Crisil Intelligence

Saatvik Green Energy Limited

Strategic assessment of renewable energy market in India

Final report

August 2025

by S&P Global

Crisil Intelligence

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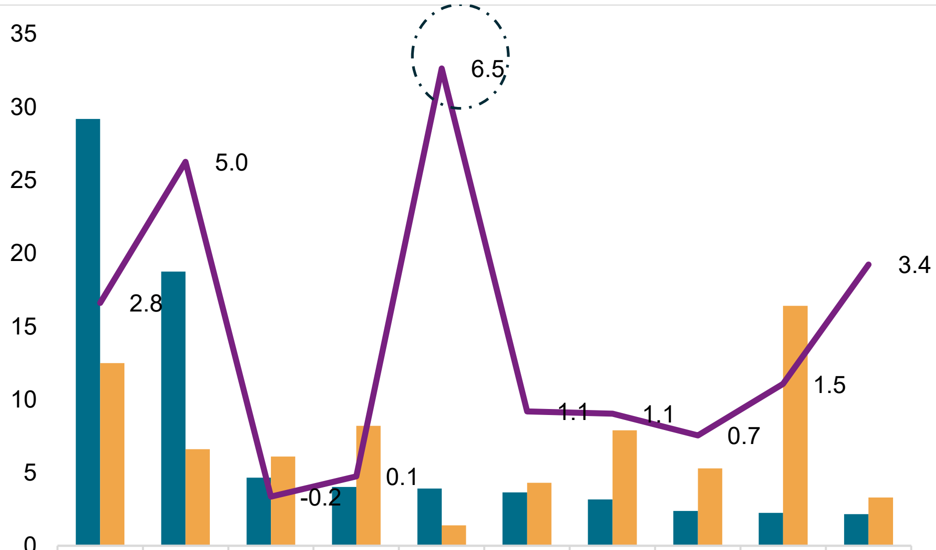
1.1 Economic indicators

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

India is expected to become the fourth largest economy in the world in fiscal 2026, according to the International Monetary Fund's (IMF) World Economic Outlook (April 2025). As per IMF GDP Forecasts, India's GDP growth is estimated at 6.2% in fiscal 2026 and 6.3% in fiscal 2027, the highest amongst the top 10 economies. Additionally, World Bank has estimated India's GDP to grow at 6.3% in fiscal 2026.

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



	United States	China	Germany	Japan	India*	United Kingdom	France	Italy	Canada	Brazil
Nominal GDP (Tn USD) CY24	29.2	18.7	4.7	4.0	3.9	3.6	3.2	2.4	2.2	2.2
Per capita electricity consumption 2023 (MWh)	12.5	6.6	6.1	8.2	1.4	4.3	7.9	5.3	16.4	3.3
Real GDP Growth CY24 (in %)	2.8	5.0	-0.2	0.1	6.5	1.1	1.1	0.7	1.5	3.4

** India GDP data as per NSO for Financial Year 2024,*

Source: World Economic Outlook Database (April 25) by IMF; IEA, CEA, Crisil Intelligence

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

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

Year	India*	Brazil	Canada	China	France	Germany	Italy	Japan	United Kingdom	United States
CY19	3.9	1.2	1.9	6.1	2.1	1.0	0.4	-0.4	1.6	2.6
CY20	-5.8	-3.3	-5.0	2.3	-7.6	-4.1	-8.9	-4.2	-10.3	-2.2
CY21	9.7	4.8	6.0	8.6	6.8	3.7	8.9	2.7	8.6	6.1

Year	India*	Brazil	Canada	China	France	Germany	Italy	Japan	United Kingdom	United States
CY22	7.6	3.0	4.2	3.1	2.6	1.4	4.8	0.9	4.8	2.5
CY23	9.2	3.2	1.5	5.4	1.1	-0.3	0.7	1.5	0.4	2.9
CY24	6.5	3.4	1.5	5.0	1.1	-0.2	0.7	0.1	1.1	2.8
CY25	6.2	2.0	1.4	4.0	0.6	-0.1	0.4	0.6	1.1	1.8
CY26	6.3	2.0	1.6	4.0	1.0	0.9	0.8	0.6	1.4	1.7
CY27	6.5	2.2	1.7	4.2	1.2	1.5	0.6	0.6	1.5	2.0
CY28	6.5	2.3	1.6	4.1	1.3	1.2	0.7	0.6	1.5	2.1
CY29	6.5	2.4	1.6	3.7	1.2	1.0	0.7	0.5	1.4	2.1
CY30	6.5	2.5	1.5	3.4	1.2	0.7	0.7	0.5	1.4	2.1
CAGR(CY19-24)	6.7	2.1	4.1	4.7	2.8	3.1	3.1	- 3.3	5.1	6.0
CAGR(CY25-30)	6.6	3.4	3.0	4.0	2.1	2.1	1.8	2.2	3.5	2.7

**India GDP data as of February 2025 for Financial Year,*
Source: World Economic Outlook Database (April-2025) by IMF; Crisil Intelligence

In April 2025, the IMF released World Economic Outlook (WEO). As per the IMF, Economic activity was resilient through the global disinflation of calendar year (CY) 2022–23. Further, as per WEO (April-2025), the IMF estimated global growth to drop to 2.8% in 2025 and 3% in 2026—down from 3.3% for both years in the January 2025 WEO Update. For India, the growth outlook is relatively more stable at 6.2% in fiscal 2026, supported by private consumption, particularly in rural areas, but this rate is 0.3% point lower than that in the January 2025 WEO Update on account of higher levels of geopolitics and conflicts.

1.2 India's GDP recovered with subsiding of the pandemic

In the past 11 years (during fiscal 2014 to 2025), India's GDP at constant (fiscal 2012) prices grew at a compounded growth of ~6.3% (CAGR).

After strong GDP print in the past three years, Crisil Intelligence[1] expects stable growth to 6.5% this fiscal 2026. The growth will be near to the pre-pandemic decadal average of 6.7%, continuing to position India as the fastest growing major economy.

