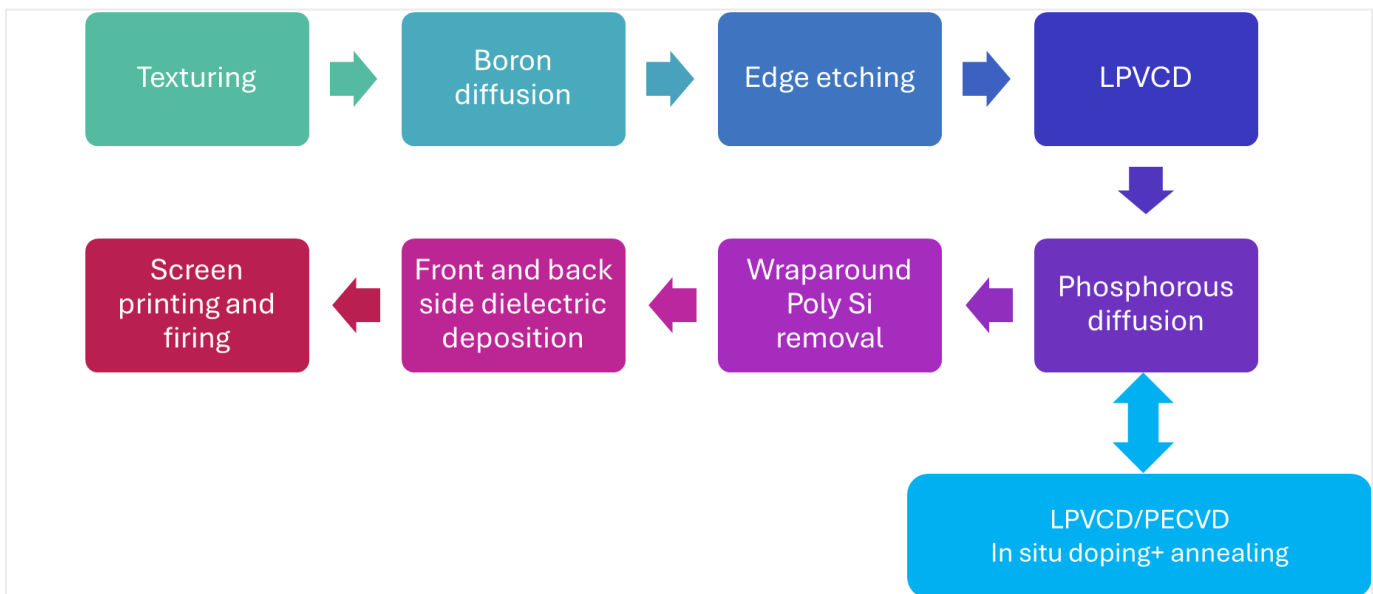
Other Gases and Chemicals: Various gases and chemicals are utilized throughout the solar cell manufacturing process. The two most common doping elements used are boron and phosphorus; Boron creates p-type silicon with positive charge carriers (holes) and Phosphorus creates n-type silicon with negative 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.

6.2.2 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 103: Schematic diagram of solar cell manufacturing process



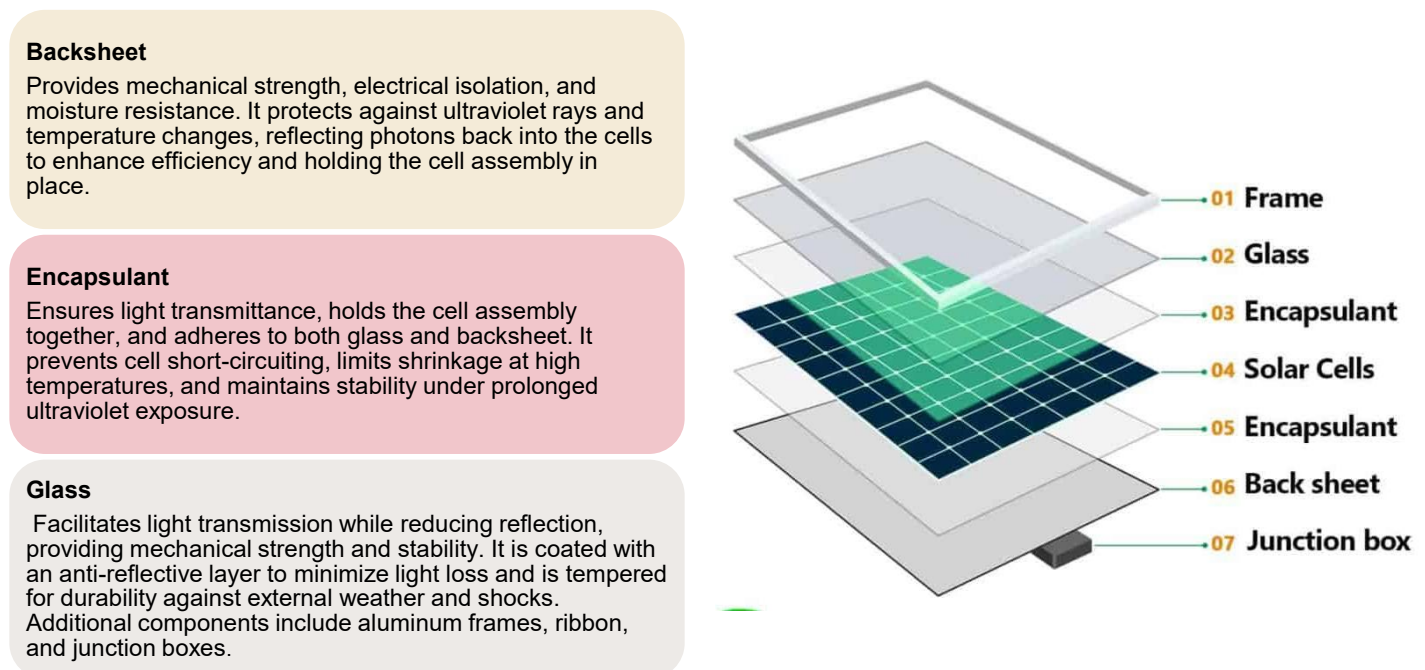
LPVCD: Low Pressure Chemical Vapor Deposition; PECVD: Plasma-enhanced chemical vapor deposition

Source: Industry, Research Reports, 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.

Solar module is a framework of photovoltaic cells that converts sunlight into direct current electricity. The performance of solar modules can differ based on specific site conditions, including irradiance, temperature, shading and voltage levels. The key components of solar modules are shown in the following figure.

Figure 104: Solar module key components



Source: Industry, Crisil Intelligence

6.2.3 Backsheet

The backsheet of a solar module provides structural durability, electrical insulation and resistance to moisture. It acts as a protective layer for the solar cells, ensuring insulation from direct current and reducing the risk of electrical shocks. The backsheet also serves as a barrier against ultraviolet ("UV") rays, humidity and temperature fluctuations, all of which could adversely affect the performance of the solar module. An additional function of the backsheet is to support the internal reflection of photons, redirecting them back towards the solar cells to maximize energy generation. The innermost layer bonds with the encapsulant, securing the entire cell assembly in place over an extended period.

6.2.4 Encapsulant

Encapsulants help with light transmission, ensuring that the solar cells receive sufficient photons for effective power output. They also help hold the solar cell assembly together, preventing individual solar cells from touching or short-circuiting. This is achieved through the encapsulant's gel content, which provides the necessary molecular strength to stabilize the module and minimize shrinkage during the high-temperature lamination process. The lamination process provides protection against harsh weather conditions, such as high UV radiation, elevated humidity levels, wind forces and the abrasive effects of sand. It is important for encapsulants to maintain strong adhesion to both the front glass and the backsheet, and to be durable under elevated temperatures and prolonged UV exposure to ensure the long-term stability of the solar module. Encapsulation also prevents the cells from mechanical stress, water ingress, enhances UV protection and keeps the efficiency of the solar cells intact. Additionally, it helps safeguard the solar modules during transport, minimizing the risk of damage that could impair their performance.

Following the lamination stage, the solar modules are enclosed within an aluminum frame, which enhances their mechanical strength and durability.

6.2.5 Glass and Auxiliary Components

The glass used in solar modules is essential for light transmission while minimizing reflection. It also provides the solar module with structural strength and compositional stability. Glass is the initial surface that sunlight interacts with, making its ability to transmit light effectively while reducing reflective losses critical to the solar module's performance. Untreated glass naturally reflects approximately 4% to 10% of incoming light, which can significantly lower energy output. To address this, solar glass is coated with an anti-reflective layer that reduces reflection to as little as 1%, depending on the quality. The glass is also tempered to provide mechanical strength, protecting the module from external forces, weather fluctuations and impact.

In addition to solar glass, other essential raw materials and auxiliary components used in manufacturing solar modules include aluminum frames for structural support, ribbons for connecting cells and junction boxes for electrical connections.

6.2.6 Solar Module manufacturing process

Solar Module is an assembly of photovoltaic cells mounted in a framework that uses sunlight as a source of energy to generate direct current electricity, which is converted to Alternate Current (AC) by an inverter. Most modules use either wafer-based crystalline silicon cells or thin-film cells.

The solar module manufacturing process begins with the electrical connection of photovoltaic (PV) cells in series using thin wires or metal ribbons. These connections are carefully soldered to the front and back contacts of each cell, enabling the flow of electrons between cells. The number of cells connected in series determines the module's voltage, while the number of parallel cell strings determines its current.

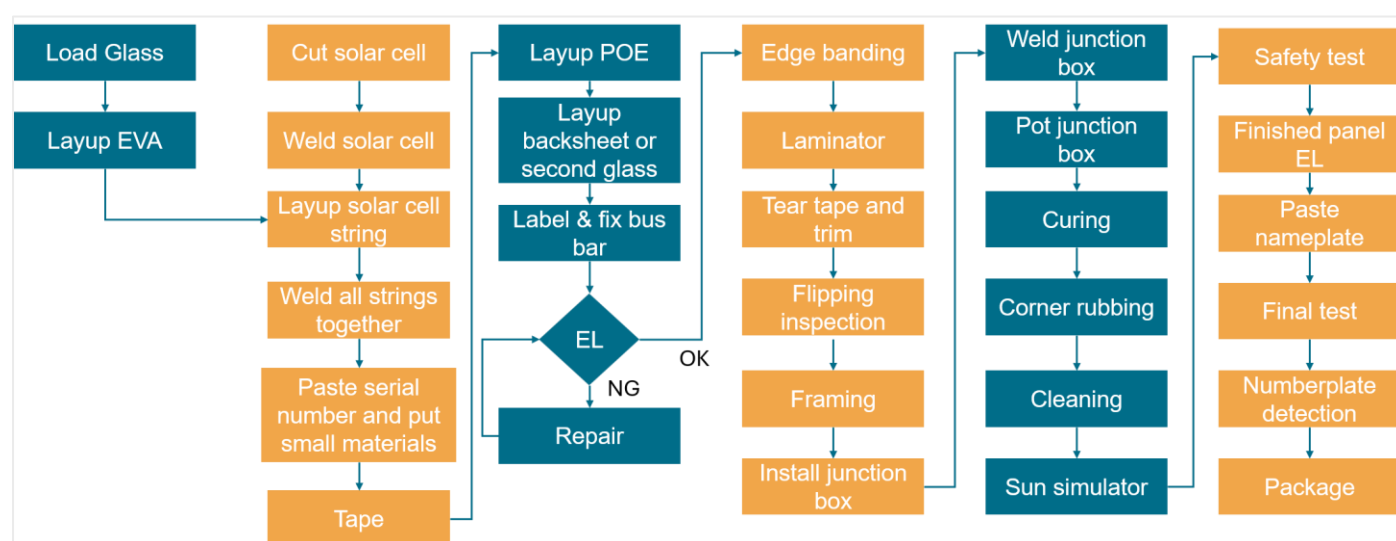
Next, the connected cell matrix is laminated between layers of ethylene-vinyl acetate (EVA) and tempered glass on the front, with a polymer backsheet on the back. This encapsulation process, which involves applying heat and

pressure to melt the EVA, protects the cells from environmental stressors such as moisture, dust, and mechanical stress.

The laminated cell matrix is then framed, typically using anodized aluminium, to provide structural support and facilitate easy installation. Junction boxes are attached to the back of the module, housing the output terminals and bypass diodes that safeguard the cells against overheating caused by shading or damage.

Finally, the completed PV module undergoes rigorous testing to ensure it meets performance and safety standards. Before being released to the market, each solar module undergoes thorough quality assurance testing to ensure it meets performance and reliability standards. This quality control process guarantees that the module can withstand environmental conditions and generate clean electricity for an extended period. By connecting and packaging individual cells into larger modules, manufacturers create a durable and efficient product that can produce electricity for decades.

Figure 105: Solar Module manufacturing process



EVA: Ethylene-vinyl acetate, EL: Electroluminescence

Source: Industry, Crisil Intelligence

6.3 Indian solar PV Module manufacturers

There are few GW-scale companies are present in India. There are many the smaller companies also present having capacities in the 100-500 MW range, with very high operational costs.

Table 19: Key domestic solar module manufacturers with capacity as of June 2026

Sr. no.	Name	Installed capacity (MW)
Pure play Module Manufacturers		
1.	Waaree Energies	25,800#
2.	Goldi Solar	15,200
3.	Emmvee Photovoltaic	10,300
4.	Rayzon Solar	11,300
5.	Premier Energies	11,100
6.	Vikram Solar	9,500

Sr. no.	Name	Installed capacity (MW)
7.	Saatvik Green Energy	4,800
8.	First Solar	3,300
Players with own demand		
9.	Avaada Electro	8,500
10.	ReNew Power	6,400
11.	Inox Clean	6,000^
12.	TATA Power	4,900
13.	Adani Mundra PV	4,000
14.	SAEL	3,625

#including 1.3 GW of Indosolar and 1.6 GW capacity in USA, ^As of August 31, 2026, including 3 GW in USA

Source: Company websites, Crisil Intelligence.

In contrast, global manufacturers such as LONGi Solar, Trina Solar, JA Solar, Jinko Solar, etc. are present across the PV value chain, and operate on a larger scale; hence, enjoy significant cost advantages.

The development of the Solar PV industry in India is at a critical point. Following COVID-19, it underwent an expedited change that was largely made possible by a supportive policy initiative. As a result, the sector is preparing to meet the growing demand for solar energy on both domestic and global markets.

India and other net PV importers, like the U.S., have implemented several policies throughout time to reduce their reliance on China for PV products. The use of tariff barriers, such as safeguard duties (SGD) in India and anti-dumping taxes in the US, is one of them.

India's cumulative module manufacturing nameplate capacity has reached ~193 GW in May 2026 from 8.4 GW in 2018 (CAGR of ~48%) and the cumulative cell manufacturing capacity is about ~31 GW in May 2026 from 3.2 GW in 2018 (CAGR of ~33%). The nameplate module capacity in India is expected to touch 225 GW and cell capacity of 40-50 GW by March 2028. 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. Domestic solar cell manufacturing capacity remains substantially below module manufacturing capacity, creating an opportunity for integrated domestic manufacturers.

Further, regarding ingots/wafer manufacturing, Adani Solar in December 2022 introduced a large-sized monocrystalline silicon ingot in its Mundra (Gujarat) facility. This development led the company to become India's first manufacturer of monocrystalline silicon ingots, capable of producing M10 (182mm) and M12 (210mm) size wafers. Lastly, Polysilicon, the first stage in the PV manufacturing chain, involves the most complex manufacturing process. Currently there are no manufacturers for domestic polysilicon manufacturing, but it is expected that under the PLI scheme the winners would set up the first of the future polysilicon product.

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.

It is also noteworthy that the majority of solar module production is centred on a small number of states. Manufacturing of solar modules is concentrated in these states for a number of reasons, including easy access to ports (for international trade), affordable land, and readily available power close to special economic zones (SEZ). Gujarat will still house most of the manufacturing capacity.

Table 20: Key players in solar module manufacturing and their presence

Player	Polysilicon	Wafers	Cells	Modules	Sale in Market	Captive use
Category I Pure Play Solar Module Manufacturers (Operational as well upcoming)						
First Solar	✓	✓	✓	✓	✓	✗
Goldi Solar	✗	✗	✗	✓	✓	✗
Premier Energies	✗	✗	✓	✓	✓	✗
Rayzon	✗	✗	✓	✓	✓	✗
Renewsys	✗	✗	✓	✓	✓	✗
Saatvik Solar	✗	✗	✗	✓	✓	✗
Waaree Energies	✗	✗	✓	✓	✓	✗
Vikram Solar	✗	✗	✗	✓	✓	✗
Category II IPPs with solar module manufacturing (Operational as well upcoming)						
ACME	✗	✗	✗	✓	✗	✓
Adani	✓	✓	✓	✓	✓	✓
Avaada	✗	✓	✓	✓	✓	✓
Inox Clean	✗	✗	✓	✓	✗	✓
Jakson	✗	✗	✗	✓	✓	✓
Reliance	✓	✓	✓	✓	✓	✓
Renew	✗	✓	✓	✓	✓	✓
TATA Power	✗	✗	✓	✓	✓	✓

- *Inox Clean: Inox Clean Energy Limited, set up under the Inox GFL Group, is the holding company for the Renewables IPP business held under Inox Neo Energies Private Limited and solar manufacturing business under Inox Solar Limited*
- *Adani: Adani Group conducts the IPP business under the company Adani Green Energy Limited whereas solar module manufacturing is conducted through Adani Solar and wind turbine generator manufacturing is conducted through Adani Wind.*
- *Acme: Acme Solar Holdings Limited is an IPP and MKU Holdings Private Limited has been incorporated to conduct solar module manufacturing business.*
- *Tata: IPP business in Tata Group is conducted by Tata Power Renewable Energy Limited and solar module manufacturing is conducted through Tata Power Solar Systems Limited*

Source: Industry, Company websites, Crisil Intelligence

The solar module manufacturing industry in India is currently fragmented, with many small and medium-sized players (compared Chinese players) operating in the market. The industry is witnessing increasing competition from big players, both domestic and international, who are expanding their manufacturing capacities and offering competitive pricing. Big players are able to achieve economies of scale, which enables them to reduce their costs and offer competitive pricing, making it challenging for small players to survive. Furthermore, some players are also doing forward as well as backward integration. Small players may not be able to integrate backwards, or they may be able to go forward by way of becoming IPPs.

Big players are likely to acquire or merge with small and medium-sized module manufacturers to expand their capacities and increase their market share. Big players may also form partnerships and collaboration with small players to access new technologies, markets, and customers. Small players who are unable to compete with big players may exit the market, leading to consolidation in the industry.

Overall, in the medium to long term, the Indian solar module manufacturing industry may witness consolidation, with big players acquiring or merging with small and medium-sized module manufacturers. Small players may face

increased competition, reduced pricing power, and limited access to technology, making it challenging for them to survive in the industry.

Indian solar manufacturing is increasingly shifting from standalone module assembly toward integrated cell–module–IPP platforms, although most players remain dependent on imported wafers and polysilicon. Overall, groups combining qualified domestic cells, efficient module capacity, captive IPP demand, EPC execution, infrastructure access and low-cost capital are best positioned to improve plant utilization, secure project supplies and capture margins across the solar value chain.

Figure 106: Benchmarking of India's leading module manufacturers and IPPs

Criteria													
Entity	INOX Clean Energy Ltd.	Adani Green Energy Ltd.	Tata Power Company Ltd.	JSW Energy Ltd.	NTPC Green Energy Ltd.	ReNew Energy Global	Waaree Energies Ltd.	Premier Energies Ltd.	Juniper Green Energy Ltd.	Avaada Energy Private Ltd.	SAEL Industries Ltd.	ACME Solar Holdings Ltd.	Clean Max Enviro Energy Solutions Ltd.
Integration (IPP + Cell+ Module)													
Global Presence													
Group Synergies													

Source: Crisil Intelligence

6.4 Policy and Regulatory Framework

The Indian government has taken several policy initiatives to promote solar module manufacturing in India. These initiatives include DCR mandate for use of domestically manufactured solar cell and modules, PLI Scheme, imposition of BCD on import of solar PV cells & modules, mandated registration of solar cell and module under the ALMM for complying with BIS standards, incentives for research and development, and support for training and skill development. Some of the key government initiatives to support a domestic PV manufacturing industry are as follows:

Domestic content requirement - The DCR mandates the use of solar cells and modules manufactured domestically as per specifications and testing requirements fixed by MNRE. There are various schemes announced by the government to promote the use of domestically manufactured modules such as CPSU scheme, PM-KUSUM scheme, grid connected rooftop solar programmes. It is mandatory to use DCR cells and modules to avail the financial aid provided by the central/state government.

Table 21: Safeguard and customs duty trajectory

Year of imposition	July 30, 2018, to July 29, 2019	July 30, 2019, to January 29, 2020	January 30, 2020, to July 29, 2020	July 30, 2020, to January 29, 2021	January 30, 2021, to July 29, 2021	From April 1, 2022 (BCD)	From February 2, 2025 (BCD)
Duty rate	25%	20%	15%	14.9%	14.5%	Module – 40% Cell – 25%	Module – 20% Cell – 20%

Source: Crisil Intelligence

The government imposed a safeguard duty on solar cells and modules imported from China, Malaysia, Thailand, and Vietnam in July 2018. The duty was initially set at 25% for the first year, followed by a phased down approach

for the second year, with the rate reduced by 5% every six months until it ended in July 2020. The purpose of the duty was to protect the domestic solar manufacturing industry from cheap imports from China. In July 2020, the government extended the safeguard duty for another year, with the rate set at 14.90% from July 30, 2020, to January 29, 2021, and 14.50% from January 30, 2021, to July 29, 2021. Later, the Ministry of Finance imposed basic customs duty (BCD) of 25% and 40% on solar cells and modules, respectively, effective April 1, 2022. This was done in an effort to boost domestic manufacturing of solar components and reduce India's reliance on imports. The BCD applies to all imports of solar modules and cells, regardless of the country of origin. With the introduction of BCD, the domestic manufacturing landscape has become increasingly competitive against overseas suppliers. These duties aim to reduce reliance on imports.

In the Budget for fiscal 2026, the government has reduced the import duties on solar cells to 20% from 25% and solar modules to 20% from 40%, effective May 1, 2025. However, the Agricultural and Infrastructure Development Cess (AIDC) of 20% on modules and 7.5% on cells keep the effective BCD rate of solar modules and cells unchanged.

- **Approved list of models and manufacturers** - The ALMM was introduced in 2019 to ensure the quality and performance of solar modules used in India. It is a list of solar module manufacturers in India that have been certified by the Bureau of Indian Standards. Only modules that are listed on the ALMM are eligible for use in government sponsored solar projects. To be eligible for enlistment under ALMM, the PV module manufacturers need to comply with the BIS Standards and must have minimum module efficiency of 20% for application in grid scale solar power plants, 19.5% for rooftop and solar pumping and 19% for solar lighting. Further, the MNRE has mandated ALMM List-II for solar PV cells from 1st June 2026 onwards. ALMM List-II is expected to reshape the domestic supply chain. All projects including government-backed schemes, net-metering projects, and open access will be required to source their solar cells from ALMM List-II for module manufacturing. MNRE on 12th September 2025 issued a draft Amendment to ALMM Order for Implementation of ALMM for Wafers. According to the said amendment it is proposed to issue List-III of wafers under ALMM, which shall be effective from 1st June 2028. For enlistment in ALMM list of Wafers, the Wafer-Manufacturer should also have the ingot manufacturing capacity equivalent to the wafer manufacturing capacity that it intends to get enlisted in ALMM.
- **Tariff ceiling provisions:** In 2019, for Phase II of the CPSU programme for developing 12 GW of capacity solar projects, the MNRE has provided a lucrative usage charge ceiling of Rs. 3.50 per unit. Subsequently the said ceiling charge was reduced to Rs. 2.80 per unit in 2020 and to Rs. 2.45 per unit in 2021. The ceiling/usage charges were exclusive of any other third-party charges like wheeling and transmission charges and losses, point of connection charges and losses, cross-subsidy surcharge, SLDC/ RLDC charges, etc. as may be applicable.
- **Solar manufacturing linked tender:** SECI had floated an EOI with the proposition of linking solar project tendering to setting up of module manufacturing capacities. The initial proposal had been floated for 5 GW of manufacturing-linked capacities linked to 10 GW of solar projects, which was then reduced to 3 GW of manufacturing capacities but linked to 10 GW of projects. Under this initiative, developers would have to comply with a 1:3 ratio between manufacturing capacities and projects and adhere to the timelines, otherwise strict penalties were stipulated. Additionally, developers could only import polysilicon while the remaining manufacturing chain from silicon wafers to modules would have to be set up. However, the above tenders failed to attract bidder response except for a single bid from Azure Power for 600 MW of manufacturing capacity and 2,000 MW of solar projects. This bid was, however, cancelled due to disagreement over the final bid price (no auction conducted as only one bidder). After a few extensions and revised tenders, In October 2019, the tender was scaled up to 7 GW of power generation capacity linked to 2 GW of photovoltaic manufacturing capacity. This also included a greenshoe option if the developers wished to avail themselves of it. The tender finally got allocated in January 2020, with even a 1 GW over-subscription (several clauses were amended, and tariff ceiling raised). The bid was won by Adani Green Energy (6GW of power generation) and Azure Power (2 GW). They also availed 2 GW each under the greenshoe option. Both recently signed PPAs with SECI for ~4.67 GW and 2.3 GW respectively. The capacities for manufacturing-linked tenders are expected to be commissioned from fiscal 2025 onwards in phases. Additionally, in September 2021, SECI revised the tariff to Rs 2.54/unit from Rs

2.92/unit. This led to pick-up in PSA signing activity for manufacturing-linked tender with 1 GW of PSA signed by TANGEDCO, 0.5 GW by GRIDCO and 5.5 GW by AP discom.

- *Pradhan Mantri Kisan Urja Suraksha evam Utthan Mahabhiyan (PM-KUSUM) Scheme* – It aims to reduce diesel use in agriculture and boost farmers' income. It offers central government subsidies of up to 30-50% for installing standalone solar pumps and solarizing existing grid-connected pumps. Additionally, farmers can install grid-connected solar power plants up to 2 MW on barren land and sell electricity to DISCOMs. The scheme, implemented by state departments, targets 34,800 MW of solar capacity by March 2026 with total central financial support of Rs 344.22 bn.
- The CPSU Scheme *Phase-II 12 GW - Government Producer Scheme*, is a significant initiative from the Indian government to promote domestic solar power generation and enhance energy security. Key features of the scheme are:
 - *Financial Assistance*: The scheme offers VGF of up to Rs 7 million per MW to incentivize participation and address project cost viability concerns.
 - *Capacity Target*: The scheme initially aimed to develop a total of 12,000 MW of grid-connected solar power capacity through plants set up by the eligible entities. While the deadline for the project commissioning has already passed, the scheme continues to be operational for unallocated projects.
 - *Implementation*: The scheme is implemented through a competitive bidding process managed by SECI. Eligible entities can submit proposals for setting up solar power plants, and SECI selects the most competitive proposals based on pre-defined criteria. With government initiatives like the PM-KUSUM, PM-Surya Ghar Muft Bijli Yojana, and the CPSU scheme in play, there is an emphasis on the utilization of DCR solar modules within the domestic solar market.