Figure 2: CRISIL's key projections

Parameters	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26E
CAD/GDP (%)	-1.8%	-2.1%	-0.9%	0.9%	-1.2%	-2.0%	-0.7%	-1.0%	-1.3%
CPI (%, average)	3.6%	3.4%	4.8%	6.2%	5.5%	6.7%	5.4%	4.6%	4.0%
Exchange rate (Rs/$ March-end)	65.0	69.5	74.4	72.8	76.2	82.3	83.0	86.6	87.5
10-year G-sec yield (%, March-end)	7.6%	7.5%	6.2%	6.2%	6.8%	7.4%	7.0%	6.7%	6.3%
FAD/GDP (%)	3.5%	3.4%	4.6%	9.2%	6.7%	6.4%	5.6%	4.8%	4.4%
GDP growth (%)	6.8%	6.5%	3.9%	-5.8%	9.7%	7.0%	8.2%	6.5%	6.5%

E: Estimated; CPI: Consumer Price Index-linked; CAD: Current account deficit; G-sec: Government security; FAD: Fiscal account deficit
Source: CSO, Reserve Bank of India (RBI), CRISIL Intelligence estimates

Investments, a key factor that boosts growth, are expected to moderate as the government focuses on fiscal consolidation. The extent of revival in private investment cycle will determine the investment momentum this

[1] Based on CRISIL Centre for Economic Research (C-CER) projections
Projections of key economic indicators for India in this Chapter are as per the C-CER

fiscal. The other strong segment, urban demand, could moderate as credit conditions tightened this year. Transmission of past rate hikes to broader lending rates remains incomplete.

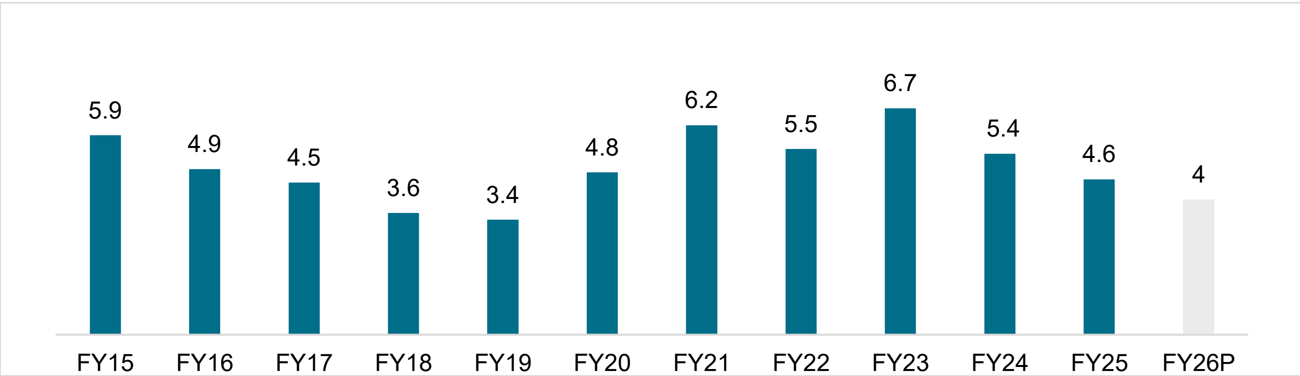
Crisil Intelligence expects a normalisation of the net indirect tax impact on GDP, after strong growth in the last fiscal. Slower global growth can restrict the upside to goods exports owing to normalisation of supply chains and an expected pick-up in volume of trade in calendar 2024. S&P Global expects global GDP growth to slow to 2.9% in 2025 from 3.3% the previous year, weighed by interest rates staying elevated for longer. Any spike in the prices of commodities — particularly crude oil — remains a risk for the country's growth. Overall, Crisil Intelligence expects India's real GDP to grow 6.5% in fiscal 2026, compared with 6.5% past fiscal projected by NSO.

1.3 Outlook

1.3.1 Consumer price index

Crisil Intelligence expects CPI inflation to moderate to 4.0% in fiscal 2026 from 4.6% this fiscal 2025. A sharper-than-expected weakening in the rupee, price shock to global oil prices due to any geopolitical turmoil and risks from climate change could impose upside pressures on the forecast.

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

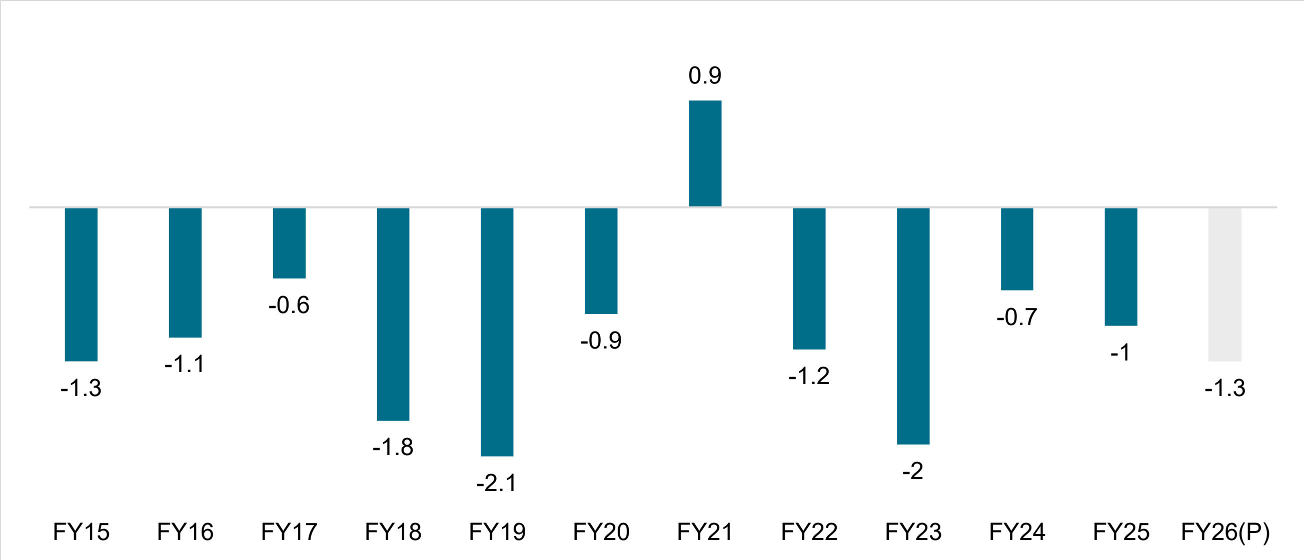


Source: NSO, CEIC, Crisil Intelligence

1.3.2 Current account deficit

India's current account deficit (CAD) was largely stable at $11.5 billion (1.1% of gross domestic product, or GDP) in the third quarter (Q3; October-December) of fiscal 2025 compared with $10.4 billion (1.1% of GDP) in the corresponding quarter a year-ago. Crisil Intelligence expects CAD at ~1.3% of GDP in fiscal 2026, as against 1% of GDP in fiscal 2025. The impact of geopolitical issues will remain a monitorable.