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

India's solar energy market is experiencing unprecedented growth, driven by the nation's ambitious targets and policies aimed at increasing the share of renewable energy in the country's energy mix.

Under some of the current schemes of the MNRE, namely NSM, 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. NSM had a requirement of 30% domestic content. JNNSM Phase II, launched in 2013, had a DCR of 50% for solar PV cells and modules used in solar power projects. PM-Kusum Scheme and the Solar Rooftop Program announced in 2019 mandated domestically produced modules for getting central financial assistance and other government incentives. DCR promotes domestic manufacturing and reduces India's dependence on imported solar PV cells and modules.

In 2018, India imposed safeguard duty on solar panels and modules imported from China and Malaysia to protect the domestic solar PV manufacturing industry from a flow in imports and promote self-reliance in the sector. The duties are expected to protect the domestic solar manufacturing industry from cheap imports and encourage the growth of local manufacturers. The duties also incentivize domestic manufacturers to increase production, leading to a growth in the domestic solar manufacturing sector. The growth of the domestic solar manufacturing sector will lead to the creation of new jobs in the industry. The duties will reduce India's dependence on imported solar cells and modules, promoting self-reliance in the sector. The duties will encourage domestic manufacturers to improve the quality of their products to compete with international standards.

However, along with these positive impacts, there are certain negatives also come with imposition of duties. The duties will increase the cost of solar cells and modules, making solar energy more expensive for consumers and potentially slowing down the adoption. Also, this may lead to higher tariffs for solar power projects, making them less competitive with other forms of energy. The higher costs and tariffs may reduce demand for solar energy, potentially slowing down the growth of the solar industry in India.

With limited manufacturing capacity and increased demand for solar PV, duties will boost domestic production of solar cells and modules, with several manufacturers planning to set up new manufacturing facilities in India.

Further, The Indian module manufacturers are uniquely positioned to benefit from the global 'China Plus One' strategy, which encourages countries and corporations to diversify manufacturing operations outside of China given the overdependence on China for solar cells, solar modules, wafers and other raw materials. India's favorable labour costs, government support and incentives position it as an attractive and competitive location for solar manufacturing.

6.5.1 DCR and non-DCR modules with and without duties

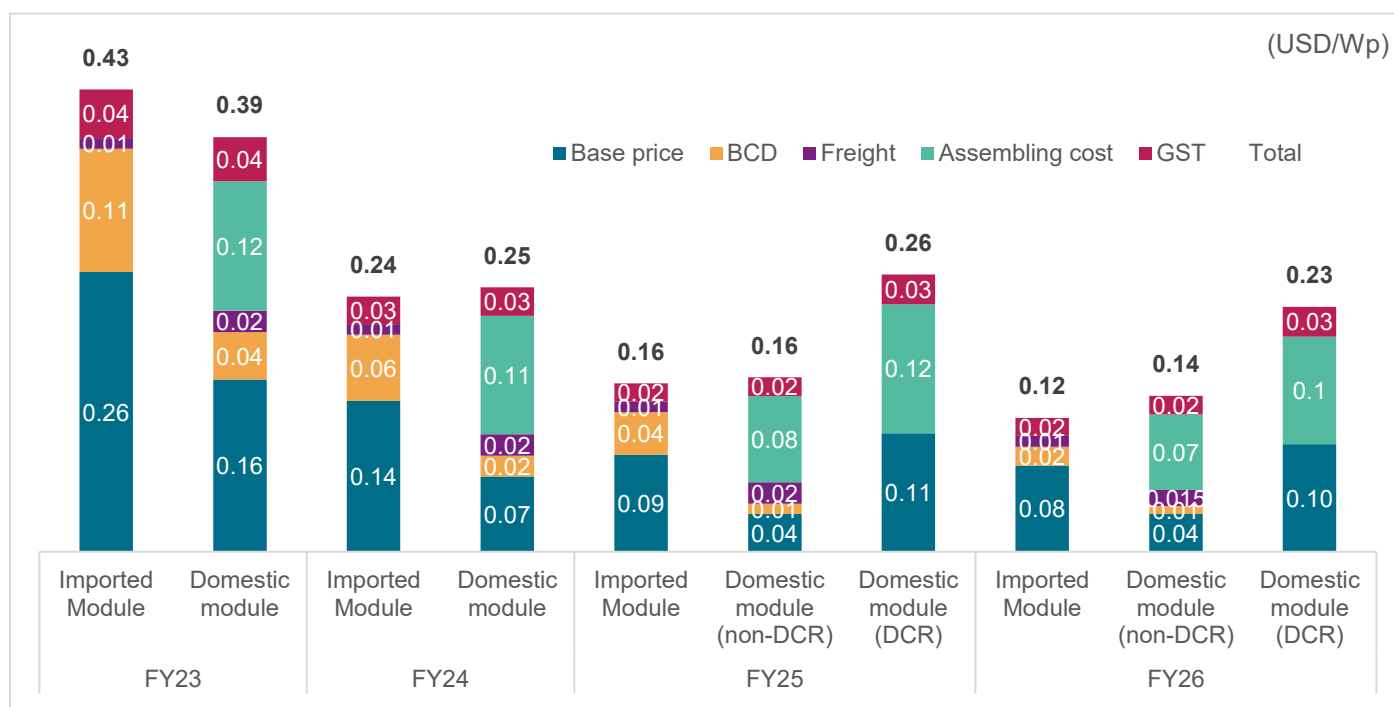
The Ministry of New and Renewable Energy and Ministry of Finance approved a basic custom duty of 40% on photovoltaic modules and 25% on photovoltaic cells which was later amended in the budget FY26 to simplify the duty structure.

In the Budget for fiscal 2026, the government has reduced the import duties on solar cells to 20% from 25% and solar modules to 20% from 40%, effective May 1, 2025. However, the AIDC of 20% on modules and 7.5% on cells keep the effective BCD rate of solar modules and cells more or less unchanged.

As India largely relies on imported cells for module manufacturing, a steep fall in upstream component prices also resulted in fall in module prices. The recent simplification of duty structure in budget FY26 is also not expected to impact the industry owing to limited imports of solar modules. Cells prices may witness a marginal increase of 1%.

However, due to significant difference in cost of solar cells, the landed cost of solar modules for DCR and Non-DCR solar modules varies significantly against the imported modules. Due to limited economies of scale and high raw material costs, the domestic cell prices are on higher side. Furthermore, there is additional demand for government programs like PM Surya Ghar Yojana and PM KUSUM and due to limited availability of domestic cells, the industry faces domestic cell shortages.

Crisil Intelligence anticipates China module prices to remain stable or decline marginally over fiscal 2025 due to the supply glut. China's anti-involution measures, coupled with stricter power consumption and efficiency norms, are expected to phase out low-quality overcapacity that previously enabled the dumping of low-cost modules and cells into India. With compliance standards pushing up production costs in China, the pricing gap with Indian manufacturers is set to narrow. This will likely reduce dumping significantly, enhance the cost-competitiveness of Indian players, and strengthen the pricing power.

Figure 107: Module prices in US Cents/Wp


For domestic- using imported Cell; BCD comprises of BCD+AIDC

Source: Industry, Crisil Intelligence

6.6 Insights on PLI Scheme

The PLI scheme for domestic module manufacturing was introduced by the government on November 11, 2020, for 10 key sectors to enhance India's manufacturing capabilities and exports under its *Aatmanirbhar Bharat* initiative.

One of the 10 sectors for which PLI was approved is high-efficiency solar PV modules, for which, the MNRE has been designated as the implementing ministry. The financial outlay for the PLI scheme is Rs 45 bn over a five-year period. This was later increased to Rs 240 bn.

In September 2021, IREDA, the implementing agency, released the list of PLI scheme participants, and the scheme received a response of 54.8 GW worth of bids for a 10 GW scheme. Bids of ~19 GW were submitted for the manufacture of polysilicon, 32 GW for wafers, and 54.8 GW for cells and modules.

Reliance New Energy Solar's PLI award amount was Rs 19.17 bn for a capacity of 4 GW. Shirdi Sai Electricals was Rs 18.75 Bn for 4 GW and Adani Infrastructure's was Rs 6.63 bn, out of the total quoted amount of Rs 3.6 bn for a capacity of 737 MW under the bucket-filling method.

In March 2023, the government, through SECI, allocated 39.6 GW of domestic solar PV module manufacturing capacity under the PLI scheme (Tranche-II) to 11 companies, with a total outlay of ~Rs 140 bn. As per Crisil Intelligence estimates, ~55-65 GW of module capacity is expected to be added by fiscal 2029 due to the boost from PLI. India's solar module manufacturing capacity has grown from 21 GW in fiscal 2022 to 63 GW in fiscal 2024 and further to an estimated 82-87 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.

Table 22: Capacity awarded (in MW) under the PLI scheme (Tranche-I and II)

Player	Polysilicon	Wafer	Cells	Modules
Shirdi Sai Electricals Ltd.	4,000	4,000	4,000	4,000

Player	Polysilicon	Wafer	Cells	Modules
Reliance New Energy Solar Ltd.	4,000	4,000	4,000	4,000
Adani Infrastructure Pvt. Ltd.	737	737	737	737
Total PLI Tranche I	8,737	8,737	8,737	8,737
Indosol (SPV of Shirdi Sai)	6,000	6,000	6,000	6,000
Reliance	6,000	6,000	6,000	6,000
First Solar	3,400	3,400	3,400	3,400
Waaree	-	6,000	6,000	6,000
Avaada	-	3,000	3,000	3,000
ReNew	-	4,800	4,800	4,800
JSW	-	1,000	1,000	1,000
Grew	-	2,000	2,000	2,000
Vikram Solar	-	-	2,400	2,400
AMPIN	-	-	1,000	1,000
Tata Power Solar	-	-	4,000	4,000
Total PLI Tranche II	15,400	32,200	39,600	39,600
Total PLI Tranche I+II	24,137	40,937	48,337	48,337

Source: MNRE, SECI, IREDA, Crisil Intelligence

6.7 Overview of solar PV integration and capital intensity

Solar PV manufacturing can be integrated in stages, from module-only assembly at the low-capex end to a fully integrated polysilicon-to-module plant at the high-capex end. As integration moves upstream, capital intensity can rise by roughly 12-15 times because each added step requires more complex equipment, higher energy and utility infrastructure, tighter process control, and larger working-capital commitments.

Indicative capital intensity varies by region, technology, scale, and equipment sourcing, but the relative increase is broadly as follows:

Table 23: Relative Capital Intensity increases with degree of integration

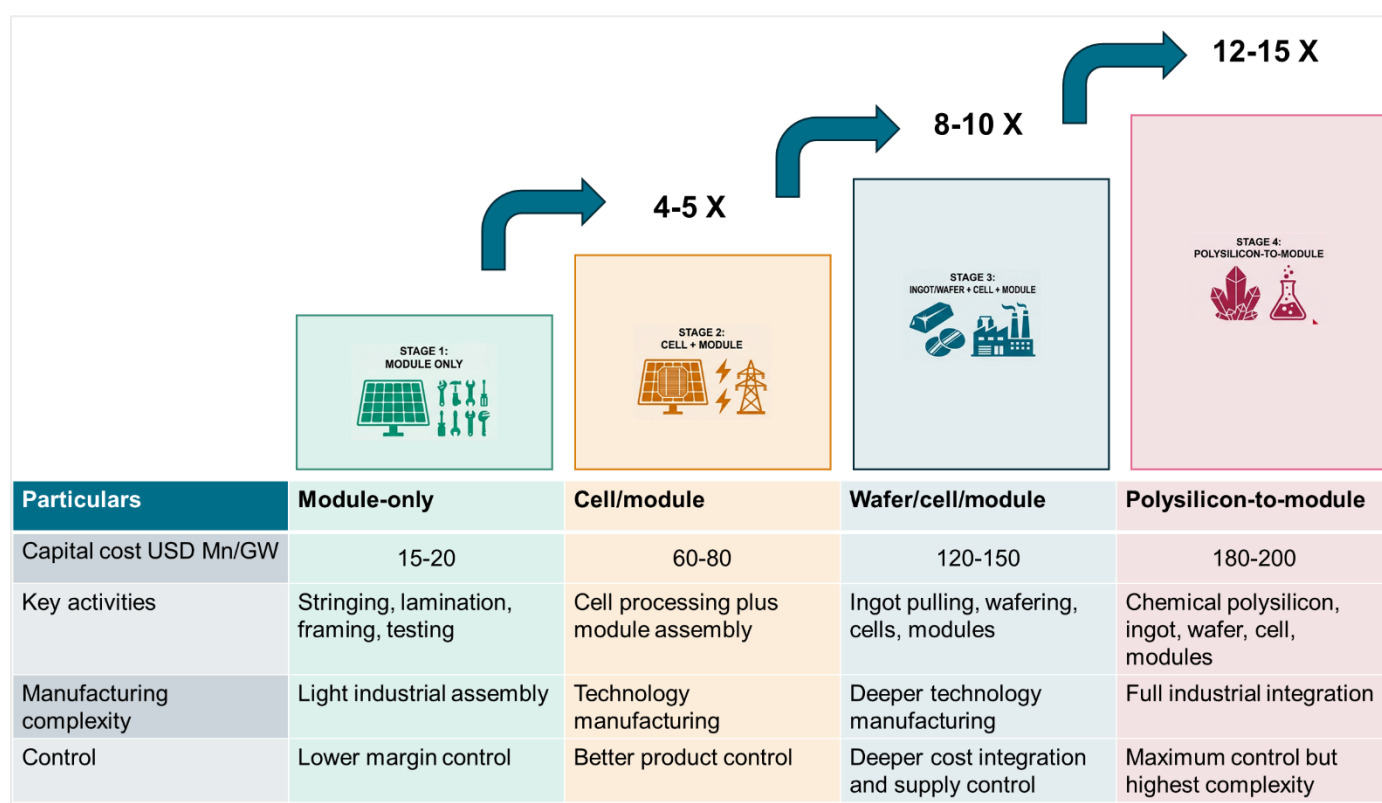
Integration Level	Main Activities	Relative Capital Intensity	Typical Capex Character
Module only	Stringing, lamination, framing, testing	1.0x	Lowest capex, assembly-oriented
Cell + module	Cell processing plus module assembly	4–5x	Requires precision semiconductor-like equipment
Ingot/wafer + cell + module	Ingot pulling, wafering, cells, modules	8–10x	Adds furnaces, slicing, slurry/wire systems

Integration Level	Main Activities	Relative Capital Intensity	Typical Capex Character
Polysilicon-to-module	Chemical polysilicon, ingot, wafer, cell, module	12–15x	Full chemical and semiconductor manufacturing chain

Source: Crisil Intelligence

Thus, if a module-only plant requires a capital intensity index of 1, a fully integrated polysilicon-to-module facility can require around 12-15 times that level, sometimes more in higher-cost regions or where infrastructure is not already available.

Figure 108: Only select players can afford full integration



Source: Crisil Intelligence

The multifold rise in capital intensity from module-only assembly to polysilicon-to-module integration reflects a fundamental shift in business model. Each upstream step adds not only equipment cost, but also utilities, process control, safety systems, environmental infrastructure, technical labor, and balance-sheet requirements.

Only a limited set of firms can realistically operate at meaningful polysilicon-to-module scale because upstream steps require high capex intensity (chemicals, furnaces, deposition/diffusion, wafering, etc.), long learning curves and commissioning risk, utilities, safety, environmental systems, and complex supply chains and minimum efficient scale to achieve unit cost targets. As a result, most companies concentrate at early-stage integration (module/cell) while later-stage integration (ingot/wafer, polysilicon) remains concentrated among fewer leaders.

6.8 Advantages of fully integrated solar PV 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 data 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.

Various Indian players in the solar industry are opting for a comprehensive approach, building facilities that integrate all components of the PV value chain, from raw material production to finished solar modules.

The increasing implementation of domestic manufacturing policies and localization frameworks in India is expected to support demand for domestically manufactured solar cells and modules and improve realization opportunities for integrated cell and module manufacturers.

6.9 Assessment of share of domestic & imported modules in Indian market

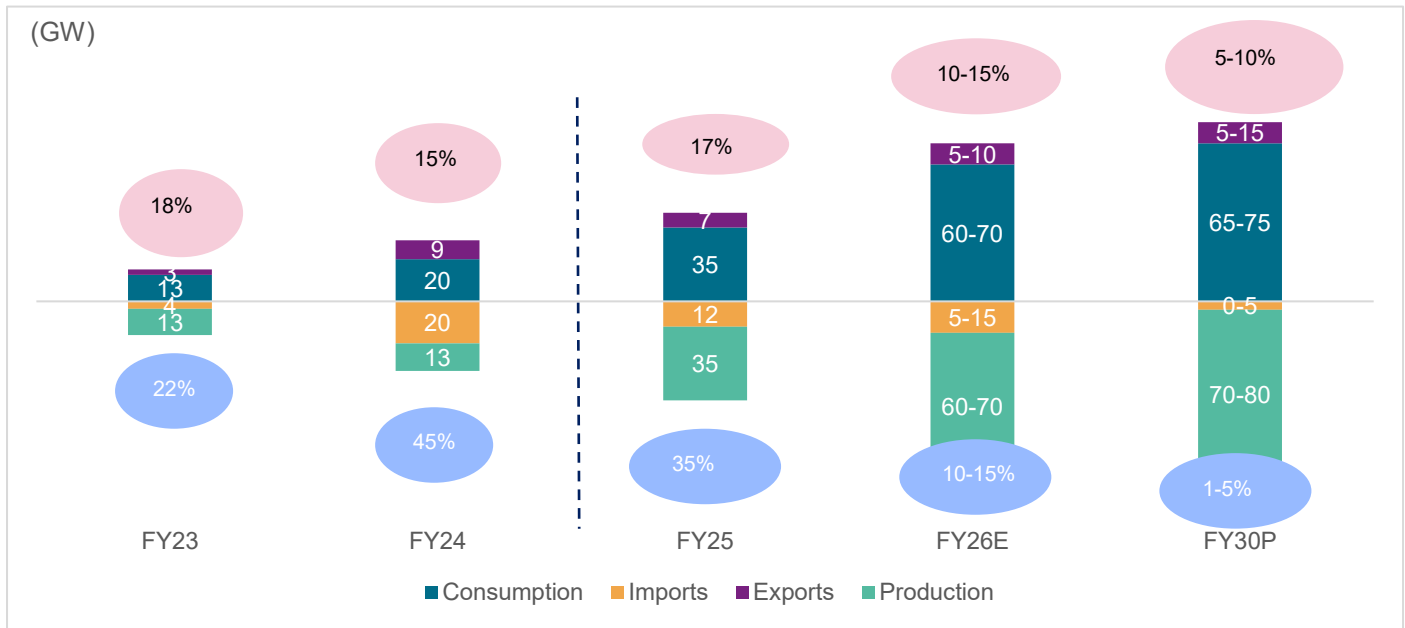
As of May 2026, India has ~31 GW installed capacity of solar cells and ~193 GW of modules (ALMM lists May 2026). Even though India is one of the top ten solar module producers, it is far behind its biggest competitor China. Considering this, large numbers of solar cells need to be imported due to inadequate capacity as well as technology.

Domestic module production capacity increased to 172 GW in March 2026. Utilisation rate is expected to average between 32-42% between fiscals 2027-2030. About 8-16% of production is to be driven towards exports to the extent of 10-20 GW in fiscal 2030. Exports in fiscal 26 in terms of value fell by 7% due to weak demand as well as geopolitical tensions.

Re-emergence of ALMM coupled with increasing production capacity is expected to reduce import reliance by fiscal 2030. Demand from solar energy remains robust with 220-250 GW of additions expected between fiscals 2027-2030. Further, the application of BCD creates level playing field for manufacturers.

Crisil Intelligence anticipates that import dependency for modules will decline to 1-5% by fiscal 2030. Nevertheless, India will continue to depend on imports for upstream components such as polysilicon, wafers, and cells.

Figure 109: Domestic production to increase 2 times by FY2030 and reliance on imports to reduce



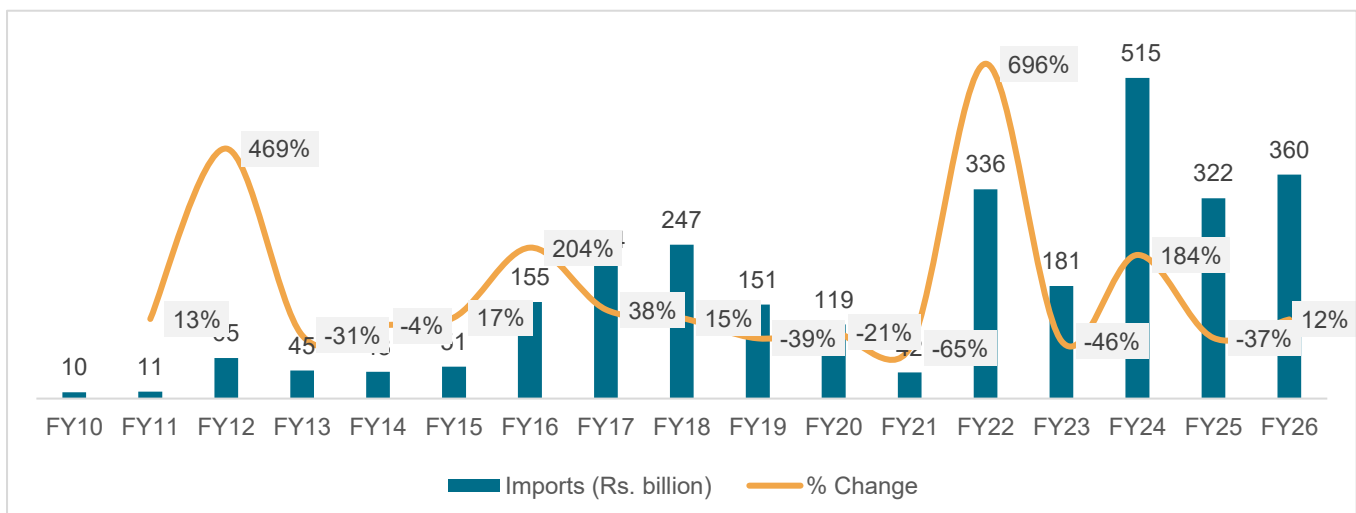
Note: The nos. are in W_p basis; DC Capacity with 140-150% overloading

Source: Crisil Intelligence

Average module production is expected to increase to 70-80 GW between FY27 and FY30 owing to PLI capacities. The average exports between fiscals 2027 and 2030 are expected to 5-10% of the production. US likely to account for major share in the short term while emerging economies and African continent also expected to open. Imports are expected to account for 10-15% in fiscal 2026 and fall to 1-5% by fiscal 2030 owing to increase in domestic capacity of technologically progressive solar modules and upstream manufacturing. Demand from solar energy remains robust with 220-230 GW of addition expected between FY27-FY30. Further, the application of BCD creates level playing field for manufacturers.

Given various government initiatives such as the domestic content requirement which requires solar cells and modules to be manufactured domestically as per specifications and testing requirements fixed by MNRE, the PLI scheme, the imposition of BCD on the import of solar cells and solar modules, mandated registration of solar cell and solar module under the ALMM for complying with the Bureau of Indian Standards (BIS) standards, incentives for research and development, and support for training and skill development, demand for domestically manufactured solar cells and modules is set to grow.

Figure 110: Solar cell and module imports



Note : Till FY 22 (HS Code 85414011+85414012) ; FY 23 onwards (HS Code 85414300 +85414200),

Source: Ministry of Commerce, Crisil Intelligence

China continues to be the largest module exporter to India, followed by Southeast Asia (SEA). BCD along with the PLI scheme is expected to improve the demand for domestic modules. However, till that time imports will continue to form majority portion of domestic demand due to lower price and better technology.

Imports have been the primary source of modules installed in the country over the past 7-8 years, with China's share reaching 77% in fiscal 2024. While China has historically maintained the majority share in imports, SEA imports, eligible for zero custom duty under the Free Trade Agreement (FTA) are gaining strong traction. Module imports from countries other than China and SEA have been negligible. Going forward, reliance on module imports is expected to decrease after fiscal 2024 due to reimposition of ALMM coupled with rapid growth of domestic manufacturing capacity. Crisil Intelligence anticipates that import dependency for modules will decline to 1-5% by fiscal 2030. Nevertheless, India will continue to depend on imports for upstream components such as polysilicon, wafers, and cells.

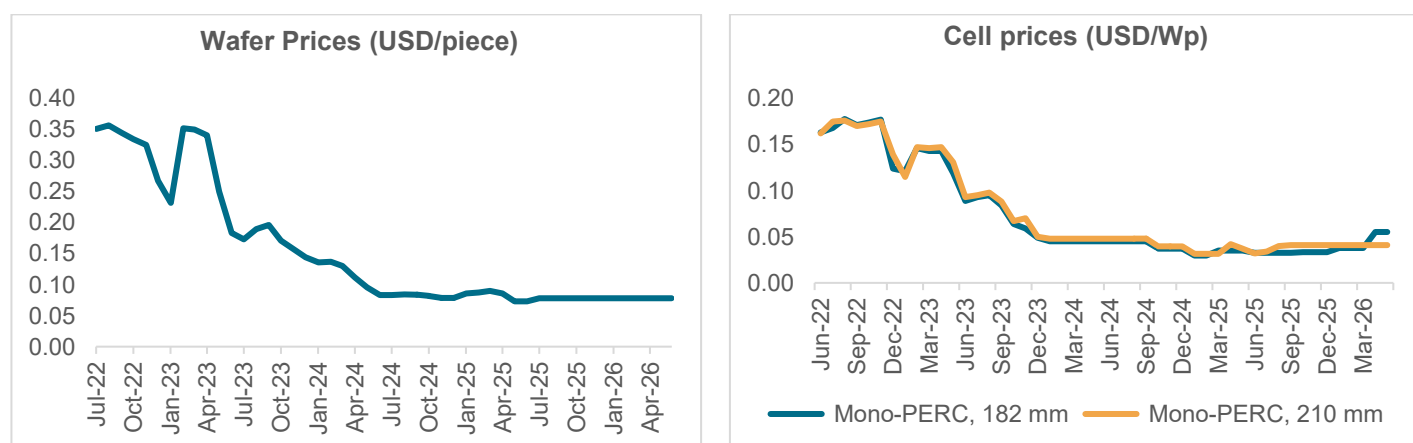
6.10 Price trend of solar PV cells and modules

Low prices to prevail across the value chain

On a global scale, the polysilicon base expanded by 68% year-on-year by the end of December 2022, reaching a range of 1000-1100 metric tons from the previous 600-650 metric tons. Weakened demand and lower consumption coupled with oversupply, resulted in a dramatic drop 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% \$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 58% over December 2022 levels, reaching \$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.