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



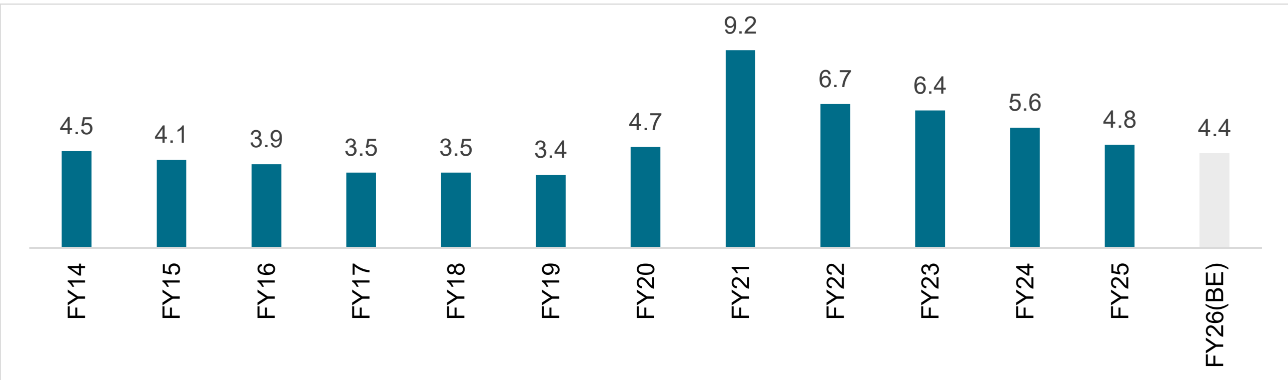
Negative: current account deficit; Positive: current account surplus
P: Projected
Source: RBI, SBI, Crisil Intelligence

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 2024 stood at 5.6% of the GDP was better than previous estimates of 5.8% on account of higher revenue realisation and lower expenditure according to data released by the Controller General of Accounts (CGA) on May 31, 2024. In actual terms, the fiscal deficit--the gap between expenditure and revenue, was at Rs. 16.53 trillion.

Gross market borrowings have been revised upward to ₹148.2 trillion for fiscal 2026 from ₹140 trillion estimated for fiscal 2025. Fiscal deficit is estimated to be 4.4% of GDP for fiscal 2026 as compared to 4.8% of the GDP estimated for fiscal 2025.

Figure 5: Fiscal Deficit as % of the GDP



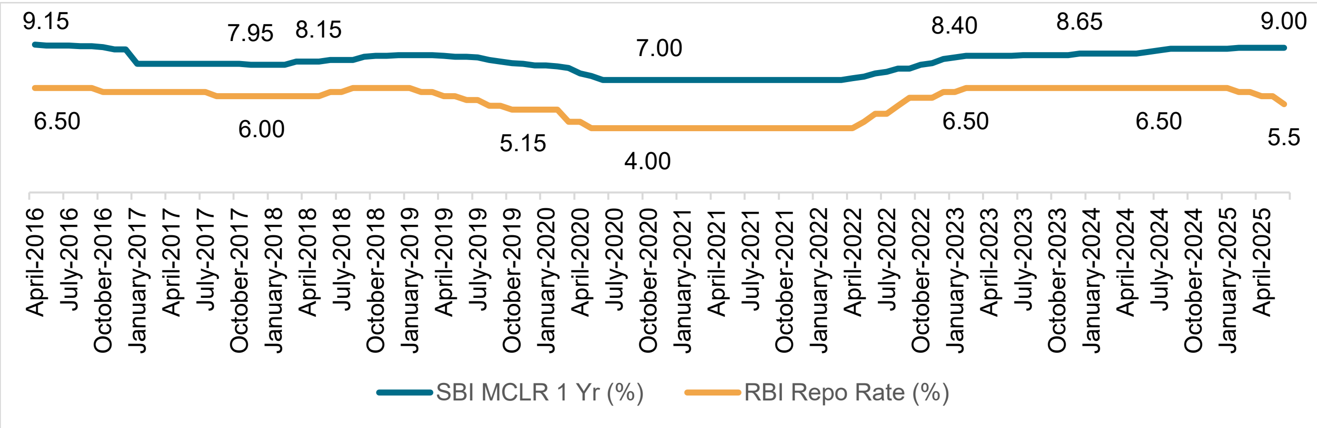
BE: Budgeted Estimates
Source: RBI, Provisional Accounts for 2023- 2024 by Controller General of Accounts, Crisil Intelligence

1.3.4 Interest Rates

Focused on paring inflation towards its 4% target and comforted by high GDP growth, the Monetary Policy Committee (MPC) has reduced the repo rate by 50 basis points bringing down the interest rate to 5.50% at its June 2025 meeting. There is uncertainty on the crude oil price front amid geopolitical uncertainties. Hence, the MPC retained its forecast for CPI inflation at 4.0% for the fiscal 2026. Softer crude oil prices and moderation in domestic growth has kept the trade deficit in check and it was ~ 0.6% of GDP in fiscal 2025 and is expected to remain at ~1.3% of GDP in fiscal 2026 due to surplus in services and healthy remittances.

Crisil Intelligence expects monetary easing to continue in fiscal 2026 in the form of rate cuts and liquidity support. Thus, Crisil Intelligence believes, will support India's GDP growth and offset some of the impact of the global tariff tensions.

Figure 6: Interest rates increasing (%)

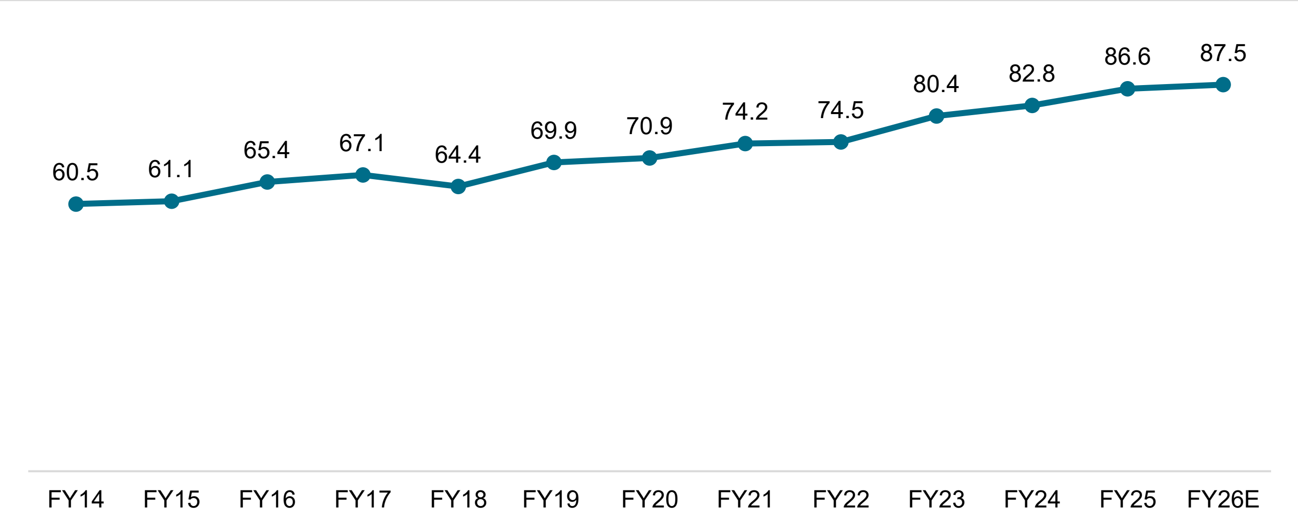


Source: RBI, SBI, Crisil Intelligence

1.3.5 Currency

US Dollar to Indian Rupee Exchange Rate was at around INR 86.6 as of March 2025 (annual average) up from INR 82.8 one year ago. This is a change of ~4.6% from one year ago. The rupee depreciated ~2.8 % on-year in June 2026. The depreciation in some emerging market currencies was sharper, including the Turkish lira (21.2% on-year) and Brazilian real (3% on-year). Crisil Intelligence expects the rupee to average to ~ INR 87.5 against the dollar by March 2026. While the current account deficit is expected to remain manageable, it could face some risks due to disruptions in global growth and geopolitical uncertainties. However, India's healthy macroeconomic parameters will provide some cushion to the rupee. We believe the pressure on the rupee will ease once the uncertainty around US tariffs reduces.

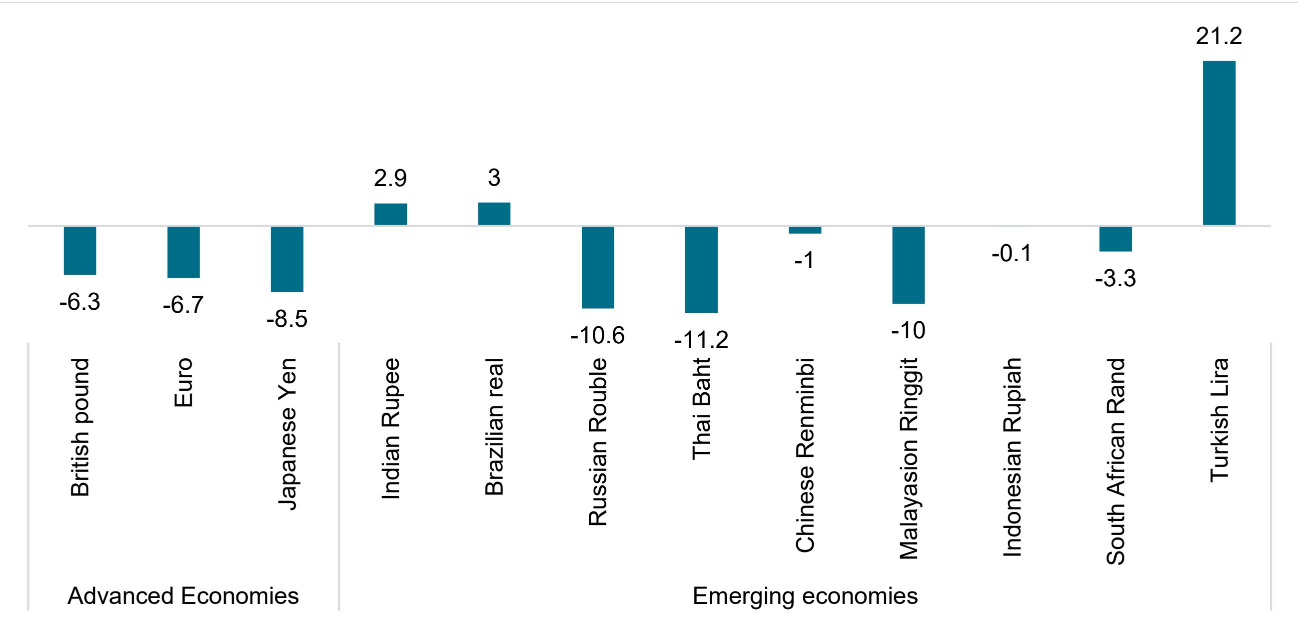
Figure 7: Exchange rates USD and INR



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

Most emerging market currencies appreciated against the dollar in June, barring the Indian rupee, Brazilian real and Turkish Lira. Among advanced economies, the British pound, euro and Japanese yen appreciated on month.