Figure 111: Wafer and cell prices



Note: Prices are free-on-board (FOB) China basis as applicable at the end of each quarter.

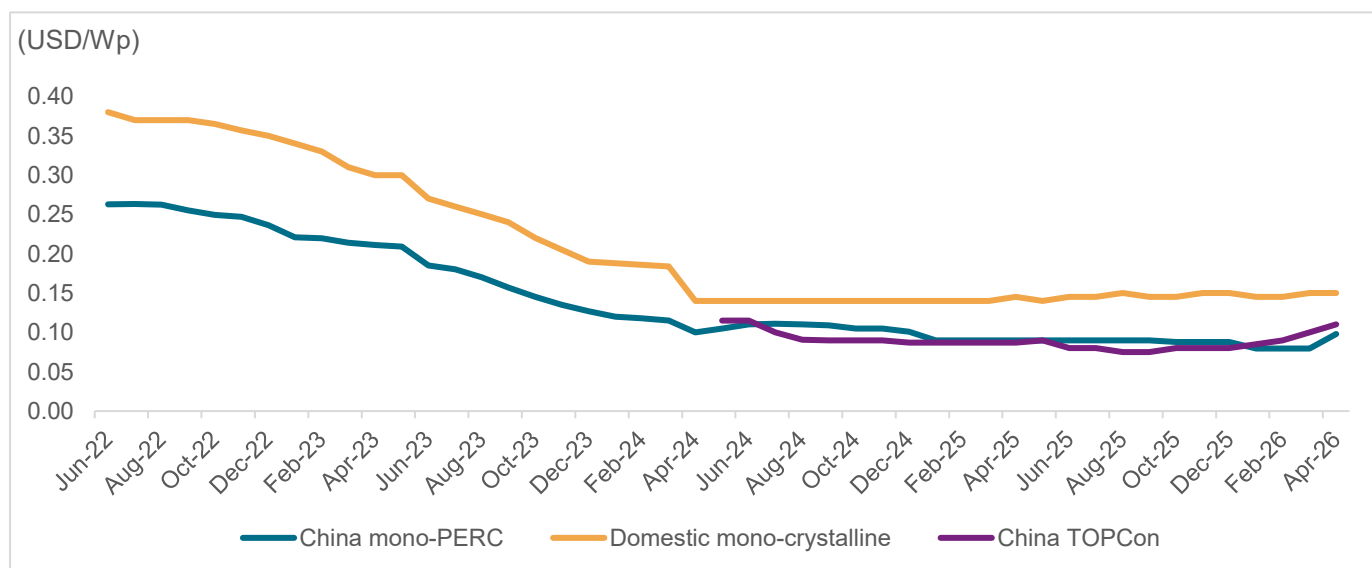
Source: Crisil Intelligence

Declining module prices

Despite increase in prices for polysilicon and wafer, China module prices continued to witness a decline due to supply glut. 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 (based on imported cells) declined in line with China prices to \$0.14-

0.16 per Wp in fiscal 2025 but maintained a sizeable premium over China prices. As of May 2026, India had approximately ~193 GW (as per ALMM list May 2026) module capacity, in contrast to only around 31 GW of cell capacity.

Figure 112 : Module prices, USD/ Wp



Note: Prices are free-on-board (FOB) China basis as applicable at the end of each quarter.

Source: Industry, Crisil Intelligence

6.10.1 Global solar cell and module manufacturing landscape

Over the past decade, there has been a significant geographical transformation in solar PV manufacturing capacity and production. China reinforced its dominant position as a manufacturer of wafers, cells, and modules by increasing its share of global polysilicon production capacity nearly three times. China's role in supply chain becomes more critical as it holds more than 75% of cells and module lines, leading to high dependence from a global supply chain perspective.

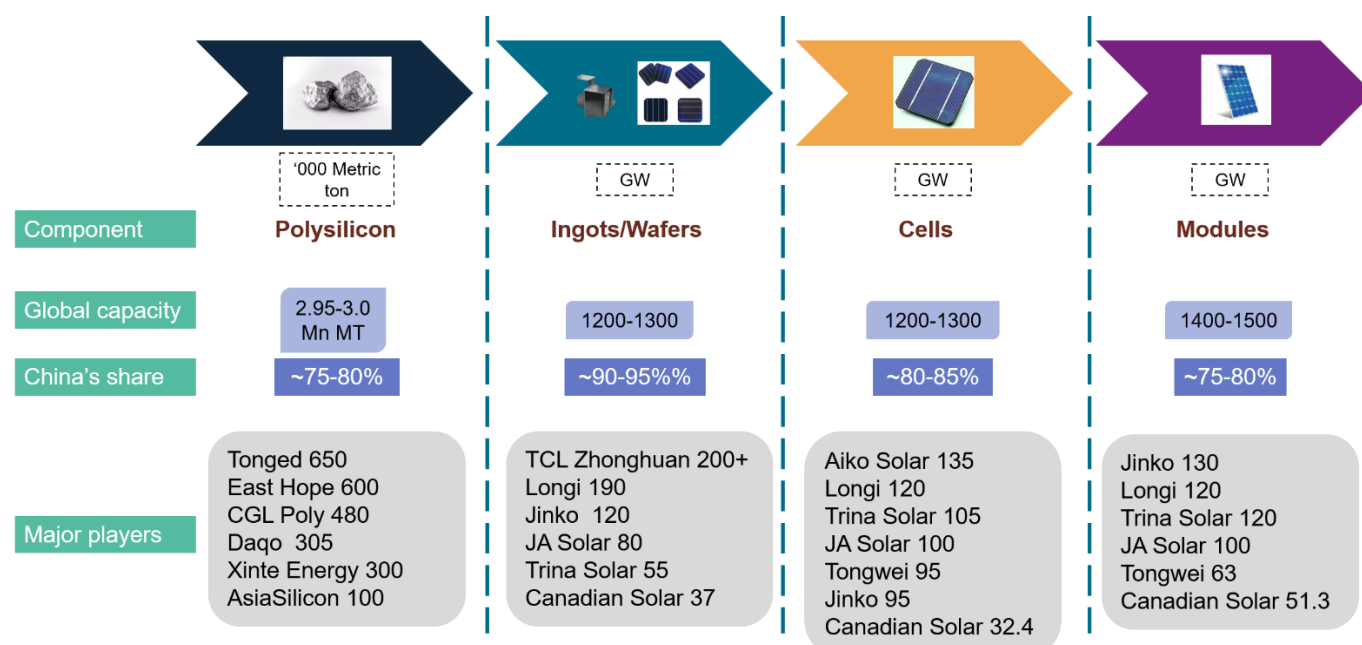
In terms of wafers, China faces minimal competition as it dominates the manufacturing sector. However, when it comes to cells and modules, Southeast Asia, particularly countries like Vietnam, Malaysia, and Thailand, possesses significant manufacturing capacity. These countries have emerged as key players in cell and module production, offering strong competition to China in this segment of the solar PV industry.

Germany maintains its status as a major supplier of polysilicon for the crystalline silicon (c-Si) PV module industry. In addition to Germany, the United States and Japan also possess significant polysilicon manufacturing capacity. However, these countries primarily focus their production on semiconductor-grade products, rather than specifically catering to the PV industry.

Module assembly in the solar PV industry has a relatively diversified geographic distribution. However, it is important to note that the majority of inputs required for module assembly, such as wafers, cells, and other components, are manufactured in China. Despite the diversified assembly locations, China remains the primary source for the manufacturing of essential PV components.

Having integrated solar PV manufacturing plants that produce wafers, cells, and modules all under one roof have certain advantages such as improved efficiency and cost reduction. With reduced transportation costs and economies of scale, these plants can optimize their production flow and have better quality control. Integrated solar PV manufacturing plants also provide greater flexibility and supply chain security. The manufacturer can respond to changes in demand efficiently, dependence on external suppliers gets reduced and with access to advanced technologies, it can certainly gain competitive advantages in terms of quality as well as price.

Figure 113 : China's share in solar value chain



As on end of CY 2024; Source: Company websites, Crisil Intelligence

First mover advantage combined with technological development under various incentive programs, has helped large scale integrated manufacturing base to be set up in China. Chinese dominance can be expected to continue as

players such as Jinko are looking to expand their capacities more than 1.5 times, while polysilicon manufacturers such as Xinte have already booked orders for next 3-5 years for a facility yet to commission.

Over the past decade, China has emerged as the top destination for solar PV manufacture as a result of favourable government policies, continuous innovation and accelerated investments in the segment, surpassing Europe, Japan, and the United States. As per NREL, in 2024, global PV shipments were approximately 770 GW an increase of 37% from 2023, with 90% of the increase coming from China. In 2023, 98% of PV shipments were mono c-Si technology, with 58% TOPCon, compared to 35% in 2015.

Global manufacturing capacity for solar PV modules increased dramatically in 2023, by almost 500 GW, with the vast majority – nearly 440 GW – added in China. Output also grew to around 560 GW, compared to around 360 GW in 2022. However, there was a slight decrease in average utilisation rates across PV module manufacturing facilities, which hovered around 50% in 2023, with facilities for newer technologies, like TOPCon cells, having higher utilisation rates than older ones.

The cumulative global solar module and cell manufacturing capacity crossed 1 TW in CY2022 – China is leading the pack, but Asia is showing signs of diversification, particularly with India's rapid growth. China has been leading the solar manufacturing sector with an installed capacity of 504 GW of solar modules in CY2022. The country's sustained investment in solar energy infrastructure, ambitious energy targets, and favorable regulatory environment have propelled its position as the world's largest solar market. While China remains the dominant player in the global solar market, the ongoing trends suggest potential diversification within the supply chain. The Asia-Pacific region ranks second in solar module installations, with a total capacity of 83 GW. Countries like Japan, South Korea and Australia have emerged as significant contributors to solar energy deployment, driven by supportive policies, technological advancements and growing environmental awareness. India's solar module installations have shown significant growth, reaching 39.5 GW. Overdependence on China for cells, modules, wafers, and other raw materials have created an environment which is fostering a 'China Plus One' strategy in the industry, encouraging the diversification of manufacturing bases. These positive external factors coupled with favorable labor costs, government support and incentives position India as an attractive and competitive location for solar manufacturing. The country's strong commitment to renewable energy, ambitious targets, and favorable regulatory framework have attracted substantial investments in solar power projects, positioning India as one of the key players in the global solar market. Solar cell capacity serves as a fundamental indicator of a region's readiness to harness solar energy for electricity generation. China leads the global solar cell capacity market with a capacity of 493 GW. India also made notable strides with a solar cell capacity of 7.6 GW at the end of CY2022. A heightened focus on solar photovoltaic supply chain diversification has emerged in recent months, with governments in the United States, Europe and India spearheading the initiative. However, differences in policy design between India and the United States have led to the promotion of different PV production segments. While India's PLI focuses on integrated facilities, the US Inflation Reduction Act (IRA) provides tax credits for various PV segments, leading to mostly segment-specific project announcements. The IRA provides manufacturing incentives under Section 45X of the United States Internal Revenue Code, including production tax credits of 7 cents per watt for modules, 4 cents per watt for cells and 6 cents per watt for wafers manufactured domestically, and investment tax credit benefits under Section 48E linked to domestic content requirements. Over the past decade, China has emerged as the top destination for solar PV manufacture as a result of favourable government policies, continuous innovation and accelerated investments in the segment, surpassing Europe, Japan, and the United States. Global PV shipments during 2024 crossed 700 GW, of which the top 10 players, including Jinko Solar, JA Solar, LONGi Solar, Trina Solar etc. accounted for a share of ~ 90% in shipments.

6.11 Supply chain and technology trends

In 2020, COVID-19 and subsequent lockdowns posed considerable challenges globally. Despite the slowdown, PV deployment will continue to flourish due to its competitive cost. 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%² (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.

The future of PV modules is heavily reliant on technological innovations. Innovation plays a vital role in driving technological advancements throughout the clean energy supply chains. Within the solar PV sector, continuous technological innovation has led to notable improvements such as increased conversion efficiency of solar cells, reduced material usage, and enhanced energy efficiency per module.

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.

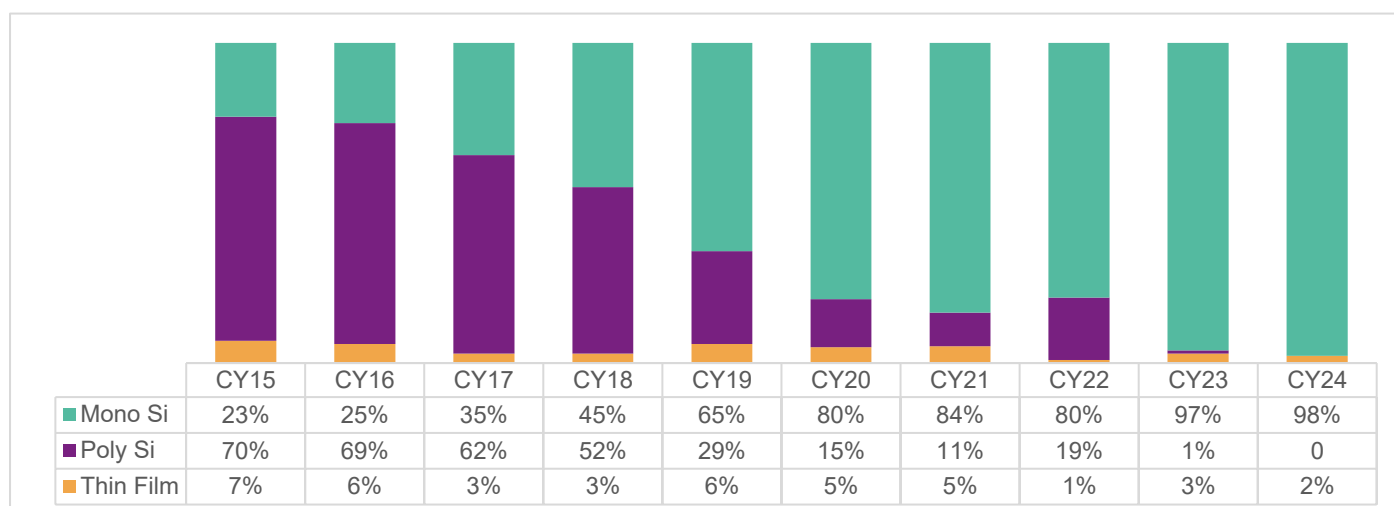
The affordability of solar PV as an electricity generation technology in various parts of the world can be attributed to these investments in R&D. Without such dedicated support, the cost reductions and advancements witnessed in the solar PV industry would not have been attainable. Hence, ongoing investments in R&D, both from the public and private sectors, continue to be essential to drive further innovation, cost reduction, and efficiency gains in the solar PV sector. Japan, Germany, United States and Switzerland, are considered pioneers in solar technology and have high-quality equipment in relation to solar.

Currently, the solar PV market is predominantly dominated by monocrystalline silicon technology. This is primarily due to its high efficiency levels and competitive pricing. However, ongoing technology innovation in manufacturing processes is crucial to reduce material intensity, especially for critical minerals like silver and copper. These efforts aim to minimize vulnerabilities in the supply chain.

In addition to process improvements, the development of new solar cell designs is essential for achieving further efficiency gains while simultaneously reducing material intensity and manufacturing costs. Multiple companies are actively working on tandem and perovskite technologies. These innovative designs have 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.

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

² Fraunhofer ISE: Photovoltaics Report, updated: 17 May 2024

Figure 114: Module technology share


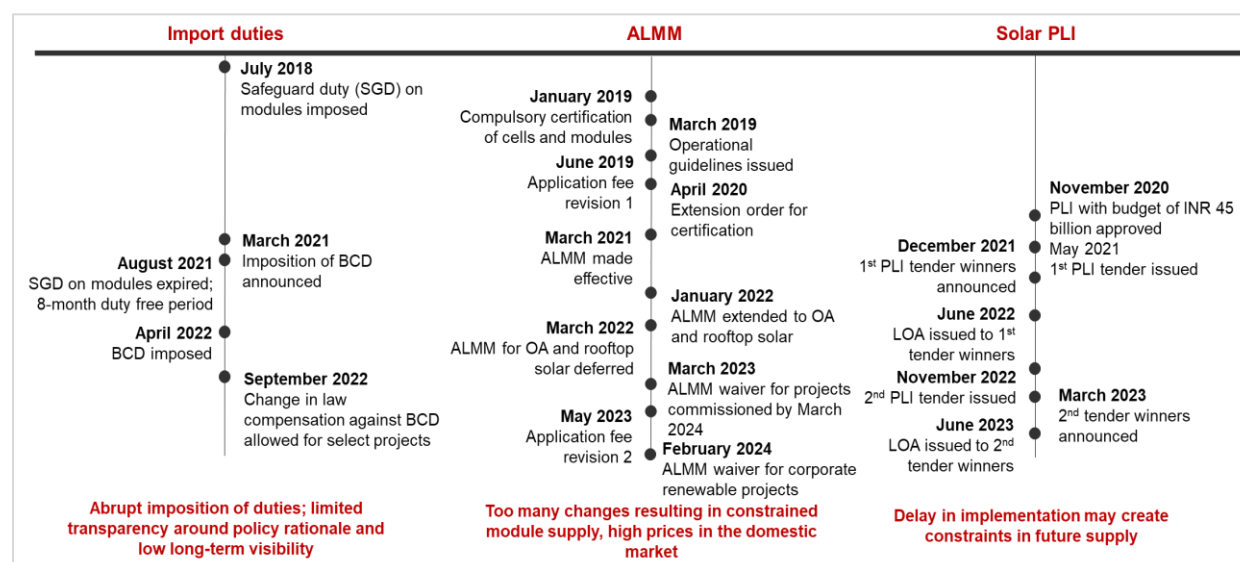
Source: Industry, Crisil Intelligence

6.12 Threats and challenges for PV manufacturing sector

6.12.1 Threats

6.12.1.1 Policy and regulatory uncertainty

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. Key policy measures include applicability of ALMM, safeguard duty, BCD, and solar module manufacturing PLI scheme. Despite a very 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.



6.12.1.2 Market demand variability

Market demand fluctuations are influenced by changes in government policies, incentives for solar projects, changes in solar tendering capacity, shifts in export markets. The government tenders play a crucial role in driving demand

for solar modules in India. Inconsistent tender schedules can create uncertainty for manufacturers, making it difficult to plan production and manage inventory. Indian Solar PV manufacturers still operate their plants at ~50% of its capacity due to lack of demand from private IPPs. Sudden spikes in demand can strain production capacity, while dips can lead to underutilisation of resources. Similarly, an economic downturn or growth spurts in export markets can lead to fluctuating demand for solar modules.

6.12.1.3 Competitive pressure

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. China revised its catalogue of technologies prohibited or restricted from export in December 2023.

6.12.2 Challenges

6.12.2.1 Technological challenges

Solar PV manufacturing is advancing towards more efficient and cheaper modules. Any changes in solar technology can shift demand towards newer products, rendering existing inventory less desirable. All technology know-how and even manufacturing lines and installation personnel for new PV cell and module lines, being set up currently, are coming mostly from Chinese suppliers. Therefore, maintaining high-quality standards and keeping up with rapid technological advancements can be challenging for this industry.

6.12.2.2 Supply chain disruptions

India heavily relies on imports for critical components like solar cell, wafers, EVA sheet, glass, etc. This dependence makes the industry vulnerable to global supply chain disruptions, price volatility and trade policies. An unreliable supply chain can lead to production delays and inconsistencies affecting the ability to meet demand.

6.12.2.3 Environmental factor

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 on costs, operational efficiency, and the overall feasibility of the project.

6.13 Future Growth Opportunities

6.13.1 Module and cell manufacturing capacity in India over the past five years

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.

India's solar PV industry has witnessed rapid expansion in recent years, establishing itself as a significant player in the global renewable energy market. The central government's PLI scheme has been instrumental in driving a significant increase in solar module and solar cell manufacturing capacity. The country's solar module manufacturing capacity has grown from 21 GW in fiscal 2022 to 63 GW in fiscal 2024 and further 116 GW in October 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 of modules declined in last 2 years. Fiscal 2026 saw a decline of 7% whereas fiscal 2025 saw a decline of 43%. The key reason for declines includes increased domestic demand, tariffs by USA, and heightened scrutiny over Chinese component sourcing in the global supply chain. 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 31 GW in May 2026. 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.

6.13.2 Opportunities in export markets for Indian-manufactured solar modules

India has the potential to become a global leader in the manufacturing of solar modules. The country has a large pool of skilled labor, a growing manufacturing ecosystem, and abundant access to raw materials. Additionally, the Indian government has introduced several policies to support the domestic solar industry. India's solar module manufacturing capacity is expected to reach ~240-260 GW by fiscal 2030. Domestic demand for solar modules is estimated to be around 50-60 GW in the same year. This means that India will have a surplus of solar modules that can be exported to other countries.

Developing countries are increasingly investing in solar energy to meet their growing energy demand. This presents a significant export opportunity for Indian solar module manufacturers. The Indian government is providing several incentives to support the export of solar modules. Indian solar module manufacturers can diversify their markets by exporting to countries where there is high demand for solar modules and low import duties.

India has an immense opportunity to export solar modules. This can help the country achieve its energy security goals and usher in a manufacturing renaissance. Indian solar module manufacturers need to overcome a few challenges, such as competition from China and high import duties in some countries. However, there are several opportunities for Indian solar module manufacturers to export their products, such as growing demand in developing countries, government support, and diversification of markets. Overall, the export demand for Indian solar modules is potentially on the rise due to anti-China sentiment and government support.

6.13.3 Integration of advanced manufacturing techniques such as automation and AI-driven quality control

The integration of advanced manufacturing techniques such as automation and AI-driven quality control can significantly improve efficiency, productivity, and quality of solar module manufacturing.

Automation can help reduce labor costs, improve production speed, and increase overall efficiency in solar module manufacturing along with improved quality, reduced wastage, and enhanced safety. AI-powered quality control systems can monitor production in real-time, detecting defects and anomalies as they occur. AI powered quality control systems also help with predictive maintenance, defect detection and yield optimisation. Some of the applications in solar module manufacturing include cell sorting and inspection, module assembly, testing and inspection and supply chain optimisation.

However, these advanced manufacturing techniques come with certain challenges such as high upfront costs, complex systems, data quality, and risks of cyber-attacks.

With increased competition, advanced manufacturing techniques are likely to become more widespread in the solar industry as manufacturers seek to improve efficiency, quality, and competitiveness. Advances in automation, AI, and

computer vision will continue to improve the efficiency and effectiveness of solar module manufacturing. The adoption of advanced manufacturing techniques will increase global competition in the solar industry, driving innovation and improvement in manufacturing processes.

6.14 Overview of global solar market

6.14.1 Review of Global Solar PV Capacity Additions

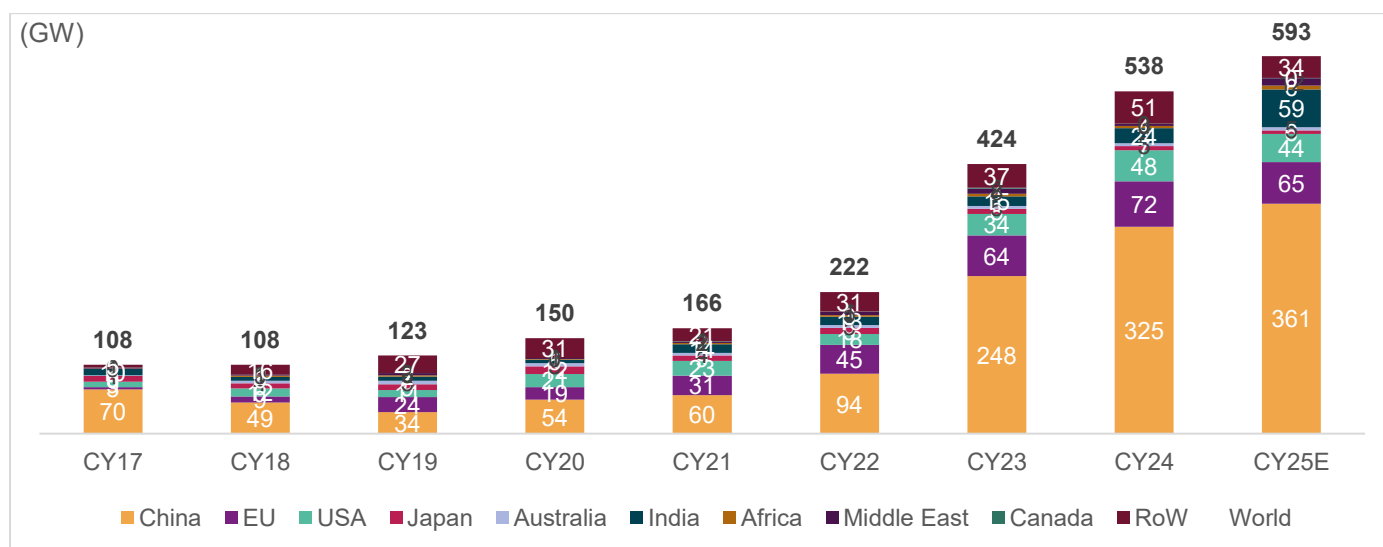
The strong global thrust on clean energy is driving renewable installations worldwide led by reducing RE generation costs, favourable policies, improved emphasis on energy security and access, and socio-economic benefits. The last decade saw a remarkable evolution in the solar PV segment marked by large scale installations, signification reduction in tariffs and technological advancements.

Concerns over climate change are at the heart of the energy shift towards RE and its increasing utilisation will be the key to decarbonisation. Various initiatives, such as Kyoto Protocol, Paris Agreement, COP, RE100, ISA, and subsequent favourable policy interventions, have helped strengthen the RE segment. The transition towards RE is critical to limit the rise in global average temperatures to well below 2 degrees Celsius and ideally below 1.5 degrees Celsius above pre-industrial levels.