Figure 8: Major currencies vs dollar % y-o-y (As of June 2025)



Note: Positive growth indicates depreciation, negative indicates appreciation

Source: CEIC, Crisil Intelligence

1.4 Overview of other demographic factors

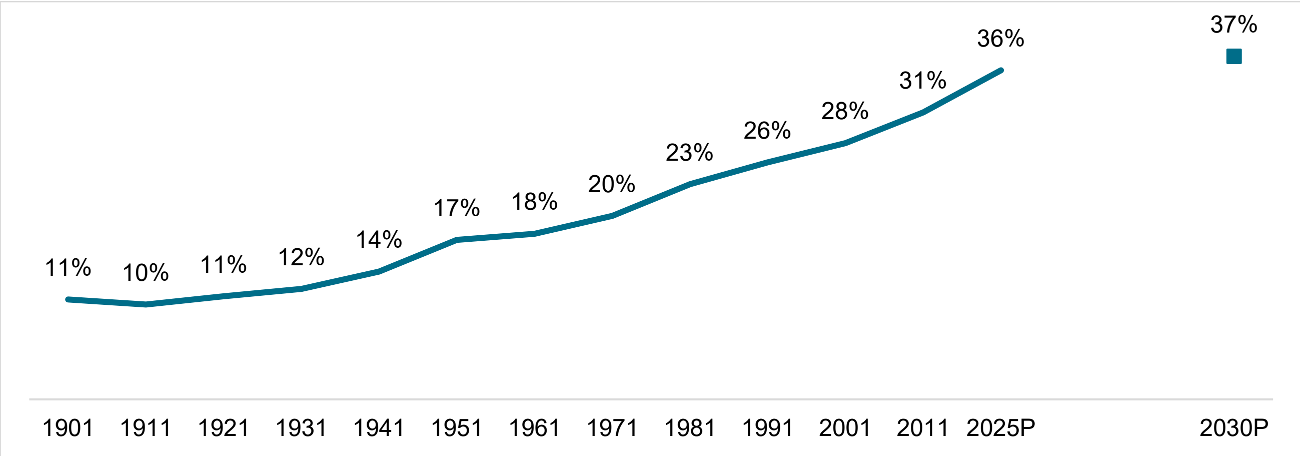
1.4.1 Urbanisation

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 37% 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 9: Urban population as a % of total population of India



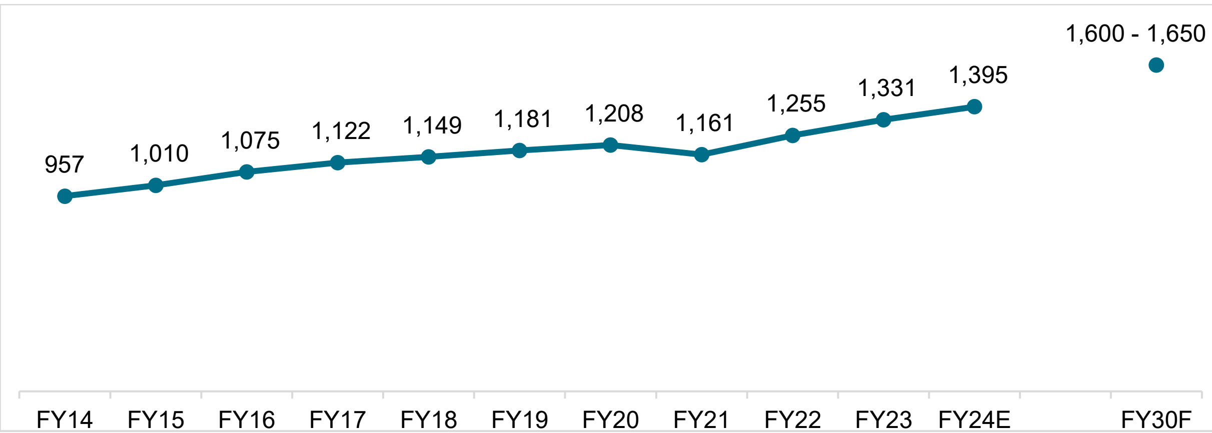
P: Projected

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 1,395 kWh in fiscal 2024 (as per CEA's provisional data), from 1,010 kWh in fiscal 2015 at a CAGR of 3.65%, 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 a similar trend witnessed in fiscal 2023 and 2024. Similarly, the energy requirement grew at 4.8% CAGR over fiscals 2015 to 2024 i.e. from 1,069 BUs to 1,627 BUs.

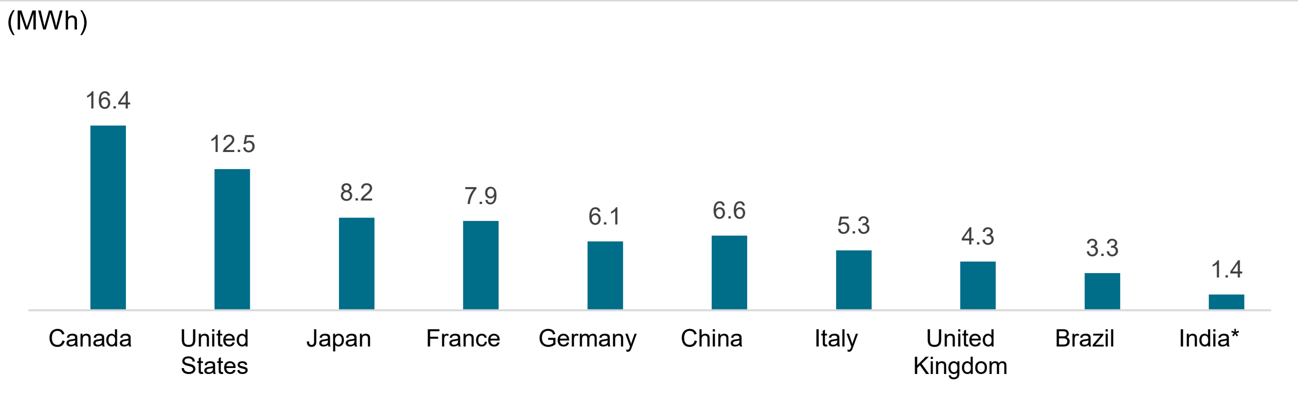
Figure 10: Per capita electricity consumption (in kWh)



E: Estimated; F: Forecast
Source: Central Electricity Authority of India (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 11: Per capita electricity consumption 2023



** As per Central Electricity Authority of India (CEA); Source: World Bank, IMF, EIA, Crisil Intelligence*

Between fiscals 2023 and 2029, it is expected that India's per capita electricity consumption is expected to grow at ~5-7% CAGR to reach 1,600-1,650 kWh by fiscal 2029 on the back of improvement in access to electricity, in terms of quality and reliability, rising per capita income, increasing EV penetration, railway electrification, on account of intensive rural electrification, resulting in realisation of latent demand from the residential segment, increased penetration of consumer durables.