Countries that are part of the Paris Agreement are required to submit their plans for climate action, known as the Nationally Determined Contributions (NDCs). These NDCs represent the efforts these countries need to take to reduce national emissions. Various countries have provided policy impetus to the solar PV industry through various mechanisms, such as FiT, 'must run' status, renewable purchase obligations, tax incentives, AD, favourable regulatory frameworks, subsidies, and PLIs. This has accelerated global growth in solar PVs.

Investments in solar PV are expected to increase further as it is rapidly becoming the preferred and lowest-cost option for electricity generation globally. As per IEA, average annual solar generation should grow by an average of 25% between 2022 and 2030 to meet the Net Zero Emissions Scenario by 2050. This translates to an over threefold increase in annual capacity deployment until 2030. As per IEA, globally, ~538 GW of solar PV capacity was added in 2024, taking the installed capacity to 2,161 GW, which is a ~33% increase over the previous year. China continued to lead the market with a total cumulative capacity of ~1,006 GW, whereas the US came in second with ~220 GW, followed by Japan at ~120 GW.

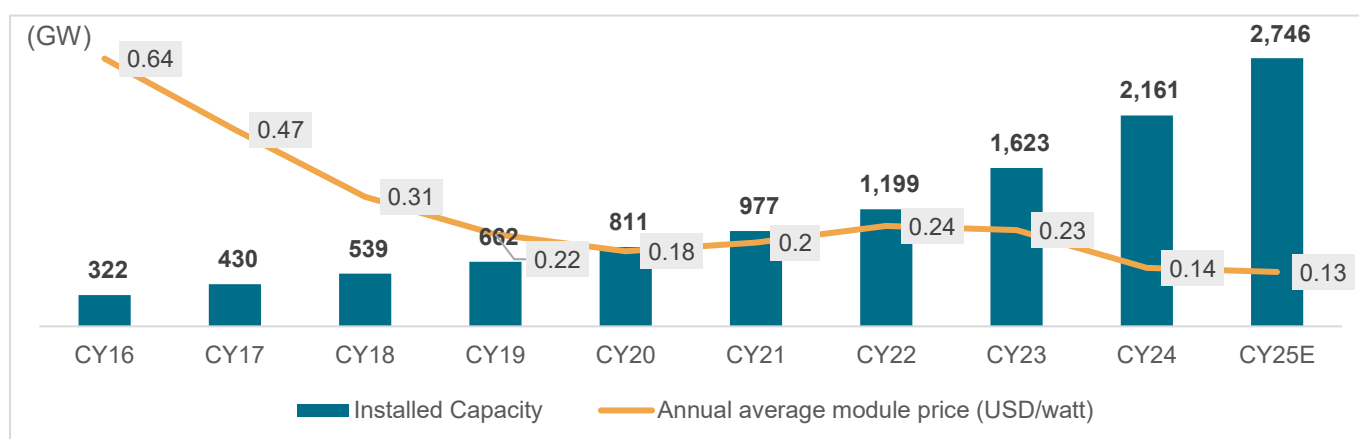
Figure 115: Annual solar capacity additions in major economies



Note: The annual capacity addition numbers pertain to calendar year (January-December).

Source: CEA, IEA Renewable Energy 2025; Crisil Intelligence

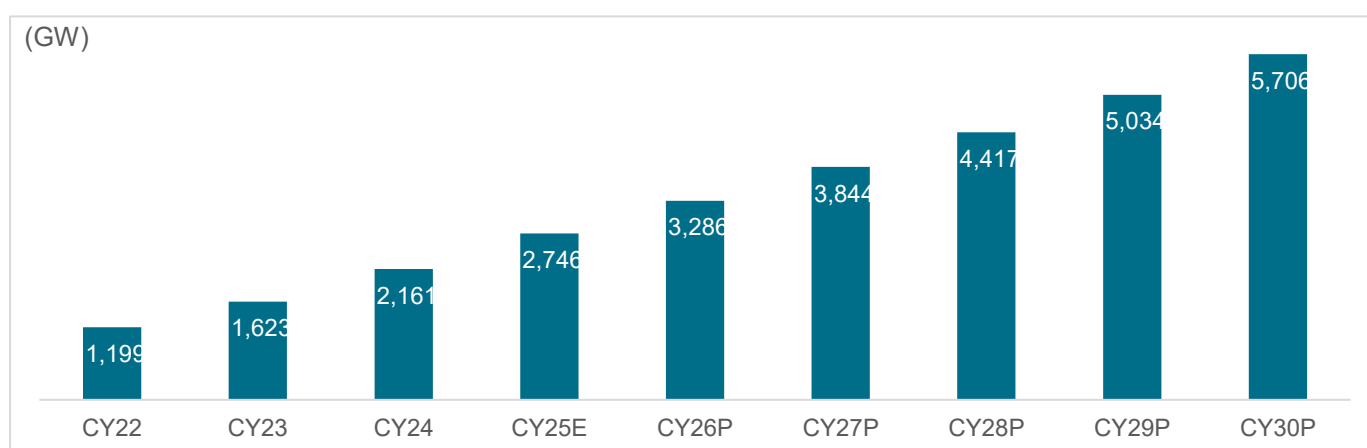
Figure 116: Global solar PV installed capacity registered about 27% CAGR between 2016 and 2025



Source: IEA Renewable Energy 2025; Crisil Intelligence

IEA has estimated a Solar PV capacity (utility scale) addition of ~2,953 GW over a period of CY2026-30. As per IEA, global renewable capacity additions will continue to increase every year, reaching almost 672 GW annually by 2030 – 25% more than the record level achieved in 2024. Solar PV and wind together account for 96% of all renewable capacity growth through the end of this decade due to their growing economic attractiveness in almost all countries.

Figure 117: Projected cumulative solar PV capacity CY25-30



(P): Projected; For Utility scale systems and PV distributed systems

Source: IEA Renewables 2025, IEA, Crisil Intelligence.

6.15 Major export destinations for Indian solar modules

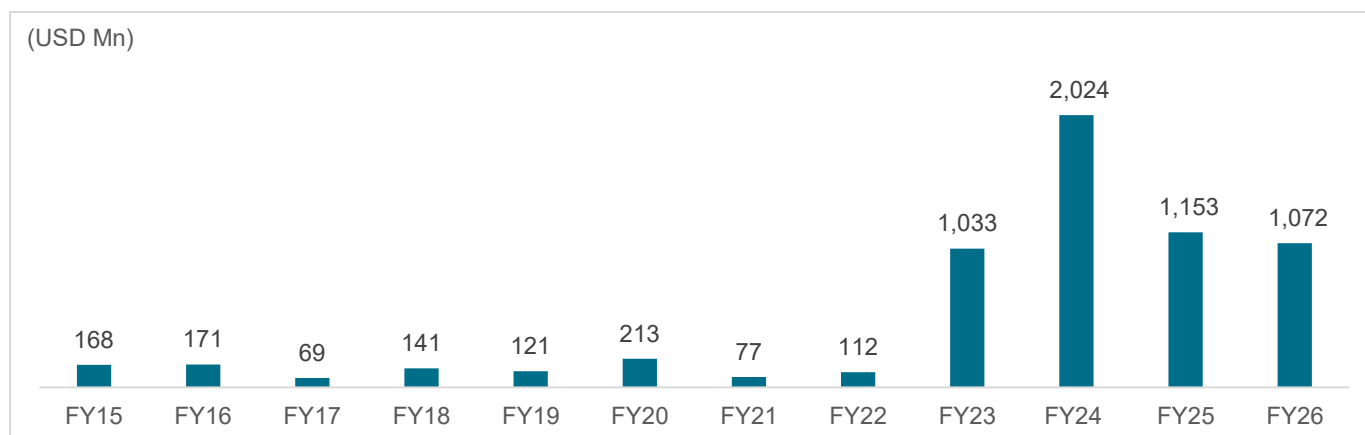
Although India had been importing around 80% of its solar module requirement, it is worthwhile to note that exports in fiscal 2020 saw a massive increase of 75% over fiscal 2019 levels. However, during fiscal 2021, exports reduced by around 65% due to restrictions imposed globally amid the COVID-19 pandemic.

US enacted the Uyghur Forced Labor Prevention Act (UFLPA) in December 2021 with June 21, 2022, as effective date. Implementation of UFLPA has supported India's solar module exports. The UFLPA prohibits importation of goods into the United States manufactured wholly or in part with forced labor in the People's Republic of China, especially from the Xinjiang Uyghur Autonomous Region, or Xinjiang. This has provided an opportunity for alternative sources such as India for demand for solar modules.

With its strong solar manufacturing capabilities and being a reputed supplier of high-quality solar modules, India benefitted to a large extent because of this shift. Indian solar module manufacturers have been able to capitalize the

opportunity created by UFLPA by expanding production capacities as well as meeting the stringent requirements for exporting to the US market. Resultantly, India's export to US have been surged significantly after implementation of UFLPA and exports to US have seen substantial increases in fiscal 2022.

Figure 118: Export of modules and cells from India in value terms



*FY 25: April 2024 -Jan 2025

Source: Ministry of Commerce; FY 21-22 (HS Code 85414011+85414012); FY 23 onwards (HS Code 85414300 +85414200); Crisil Intelligence

During fiscal 2025, USA accounted for ~97% of the exports of solar modules (in value terms), followed by Bangla Desh, Sri Lanka, Canada and Viet Nam. Also, during fiscal 2026, US accounted for ~96% of the total exports of solar module followed by Bangla Desh and UAE.

Table 24: % Share of export of solar modules (in value terms USD Mn)

Country	2024-2025 (in \$ Million)	Export Share (%)	Country	2025-2026 (in \$ Million)	Export Share (%)
U S A	1,119.12	97.08%	U S A	1,028.94	96.03%
Bangladesh	19.81	1.72%	Bangladesh	18.53	1.73%
Sri Lanka	3.41	0.30%	U A E	14.79	1.38%
Canada	2.56	0.22%	China	2.00	0.19%
Vietnam	1.18	0.10%	Kenya	2.00	0.19%
China	0.8	0.07%	Thailand	0.49	0.05%
Guyana	0.79	0.07%	Irna	0.44	0.04%
Uganda	0.69	0.06%	Togo	0.33	0.03%
Thailand	0.47	0.04%	Canada	0.32	0.03%
U A E	0.37	0.03%	Libya	0.30	0.03%
Total	1,152.75	100%		1,071.51	100%

Source: Ministry of Commerce; HS Code 85414300+ 85414200; Crisil Intelligence

While China dominates solar PV manufacturing, the United States and the European Union have also emerged as global PV hubs. The US imported ~75%% of its cells and modules requirements from Southeast Asian countries namely, Malaysia, Thailand, Vietnam and Cambodia. In order to reduce dependence on imported products, the US government announced several measures such as anti-dumping duty on shipments from China and Taiwan, 18% safeguard duty on cells and modules, as well as the passing of the Inflation Reduction Act in 2022. US PV module production stood at ~70 GW in March 2026. The US IRA has allocated ~\$400 Bn for clean energy. It is expected that it will lead to critical implications for climate change, trade, security, and foreign policy. The tax credits provide financial incentives to both domestic solar demand and supply. The "Section 45X Advanced Manufacturing Tax Credit" pertains to manufacturers who produce eligible components within the United States and sell them to

unrelated parties. The credit rates for Section 45X vary and are determined based on the specific component being manufactured. Some credit rates are tied to the cost of production, while others are influenced by certain capacity factors.

6.15.1 Geopolitical crises are accelerating renewable energy adoption

Geopolitical shocks are increasing the urgency for energy security, grid resilience, and supply-chain diversification, pulling forward renewable deployment especially solar.

- **Russia–Ukraine war (2022):** The EU revised renewable energy framework to materially raise the renewables share. The European Commission has also mobilized close to €300 billion investments to fund the REPowerEU Plan. Decentralized rooftop solar supported resilience in conflict-affected grids (e.g., Ukraine adding ~1,500 MW rooftop solar).
- **Israel–Gaza & broader Middle East instability (2023–24):** Gulf clean-energy roadmaps regained momentum as governments prioritize resilience and reduced exposure to external energy shocks. e.g. Saudi: 50% renewables by 2030, UAE: 30% clean energy, Saudi increased solar imports by ~115% in 2025 etc.
- **Iran-related escalation & Hormuz closure risk (2026):** Higher risk of shipping/energy disruption shifts the investment case toward domestic power buildout. Key outcomes include global solar additions in 2024 around ~600 GW and record Chinese solar and battery exports
- **India expansion (FY26):** India achieved a historic milestone by adding a record 55.29 GW of non-fossil fuel capacity in FY26. Addition of Solar Energy: 44.61 GW and Wind Power 6.05 GW in FY26.

Across regions, geopolitics is acting like a deployment catalyst: renewables particularly solar are being used to improve energy independence, reduce vulnerability to fuel and logistics shocks, and strengthen grid resilience.

6.15.2 Review and outlook on USA solar capacity additions

The United States solar module manufacturing sector has reached a critical inflection point, transitioning from a heavy reliance on imports to establishing a robust, localized industrial base. Driven by unprecedented federal policy support, escalating energy demands from artificial intelligence and data centers, and a strategic imperative to secure clean energy supply chains, the landscape offers compelling opportunities for institutional investors. As of mid-2026, the sector is experiencing a massive industrial buildout, though it must navigate a complex web of trade tariffs, policy uncertainties, and supply chain bottlenecks.

The United States solar module manufacturing sector is experiencing significant growth, spurred by robust federal incentives, increasing demand for clean energy, and a drive to localize the supply chain. The Inflation Reduction Act (IRA) has catalyzed domestic investments, with new manufacturing capacity announcements exceeding 69 GW as of May 2026. Despite historical reliance on imports, the U.S. is poised to become a global leader in solar module production, presenting substantial opportunities for investors across the value chain.

Regulatory Framework and Policy Environment

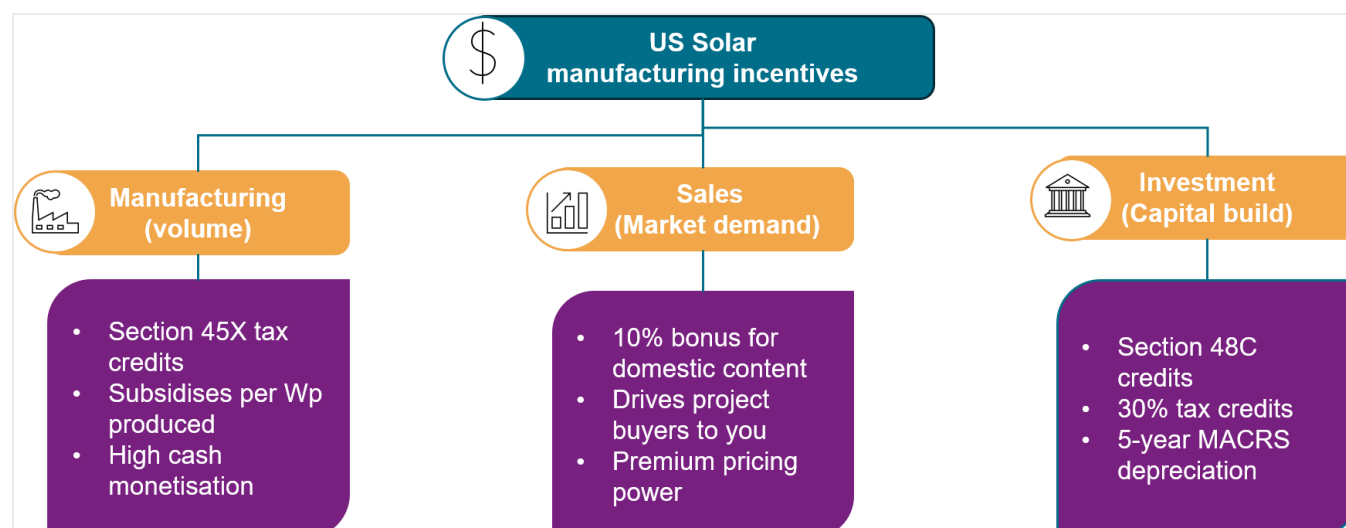
The regulatory landscape governing solar module manufacturing in the United States has undergone a dramatic transformation in recent years, creating a favorable policy environment.

At the federal level, the Inflation Reduction Act of 2022 (IRA) represents the cornerstone of this new policy architecture, fundamentally reshaping the economics of domestic solar production through a combination of production tax credits, investment incentives, and domestic content requirements that collectively amount to hundreds of billions of dollars in support over the coming decade. The IRA is the most transformative policy for U.S. solar manufacturing, offering direct production tax credits (PTCs) and investment tax credits (ITCs) for domestic solar production.

Solar manufacturers with U.S.-based facilities can access a range of federal tax incentives created under the Inflation Reduction Act (IRA) and maintained through later updates, including the One Big Beautiful Bill Act (OBBBA).

Manufacturers may claim production tax credits for solar components. These incentives are structured into three categories manufacturing incentives, which support production volume; sale incentives, which help stimulate market demand; and Investment incentives, which offset costs associated with building factories and purchasing equipment.

Figure 119: US solar manufacturing benefits



Source: Industry, Crisil Intelligence

A) Manufacturing Benefits

A key driver of U.S. solar manufacturing is the Section 45X Advanced Manufacturing Production Credit (AMPTC). This is a performance-based incentive: the greater a solar manufacturer's production in the United States, the larger the amount of tax credits it can claim. Section 45X credits are also transferable.

- **Section 45X Advanced Manufacturing PTC:** Per-unit tax credits for U.S.-made solar wafers, cells, modules, and related components.
 - \$0.07/watt for solar modules
 - \$0.04/watt for PV cells
 - \$0.40 /square meter for polymeric backsheet
 - \$12.00/square meter for PV wafers
 - \$3.00/kg for Solar-Grade polysilicon

These credits are structured to incentivize vertical integration and complete supply chain localization, as manufacturers can claim credits at multiple stages if they control production across the value chain. The credits are available for 10 years from the date of commissioning of manufacturing facility, providing long-term visibility, and planning certainty that has proven crucial in attracting major capital commitments from both domestic and international manufacturers.

Under the transferability rules, companies can sell their 45X credits directly to third-party corporations or financial institutions in exchange for cash. 45X credits are highly liquid and generally trade at roughly \$0.91 to \$0.94 per \$1 of credit value. T1 Energy completed a \$160 million sale of Section 45X production tax credits to a leading investment-grade U.S. financial institution on December 30, 2025. T1 executed the Tax Credit Purchase and Sale Agreement in December at a price of \$0.91 per dollar of PTC generated. Similarly, First Solar's cumulative Section 45X Advanced Manufacturing Production tax credit sales surpassed \$2 billion in October 2025 following a major transfer deal valued at approximately \$775 million.

For taxable years beginning after December 31, 2026, a 65% domestic direct material cost threshold will apply to secondary components. Eligibility also becomes strictly prohibited for any company that uses materials sourced from a defined Foreign Entity of Concern (FEOC), such as China or Russia.

The OBBB updated the program timeline in two keyways. First, wind components are no longer eligible for 45X credits for credits generated after 2027. Second, critical minerals—previously exempt from the phaseout—are now subject to a phased reduction from 2031 through 2034.

For all other manufactured items (including solar components, battery components, and inverters), the original phaseout schedule continues: 75% of the full credit value in 2030, 50% in 2031, and 25% in 2032.

B) Sale Benefits

U.S. manufacturing benefits also extend downstream: by putting a “Made in USA” stamp on the product, buyers can unlock significant financial advantages.

Commercial solar developers and utility-scale operators that purchase solar equipment may qualify for an extra 10% bonus on top of their base Investment Tax Credit (ITC) or Production Tax Credit (PTC). This additional benefit applies only when they meet the program’s strict domestic component requirements. The domestic content bonus, which adds 10% to the base credit, creates strong demand-side pull for U.S.-manufactured modules, as project developers seek to maximize their tax benefits. This demand-side incentive works in concert with the supply-side production credits to create a powerful dual incentive structure that addresses both production economics and market demand simultaneously.

By requiring U.S.-made cells or modules to qualify for these financial incentives, the policy allows domestic producers to charge a premium and secure highly stable, long-term purchasing agreements (off-take agreements) that protect them from cheaper foreign competition.

C) Investment Benefits

Complementing the PTCs, the ITC under Section 48 of the tax code offers solar project developers a baseline credit of 30% of project costs, with additional bonus credits available for projects that meet domestic content requirements or satisfy prevailing wage and apprenticeship standards.

Equipment, specialized machinery, and building structures that are integral to the manufacturing operation can qualify for the 5-year Modified Accelerated Cost Recovery System (MACRS). This treatment allows facilities to write off the asset value quickly during the early years of operation, substantially improving initial cash flows.

Beyond federal incentives, state-level policies add additional layers of support that vary significantly by jurisdiction but collectively enhance the attractiveness of specific locations for manufacturing investment. States such as Georgia offer substantial property tax abatements, workforce training grants, and infrastructure support that can reduce capital costs by 10-20%. New York has created a comprehensive solar manufacturing ecosystem through its NY-Sun initiative and related programs, offering grants, low-interest financing, and research partnerships that support both established manufacturers and emerging technology companies. Texas, with its combination of low energy costs, favorable business climate, and growing solar market, has attracted multiple manufacturing announcements, while California’s aggressive renewable energy mandates create substantial in-state demand that justifies local production capacity.

The United States maintains various tariff structures on imported solar products, including Section 201 safeguard tariffs on crystalline silicon photovoltaic cells and modules. Additionally, anti-dumping and countervailing duties apply to imports from China and, increasingly, to products from Southeast Asian countries that are suspected of serving as transshipment points for Chinese-manufactured components. These trade barriers, while creating some protection

for domestic manufacturers, also introduce supply chain risks and cost considerations that manufacturers must navigate carefully.

As of May 2026, the United States continues to aggressively protect its domestic solar industry by applying a mix of Section 201 safeguard tariffs, heavy preliminary Anti-Dumping (AD), and Countervailing Duties (CVD). These dual-layer AD/CVD penalties have pushed the total cumulative tariff burden on solar imports from some regions above 200%.

Current Tariff Breakdown by Country

Country	Weighted-Average Dumping Margin AD)		Cash Deposit Rate*		Subsidy Rates (CVD)		Total	
	From	to	From	to	From	to	From	to
	(1)		(2)		(3)		(4)=(2)+(3)	
India	123.04%	123.04%	107.77%	107.77%	125.87%	125.87%	233.64%	233.64%
Indonesia	35.17%	35.17%	35.17%	35.17%	85.99%	143.30%	121.16%	178.47%
Laos	22.46%	22.46%	22.06%	22.06%	80.67%	80.67%	102.73%	102.73%
China	26.71%	165.04%	26.71%	165.04%	9.07%	117.41%	35.78%	282.45%
Taiwan	11.45%	27.55%	11.45%	27.55%	0.00%	0.00%	11.45%	27.55%
Cambodia	125.37%	125.37%	117.18%	117.18%	534.67%	3403.96%	651.85%	3521.14%
Malaysia	8.59%	81.24%	1.92%	81.24%	32.49%	168.80%	34.41%	250.04%
Thailand	111.45%	202.90%	111.45%	172.68%	263.74%	799.55%	375.19%	972.23%
Vietnam	58.07%	271.28%	52.54%	271.78%	68.15%	542.64%	120.69%	814.42%

*Adjusted from subsidy provided in respective Country

Source: US DOC, Crisil Intelligence

Furthermore, the US administration has also imposed new tariffs on solar imports from Southeast Asian Countries namely Cambodia, Vietnam, Malaysia, and Thailand. These new tariffs will be in addition to the 10% baseline tariffs already imposed. On July 31, 2025, USA issued an executive order setting out the new reciprocal tariff rates for individual countries. As per the terms of the order, the new tariff rates took effect on August 7, 2025. For India, the initial 25% tariff came into effect from August 7, 2025, the additional 25% tariff came into effect from August 27, 2025. However, as of February 2026, a new U.S.-India trade deal has reduced tariffs on Indian solar modules and energy storage components to 18%, down from a previous high of nearly 50% (combining penalties and base duties). This reduction offers significant relief, strengthening the competitiveness of Indian modules in the U.S. market, which represents 97% of India's exports.

Table 25: Summary of Tariff imposed by USA on various SA countries

Country	Total Tariffs*
China	30%
Cambodia	19%
Malaysia	19%
Vietnam	20%
Thailand	19%
Laos	40%
Indonesia	19%
India	18%

*Incl. additional tariffs

Source: Industry, U.S. Dept. of Commerce, Crisil Intelligence

Indian solar module manufacturers can leverage the tariff barriers against Asian competitors to establish US-based manufacturing, capitalize on local incentives, and gain a foothold in a rapidly growing market. This strategic move not only avoids punitive tariffs but also aligns with US policy priorities for clean energy and supply chain resilience. US policies (like the Inflation Reduction Act) incentivize domestic manufacturing through tax credits and subsidies, further improving profitability for Indian firms operating in the US. However, challenges such as substantial capital expenditure, navigating US labor, environmental, and trade regulations requires expertise and Other global players are also eyeing the US market, so differentiation will be a key.

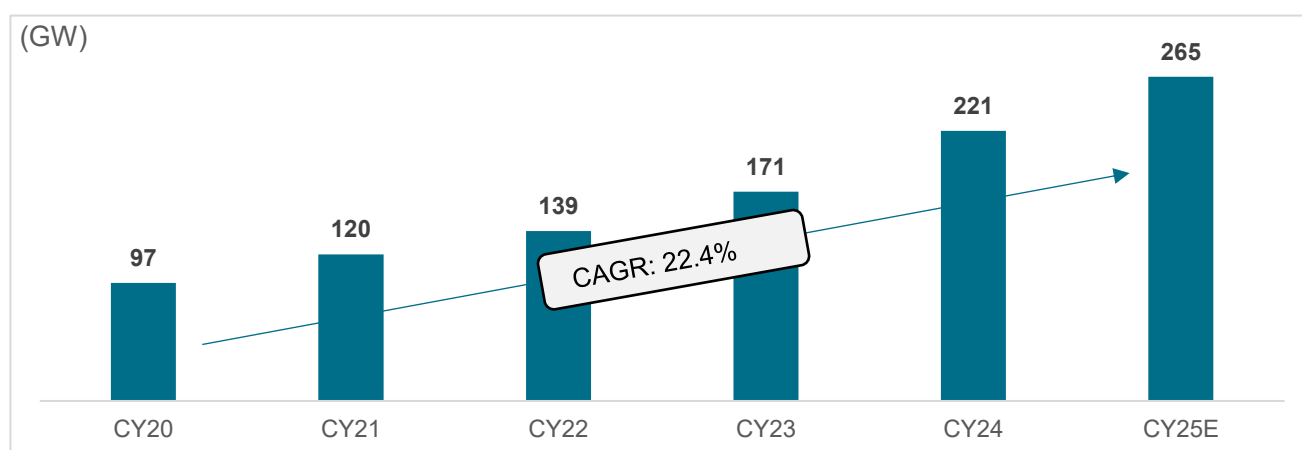
Historically, U.S. solar installations grew from approximately 8 GW in 2012 to over 265 GW in 2025, representing a growth rate exceeding 30% (CAGR) over the period. This growth was driven by declining costs, improving technology performance, supportive policies at federal and state levels, and increasing corporate and utility commitments to renewable energy. However, this growth was served primarily by imported modules, predominantly from Chinese manufacturers and, increasingly, from Southeast Asian facilities owned by Chinese companies. Domestic manufacturing capacity remained limited, rarely exceeding 20% of total demand, as cost differentials of ten to twenty cents per watt made imports economically attractive despite tariffs and transportation costs.