1.5 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 2: Sector-wise focus of *Aatmanirbhar Bharat* Vision

Sector	Government spends	Key schemes
Renewable energy	~Rs 1300 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 PLI.

Sector	Government spends	Key schemes
		• 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. • 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, 2026 • Approved Models & Manufacturers of Solar Photovoltaic Modules (Requirement for Compulsory Registration) Order, 2019 • List of manufacturers and models of solar PV modules recommended under ALMM Order • Scheme of grid connected wind-solar hybrid power projects • Basic customs duty (BCD) of 25% on solar cells and 40% on modules, respectively, effective April 1, 2022 which subsequently revised to 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%.
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. 370 billion	• Rs 181 billion under PLI scheme for Advanced Chemistry Cell (ACC) Battery Storage in India launched in October to achieve 50 GWh manufacturing capacity • Green Hydrogen Policy launched in February 2022 to facilitate production of green hydrogen/green ammonia • PLI scheme on green hydrogen manufacturing with an initial outlay of Rs 197.44 billion with an aim to boost domestic production of green hydrogen
Nuclear energy	INR 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

1.6 Overview of global economy

After reopening, the global economy showed tremendous resilience, with sharp growth in 2021. However, in 2022, the economy faced multiple challenges, including the Russia-Ukraine war, inflation, slowdowns in the United States and Europe, and supply chain issues. These factors moderated in 2023, resulting in a global real GDP growth rate of 3.3%. The global economy maintained the same growth rate at 3.3% in 2024 and is projected to drop to 3.0% in 2025 and 3.1% 2026.

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.

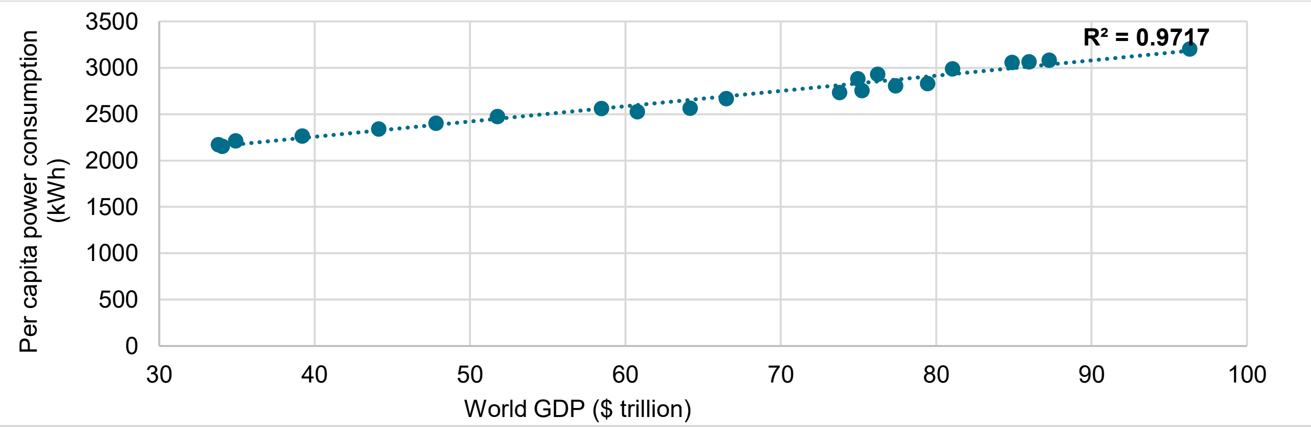
Global growth is estimated to have stabilized at 2.7 percent in 2024 and is forecast to hold steady at that pace over 2025–26, according to the Global Economic Prospects Report by World Bank. However, the pace of growth appears insufficient to offset the damage done to the global economy by several years of successive negative shocks, with particularly detrimental outcomes in the most vulnerable economies. From a longer-term perspective, catch-up toward advanced-economy income levels has steadily weakened across emerging market and developing economies (EMDEs) over the first quarter of the twenty-first century. Progress in reducing extreme poverty has also slowed markedly. Heightened policy uncertainty and adverse trade policy shifts represent key downside risks to the outlook. The global economy appears to be settling at a steady, albeit relatively subdued, rate of growth. Over 2025–26, decelerating growth in the United States and China is expected to be offset by firming growth elsewhere, including in many EMDEs. Overall, the global economy is projected to expand at a slower pace compared to the pre-pandemic decade.

1.7 Global correlation between GDP and per capita power consumption

Gross Domestic Product (GDP) is a standard measure of economic health of a country. If the evolution of GDP for a nation is plotted against energy consumption, both show a strong correlation. This is especially true for evolving economies where energy access is constrained. As the nation grows, industrialization and prosperity improve, thereby impacting per capita energy consumption. At some point, for industrialized countries, energy consumption per capita levels off, while GDP may continue to move upwards. Energy intensity grows as investments in the development of the energy sector shift to energy efficiency improvements. However, for developing nations, a direct causality between per capita energy consumption may be established.

With power being a large contributor of end-use energy, power consumption is supposedly a priori of the total energy consumption basket. The plot of per capita electricity consumption (world average) against world GDP for 2000-2021 shows a strong correlation of 0.9717.