The demand trajectory experienced significant volatility around policy changes and trade actions. The introduction of Section 201 tariffs in 2018 created temporary supply constraints and price increases that slowed installation growth in 2018 and 2019. The COVID-19 pandemic disrupted supply chains and project development in 2020, though the sector recovered strongly in 2021 and 2022. Most significantly, the announcement of potential anti-circumvention tariffs on Southeast Asian imports in 2022 created severe supply constraints and project delays, as developers faced uncertainty about module costs and availability, leading to installation volumes in 2022 falling short of expectations despite strong underlying demand.

The USA is one of the world's largest solar markets, which gives manufacturers an important demand base. There are number of positives such as strong utility-scale solar pipeline, continued corporate procurement of clean power, rising electricity demand from data centers, electrification and manufacturing reshoring and growing customer interest in domestic supply security, traceability, tariff-resistant sourcing, and domestic content compliance.

The passage of the Inflation Reduction Act in August 2022 fundamentally altered demand dynamics by providing long-term policy certainty and substantially improving project economics through the enhanced Investment Tax Credit. Industry forecasts project annual installations reaching 35-40 GW by 2026 and potentially exceeding 30-35 GW annually by 2030, driven by utility-scale projects seeking to meet renewable energy mandates, corporate procurement to achieve sustainability goals, and residential installations benefiting from improved economics and growing environmental awareness. This demand growth, if realized, would represent a near-doubling of market size over the next four years, creating substantial opportunities for manufacturers while also requiring significant supply chain expansion.

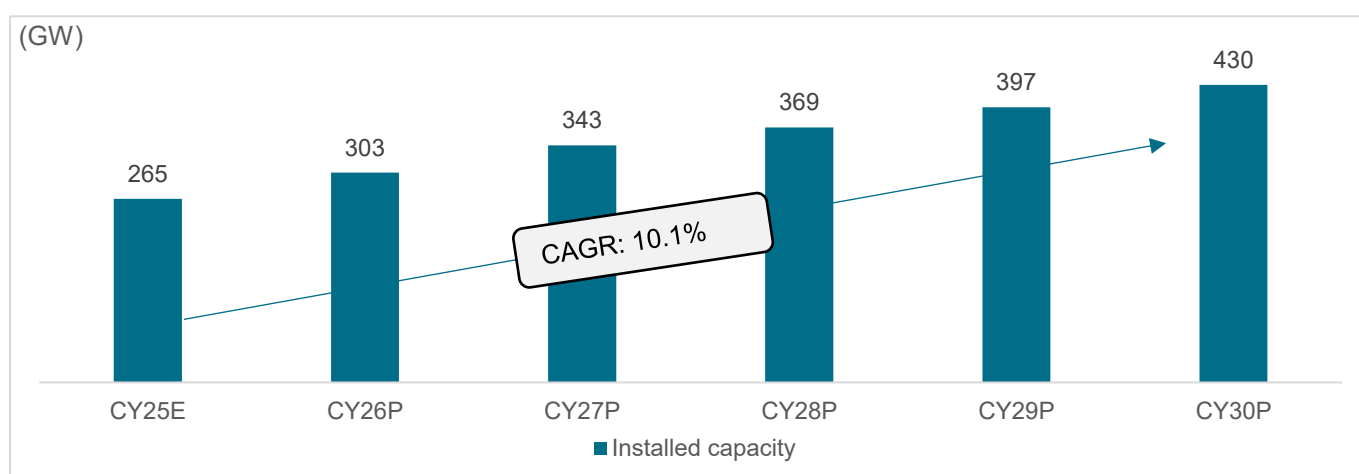
U.S. solar installed capacity experienced massive growth from 2020 to 2025, expanding by 22.4% (CAGR) to reach roughly ~265 GW by end of 2025, driven by utility-scale projects, the Inflation Reduction Act, and strong, consistent investments. The primary drivers for strong capacity additions were the 2022 Inflation Reduction Act (IRA) tax incentives, falling technology costs, increasing corporate net-zero commitments, and rising demand for paired battery storage solutions.

Figure 120: Growth in cumulative Solar PV installed capacity in USA


Note: Including solar PV utility scale and distributed systems

Source: IEA, Crisil Intelligence

US solar additions remain structurally high through 2030, but forecasts have been revised down vs. mid-2025 due to accelerated federal credit phaseouts, new supply-chain compliance frictions (FEOC), permitting headwinds on federal lands, and grid constraints. It is expected that US will add around 30-35 GW of solar PV capacity per annum (utility scale as well as distributed systems). The key drivers for consistent solar capacity additions include load growth from data centers/manufacturing keeps procurement strong, even with policy headwinds, solar remains cost-competitive; developers cite short development timelines (18–24 months) for utility-scale and domestic manufacturing ramp (modules and upstream components) improves resilience, though output may lag demand in the near term.

Figure 121: Expected installed solar capacity in US


Note: Including solar PV utility scale and distributed systems

Source: IEA, Crisil Intelligence

6.15.3 Key developments in Solar PV module imports and manufacturing in USA

Driven by the IRA, U.S. solar PV module manufacturing capacity has surged to over 65 GW, with significant domestic, vertically integrated production (ingots to modules) coming online. Simultaneously, stringent trade policies and tariffs and anti-dumping duties have forced a diversification of imports away from China toward Southeast Asian nations, while rising domestic capacity aims to reduce reliance on foreign components. Some of the key measures

include Section 201 tariffs (extended to 2026), anti-dumping/countervailing duties (AD/CVD) on Southeast Asian imports, and strict supply chain traceability under the Uyghur Forced Labor Prevention Act (UFLPA).

- **Section 201 Tariffs:** Section 201 safeguard tariffs on imported crystalline silicon (c-Si) photovoltaic cells and modules are in place in the United States, with a 14.25% rate effective from February 7, 2024, through February 6, 2025, dropping to 14% for the final year, ending on February 6, 2026.
- **UFLPA Compliance:** Under the UFLPA, all goods produced wholly or in part in China's Xinjiang region, especially solar-grade polysilicon, are presumed to be made with forced labor and banned from U.S. entry. Importers must provide "clear and convincing" evidence, including full supply chain mapping and documentation, to prove products are free from forced labor.
- **Section 301 Tariffs:** In May 2024, the US administration announced a doubling of Section 301 tariffs on Chinese solar cells (whether or not assembled into modules) from 25% to 50% to counteract unfair trade practices and bolster domestic manufacturing. The policy also targets solar-grade polysilicon and wafers, with rates increasing to 50% by early 2025.
- **Tariff-Rate Quota (TRQ):** As of August 2024, the U.S. government increased the annual tariff-rate quota (TRQ) for imported solar cells, allowing up to 12.5 GW to enter duty-free under Section 201. This policy, which previously set a 5 GW exemption, aims to support domestic solar module assembly by providing a steady supply of cells not yet produced in sufficient quantities domestically, while maintaining a 14.25% tariff on excess imports.
- **Bifacial Exemption Removal:** On June 21, 2024, US Government issued Proclamation 10779, ending the exemption from Section 201 duties on bifacial solar panels imported on or after June 26.
- **AD/CVD Investigations:** Following an investigation initiated in April 2024, the Department of Commerce (DOC) has finalized its affirmative determinations, finding that crystalline silicon (c-Si) solar cells and modules produced in Vietnam, Malaysia, Thailand, and Cambodia are being used to circumvent existing antidumping and countervailing duty (AD/CVD) orders on solar products from China.

6.15.4 USA module demand and supply

Since the passage of the Inflation Reduction Act in August 2022, there had been announcements solar manufacturing capacity additions in the United States, with commitments exceeding 50 GW of new module production capacity announced. This investment wave, totaling over USD 50 billion in committed capital, reflects the transformative impact of the policy framework described earlier and creates substantial opportunities for investors across multiple segments of the value chain, from equipment suppliers and construction contractors to component manufacturers and the module producers themselves. Critically, the capacity addition pipeline extends beyond module assembly to encompass upstream supply chain components that have historically been absent from U.S. manufacturing.

Several companies have announced ingot and wafer manufacturing projects, though these remain at earlier stages of development and face greater technical and economic challenges than module assembly. Cell manufacturing capacity is expanding more rapidly, with multiple announcements totaling over 30 GW of new capacity, as the Section 45X production credit makes cell manufacturing economically attractive even for companies that previously focused solely on module assembly.

The timeline for these capacity additions varies significantly, with some facilities already under construction and scheduled for commissioning in late 2026, while others remain at the planning or permitting stage with production starts potentially extending into 2026 or beyond. This phased ramp-up creates both opportunities and challenges for the industry, as early movers may capture market share and establish customer relationships before competition intensifies.

The demand-supply balance also depends critically on the domestic content requirements embedded in the ITC bonus structure. Projects seeking the additional 10% point ITC adder must meet stringent domestic content thresholds that increase over time, requiring that manufactured products including steel, iron, and other components be produced domestically, and that a specified percentage of total project costs represent U.S.-manufactured

content. These requirements create strong preference for domestically manufactured modules, but only if sufficient supply is available at competitive prices.

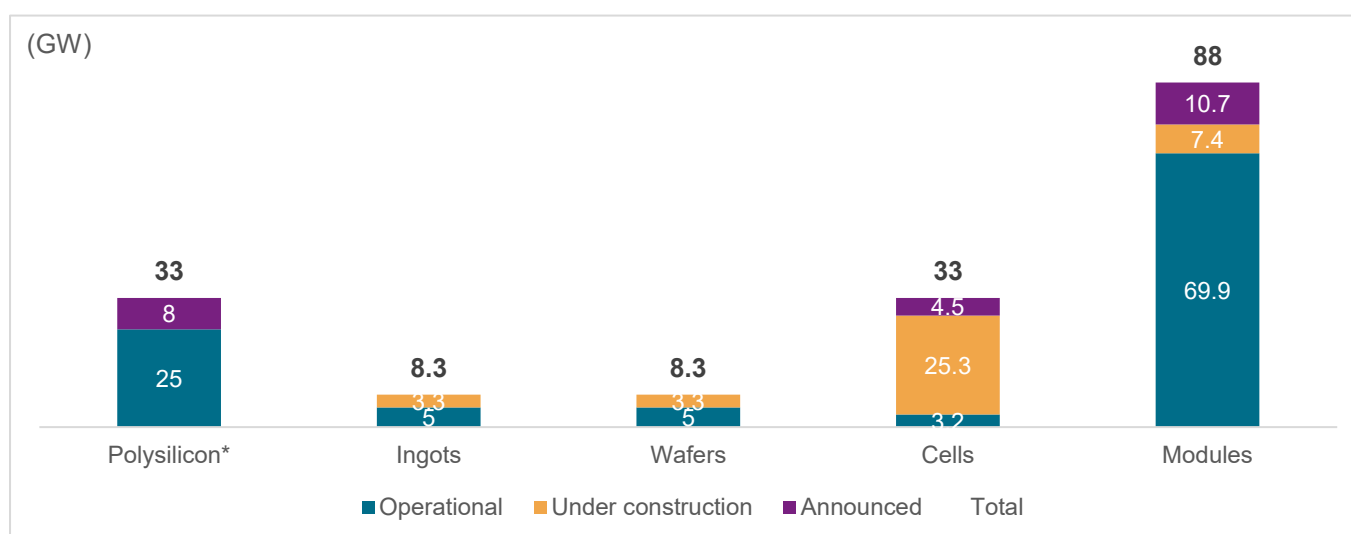
The international competitive context cannot be ignored when assessing U.S. demand-supply dynamics. Chinese manufacturers maintain substantial cost advantages due to scale, vertical integration, and government support, with leading producers achieving all-in manufacturing costs below fifteen cents per watt for standard modules. Southeast Asian manufacturers, many owned by Chinese companies, achieve similar cost levels while potentially avoiding some trade barriers. U.S. manufacturers, even with Section 45X production credits, face manufacturing costs in the range of \$0.20-0.25 cents per watt peak, requiring tariff protection, domestic content preferences, or quality/service differentiation to compete effectively. The persistence of this cost gap, despite substantial policy support, raises questions about long-term competitiveness and the sustainability of U.S. manufacturing absent continued government intervention.

The transformation of U.S. solar module manufacturing creates diverse investment opportunities across multiple segments of the value chain, each with distinct risk-return profiles, capital requirements, and strategic considerations.

Greenfield module manufacturing represents the most visible and heavily capitalized opportunity segment, with individual projects requiring three hundred million to over one billion dollars in capital investment depending on scale and technology. These projects offer potential returns in the mid-teens to low-twenties percentage range when including Section 45X production credits, assuming successful execution, market access, and sustained policy support. The investment case rests on capturing market share in a growing market while benefiting from substantial government subsidies that improve economics relative to international competitors. However, these projects also face significant risks including execution challenges in ramping complex manufacturing operations, potential oversupply as multiple projects reach completion simultaneously, technology obsolescence as cell architectures evolve rapidly, and policy risk if government support weakens or expires. Greenfield module manufacturing opportunities are best suited for those with patient capital, operational expertise in manufacturing, and ability to weather cyclical downturns while maintaining long-term strategic positioning.

Cell manufacturing represents a higher-value segment of the production chain, with Section 45X credits of \$0.04 per watt providing attractive economics for standalone cell production. Cell manufacturing requires greater technical sophistication than module assembly, involving complex processes including texturing, diffusion, passivation, and metallization that demand cleanroom environments, specialized equipment, and skilled technical workforce. Capital intensity is higher than module assembly on a per-watt basis, with state-of-the-art cell lines requiring USD 400-600 million/GW of capacity. However, the combination of higher production credits, greater technical barriers to entry, and potential for technology differentiation creates attractive investment characteristics for those with relevant expertise. The transition from p-type PERC to n-type technologies including TOPCon and heterojunction creates particular opportunities for investors able to deploy next-generation technology ahead of competitors, potentially achieving premium pricing and market share gains during the transition period.

The IRA created increased interest in US solar manufacturing. Over 28 GW of new US module manufacturing capacity came online in 2024. In early 2025, the United States passed 50 GW of online module manufacturing capacity, up from just 8 GW in Q3 2022. As the industry faces uncertainty as a result of new trade action, US solar manufacturing will help to ease the supply challenges that have hampered the industry in years past. Currently, there is 69.9 GW of domestic module manufacturing capacity online.

Figure 122: Total US module supply chain capacity by component and status


*Polysilicon values have been converted to GW by SEIA using NREL's assumption of 2.0 g/W

Source: SEIA Solar and Storage Supply Chain Dashboard, May 2026, Crisil Intelligence

Solar installations in the United States were approximately 50 GW during the calendar year 2024 and approximately 43 GW during the calendar year 2025, and the United States is expected to witness approximately 160-170 GW of cumulative solar additions during the period from 2025 to 2030. Domestic solar module manufacturing capacity in the United States exceeds 69 GW, while domestic solar cell manufacturing capacity remains materially lower, creating a structural supply gap within the United States domestic solar manufacturing ecosystem that we are well-positioned to address.

Opportunities for Indian Manufacturers

Indian manufacturers are becoming increasingly relevant participants in the U.S. market. India itself has emerged as a major alternative manufacturing base amid global diversification away from China. Indian module manufacturing capacity has expanded dramatically in recent years, supported by India's own PLI schemes and domestic localization policies.

For Indian module manufacturers, the U.S. market presents both an existential threat to their export models and a massive greenfield investment opportunity. Historically till March 2025, the U.S. accounted for over 95% of India's solar cell and module exports, driven by the cost competitiveness of Indian products. However, the August 2025 imposition of 50% tariffs and 125.87% preliminary countervailing duties have made direct exports from India economically unviable, rendering them at least 30% more expensive than U.S.-made alternatives. In response, leading Indian players are aggressively pivoting from an export strategy to a foreign direct investment strategy, setting up manufacturing facilities directly on U.S. soil to bypass tariffs and capture the lucrative Section 45X production tax credits.

Waaree Energies is leading this charge, having established an initial U.S. module manufacturing capacity of 2.6 GW, bolstered by its acquisition of the Meyer Burger facility, with definitive plans to ramp up to 4.2 GW. Waaree's strategy reflects a broader trend among Indian manufacturers to move closer to end markets while mitigating tariff and trade risks.

Other Indian manufacturers such as Adani Group, Vikram Solar, Tata Power Solar, and Avaada are also evaluating export-led and international manufacturing strategies, although Waaree currently appears the most advanced in physical U.S. manufacturing presence. these Indian manufacturers represent a unique opportunity; they possess deep operational expertise, established global supply networks, and lower corporate overhead compared to Western

startups. By funding the U.S. expansion of these Indian tier-1 manufacturers, investors can gain exposure to highly efficient operators who are perfectly positioned to capture IRA subsidies while servicing a domestic market desperate for high-quality, tariff-free solar components.

However, Indian manufacturers also face risks in the U.S. market. The U.S. has intensified trade scrutiny around circumvention, origin labelling, and sourcing practices. Preliminary duties and investigations targeting solar imports from India and Southeast Asia highlight the evolving trade environment. Investors therefore need to assess not just manufacturing scale, but also supply-chain traceability, upstream integration, and geopolitical compliance capabilities.

The USA is currently a compelling destination for solar module manufacturing investment, especially relative to what it was before the IRA. For investors, the opportunity is strongest where projects can combine federal manufacturing incentives, strong domestic demand, trade-protected market access, high automation, sound site selection, secure upstream sourcing, and commercial contracts with bankable buyers. The strongest risk-adjusted opportunities are typically module plants with a clear path to cell integration, or integrated cell + module platforms that can fully monetize policy support and offer customers reliable domestic supply

Key risks

While the opportunities in U.S. solar module manufacturing are substantial, investors must carefully evaluate multiple risk factors that could significantly impact returns and even threaten project viability. A comprehensive risk assessment requires examining policy, market, technology, execution, and competitive dimensions that interact in complex ways to determine ultimate investment outcomes.

- Policy risk represents perhaps the most significant concern for investors in U.S. solar manufacturing, as the sector's current economics depend heavily on government support that could potentially be modified or eliminated through legislative action or regulatory changes.
- Regulatory actions in international markets could affect module manufacturing. In December 2022, the US Department of Commerce determined that certain solar cell manufacturers in Vietnam, Malaysia, Thailand and Cambodia are circumventing anti-dumping and anti-subsidy duties on solar products originating from China. This determination could lead to the imposition of anti-circumvention duties of up to 254% on solar cells imported from these South-East Asian countries.
- Market risk encompasses both demand-side uncertainties around installation growth rates and supply-side risks related to potential oversupply as announced capacity additions reach completion. If installation growth disappoints due to economic recession, interest rate increases that affect project finance, or slower-than-expected corporate renewable energy procurement, manufacturers could face sustained periods of excess capacity and price pressure that erode margins and returns. Conversely, if domestic manufacturing capacity proves insufficient to meet demand, imports may capture market share despite tariffs and domestic content preferences, limiting the addressable market for U.S. manufacturers.
- Technology risk manifests in multiple dimensions, from the potential obsolescence of current manufacturing technologies to execution challenges in deploying new technologies on a commercial scale. The rapid evolution of cell architectures from PERC to TOPCon to heterojunction and potentially to perovskite tandems creates risk that facilities designed for current technologies may become uncompetitive within five to seven years, well before capital costs are fully recovered. Manufacturers must balance continued production of proven technologies against investments in next-generation capabilities, with timing and technology choices critically important to long-term competitiveness.
- Execution risk in manufacturing ramp-up and operations represents a substantial concern, particularly for greenfield projects or manufacturers expanding into new technology areas. Solar module manufacturing, while increasingly automated, remains a complex process requiring precise control of multiple steps, skilled workforce, and continuous optimization to achieve target yields and costs. Historical experience shows that

new facilities typically require twelve to eighteen months to reach nameplate capacity and target cost structures, during which period cash consumption can be substantial and returns delayed.

- Supply chain risk extends beyond the obvious concerns about component availability to encompass pricing volatility, quality issues, and geopolitical dependencies that could disrupt operations or increase costs. While domestic manufacturing aims to reduce supply chain risk relative to imports, U.S. manufacturers remain dependent on global supply chains for many critical inputs including polysilicon, silver paste, specialized glass, and manufacturing equipment. Disruptions in these supply chains, whether due to geopolitical tensions, natural disasters, or market imbalances, could significantly impact production costs and timelines.
- Competitive risk from both domestic and international manufacturers requires careful assessment, as the attractive policy environment drawing investment to U.S. solar manufacturing also ensures intense competition for market share. Established manufacturers with global scale, proven technologies, and strong balance sheets enjoy significant advantages over new entrants or smaller players, potentially leading to market consolidation that leaves some investors with stranded assets or impaired returns. Chinese manufacturers' continued cost leadership and potential for further cost reductions through technology improvements and scale economies creates persistent competitive pressure that U.S. manufacturers must overcome through policy protection, quality differentiation, or service advantages.
- Financial risk encompasses multiple dimensions including construction cost overruns, working capital requirements during ramp-up, and potential for project delays that extend payback periods and reduce returns. Solar manufacturing projects typically require substantial working capital to fund inventory and receivables as production scales, with requirements potentially reaching tens of millions of dollars for gigawatt-scale facilities.
- Environmental, social, and governance considerations increasingly influence investment decisions and could create both risks and opportunities for solar manufacturers. While solar manufacturing generally enjoys favorable ESG perceptions due to its role in clean energy transition, specific concerns around water usage, chemical handling, waste disposal, and carbon footprint of manufacturing operations require careful management. Manufacturers able to demonstrate superior ESG performance may achieve premium valuations and preferential access to capital, while those with ESG deficiencies could face investor pressure, regulatory challenges, or reputational damage that impacts market positioning.

The U.S. solar module manufacturing sector stands at a transformative moment, with unprecedented policy support, substantial capital commitments, and growing market demand creating conditions for dramatic industry expansion over the coming years. This transformation presents compelling opportunities across multiple segments of the value chain, from upstream polysilicon production through cell and module manufacturing to equipment and materials supply. However, realizing attractive returns requires careful navigation of significant risks including policy uncertainty, technology evolution, competitive dynamics, and execution challenges that could substantially impact investment outcomes.

6.15.5 Invocation of Section 232 Trade Expansion Act of 1962

Section 232 of the U.S. Trade Expansion Act of 1962 authorizes the President to restrict imports that are considered a threat to U.S. national security. On August 6, 2026, President Trump invoked Section 232 for polysilicon and its derivatives, introducing a 15% tariff and Minimum Import Prices (MIPs) across the silicon-based solar value chain. The measures are scheduled to take effect on December 4, 2026.

This marks a significant shift in U.S. solar trade policy. The United States is moving away from country-specific trade barriers targeting China, Southeast Asia, or reciprocal tariff structures, toward a broader policy designed to protect the entire domestic solar manufacturing ecosystem.

Unlike earlier tariff actions, this policy is not based primarily on the country of origin. Instead, it is structured around technology and value-chain dependence. As a result, companies that manufacture across the solar value chain within

the United States are likely to be rewarded, while those relying on imported upstream components will face higher costs.

The policy also signals that the U.S. is no longer focused only on protecting domestic module assembly. Instead, it is seeking to build a fully integrated domestic solar supply chain covering polysilicon, ingots, wafers, cells, and modules. In this environment, future market leaders in the U.S. are likely to be companies that control a larger share of the manufacturing stack.

Importantly, the MIP applies even when the final module is assembled in the U.S., if imported polysilicon, wafers, or cells are used in production. This reduces the advantage of simple module assembly operations and increases the strategic value of upstream integration.

Key Policy Measures

- Additional tariff: 15% on silicon-based solar products
- Minimum Import Prices:
 - Polysilicon: US\$21/kg
 - Ingot/Wafer: US\$100/kg
 - Cell: US\$0.22/W
 - Module: US\$0.38/W

Market Impact

The U.S. solar market currently requires around 45-50 GW of annual supply. First Solar accounts for approximately 17 GW, while additional fully integrated U.S.-based silicon manufacturing capacity is estimated at only 5–6 GW.

This leaves around 20–25 GW of supply, or roughly 80% of the market excluding First Solar, still dependent on imported upstream components. These volumes are therefore likely to be exposed to the new MIP framework.

As a result, the policy could push U.S. module prices higher by approximately 33% to 53%, depending on the level of upstream import dependence and the degree of domestic integration achieved by manufacturers.

Strategic Implications for Indian Module Manufacturers

Section 232 may be negative for Indian companies exporting solar products to the U.S. from India, but it can be positive for Indian companies willing to manufacture in the U.S. Section 232 pushes Indian solar manufacturers to shift from an export-to-U.S. model to a manufacture-in-U.S. model. The companies that make that shift early could gain a meaningful competitive advantage. Key positives can be

- Lower exposure to U.S. import tariffs and minimum import prices
- Access to IRA manufacturing credits
- Better acceptance by U.S. developers and utilities
- Domestic-content advantage
- Reduced AD/CVD and origin-risk exposure
- Stronger pricing power in a protected market
- Better long-term positioning against China-linked supply chains

Indian module manufacturers planning to establish manufacturing facilities in the U.S. could benefit materially from this evolving policy environment. Companies that localize production in the U.S., particularly across multiple stages of the value chain, would be better positioned to avoid the cost impact of Section 232 tariffs and MIPs.

In addition, Indian manufacturers may also benefit from the 45X Advanced Manufacturing Production Credit under the Inflation Reduction Act. This could provide a meaningful financial advantage for companies investing in U.S.-based manufacturing of solar components.