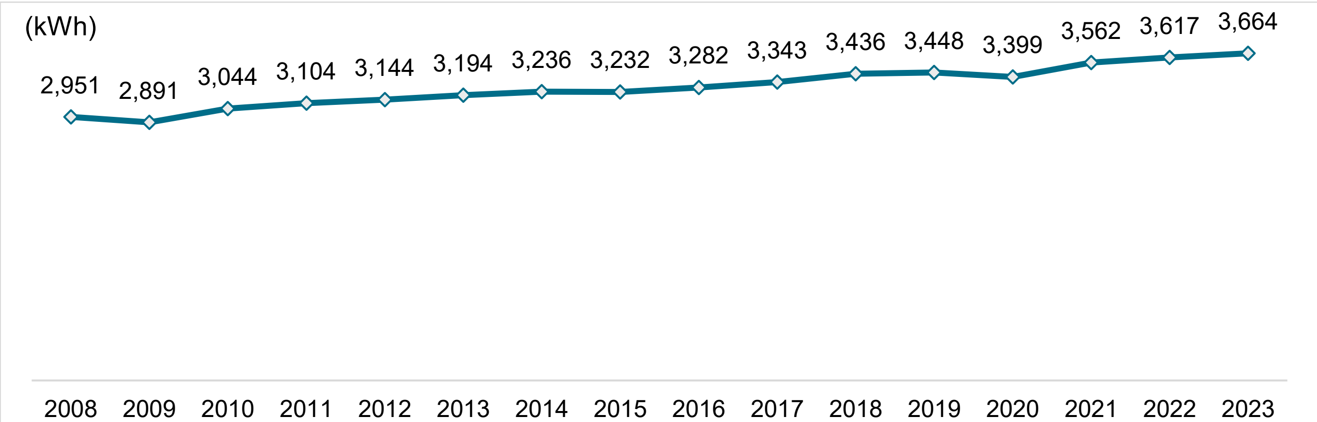
Figure 12: Correlation between GDP and per capita electricity consumption



Source: World Bank, IMF, EIA, UN, Crisil Intelligence

Per capita consumption has grown steadily at the global level led by developing nations. In developed nations, although total power usage has moved northwards, consumption on a per capita basis has remained firm owing to efficiency measures. On the other hand, developing nations have shown a strong uptick in per capita electricity usage as large-scale electrification programmes continue to connect rural areas and living conditions of the population improve. With millions still not connected to the electric grid, the uptick is expected to continue in the short to medium term.

Figure 13: Average Per capita electricity consumption: Global



As per the latest data published by EIA.
Source: World Bank, IMF, EIA, UN, Crisil Intelligence

1.8 Key global initiatives

1.8.1 RE 100

RE100 is a collaborative, global initiative of influential businesses committed to 100% renewable electricity, working to massively increase demand for and delivery of renewable energy. RE100 is brought by the Climate Group in partnership with CDP, as part of the We Mean Business coalition.

Various progressive companies are opting for 100% renewable energy and optimising the benefits of cost reduction and enhanced reputation. By doing so, they are also encouraging the global market for renewable energy and helping reduce emissions.

1.8.2 Green Grids Initiative – One Sun One World One Grid

In a big boost to accelerate global adoption of solar energy, United States of America (USA) has joined the ISA as a member country. The U.S became the 101st country to sign the framework agreement of the ISA to catalyze global energy transition through a solar-led approach.

The One Sun One World One Grid (OSOWOG) is a globally interconnected power grid project aimed at seamless sharing of renewable energy resources among countries for mutual benefits and global sustainability. MNRE is the programme support agency for the OSOWOG Initiative, ISA the nodal implementing agency, and the World Bank the strategic advisory and funding agency.

The idea for OSOWOG initiative was put forth by the Indian Prime Minister at the First Assembly of the ISA in October 2018. He had called for connecting solar energy supply across borders. In May 2021, the United Kingdom and India agreed to combine forces of the Green Grids Initiative and the One Sun One World One Grid initiative and jointly launch GGI-OSOWOG at the COP26 summit at Glasgow in November 2021. The Prime Minister of

India has launched the Green Grids Initiative—One Sun One World One Grid (GGI-OSOWOG), the first international network of global interconnected solar power grids, jointly with Prime Minister of UK at COP26.

OSOWOG will not only reduce storage needs but also enhance the viability of solar projects. The OSOWOG will not only reduce carbon footprints and energy costs but also open a new avenue for cooperation between different countries and regions. This will be a very innovative, transformative initiative which will enable to meet the targets of the Paris Agreement. The end objective of this is to develop a global ecosystem of interconnected renewable energy resources that are seamlessly shared for mutual benefits and global sustainability.

1.8.3 COP 28

The 2023 United Nations Climate Change Conference (COP26) was held at Dubai, UAE during Nov-Dec 2023. COP 28 was important as it witnessed the conclusion of the first global stocktake of the world's efforts to address climate change under the Paris Agreement. This comprehensive review assessed the collective efforts in reducing emissions and adapting to climate change. The results state that the current action is falling short to achieve the Paris Agreement's goal.

Global Stocktake is a process for countries and stakeholders to see where they're collectively making progress towards meeting the goals of the Paris Climate Change Agreement. It helps in outlining bold actions for government to be undertaken for limiting global warming to 1.5 degrees Celsius target under control, securing lives and livelihoods. The stocktake concluded that global greenhouse gas emission needs to be cut by 43% by 2030 against 2019 emissions for limiting global warming to 1.5 degrees Celsius.

COP28 was a landmark event, as it saw a number of important decisions including-

- Signaling the beginning of the end for the fossil fuel era.
- Funding arrangement for addressing loss and damage with an initial pledge of $792 million.
- Ambitious reduction targets, 43% by 2030 and 60% by 2030 to 2019 emission levels.
- A pledge to triple renewable energy capacity and double the global rate of energy efficiency by 2030.
- Signing of Oil and gas decarbonization charter by companies representing 40% global production. Below are the three main aims:
    - to achieve net zero emissions in each company's direct operations by or before 2050.
    - to achieve near-zero methane leakage from the production of oil and gas by 2030.
    - to achieve zero routine flaring (burning excess gas) by 2030.

India has updated NDC working towards climate justice at COP28. Some of the initiatives are:

- To reduce Emissions Intensity of its GDP by 45 percent by 2030, from 2005 level
- To achieve about 50 percent cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030.
- Launching of Green Credit Initiative which will encourage voluntary environmental positive actions resulting in the issuance of green credits.

These are more ambitious and way beyond the current NDCs agreed under the Paris Agreement. These will provide a new thrust to the RE Sector in India and will boost the already accelerating RE Sector. These will also provide guidelines to the Regulators as well as Government Authorities while setting the rules, regulations, and targets.