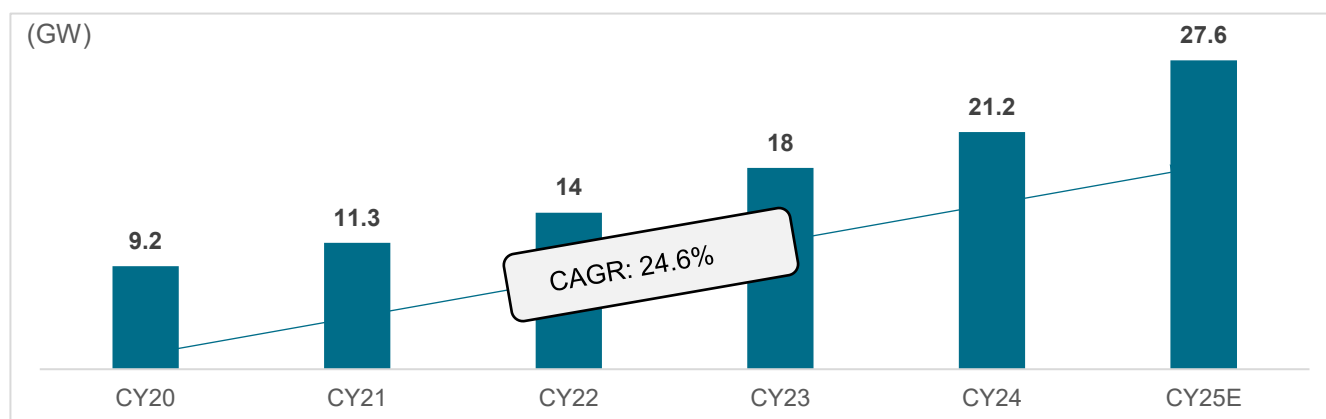
Overall, the combination of Section 232 protection, MIP-based import cost increases, and IRA manufacturing incentives creates a strong strategic case for Indian solar manufacturers to establish integrated production capacity in the United States. Companies that move beyond module assembly and invest in cells, wafers, and upstream integration are likely to be best positioned to compete in the U.S. market.

6.15.6 Review and outlook for solar capacity additions in Africa

Africa's energy landscape is characterised by a profound access deficit. According to the International Energy Agency (IEA), approximately 600 million people in Sub-Saharan Africa lacked access to electricity. The continent's total installed power generation capacity of approximately 250 GW for 1.4 billion people is roughly equivalent to that of a single large economy. Of this, solar PV accounts for around 20 GW of installed capacity, representing enormous headroom for growth. Africa is home to roughly 60% of the world's best solar resources, largely due to the massive, consistently clear skies over regions like the Sahara Desert and Sub-Saharan Africa.

Electricity demand is expected to more than double by 2040, driven by industrialisation, urbanisation and energy-intensive sectors including mining and critical minerals, requiring significant additions to power generation capacity. The African Union's Agenda 2063 and the United Nations Sustainable Development Goal 7 (SDG 7) both call for universal energy access by 2030, a target that will require massive investment in generation capacity, with solar PV expected to play a dominant role given its cost competitiveness and suitability for distributed generation. The IEA estimated that Africa will need to add at least around 25 GW of new power generation capacity per annum to achieve universal access, with solar PV accounting for 40–50% of this addition. Africa's solar PV deployment has accelerated significantly over the past decade. From a base of around 1.5 GW of cumulative installed capacity in 2015, the continent reached approximately 8 GW by 2020 and an estimated 28 GW by end of 2025. IEA projects cumulative installed solar PV capacity in Africa could reach 80-100 GW by 2030 under various scenarios, implying annual additions of 12–15 GW per year in the latter half of the decade.

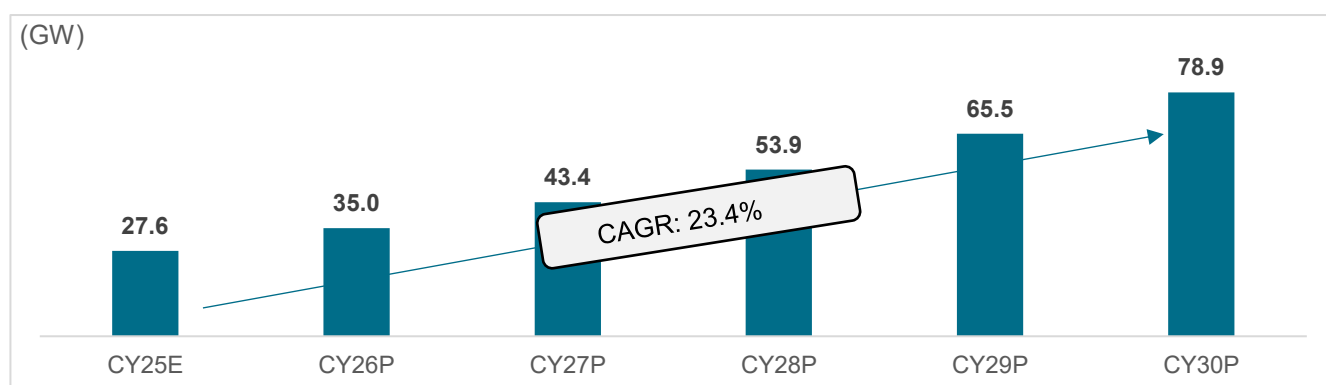
Africa's solar PV sector experienced record growth in 2025, with an estimated growth of ~6.4 GW of new capacity added driven by South Africa, Nigeria, and Egypt, and a boom in BESS. The continent's total installed solar capacity crossed 25 GW, with strong growth in both utility-scale and decentralized, C&I projects. The surge is driven by high, unmet energy demand, persistent grid failures, and falling costs of technology, with solar-plus-storage becoming competitive with, or cheaper than, fossil fuels

Figure 123: Growth in installed solar capacity in Africa


Note: Including solar PV utility scale and distributed systems

Source: IEA, Crisil Intelligence

Africa's installed solar capacity is experiencing rapid growth, with total operational capacity reaching approximately 35 GW by 2026, marking a ~25% increase over 2025. Projections indicate that the continent could install over 50 GW of additional solar capacity by 2030, with total capacity expected to exceed 75 GW by 2030, driven by both utility-scale projects and decentralized, off-grid solutions.

Figure 124: Expected installed solar capacity in Africa


Note: Including solar PV utility scale and distributed systems

Source: IEA, Crisil Intelligence

Africa represents one of the most significant long-term growth opportunities in the global renewable energy transition, driven by structural energy deficits, significant untapped renewable resource potential and increasing sovereign and multilateral institutional focus on clean energy infrastructure development.

Africa's solar module manufacturing sector is at a nascent but rapidly evolving stage, driven by the continent's vast solar potential (Africa receives some of the highest solar irradiation globally 2,000–2,500 kWh/m²/year in many regions), accelerating electrification needs, and increasing government and multilateral support. Africa's solar module manufacturing sector remains highly fragmented and underdeveloped relative to demand. The continent's total module manufacturing capacity is estimated at 5.5–7 GW/year as of 2026, concentrated primarily in South Africa, Egypt, and Morocco. Most of these facilities are engaged in module assembly combining imported solar cells with locally sourced glass, frames, and encapsulants rather than integrated cell or wafer manufacturing. The upstream segments of the value chain (polysilicon, ingot, wafer, and cell production) are virtually absent from the continent, representing both a gap and a long-term opportunity.

Africa imports approximately 70–80% of its solar modules, primarily from China (which accounts for over 80% of global module production), followed by India, Vietnam, and Southeast Asian countries. In 2024, Africa's solar module imports were valued at approximately USD 4–5 billion. This heavy import dependency exposes the continent to supply chain disruptions, currency volatility, shipping costs, and geopolitical risks. It also means that a significant portion of the economic value generated by Africa's solar transition is captured outside the continent.

Local manufacturing can reduce Africa's dependency on imports, lower costs (customs, logistics), and mitigate currency risks. African Union's African Continental Free Trade Area (AfCFTA) enables tariff-free trade across 54 countries, positioning manufacturers to serve the continent from strategic locations. Indian manufacturers, with established PV supply chains and cost advantages, can leverage joint ventures, technology licensing, and greenfield investments.

Africa's solar PV market is experiencing rapid growth driven by high demand for decentralized energy and utility-scale projects. While demand is surging, the continent heavily relies on Chinese imports for modules. Local manufacturing is limited but expanding, with key developments in Morocco, South Africa, Egypt, and Nigeria aiming for gigawatt-scale capacity. The majority of solar modules are imported from China. The sector is currently transitioning from a pure import model to developing a localized manufacturing base to meet growing demand and create regional economic value. Almaden Morocco operates a 1 GW solar module manufacturing plant in Al Hoceima, Morocco, which was expanded by Ecoprogetti to meet growing regional and global demand. This facility, the largest in North Africa, uses advanced TOPCon G12 18BB half-cut, glass-glass cell technology. South Africa has a limited but growing solar module manufacturing capacity, with at least three operational facilities, such as ART Solar and Seraphim, providing a cumulative capacity of roughly 620 MW to 1 GW annually. Nigeria is rapidly expanding its solar module manufacturing capacity through several large-scale projects aimed at reducing import dependency. Key projects initiated in 2025, including a 1.2GW plant by Oando/REA, a 1GW factory with LONGi, and an 800MW facility by Tranos, suggest a combined planned capacity of over 3GW in the coming years. Algeria has established a PV module manufacturing capacity of approximately ~470 MW annually, driven by six key assembly and encapsulation plants. Major facilities include a 180 MW plant in Ouargla operated by Zergoun Green Energy and a 100 MW facility by Milltech in Constantine. It is expected that the solar module manufacturing of Middle East and Africa region to cross 60 GW by 2030.

Key Drivers for solar module manufacturing in Africa

Demand Growth: Africa's solar module demand is projected to grow through 2030, significantly outpacing global averages.

Import Substitution: With 70–80% of modules currently imported, there is substantial room for local manufacturing to capture market share, particularly as governments introduce local content requirements.

Policy Support: Multiple African governments have identified solar manufacturing as a priority sector, offering tax holidays, duty exemptions, subsidized infrastructure, and concessional financing.

Trade Agreements: AfCFTA enables duty-free access to a continental market of 1.4 billion people, while agreements with the EU (Morocco, Egypt, Tunisia) and preferential access programmes (AGOA, EBA) enable exports to premium markets.

Development Finance: Multilateral institutions (World Bank, AfDB, IFC, EBRD, DFIs) are actively financing solar manufacturing projects in Africa, providing concessional debt, equity, and guarantees.

Country wise Analysis

South Africa: South Africa is the most mature solar market in Sub-Saharan Africa and the continent's largest module manufacturing hub. The country's Renewable Energy Independent Power Producer Procurement Programme

(REIPPPP), launched in 2011, has been the primary driver of utility-scale solar deployment. As of December 2025, the REIPPPP has successfully procured 7,825 MW from 104 IPPs (that reached financial close) in Bidding Window-BW1 to BW6, which are at various stages of construction or have commenced with commercial operation. Out of this, around 3,000 MW is from solar PV.

South Africa's energy policy is governed by the Integrated Resource Plan (IRP) 2023, which envisages 7.8 GW of new solar resources (most paired with battery storage). The REIPPPP mandates local content requirements. The Department of Trade, Industry and Competition (DTIC) also administers the Solar PV Localisation Roadmap, which aims to develop a vertically integrated domestic solar manufacturing value chain. Import duties on solar modules stand at 10–15%, though exemptions are available for projects under certain government programmes. The South African Revenue Service (SARS) also administers anti-dumping duties on certain Chinese solar products, which has created a more level playing field for local manufacturers and Indian exporters.

The government offers several incentives for local manufacturing, including the 12I Tax Allowance (now succeeded by the Energy Investment Allowance), which provides accelerated depreciation for qualifying manufacturing investments. The Industrial Development Corporation (IDC) provides concessional financing for renewable energy manufacturing projects. Additionally, the Department of Science and Innovation funds research and development in solar technologies through institutions such as the Council for Scientific and Industrial Research (CSIR). In 2023, the government introduced a rooftop solar tax incentive allowing businesses to deduct 125% of the cost of qualifying solar installations, which has significantly boosted C&I solar demand and, by extension, module demand.

South Africa's module manufacturing capacity is estimated at 500–1000 MW/year. Some of the key players include ARTsolar (300-350 MW), Jinko Solar (SA) (100-120 MW), Seraphim (SA) (80-100 MW), Canadian Solar (SA) (60-80 MW) etc. South Africa's annual solar module demand has grown from approximately 500 MW in 2019 to 1.5–2.0 GW in 2025, driven by the REIPPPP, C&I installations, and residential rooftop solar. With the IRP 2023 targeting 7.8 GW by 2030 and the government considering upward revisions due to the ongoing energy crisis (load-shedding), annual demand could reach 2-2.5 GW by 2030. Local manufacturing capacity covers only 25–35% of current demand, with the balance imported.

South Africa offers the most immediate and substantial opportunity for Indian module manufacturers. The combination of strong demand growth, local content requirements, anti-dumping duties on Chinese products, and an established regulatory framework creates favourable conditions for Indian companies to set up local assembly or manufacturing operations. Indian companies such as Waaree, Vikram Solar, and Adani Solar have already explored or established export relationships with South African EPC contractors and developers. A local manufacturing presence would allow Indian companies to qualify for REIPPPP local content requirements and access concessional IDC financing.

Egypt: Egypt is North Africa's largest solar market and has emerged as a significant hub for renewable energy investment, driven by the government's ambitious targets and its strategic location bridging Africa, the Middle East, and Europe.

The Integrated Sustainable Energy Strategy (ISES) 2035, which builds on previous national frameworks, emphasizes the importance of renewable energy as a cornerstone of Egypt's energy transition. Egypt has revised its targets upward, now aiming to generate 42 percent of electricity from renewable sources by 2030 and over 60 percent by 2040, leveraging wind, hydropower, photovoltaic solar, and emerging technologies such as green hydrogen. The government has implemented multiple policy mechanisms to drive solar deployment, including a FiT programme launched in 2014 (offering tariffs of USD 0.084–0.143/kWh depending on project size), competitive auctions for utility-scale projects, and net metering for distributed generation.

The Egyptian Electricity Holding Company (EEHC) and the New and Renewable Energy Authority (NREA) are the primary regulatory bodies. The government has also established SEZs particularly the Suez Canal Economic Zone (SCZone) with streamlined regulations, tax incentives, and infrastructure support for manufacturing investments.

Egypt imposes no import duty on solar cells and modules, which has facilitated rapid deployment but also limited the incentive for local manufacturing. However, recent policy discussions have focused on introducing local content requirements for government-backed projects and potentially imposing modest tariffs on imported modules to encourage domestic production.

Egypt's government offers a robust portfolio of incentives under its Investment Law, tailored to boost domestic manufacturing, deepen local supply chains, and stimulate export-oriented production. These benefits target everything from technology and electronics to pharmaceuticals and heavy industries. The government links tax deductions directly to the geographical location of facility and the strategic nature of industry. Sector A: A 50% deduction on investment costs from net taxable profits for projects established in the most-in-need areas, including the Suez Canal Economic Zone and the Golden Triangle Economic Zone. Sector B: A 30% deduction on investment costs for the rest of Egypt, applicable to priority industries (e.g., automotive, renewable energy, textiles, engineering, and chemicals). These deductions are applied over a seven-year period and are capped at 80% of the project's paid-in capital.

Egypt has also benefited from significant international development finance, including new US\$1 Billion World Bank Group development financing to support Egypt's private sector, a € 7.4 billion package from the European Union, the European Bank for Reconstruction and Development (EBRD), and other institutions to support green hydrogen and renewable energy manufacturing.

Egypt's historical or legacy solar manufacturing baseline hovers around 350–400 MW/year. However, the nation's photovoltaic (PV) capacity has exponentially expanded, with developers like EliTe Solar commissioning a massive 5 GW PV manufacturing facility (2GW cell and 3 GW Module) in the Suez Canal Economic Zone. Other key players include Arab International Optronics (AIO) (100-120 MW), Infinity Solar (80-100 MW) etc.

The Atum Solar Complex, broke ground in Egypt's Suez Canal Economic Zone (SCZone). It is backed by a \$220 million investment and a four-nation consortium (Egypt, China, the UAE, and Bahrain). The Atom Solar Egypt complex will produce 2 GW of solar cells, 2 GW of solar panels, and 1 GWh of energy storage.

Egypt's annual solar module demand has grown from approximately 300 MW in 2019 to 700–900 MW in 2025, driven by the Benban Solar Park (1.8 GW), distributed generation, and new utility-scale tenders. Demand is projected to reach 1.5–2.0 GW/year by 2030 as the government accelerates its renewable energy targets and green hydrogen projects (which require large-scale solar installations) come online.

Egypt's strategic location, established SEZ infrastructure, and growing domestic and regional demand make it an attractive base for Indian manufacturers seeking to serve North Africa, the Middle East, and potentially Southern Europe. The absence of import duties on raw materials and components, combined with tax holidays and subsidized infrastructure in the SCZone, significantly reduces the cost of establishing manufacturing operations. Indian companies could also leverage Egypt's free trade agreements with the EU (under the EU-Egypt Association Agreement) and other regional blocs to export modules to premium markets.

Morocco: Morocco has positioned itself as a renewable energy leader in Africa, with one of the continent's most ambitious clean energy programmes and a sophisticated regulatory and institutional framework.

Morocco's National Energy Strategy targets 52% of installed electricity capacity from renewable sources by 2030, with solar contributing approximately 20% (equivalent to roughly 4–5 GW). The Moroccan Agency for Sustainable Energy (MASEN) is the primary institution responsible for planning, developing, and managing renewable energy

projects. MASEN administers competitive auctions for utility-scale solar projects and has overseen the development of the iconic Noor-Ouarzazate Solar Complex (580 MW, combining CSP and PV technologies).

Morocco's Investment Charter (2022) provides a comprehensive framework for industrial investment, offering incentives for manufacturing in priority sectors including renewable energy. The country has established multiple Industrial Acceleration Zones (formerly free zones) with streamlined regulations, tax benefits, and integrated infrastructure.

Morocco offers a competitive incentive package for solar manufacturing investments. Companies establishing operations in Industrial Acceleration Zones benefit from corporate tax exemption for the first five years followed by a reduced rate of 8.75% for the subsequent 20 years, exemption from VAT and customs duties on imported equipment and raw materials, subsidized land (as low as MAD 250/m² in some zones), and access to trained labour through government-funded vocational training programmes. MASEN also provides offtake certainty through long-term power purchase agreements (PPAs) for solar projects, which underpins demand for locally manufactured modules.

Morocco's solar module manufacturing capacity is anchored by Almaden Morocco, which operates the largest photovoltaic (PV) facility in North Africa. Ecoprogetti has recently completed the expansion of Almaden Morocco's photovoltaic production line, bringing its total production capacity to 1 GW.

Morocco's annual solar module demand has grown from approximately 150 MW in 2019 to 400–500 MW in 2025, driven by MASEN's auction programme, C&I installations, and self-generation projects. With the Noor PV II and III programmes, green hydrogen projects, and regional interconnection plans, demand is projected to reach 0.5–1.0 GW/year by 2030.

Morocco's proximity to Europe (14 km across the Strait of Gibraltar), its free trade agreements with the EU and the United States, and its well-developed industrial infrastructure make it an exceptionally attractive manufacturing base. Indian manufacturers could establish operations in Morocco not only to serve the domestic and African markets but also to export to Europe, where demand for non-Chinese solar modules is growing due to supply chain diversification policies. Morocco's stable political environment, strong rule of law, and sophisticated financial sector further enhance its attractiveness. Indian companies could also partner with MASEN on technology transfer and local capacity building initiatives.

Nigeria: Nigeria represents Africa's largest potential solar market by population (over 220 million people) and energy access deficit (approximately 80-85 million people without electricity access). The country's solar sector is dominated by off-grid and mini-grid applications, though utility-scale projects are beginning to emerge.

Nigeria's energy sector is governed by the Nigerian Electricity Regulatory Commission (NERC) and the Energy Commission of Nigeria (ECN). The National Renewable Energy and Energy Efficiency Policy (NREEEP) 2015 set a target of 30 GW of renewable energy capacity by 2030, including 5 GW of solar PV. The Rural Electrification Agency (REA) administers off-grid electrification programmes, while the Nigerian Bulk Electricity Trading Company (NBET) manages power purchase agreements for grid-connected projects.

The regulatory environment has been challenging, with issues including grid infrastructure limitations, foreign exchange constraints, and policy implementation gaps. However, recent reforms including the Electricity Act 2023, which liberalises the power sector and allows states to generate and distribute electricity have created new opportunities for decentralised solar deployment.

Nigeria offers several incentives for solar manufacturing and deployment. The Pioneer Status Incentive provides a 3–5 year tax holiday for qualifying manufacturing investments. Import duty waivers are available for solar equipment and components under the National Automotive Industry Development Plan (extended to renewable energy).

Nigeria's active domestic solar panel manufacturing capacity stands at roughly 300 MW, a sharp increase from the 120 MW reported in 2024. Driven by government policies, private investments, and rural electrification initiatives, the country is currently developing a massive pipeline of over 3.7 GW of additional module manufacturing capacity. Notable domestic manufacturers include Auxano Solar (which commissioned a 100 MW module production line in 2023) and the National Agency for Science and Engineering Infrastructure (NASENI), which operates a 21 MW module assembly plant. Nigerian engineering firm Tranos is constructing an 800 MW solar panel factory in Ogun State. The first 400 MW phase is currently under development. The Rural Electrification Agency (REA) partnered with Dutch renewables company Solarge and development vehicle InfraCorp to build a 1 GW module manufacturing facility in the country. REA signed an MOU with Oando Clean Energy to develop a 1.2 GW PV module assembly facility in stages.

Nigeria's solar module demand is driven primarily by the off-grid segment (solar home systems, mini-grids) and increasingly by C&I rooftop installations. Annual demand has grown from approximately 100 MW in 2019 to 300–400 MW in 2025. With the Solar Power Naija programme, mini-grid expansion, and emerging utility-scale projects, demand could reach 1.0–1.5 GW/year by 2030. Nigeria has recently launched (March 2026) a landmark \$750 million renewable energy program aimed at deploying 1,350 solar mini-grids nationwide to provide clean electricity to millions in unserved and underserved rural communities. The publicly funded initiative, overseen by the REA, is structured to unlock an additional \$1.1 billion in private-sector investment.

Nigeria's massive market potential, combined with its current manufacturing deficit, presents a significant opportunity for Indian companies. The off-grid segment, in particular, aligns well with Indian manufacturers' experience in producing smaller-format modules for solar home systems and mini-grids. Indian companies could establish assembly operations in Nigeria's free trade zones (such as the Lekki Free Zone or Calabar Free Trade Zone), leveraging duty-free import of components and tax holidays. However, investors must carefully assess risks including foreign exchange volatility, infrastructure challenges, and regulatory uncertainty. Partnerships with established Nigerian players could mitigate entry risks.

Indian Manufacturers' Competitive Advantages in Africa

Africa's solar module manufacturing sector presents significant untapped opportunities, especially as the continent aims to meet aggressive renewable energy targets and reduce import dependency. For Indian module manufacturers, the region offers potential for exports, local assembly, and long-term investments, particularly in South Africa, Egypt, Morocco, and Nigeria. A strategic approach leveraging local partnerships, understanding regulatory nuances, and aligning with government incentives will be crucial for success.

For Indian manufacturers, Africa already represents a significant export market. India exported approximately 1.5–2 GW solar modules per annum to African countries in last 2-3 years, with key destinations including South Africa, Egypt, Morocco, and Nigeria. Indian modules are competitive on price, meet international quality standards (IEC certifications), and benefit from established trade relationships and development finance linkages (such as India's Lines of Credit through Exim Bank).

Indian solar module manufacturers possess several competitive advantages for the African market:

- **Cost Competitiveness:** Indian module prices are competitive with Chinese products (USD 0.16–0.22/W for Tier-1 modules in 2025), and Indian manufacturers benefit from lower shipping costs to East African ports compared to Chinese factories.
- **Technology and Quality:** Indian manufacturers produce modules using the latest technologies (Mono-PERC, TOPCon, bifacial) and hold IEC, MCS, and other international certifications required for African tenders.
- **Development Finance Linkages:** India's Exim Bank provides Lines of Credit (LoCs) for solar projects in Africa, often with conditions favoring Indian equipment procurement.

- **Diplomatic and Trade Relationships:** India's International Solar Alliance (ISA), headquartered in India, has 90+ member countries, many in Africa. This provides a platform for technology transfer, capacity building, and market development.
- **PLI Scheme Experience:** Indian manufacturers who have scaled up under India's PLI scheme (which allocated INR 24,000 crore / ~USD 3 billion for solar manufacturing) have developed expertise in setting up integrated manufacturing facilities that can be replicated in Africa.

Africa's solar module manufacturing sector represents a compelling investment opportunity characterised by strong demand growth, significant supply gaps, supportive policy environments, and strategic advantages for Indian manufacturers. While challenges remain including scale constraints, supply chain dependencies, and country-specific risks the long-term fundamentals are overwhelmingly positive. The continent's solar module demand is projected to grow from approximately 4-5 GW in 2025 to over 12-15 GW by 2030, with local manufacturing capacity unlikely to keep pace, ensuring sustained demand for both imports and new manufacturing investments.

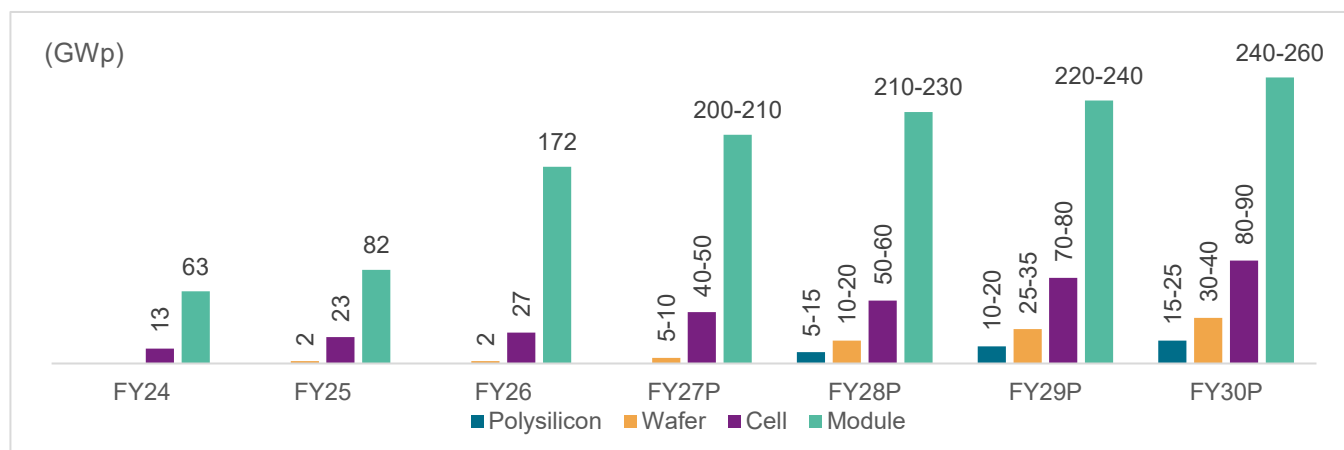
For Indian manufacturers, Africa offers a natural extension of their global strategies, combining market access, cost advantages, and development finance support. Companies that move early to establish manufacturing footholds in key markets South Africa, Egypt, Morocco, and Nigeria will be best positioned to capture the significant value creation opportunity as Africa's solar revolution accelerates.

6.16 Outlook for India-solar module manufacturing

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

Crisil Intelligence expects solar PV module manufacturing capacity to reach 240-260 GW by fiscal 2030, with full integration from polysilicon to modules expected to account for ~25% of capacities, largely driven by PLIs. Achieving this is expected to require an investment of INR 1.20-1.30 trillion by fiscal 2030. Crisil Intelligence expects module manufacturing capacity to grow twice by fiscal 2030 with ~25% of the capacity to be fully integrated and integrated units to come post fiscal 2026. Gujarat will be at the epicenter of additions with ~55-60% additions in the next 5 fiscals followed by Odisha. Gujarat, a significant hub for industrial and renewable energy activity, provides strong infrastructure, skilled labor and proximity to key raw material suppliers and end markets. Odisha offers abundant land availability, robust policy incentives and logistical advantages for serving both domestic and export markets through access to key ports. Together, these locations enable Companies to streamline supply chain operations, reduce costs and serve high-demand regions effectively.

Figure 125 : India-Current and projected manufacturing capacity, GWp



P: Projected; Source: Industry, Crisil Intelligence

7 Competitive Assessment of RE IPP and Solar module manufacturing

7.1 About Inox Clean Energy Ltd. and Inox GFL Group

Inox Clean Energy Ltd. (“Inox Clean Energy” or “the Company”) set up under the Inox GFL Group, is the holding company for the renewables IPP business held under Inox Neo Energies Private Ltd. (Inox Neo Energies”) and solar manufacturing business held under Inox Solar Ltd (“Inox Solar”). Inox Clean Energy is a part of Inox GFL Group, one of India's leading business groups, primarily operating in the specialty chemicals and renewable energy sectors. The Inox GFL Group has historical ties to the wider Inox Group which commenced operations in 1987. The Inox GFL Group is one of India's leading diversified conglomerates with a multi-decade track record across RE equipment manufacturing, EPC, O&M services and RE infrastructure development. The Inox GFL Group has a significant presence across the renewable ecosystem, including WTGs, end-to-end wind turnkey solutions, renewables EPC and O&M services. Expanding into solar manufacturing enhances the Inox GFL Group's strong presence in wind energy and broadens its customer base, positioning the Inox GFL Group among a select few globally capable of covering the entire renewable energy value chain. This integrated value chain includes project development, manufacturing, EPC, O&M, renewable power generation, and energy consumption. Inox GFL Group's manufacturing prowess, especially the experience of handling and operating complex chemical facilities and complex wind turbine manufacturing capabilities, provides strong credentials.

As part of the Inox GFL Group, Inox Clean Energy enjoys significant operational and financial advantages, drawing on over 38 years of experience across sectors such as fluoropolymers, fluorochemicals, battery chemicals, wind turbines and renewable energy. This diverse foundation grants the Company access to established relationships, resources, and opportunities in the renewables sector. The Inox GFL Group's track record in renewable energy, demonstrated through the achievements of Inox Wind Ltd. (IWL) and Inox Green Energy Services Ltd. (IGESL), underscores its technical capabilities. These have been showcased through designing and manufacturing various wind turbine models and obtaining corresponding patents. This expertise, coupled with the manufacturing experience of complex chemicals, supports the development of its solar module and solar cell manufacturing capabilities. Further, through the broader Inox GFL Group ecosystem, the Company also has access to EPC capabilities through Inox Renewable Solutions Limited (IRSL) and renewable energy O&M capabilities through IGESL, enabling it to participate across the full renewable energy value chain under a single group ecosystem. As a member of the Inox GFL Group — the Company has embedded proprietary rights and structured access to a comprehensive RE platform that spans the full value chain from wind turbine manufacturing and solar cell production through to project development, EPC execution, grid evacuation infrastructure and long-term O&M. Access to a dedicated and experienced renewable O&M platform enables the Company to target consistently higher PLFs and plant availability levels across its operational portfolio relative to industry benchmarks, thereby improving long-term energy yield, asset longevity and project-level returns.

Inox Clean Energy aims to create an integrated renewables ecosystem, wherein it will manufacture solar modules and cells which will be partly used to set up captive hybrid renewable power generation capacities as well as sold to third party customers. Inox Clean Energy is among the few renewable energy companies in India with integrated capabilities across solar module and cell manufacturing, renewable power generation, EPC and renewable energy O&M services, positioned under a single group ecosystem. The collective expertise of its Board, Key Managerial Personnel and senior management team strengthens Inox Clean Energy's strategic direction and supports

scalable growth across its renewable power generation and integrated solar manufacturing businesses. Inox Clean Energy benefits from integrated play with both forward and backward integration, de-risking supply chain and offtake.

Inox Clean Energy leverages the broader Inox GFL Group's integrated RE ecosystem across RE equipment manufacturing, EPC services, renewable infrastructure and O&M capabilities to strengthen its operational efficiency, reduce project execution risks, improve manufacturing economics and expand growth opportunities across its renewable power generation and integrated solar manufacturing businesses. This integrated Group ecosystem provides the Company with differentiated competitive advantages such as established engineering and execution capabilities, integrated supply chain coordination, preferential access to evacuation infrastructure and transmission connectivity, faster project commissioning timelines, capital expenditure optimization and disciplined lifecycle asset management, that are not readily replicable by standalone IPP or manufacturing-only platforms operating in the Indian RE sector. Supplying solar modules and solar cells manufactured at Inox Clean Energy's India facilities under Inox Solar to RE projects developed and operated by Inox Neo and related Group entities, thereby enabling integrated renewable project execution and providing a captive internal demand channel for its India manufacturing operations, complemented by external customer relationships with marquee domestic and international customers. This integrated position across manufacturing, project development, EPC, evacuation infrastructure and lifecycle O&M capabilities, enables the Company to scale its renewable power generation and solar manufacturing businesses more efficiently, at lower execution risk and with superior operating economics relative to peers that do not have access to a comparable integrated platform. Integrated platform approach of the Company spanning renewable power generation, solar manufacturing, EPC execution and O&M, combined with its ability to leverage the broader Inox GFL Group's RE ecosystem, positions it favorably to capture emerging opportunities across the RE value chain in India and internationally, while reducing execution risks and improving long-term project and manufacturing economics.

Inox Clean Energy operates as a full-stack, vertically integrated RE platform, with integration spanning both backward and forward across the RE value chain — from upstream solar cell and module manufacturing through to wind turbine supply, renewable project development, EPC services (through IRSL), grid evacuation infrastructure (through IWL and its subsidiaries), and long-term renewable O&M services (through IGESL), all operating under a single group ecosystem. The full-stack vertical integration of Inox Clean Energy, combining backward integration into solar cell and module manufacturing with forward integration into project development, EPC execution, evacuation infrastructure access and lifecycle asset management, provides it with differentiated and structural competitive advantages, including optimised supply chain coordination, reduced capital expenditure, accelerated project execution timelines, improved operational efficiencies and enhanced lifecycle asset management, which may not be readily replicable by standalone IPP or manufacturing-only platforms.

Inox Clean Energy is among the top 10 Indian renewable IPP platforms and top 10 Indian integrated solar PV module and cell manufacturing players, as of August 31, 2026. Operational IPP capacity of Inox Clean Energy has grown rapidly through a combination of greenfield project development and strategic acquisitions, scaling from approximately 107.00 MW as of the end of Fiscal 2025 to approximately 1.04 GW as of the end of Fiscal 2026 to approximately 2.37 GW as of August 31, 2026, out of an aggregate contracted capacity of 6.16 GW as of August 31, 2026, making it one of the fastest-growing renewable IPP platforms in India. Of the total 6.16 GW contracted capacities, 4.01 GW is solar, 1.15 GW is wind and 1.00 GW is wind solar hybrid, reflecting a heterogeneous mix of renewable energy generating sources. In addition to this, the Company has 3.13 GW capacity for which it has obtained, either directly or through third party arrangements, connectivity or land approvals for all or part of the project's capacity. These projects do not yet have a signed PPA or off-take arrangements or may sell some or all its power output on a merchant basis, i.e., directly into the market on the power exchanges without any long-term off-take agreements. Of the total 3.13 GW future capacities, 1.20 GW is BESS, reflecting a heterogeneous mix of renewable energy generating sources. In the IPP Business, Inox Clean Energy is the fastest scaled-up platform in India, having reached 2.37 GW of operational capacity within the past 1.5 years/ since April 2025 through an active acquisition-led strategy. Inox Clean Energy's ability to identify, evaluate, structure and consummate acquisitions has

enabled it to scale its operational IPP capacity to approximately 2.37 GW, forming part of an aggregate contracted capacity of 6.16 GW as of August 31, 2026, within approximately 1.5 years, approximately 80.00% faster than the time taken by other leading renewable energy platforms in India to reach a comparable operational scale. Successfully executing acquisitions in the RE sector requires specialized and integrated capabilities across systematic opportunity origination, rigorous technical, financial and operational due diligence, disciplined valuation and transaction structuring, efficient financing and capital allocation, and post-acquisition operational stabilization and performance optimization. Disciplined acquisition framework and demonstrated capabilities in project identification, technical and operational due diligence, transaction structuring, financing and post-acquisition integration represent a differentiated competitive advantage to Inox Clean Energy in executing and scaling inorganic renewable growth opportunities efficiently. Inox Clean Energy's ability to acquire and integrate assets previously held by experienced institutional investors reflects the depth and quality of its project evaluation, execution and operational capabilities. Demonstrated experience of Inox Clean Energy in integrating acquired renewable assets and platforms, including rapidly stabilizing acquired operations, integrating management teams and systems, improving operational performance, and unlocking cross-portfolio synergies represents a differentiated execution capability relative to peers operating in the Indian RE sector.

Inox Clean Energy intends to improve the profitability of its IPP Business by progressively re-weighting its operational portfolio towards higher-tariff, higher-yield segments across both technology and customer mix. On the technology side, it intends to grow the share of wind, WSH, FDRE and BESS-linked capacity, which generally support higher weighted average tariffs and PLFs than standalone solar generation, leveraging its exclusive access to IWL's wind ecosystem, evacuation infrastructure and hybrid project development capabilities under the Inox Neo EPC Exclusivity Agreement, and pursuing hybridisation across existing sites to add wind and BESS capacity at lower incremental capital expenditure per megawatt. India's scale, policy support and demand growth provides the Company with a significant opportunity, including through hybridisation of its existing sites to expand its round-the-clock portfolio.

Integrated approach, which will combine captive sales upon the commissioning of Inox Clean's solar manufacturing facilities, participation in tenders, and exchange transactions, can ensure revenue stability and position the Company well to capture growth opportunities in India's RE sector. This integrated model constitutes a structural and proprietary competitive advantage that is not readily replicable by standalone IPP or manufacturing-only platforms and enables execution of renewable energy projects with superior cost efficiency, de-risked execution and operation, accelerated timelines and enhanced lifecycle returns.

Increasing adoption of energy storage solutions alongside intermittent renewable generation will be critical in enabling reliable FDRE power supply and enhancing renewable power scheduling capabilities, and Inox Clean Energy intends to position its platform to capitalize on the structural growth in storage-linked renewable opportunities in India and internationally. Existing relationships with hyperscalers and digital infrastructure customers of Inox Clean Energy, its integrated platform capabilities and focus on hybrid and BESS-linked renewable solutions position it favorably to serve the evolving and growing energy requirements of hyperscalers, data center operators and energy-intensive industries.

Inox Clean Energy intends to continue participating in utility-scale and C&I renewable energy tenders, bidding competitively on the basis of its integrated execution capabilities, cost efficiency and long-term project management experience, which are expected to witness increasing demand from utilities and C&I customers seeking round-the-clock and dispatchable renewable power solutions. Further, on the customer side, the Company intends to grow the share of higher-tariff, higher credit quality C&I customers, group captive consumers and government-owned DISCOM counterparties in international markets, which generally support higher realisations than utility-scale off-take, while retaining the long-term contracted cash flow visibility of its utility-scale and government-owned DISCOM portfolio. In the IPP business, Inox Clean Energy is the fastest scaled-up renewable IPP platform in India, having reached approximately 2.37 GW of operational capacity, out of an aggregate contracted capacity of

6.16 GW, within approximately 1.5 years through a combination of greenfield development and an acquisition-led scaling strategy. As of August 31, 2026, contracted IPP portfolio of Inox Clean Energy comprised an aggregate capacity of approximately 6.16 GW, with a weighted average remaining PPA tenor of approximately 23.94 years and the weighted average tariff under our PPAs stood at approximately Rs. 4.85 per kWh, in Fiscal 2026, which compares favourably with prevailing benchmark tariffs for comparable renewable energy project categories in India. As of August 31, 2026, credit ratings were available for 78 customers of Inox Clean Energy. Of the 78 customers, 74.36% had a credit rating of 'A-' or above and 94.87% had a credit rating of 'BB+' or above, indicating the robust credit quality of customer base of Inox Clean Energy.

Track record of post-acquisition integration of Inox Clean Energy is evidenced by capacity additions of 932.42 MW achieved through acquisitions in Fiscal 2026 alone, contributing to the scaling of its IPP platform from 107 MW as of the end of Fiscal 2025 to 1.04 GW as of the end of Fiscal 2026, demonstrating its ability to scale responsibly while maintaining operational discipline. Scaling capabilities of Inox Clean Energy are further supported by its integrated RE platform, which spans across RE generation and solar manufacturing operations across India, the United States and Africa. Its ability to operate effectively across these geographies and policy environments enhances Inox Clean Energy's long-term growth optionality and resilience relative to single-market renewable energy platforms. Integrated platform capabilities of Inox Clean Energy and Inox GFL Group ecosystem synergies further position favorably to continue executing both organic and inorganic growth opportunities efficiently and at scale. The Company has demonstrated a strong and repeatable ability to rapidly scale its integrated RE platform across multiple geographies, i.e., India, the United States and Africa, through a combination of greenfield development, strategic acquisitions and disciplined platform execution.

Solar Manufacturing Business of Inox Clean Energy comprises the manufacture of PV modules and cells for the renewable energy market. Integrated solar PV module and cell manufacturing portfolio of Inox Clean Energy features 6.00 GW of module manufacturing capacity already operational, 8.00 GW of cell manufacturing capacity and 5.00 GW module manufacturing capacity under construction, as of August 31, 2026. Inox Clean Energy also intends to leverage applicable policy frameworks and localisation initiatives across its India manufacturing operations, including the ALMM for modules and cells and DCR- linked demand opportunities. These frameworks and initiatives are expected to support demand for domestically manufactured solar cells and modules and improve realisation opportunities for integrated cell and module manufacturers.

Inox Clean Energy has the largest solar manufacturing operations in the United States among Indian solar manufacturers, as of August 31, 2026. Inox Clean Energy represents a differentiated dual-engine renewable energy platform, uniquely combining scalable manufacturing revenues from its Solar Manufacturing Business with long-duration annuity cash flows from IPP Business. Inox Clean Energy is among the few Indian-origin renewable energy platforms with an operational presence across three continents, operating solar manufacturing facilities across India and the United States and renewable power generation platforms across India and Africa.

Inox Clean Energy has planned to incorporate TopCon technology in its facilities in Gujarat and Odisha. This technology, known for its efficiency in mass-scale production, will enable it to produce solar modules that align with the evolving requirements of domestic and global markets. TOPCon solar cell technology will position the Company competitively with respect to module conversion efficiency, manufacturing economics and product quality. This is aligned with evolving domestic and global solar market requirements and supports higher module conversion efficiencies, improved manufacturing yields and enhanced product competitiveness. Inox Solar manufactures and assembles glass-to-glass bifacial solar modules using TOPCon solar cells, and once Inox Solar's solar cell manufacturing capabilities become operational, modules by Inox Solar will incorporate TOPCon cells produced in-house. Inox Solar aims to rapidly scale up over the next 2 years targeting 8.0 GW of solar module and 5.0 GW of solar cell manufacturing capacity across two facilities located in the states of Gujarat and Odisha, along with strong EPC and O&M capabilities. By combining its expertise with that of the Inox GFL Group companies, Inox Solar is well-positioned to support developers with end-to-end solutions for both solar and hybrid renewable energy projects, strengthening its role as a key player in the sector. Inox Solar is supplementing Inox Wind to provide comprehensive hybrid (wind + solar) renewable energy solutions to

customers. Leveraging IWL's established customer relationships will allow Inox Clean to drive growth in the expanding WSH market. By targeting IWL's IPP customers exploring solar and WSH projects, the Company can pursue significant cross-selling opportunities for Inox Solar's products, building on existing familiarity and trust in the Inox GFL Group's capabilities. Inox Clean Energy leverages IWL's existing customer relationships and established RE infrastructure presence to expand its addressable market opportunities across WSH projects and integrated renewable solutions for utility-scale and C&I customers.

Inox Clean Energy's exclusive access to IWL's established renewable infrastructure footprint, including grid-connected substations, transmission lines and evacuation systems across multiple renewable-rich states in India, is particularly significant given transmission connectivity constraints and land aggregation challenges that constitute significant bottlenecks to scalable project development in the Indian renewable energy sector.

Inox Clean Energy has established relationships with a diversified and growing base of marquee customers across both IPP Business and Solar Manufacturing Business, including central and state utilities agencies, sovereign and government-backed entities, hyperscalers, digital infrastructure companies, C&I customers and marquee global counterparties. Across both its businesses, Inox Clean Energy's ability to secure long-term contractual arrangements with marquee counterparties is underpinned by its competitive tariff offerings, integrated execution capabilities, track record of timely project commissioning and operational reliability, and its capacity to deliver comprehensive RE solutions across multiple geographies and customer segments. Long-term and sovereign-backed nature of a significant portion of contractual arrangements, combined with its growing manufacturing order book, provide the Company with stable, recurring and increasingly diversified cash flows and a differentiated commercial foundation for long-term growth and returns across both of its IPP Business and Solar Manufacturing Business.

Inox Neo Energies leverages the expertise of IWL, an Inox GFL Group company and a leading player in wind EPC in India, for its wind projects. The primary competitors of Inox Neo are other renewable energy companies operating in India, Africa and internationally.

Make in America for America strategy of Inox Clean Energy positions it favourably to benefit from the IRA manufacturing incentives, increasing localisation trends and supply chain diversification requirements in the United States. Further, Make in America for America manufacturing strategy of Inox Clean Energy, combined with its backward integration into domestic solar cell manufacturing, addresses the structural supply gap in domestic cell manufacturing in the United States, which is currently significantly below domestic module manufacturing capacity levels. United States manufacturing footprint of Inox Clean Energy positions it favourably to benefit from the manufacturing and domestic content incentive framework under the IRA, including production tax credits under Section 45X of the United States Internal Revenue Code amounting to seven cents per watt for modules and 4 cents per watt for cells manufactured domestically.

In the United States, Inox Solar's US Manufacturing Operations through Inox Amura competes with domestic and international solar module and cell manufacturers operating within the United States market, including First Solar Inc., QCells (a subsidiary of Hanwha Solutions Corporation), T1 Energy Inc., Suniva Inc., ES Foundry, Inc. and SunPower Corporation, among others. With the acquisition of Boviet Solar, Inox Clean is positioned as one of top three (by installed capacity as of March 2026) policy-compliant leading Indian manufacturers eligible to participate in the booming US clean tech landscape. By securing 3 GW of operational TOPCon module manufacturing and a pathway to 3 GW of solar cell manufacturing, Boviet Solar's products manufactured would qualify for 45X tax incentives. Inox Clean is structured to maximize Section 45X Production Tax Credits in the US, by monetising them to ensure further revenue stream. Boviet Solar has been featuring in BloombergNEF's tier-1 PV module manufacturer rankings since 2017. Positioned at the convergence of rising US electricity demand driven by AI adoption, data center expansion and C&I energy load, Inox Clean is scaling production to meet the compounding power demands of the industrial economy in the US with 6 GW of combined module and cell capacity. Opportunity to

emerge as a scalable clean power platform in the US: With cell shortages and 45X incentives creating strong value tailwinds, Inox Clean is well positioned to build an integrated US manufacturing ecosystem.

Each of the markets in India, the United States and Africa represent a large and growing renewable energy opportunity. Scaling capabilities of Inox Clean Energy are further supported by the breadth of its integrated platform, which spans renewable power generation and solar manufacturing operations across India, the United States and, through SkyPower MENA, Africa, providing it with access to diverse renewable energy growth markets and differentiated policy ecosystems, including India's trajectory towards 500 GW of installed renewable capacity by 2030 and the manufacturing and domestic content incentive framework under the IRA in the United States.

7.2 Competitive mapping

7.2.1 Landscaping of various domestic and international players

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, Websol Energy System Limited, Waaree Energies Limited, Vikram Solar Limited. These players also have a sizeable quantum of capacity under consideration/development.

Table 26: Operating parameters of key players in RE IPP with similar offerings

Operating Parameters	Inox Clean Energy Limited	Adani Green Energy Limited	Acme Solar Holdings Limited	Tata Power Renewable Energy Limited	NTPC Green Energy Limited	JSW Energy	CleanMax Enviro Energy
Ownership/Group	Inox GFL Group	Adani Group	Acme Cleantech Solutions	TATA Power Co. Ltd.	NTPC Ltd	JSW Group	CleanMax
Group highlights	- One of the largest chemicals players in India - Manufacturing complex chemicals - The group has a strong presence across renewable	- Part of Adani Group, a diversified conglomerate - The Group has a presence across diverse businesses - The Group has a successful	- 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	- TPCL is an Indian electric utility and electricity generation company - TATA Group started its power generation in 1910 - TPCL operates	- NTPC Limited, India's largest power company (in terms of installed capacity as well as generation) - NTPC Limited is a Central	- Part of JSW Group, a diversified conglomerate - One of the largest steel manufacturing player in India - Strong presence in RE through JSW energy	- Development of renewable energy projects - Focuses on C&I PPAs - Adequate liquidity with substantial cash and bank balance - Long-term relationships

Operating Parameters	Inox Clean Energy Limited	Adani Green Energy Limited	Acme Solar Holdings Limited	Tata Power Renewable Energy Limited	NTPC Green Energy Limited	JSW Energy	CleanMax Enviro Energy
	space with manufacturing of WTG equipment, maintaining and providing EPC work across the renewable platform including wind, solar, hybrid - The group has a track record of execution of large and complex projects - The Group has experience in operating and maintaining large power stations efficiently - The Group has a healthy balance sheet with strong cash flow generation	incubation track record - The Group has a healthy balance sheet and provides need-based support to its subsidiaries - The Group has experience in operating and maintaining large power stations efficiently	financial flexibility as seen from its track record of fundraising. Above average financial risk profile, supported by large and diverse portfolio of assets	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.	Public Sector Enterprise (CPSE) under the Ministry of Power - NTPC provides support, vision, resources, and experience - NTPC has experience in operating and maintaining power stations efficiently and in acquiring land for large power projects throughout India	with diversified portfolio in wind, solar, hydro power and hybrid - Significant ESS capabilities including PSPs and BESS - The group has a strong financial profile, supported by a healthy balance sheet and robust cash flow	with reputed clientele Experience of more than a decade in developing RE projects
Years in Business (As of 30 June 2026)	~6 years	~11 years	~18 years	~19 years	~4 Years	~32 years	~15 years

Operating Parameters	Inox Clean Energy Limited	Adani Green Energy Limited	Acme Solar Holdings Limited	Tata Power Renewable Energy Limited	NTPC Green Energy Limited	JSW Energy	CleanMax Enviro Energy
Operational Capacity (MW) as on 30 June 2026							
Solar	907.82	14,207.00	2,840.00	5,426.00	9,891.00	2,275.00	3,332.00
Wind	722.58	2,670.00	150.00	1,333.00	780.00	3,125.00	843.00
Hybrid	661.25	3,266.00	-	-	NA	1,696.00	-
FDRE/Solar+BESS	-	NA	-	-	NA	-	-
Sub-Total	2,291.65	20,143.00	2,990.00	6,759.00	10,671.00	7,096.00	4,175.00
Under Construction/ Development Capacity (MW) as on 30 June 2026							
Solar	3,151.60	NA	300.00	522.00	10,103.00	3,105.00	4,445.00
Wind	1,117.90		-	834.00	6,215.00	2,245.00	4,304.00
Hybrid	567.60		750.00	1,472.00	NA	4,417.00	-
FDRE/Solar+BESS	2,166.00		4,030.00	2,447.00	NA	-	-
Sub-Total	7,003.10		5,080.00	5,275.00	16,318.00	9,767.00	8,749.00
Total Operational capacity + Under Construction/ Development Capacity (MW)	9,294.75	20,143.00 (Only operational)	8,070.00	12,034.00	26,989.00	16,863.00	12,081.00
Solutions offered	IPP, Corporate PPA, Storage, Solar PV manufacturing	IPP, Corporate PPA, Storage, Solar PV manufacturing	IPP, Storage Corporate PPA, Hybrid, FDRE	IPP, RTC/ Storage Corporate PPAs	IPP, RTC/ Storage	IPP, Storage, Corporate PPAs, Hybrid	Onsite/Offsite, Virtual PPAs, Carbon removal project development, Carbon consultancy
Key Offtakers for Operational Capacity	Third party sale through PPAs	TANGEDCO, ESCOMs, UPPCL, BESCOM, PSPCL, NTPC, SECI, GESCOM, MSEDCL, PSPCL, HESCOM,	SECI, NTPC, GUVNL, CSPDCL, MSEDCL, UPPCL, MPPMCL, PSPCL, TSNPDCL, TSSPDCL,	SECI, SJVN TANGEDCO APDISCOMs, GUVNL BESCOM, UPPCL, NPCL, MSEDCL, TPCD,	SECI, GUVNL, RUMSL, IREDA, NVVNL, REC/NTPC, MPPMCL Raj. Discoms	SJVN, GUVNL, MSEDCL, KREDL, SECI, TSSPDCL, TSNPDCL,	Only C&I Clients such as Amazon, Apple, Welspun, Ultratech Cement, Cipla, MRF etc.

Operating Parameters	Inox Clean Energy Limited	Adani Green Energy Limited	Acme Solar Holdings Limited	Tata Power Renewable Energy Limited	NTPC Green Energy Limited	JSW Energy	CleanMax Enviro Energy
		NPCL, GUVNL, TSSPDCL, Merchant	APSPDCL, NBPDC & SBPDCL	KSEB, MPPCL, JVVNL, JdVVNL	AP Discoms, UPPCL Telangana Discoms	WBSEDCL, BESCO, Others	
Global Presence	India, USA, Africa	India	India	India	India	India, Bhutan	India, UAE, Thailand, Bahrain
In-house EPC and O&M capabilities	Yes	Yes	Yes	No	No	Yes	Yes
BESS and PSP Targets/Ambitions	BESS within next 2-3 years	BESS: Yes PSP: Yes	BESS: Yes	BESS: Yes PSP: Yes	BESS: Yes PSP: NO	BESS: Yes PSP: Yes	BESS: Yes PSP: No

Source: Industry, Company websites, Crisil Intelligence

Note: Development capacity refers to projects currently in the pipeline and planned future capacity additions, if any.

Landscape of key players covers the details of companies, their products, and services within a given market to understand competitive intensity. The top 5 players namely, Waaree Energies, TATA Power Solar (incl. TP Solar), Adani Solar (Mundra Solar PV), ReNew Photovoltaic and Goldi Sun) account for about ~ 26% of the total domestic ALMM enlisted module manufacturing capacity of ~194 GW (excl. co-branding) as of May 2026.

Table 27: Comparative summary of domestic module manufacturers

Parameter	Inox Clean Energy	Waaree Energies	Vikram Solar	Adani Mundra Solar PV	Emmvee Photovoltaic	Premier Energies	RenewSys India
Number of manufacturing factories	1 in Gujarat and 1 in Odisha	4 in Gujarat	1 each in West Bengal and Tamil Nadu	1 in Gujarat	2 in Karnataka	2 in Telangana	1 each in Karnataka, Telangana, and Maharashtra
Experience in PV module manufacturing	-	16 years	17 years	8 years	19 years	26 years	12 years
Operational capacity (as on June -26)	6.0 GW Module (As of Aug-2026; incl. 3 GW US capacity))	25.8 GW modules 5.4 GW Cells	9.5 GW modules	4 GW cells and modules 2 GW ingots-wafers	10.3 GW modules 2.9 GW cells	11.1 GW modules, 3.6 GW Cells	5.5 GW modules, 4.5 GW cells
Under-construction capacity (as on June -26)	5.0 GW Solar modules and 8.0 GW of Solar cells	2.6 GW Module 10 GW Cell 10 GW Ingot+Wafer	Proposed 6 GW module & 12	6 GW cell and module	6 GW integrated TOPCon cell	7 GW Cell 10 GW Ingot-Wafers	NA

Parameter	Inox Clean Energy	Waaree Energies	Vikram Solar	Adani Mundra Solar PV	Emmvee Photovoltaic	Premier Energies	RenewSys India
			GW Cell		and module		
PLI Capacity	NA	6 GW (W+C+M)	2.4 GW (C+M)	0.737 (Group) (integrated)	NA	NA	NA
NABL Accredited Lab	-	For modules	For modules	-	-	-	For encapsulants and backsheets
Enlisted Capacity as ALMM List May-26	1,274 MW	18,645 MW	7,659 MW	4,353 MW	8,774 MW	5,153 MW	5,217 MW
% Share in total enlisted capacity as per ALMM List May-26	0.66%	9.58%	3.95%	2.25%	4.53%	2.66%	2.69%
Key Products and services	Solar PV modules, EPC services, O&M Service	Solar PV modules, Inverters, Batteries, EPC services, rooftop solutions, O&M Services, and solar water pumps	Solar PV modules, EPC services, solar O&M services, and water pumps	Solar PV cells and modules, EPC services, O&M services,	Solar PV cells and modules,	Solar PV cells and modules, EPC services, O&M services, and water pumps	Solar PV modules and cells
Cumulative Installed capacity in EPC	NA	2000+ MW	1,420 MW	NA	NA	650+ MW	NA
Key Technologies offered	NA	TOPCon, Mono and poly crystalline PV modules, Mono PERC, Bifacial, Flexible modules, BIPV	TOPCon, Mono PERC, mono-facial & bifacial, poly-Si modules	TOPCon, Multi crystalline, Mono PERC and Bifacial modules	Bifacial N-type TOPCon, N-type TOPCon, mono C-Si PERC, bifacial mono c-Si PERC	TOPCon, Polycrystalline Si cells, mono PERC, poly Si modules	TOPCon, Mono/Multi PERC, Bi-facial
Efficiency (%)	NA	19.55- 23.51	21.76 – 23.61%	21.68 – 23.16%	21.66- 23.51%	22.21-23.32%	21.18-22.98%
Recent PE Investments	NA	Rs. 10 Bn (Value quest) Rs. 10.4 Bn (family offices, HNIs etc.)	Rs. 7.15 Bn (Multiple Investors incl Viney Equity Market)	USD 394 Mn from Barclays PLC and Deutsch Banks AG through trade finance facility	NA	Rs. 2 Bn from GEF Capital	NA

NA: Not available

Source: Company, Company websites, Investors Presentation, MNRE ALMM May -2026, Crisil Intelligence

Capacity addition plan of Indian solar PV manufacturers

In order to boost domestic production and reduce imports, the central government initiated the first tranche of the PLI scheme in April 2021 with a target of 8,737 MW module manufacturing capacity as well as introduced basic customs duty on imports. The second tranche of the scheme targets a capacity addition of 39,600 MW by April 2026. Considering the favourable environment, various Indian solar PV manufacturers have planned for capacity expansion. As of December 2022, 70-75 GW module and 50-55 GW cell capacity expansion plans have been announced by various players. Also, with the announcement in Union Budget 2023 on the enhancement of the outlay of Rs 195 billion under the PLI scheme for high efficiency modules under the second tranche of the scheme, the segments could see a further boost. Moreover, the ALMM order issued by MNRE acts as a trade barrier by encouraging domestic manufacture of solar modules, thus making it one of the key drivers for the development of domestic PV manufacture.

Table 28: Existing and planned capacity additions of leading players

Players		Existing Capacity (GW)	Planned Capacity (GW)	State where capacity is planned
Waaree Energies#	Module	25.8	2.6	USA
	Cell	5.4	10	Gujarat
Adani Solar	Module	4	6	Gujarat
	Cell	4	6	Gujarat
Reliance New Energy	Module	5	5	Gujarat
	Cell	-	10	Gujarat
Shirdi Sai Electricals	Module	3.3	27.7	Andhra Pradesh
	Cell	-	30	Andhra Pradesh
Vikram Solar	Module	9.5	6	Tamil Nadu
	Cell	-	12	Tamil Nadu
Premier Energies	Module	11.1	0	Telangana
	Cell	3.6	7	Telangana
Inox Clean Energy	Module	6.0^	5	Odisha
	Cell	-	8.0	Odisha
Goldi Solar	Module	15.2	6	Gujarat
	Cell	-	16	Gujarat
ReNew	Module	6.4	-	NA
	Cell	2.5	4	Gujarat
Grew Energy	Module	6.5	4.5	Rajasthan
	Cell	-	8	Madhya Pradesh
Solex Energy	Module	4	6	Gujarat

Players		Existing Capacity (GW)	Planned Capacity (GW)	State where capacity is planned
	Cell	-	10	Gujarat
RenewSys	Module	5.5	-	Maharashtra
	Cell	0.5	2	Andhra Pradesh
TP Solar Ltd.	Module	4.9	-	NA
	Cell	4.9	-	NA
Rayzon	Module	12	0	NA
	Cell	-	3.5	Gujarat
Avaada Electro	Module	8.5	5.1	Uttar Pradesh
	Cell	-	12	MH and UP

Installed manufacturing capacity as of June 2026; #Including IndoSolar and USA; ^As of August 31, 2026, including 3 GW in USA

Source: Industry, Company websites, Crisil Intelligence

Table 29: Comparative summary of global module manufacturers

Parameter	LONGi Solar	Jinko Solar	JA Solar	Canadian Solar	First Solar	T1 Energy	QCells
Number of manufacturing factories	8 in China, 1 each in Malaysia and Vietnam	14 in China, Vietnam, Malaysia, and USA	12 in China and Vietnam	20 in Canada, China, Brazil, Thailand, and Vietnam	8 in USA, India, Malaysia and Vietnam	2 in USA	1 in South Korea, 1 in Malaysia, and 3 in the United States
Experience in PV module manufacturing	25 years	19 years	20 years	24 years	26 years	8 years	25 years
Operational Capacity 2015	NA	4.7 GW Modules 3.0 GW Cells	4.0 GW Modules 4.0 GW Cells	4.3 GW Modules 2.7 GW Cells	2.8 GW modules	NA	NA
Operational capacity (As on Dec-25)	120 GW modules 80 GW cells 170 GW wafers	130 GW modules 95 GW cells 120 GW wafers	100+ GW modules 70+ GW* cells 80+ GW* wafers	60.2 GW modules 48.4 GW cells 31 GW wafers 25 GW ingot	23.2 GW modules	5 GW solar modules	NA
Operational capacity in USA	NA	NA	NA	5 GW solar modules with expansion planned to	13 GW Cells and modules	5 GW solar modules 5 GW solar cell planned	8.6 GW Modules

Parameter		LONGi Solar	Jinko Solar	JA Solar	Canadian Solar	First Solar	T1 Energy	QCells
					10 GW			3.3 GW cells (under construction)
Product shipments (CY 25)		108.5 GW wafers 82.32 GW cells & modules	93 GW modules, 6.7 GW cells and wafers	74.2 GW modules and cells	31.1 GW modules	93 GW modules	NA	NA
Key Products and services		Solar PV modules, wafers, solutions for C&I, utility, and rooftop use	Solar PV modules, energy storage systems, C&I, and rooftop solutions	Solar PV modules, energy storage systems for domestic and C&I use	Solar PV modules, energy storage, inverters, EPC	Solar PV modules	Solar PV modules, cells, storage and RE solutions	Solar PV cells and PV Modules. ESS, and large-scale RE solutions
Ky Technologies offered		TOPCon, Mono PERC, bi-facial module, half-cut cells	Half-cell, bi-facial and tilling ribbon technologies, PERC and TOPCon	TOPCon, Mono PERC, bi-facial module, half-cut cells	TOPCon Bifacial and Monofacial, HJT modules, Dual Cell PERC,	Cadmium telluride (CdTe), thin film	PERC and TOPCon solar cells and modules	TOPCon N Type Solar Cells and Modules
Key Financials (CY 25)	Revenue	\$11.49 bn	\$12.6 bn	\$9.7 bn	\$6.0 bn	\$5.2 bn	\$0.36	NA
	Net profit	(\$1.2 bn)	\$1.4 bn	NA	(\$0.10 bn)	\$1.5 bn	(\$0.19 bn)	NA

NA: Not available; *H1 of CY2024

Canadian solar, Trina Solar, Jinko and JA Solar shipment for the FY24 as per the summary of financial statement and investor presentations, the solar cell produced are self-utilized for module production

Source: Company websites, Crisil Intelligence

Table 30: Competitive analysis of key solar cell manufacturers

Parameter	Sunlike Solar	Trina Solar	Jinko Solar	JA Solar	Canadian Solar	Hanwha Q Energy
Number of manufacturing factories	1 in China	4 in China, 1 each in Thailand and Vietnam	14 in China, Vietnam, Malaysia, and USA	12 in China and Vietnam	20 in Canada, China, Brazil, Thailand, and Vietnam	Multiple factories South Korea, Malaysia, and US
Production capacity	~ 2 GW cells		95 GW cells			NA

Parameter		Sunlike Solar	Trina Solar	Jinko Solar	JA Solar	Canadian Solar	Hanwha Q Energy
(As on Dec-25)			105 GW cells		70+ GW cells	48.4 GW cells	
Operational capacity in USA		NA	NA	NA	NA	6 GW	3.3 GW
Product shipments (CY 25)		NA	34 GW modules	93 GW modules 6.7 GW cells and wafers	74.2 GW modules and cells	31.1 GW modules	NA
Key Products and services		Solar PV modules, Solar cells.	Solar Cells, Solar PV modules, solar trackers, utility solutions, EPCM services	Solar Cell manufacturing, Wafer manufacturing, Solar PV modules, energy storage systems, C&I, and rooftop solutions	Solar PV modules, energy storage systems for domestic and C&I use	Solar PV modules, energy storage, inverters, EPC	Solar PV modules, energy storage systems, EPC services, O&M services, Solar Financing
Key Technologies offered		Poly solar cells, Monocrystalline cells, Mono PERC cells, Mono bi-facial cells, Topcon cells	Bi-facial PERC, TOPCon, HJT, half-cut cells	P-type mono PERC solar cells, Half-cell, N-Type TOPCon cells, Multicrystalline Solar cells	TOPCon, Mono PERC, bi-facial module, half-cut cells	TOPCon Bifacial and Monofacial, HJT modules, Dual Cell PERC,	Monocrystalline, Polycrystalline, Half cut cells, Bifacial cells, PERC
Key Financials (CY 25)	Revenue	NA	\$11.10 bn	\$12.6 bn	\$9.7 bn	\$6.0 bn	NA
	Net profit	NA	(\$0.05 bn)	\$1.4 bn	NA	(\$0.10 bn)	NA

NA: Not available

As per the summary of financial statement, the solar cell produced are self-utilized for module production.

Source: Company websites, Crisil Intelligence

Canadian Solar, Trina, JA Solar and Jinko Solar produces Solar Cells for self-consumption and production of Solar modules and Solar cells are majorly produced in China with expanded production facilities in countries like Vietnam, and Malaysia. However, Sunlike solar and Hanwha Q Energy solar cells are majorly procured by the solar module manufacturing companies.

7.2.2 Financial and operational parameters

Table 31: Financial and operational parameters of key players with similar offerings
A) FY2026

FY2026	Units	Inox Clean Energy Ltd.	Inox Clean Energy Ltd.	Adani Green Energies Ltd.	Acme Solar Holdings Ltd.	NTPC Green Energy Ltd.	CleanMax Enviro Energy Solutions Ltd.	JSW Energy	Waaree Energies Ltd.	Premier Energies Ltd.	Emmvee Photovoltaic Power Ltd.	First Solar, USA	Canadian Solar, USA
		RFS Basis	Proforma basis										
a) Financial KPIs													
Revenue from operations	INR Mn	1,781.29	20,464.00	129,280.00	20,233.79	28,584.20	19,128.73	189,011.30	265,367.70	78,243.74	50,498.77	454,952.68	487,703.69
EBITDA	INR Mn	322.52	11,903.87	107,680.00	17,813.36	24,750.60	11,322.22	100,109.50	59,086.40	23,772.30	17,343.75	180,085.00	20,584.10
EBITDA margin	%	18.11%	58.17%	83.29%	88.04%	86.59%	59.19%	52.96%	22.27%	30.38%	34.34%	39.58%	4.22%
Profit /(loss) after tax	INR Mn	309.81	-4,084.49	19,870.00	4,978.85	5,213.50	855.77	27,624.10	38,841.50	15,096.80	10,815.52	133,209.77	-16,017.91
Gross debt to equity	times	2.32	4.45	3.29	3.75	1.52	2.25	2.26	0.17	0.84	0.05	0.05	1.52
Net debt to equity	times	2.09	4.19	3.20	2.54	1.49	1.83	2.09	-0.28	0.35	-0.05	-0.25	1.03
EBIT ROCE	%	-0.27%	0.72%	5.77%	5.46%	2.83%	4.19%	6.24%	28.10%	24.28%	37.16%	14.84%	-3.11%
EBITDA ROCE	%	0.30%	6.14%	8.40%	7.41%	5.11%	6.31%	9.15%	33.76%	29.99%	44.79%	19.95%	2.30%
b) Operational KPIs – IPP Business													
Weighted Average Tariff of operational capacity	INR/kWh	3.85	3.93	3.12	3.40	NA	3.57	NA	NA	NA	NA	NA	NA
Weighted Average PPA Tenor	Yrs	19.45	16.79	NA	NA	NA	23.17	17.00	NA	NA	NA	NA	NA
Operational IPP Capacity	GW	1.04	3.53	19.29	2.99	10.08	3.09	6.17	NA	NA	NA	NA	NA
YoY % Growth in operational IPP capacity	%	871.42%	3200.42%	35.46%	10.54%	70.72%	80.37%	61.63%	NA	NA	NA	NA	NA
c) Operational KPIs – Solar Manufacturing Business													
Module Capacity	GW	2.10	NA	NA	NA	NA	NA	NA	25.80	11.10	10.31	23.50	51.00
Module Order Book	GW	6.38	NA	NA	NA	NA	NA	NA	NA	9.38	9.40	NA	NA

B) FY 2025

FY2025	Units	Inox Clean Energy Ltd.	Adani Green Energies Ltd.	Acme Solar Holdings Ltd.	NTPC Green Energy Ltd.	CleanMax Enviro Energy Solutions Ltd.	JSW Energy	Waaree Energies Ltd.	Premier Energies Ltd.	Emmvee Photovoltaic Power Ltd.	First Solar, USA	Canadian Solar, USA
a) Financial KPIs												
Revenue from operations	INR Mn	472.44	112,120.00	14,051.31	22,096.40	14,957.01	117,453.90	144,445.00	65,187.50	23,356.13	351,976.52	501,520.29
EBITDA	INR Mn	359.07	88,770.00	12,354.30	19,167.30	9,004.31	52,435.70	27,216.40	17,808.80	7,219.38	149,865.59	27,753.94
EBITDA margin	%	76.00%	79.17%	87.92%	86.74%	60.20%	44.64%	18.84%	27.32%	30.91%	42.58%	5.53%
Profit /(loss) after tax	INR Mn	15.56	20,010.00	2,508.21	4,741.20	194.29	19,828.80	19,281.30	9,371.32	3,690.14	108,116.48	-6,515.39
Gross debt to equity	times	0.73	3.46	2.31	0.97	2.49	1.71	0.10	0.67	3.63	0.08	1.18
Net debt to equity	times	0.01	3.29	1.66	0.78	2.12	1.54	-0.71	-0.04	3.03	-0.15	0.60
EBIT ROCE	%	2.66%	6.34%	6.35%	3.17%	5.37%	4.56%	22.01%	27.22%	22.76%	15.90%	-2.52%
EBITDA ROCE	%	4.31%	8.82%	8.27%	5.25%	8.06%	6.66%	25.83%	37.77%	29.03%	20.82%	3.81%
b) Operational KPIs – IPP Business												
Weighted Average Tariff of operational capacity	INR/kWh	3.37	3.27	3.40	3.61	3.76	NA	NA	NA	NA	NA	NA
Weighted Average PPA Tenor	Yrs	18.73	NA	NA	NA	22.73	16.00	NA	NA	NA	NA	NA
Operational IPP Capacity	GW	0.11	14.24	2.71	5.90	1.71	3.83	NA	NA	NA	NA	NA
YoY % Growth in operational IPP capacity	%	114.00%	30.26%	101.87%	12.03%	27.57%	63.09%	NA	NA	NA	NA	NA
c) Operational KPIs – Solar Manufacturing Business												
Module Capacity	GW	NA	NA	NA	NA	NA	NA	15.00	11.10	6.02	NA	61.00
Module Order Book	GW	NA	NA	NA	NA	NA	NA	25.00	9.38	4.89	NA	NA

C) FY2024

FY2024	Units	Inox Clean Energy Ltd.	Adani Green Energies Ltd.	Acme Solar Holdings Ltd.	NTPC Green Energy Ltd.	CleanMax Enviro Energy Solutions Ltd.	JSW Energy	Waaree Energies Ltd.	Premier Energies Ltd.	Emmvee Photovoltaic Power Ltd.	First Solar, USA	Canadian Solar, USA
a) Financial KPIs												
Revenue from operations	INR Mn	393.95	92,200.00	13,192.50	19,626.00	13,898.37	114,859.10	113,976.09	31,437.93	9,519.35	274,144.28	628,949.18
EBITDA	INR Mn	350.12	73,790.00	10,891.95	17,439.70	7,061.01	53,982.90	15,744.23	4,778.00	1,204.39	97,999.87	49,686.12

FY2024	Units	Inox Clean Energy Ltd.	Adani Green Energies Ltd.	Acme Solar Holdings Ltd.	NTPC Green Energy Ltd.	CleanMax Enviro Energy Solutions Ltd.	JSW Energy	Waaree Energies Ltd.	Premier Energies Ltd.	Emmvee Photovoltaic Power Ltd.	First Solar, USA	Canadian Solar, USA
EBITDA margin	%	88.87%	80.03%	82.56%	88.86%	50.80%	47.00%	13.81%	15.20%	12.65%	35.75%	7.90%
Profit /(loss) after tax	INR Mn	25.58	12,600.00	6,982.27	3,428.60	-376.43	17,246.50	12,743.77	2,313.60	288.99	68,629.13	30,039.21
Gross debt to equity	times	4.57	3.61	3.17	2.05	2.47	1.49	0.08	2.11	8.54	0.08	0.83
Net debt to equity	times	4.54	3.11	2.66	1.98	2.30	1.29	-0.83	1.50	5.46	-0.23	0.03
EBIT ROCE	%	8.16%	6.80%	7.23%	5.79%	6.25%	7.19%	29.06%	18.60%	4.88%	12.04%	4.32%
EBITDA ROCE	%	12.26%	9.17%	10.08%	9.16%	9.11%	10.31%	35.26%	23.28%	7.48%	16.27%	8.82%
b) Operational KPIs – IPP Business												
Weighted Average Tariff of operational capacity	INR/kWh	2.65	3.43	4.37	3.65	4.12	NA	NA	NA	NA	NA	NA
Weighted Average PPA Tenor	Yrs	23.11	NA	NA	NA	21.54	18.00	NA	NA	NA	NA	NA
Operational IPP Capacity	GW	0.05	10.93	1.34	2.93	1.34	2.35	NA	NA	NA	NA	NA
YoY % Growth in operational IPP capacity	%	NA	35.22%	-8.16%	12.03%	29.02%	16.43%	NA	NA	NA	NA	NA
c) Operational KPIs – Solar Manufacturing Business												
Module Capacity	GW	NA	NA	NA	NA	NA	NA	12.00	3.36	1.59	NA	NA
Module Order Book	GW	NA	NA	NA	NA	NA	NA	19.93	NA	1.10	NA	NA

Source: Company Restated Consolidated Financial Information, Company websites, Investors Presentation, Annual Reports, RHP Filings, Crisil Intelligence

Note: On consolidated basis; NA: Not Available as not available or reported for the particular period; for USA based players, information is on calendar year basis (CY2025 figures are taken for FY2026, CY2024 figures taken for FY2025 and CY2023 figures taken for FY2024), Exchange rates considered: For Balance sheet items as on last working day of calendar year for the respective year (1 USD = Rs. 89.92, as on 31st December 2025; 1 USD = Rs. 85.62; as on 31st December 2024; 1 USD = Rs. 83.12, as on 29th December 2023) and for P&L items average of daily exchange rates for the respective calendar year (1 USD = Rs. 87.17 for CY2025; 1 USD = Rs. 83.68, for CY2024; 1 USD = Rs. 82.61, for CY2023);

Inox Clean Energy Limited, set up under the Inox GFL Group, is the holding company for the Renewables IPP business held under Inox Neo Energies Private Limited and solar manufacturing business under Inox Solar Limited

Formulae used:

- Revenue from operations refers to the revenue from operations.
- EBITDA is calculated as profit before tax plus depreciation & amortization plus finance cost less other income
- EBITDA Margin means EBITDA divided by revenue from operations.
- Profit/Loss after tax refers to the profit/loss after tax.
- Gross debt to equity means total non-current borrowings plus current borrowings divided by total equity, including non-controlling interest.
- Net Debt to Equity means total non-current plus current borrowings less cash and other bank balances divided by total equity, including non-controlling interest.

- g) *EBIT ROCE means EBITDA less depreciation & amortization divided by operational capital employed as at the end of the year. Capital employed is calculated as gross debt plus total equity*
- h) *EBITDA ROCE means EBITDA divided by Capital employed as at the end of the financial year. Capital employed is calculated as gross debt plus total equity.*
- i) *Weighted Average Tariff means weighting each project's electricity tariff by its share of the aggregate capacity of the projects*
- j) *Weighted Average PPA Tenor has been calculated by assigning weights based on the respective project capacities (MW).*
- k) *Operational IPP Capacity is the total operational installed project capacity*
- l) *Year-on-Year Growth in IPP Capacity means change in operational IPP capacity from the previous financial year, expressed as a percentage of the previous financial year's operational IPP capacity*
- m) *Module Capacity means aggregating the rated production capacity of the module, expressed in GW.*
- n) *Module order book stands for capacity contracted*

8 Challenges and threats for the sector

Threats

- Any adverse shift in government policies, including reductions in incentives or changes in energy regulations, can significantly impact renewable player's revenue and profitability. However, considering the COP commitment, climate change ambitions and government push for RE, the chances of drastic changes in regulatory regime are less likely. This can also be ascertained from the fact that as against capacity addition of ~129 GW of RE, only ~22 GW of conventional capacity has been added over the last 5 years (FY21 to FY26).
- There were some delays in signing PSAs having higher tariffs by Discoms due to declining tariffs in subsequent tenders. However, with the government's plan for stricter adherence to renewable purchase obligations (RPOs), higher penalties in case of non-compliance, and revision of tariff in manufacturing-linked tenders, PSA signing activity improved during fiscal 2022 onwards.
- There are only a few states which are complying with the RPO obligations fully and there has been limited enforcement on obligated entities - discoms and open access and captive power users - to meet RPO targets. The proposed amendment to the Electricity Act 2003 has stipulated a penalty on RPO non-compliance and uniform imposition of penalties and strict enforcement would be critical for significant improvement and fair distribution of RPO compliance across states.
- The solar power industry is currently facing cost pressures on account of volatility in module prices, exchange rates, freight, and commodity prices. This may impact on the EPC margin of renewable players as they may not be able to pass on the cost increase to project developing SPVs.
- The RE sector is highly competitive, with numerous players vying for market share. Established competitors along with capable new entrants can pose challenges. Climate change and extreme weather events can affect the performance and reliability of renewable energy systems, potentially leading to disruptions or damage to infrastructure. Further, economic downturns and financial instability can reduce capital available and increase costs for renewable energy investments, affecting the renewable player's expansion plans.

Challenges:

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

- Green Energy Corridor Scheme and Renewable Energy Zones expected to add ~80 GW of transmission grid capacity taking it to more than 100 GW for RE projects. This will give comfort against the planned capacity additions in renewable energy segment.

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Crisil Limited: Lightbridge IT Park, Saki Vihar Road, Andheri East, Mumbai - 400 072, India

Phone: + 91 22 6137 3000 | Fax: + 91 22 3342 3001 | www.crisil.com

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