India is expected to have 500 GW non fossil fuel-based capacity installed by 2030. The estimated total installed capacity of India is expected to reach to 777 GW by March 2030. At present India meets only ~15-20% of its power requirement from renewable energy. Similarly, the estimated energy requirement of India will be around 2325 BUs by March 2030. The revised target is 50% of its energy requirements from renewable energy by 2030.

However, to achieve such an ambitious target, a whole host of innovative policies and financing measures will need to be adopted. Further, to accommodate such a high proportion of variable generation in the overall energy mix, there will be a need for additional investment in battery storage and green energy corridors for transmission of variable renewable energy. Given the thrust on RE capacity addition and energy efficiency measures, the emissions intensity is expected to decline. However, with revised targets, more efforts will be required in all these areas as well as non-energy sectors such as agriculture and land use.

1.9 Global policy push towards clean energy

Country	Policy Component	Details
China	Tax Incentives	Preferential 15 per cent corporate tax rate applicable to High and New Technology Enterprises (HNTE) and a 50 per cent deduction for qualifying R&D expenditure. Additionally, HNTE can also claim a two-year tax holiday followed by a 12.5 per cent corporate tax rate for 3 years.
Japan	Feed-in-tariff	The latest feed in tariffs unveiled in February 2022 are set at $0.096/kWh for 10-50 KW; $0.087/kWh for 50kW-250kW PV projects & above 250 kW to compete in auctions.
UK	Contract for Difference (CfD)	A policy which enables a contract between an RE generator and the 'Low Carbons Contract Company' (LCCC). The LCCC pays the generator the difference between the 'strike price' and the 'reference price'. The ‘Strike price' is a pre-determined set under the contract depending on the costs incurred in investing in RE technology and the 'reference price' is the average price of electricity in the Great Britain power market. If strike price is above the reference price the LCCC will compensate the generator and vice versa.
UK	Renewables Obligation Scheme (prior to March 2017)	The RO that came into effect in 2002 in England and Wales, and Scotland, places an obligation on UK electricity suppliers to source an increasing proportion of the electricity they supply from renewable sources. Operators can trade ROCs with other parties. ROCs are ultimately used by suppliers to demonstrate that they have met their obligation.
Germany	RE Auctions replace FiT regime	Revisions to the Renewable Energy Sources Act (EEG) in 2023 targets solar PV expansion to 215 GW by 2030 and to 400 GW by 2040. The government also introduced reforms in 2022 and 2023, including streamlining permitting and lifting auction ceiling prices (by 25%) to reflect higher capital cost.
Germany	KfW Renewable Energies Program	KfW funding program to fund installation costs up to 100 per cent for various RE power installations.
USA	Business Energy Investment Tax Credit	A tax incentive provided by the federal government on solar installations including lighting systems. The rebate amount is 26% for two years till Jan 1, 2023 & 22% credit till 1 Jan 2024. For projects beginning construction on or before 1 Jan 2024 and not commissioned till 1 Jan 2026, the tax credit

Country	Policy Component	Details
		will be 10%. Also, recently US president has proposed to extend the tax credit for 10 years. US Inflation Reduction Act (IRA) has allocated ~$400 Bn for clean energy US IRA provides direct financial incentives for domestic manufacturers to increase their competitiveness with Chinese counterparts Tax credits provide financial incentives to both domestic solar demand and supply; However, the 30% Residential Clean Energy Credit would be terminated from midnight of 31 December 2025; Wind and solar facilities that begin construction after 1 year from enactment would be required to be placed in service by 31 December 2027 to receive tax credit for commercial and utility-scale projects under Section 48E.

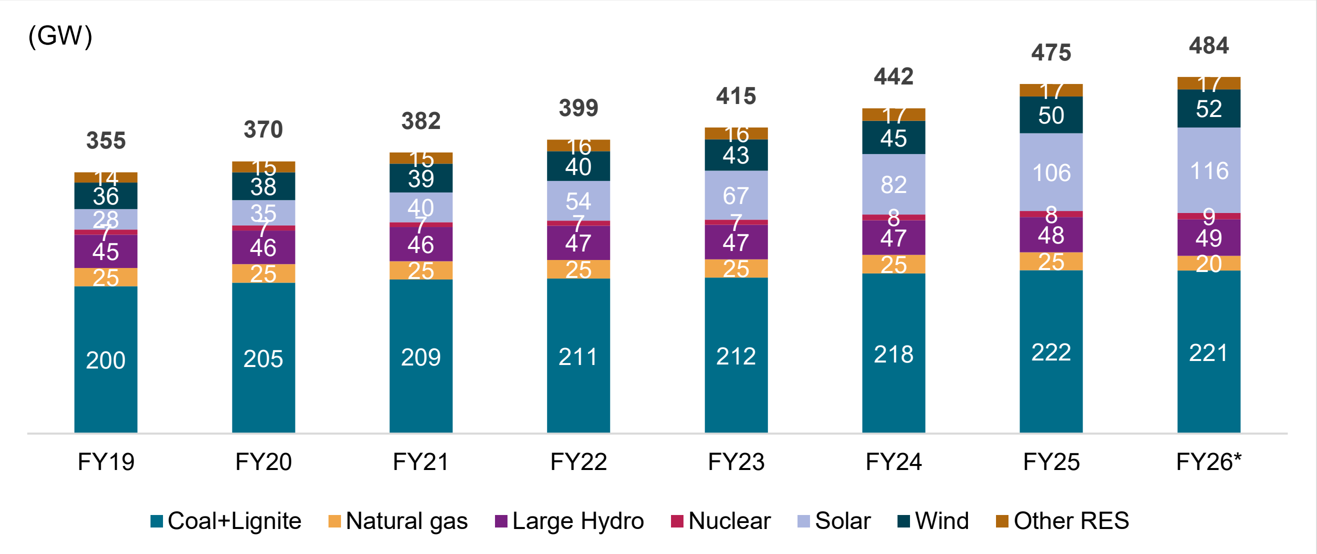
2 Indian power sector

2.1 Review of power demand supply scenario

2.1.1 Review of installed capacity and fuel mix

The total installed generation capacity as of March 2025 was 475 GW and 484 GW as of June 2025 (Q1 FY 2026), of which ~120 GW of capacity was added over fiscal 2019-25. The overall installed generation capacity has grown at a CAGR of ~ 5% over the same period.

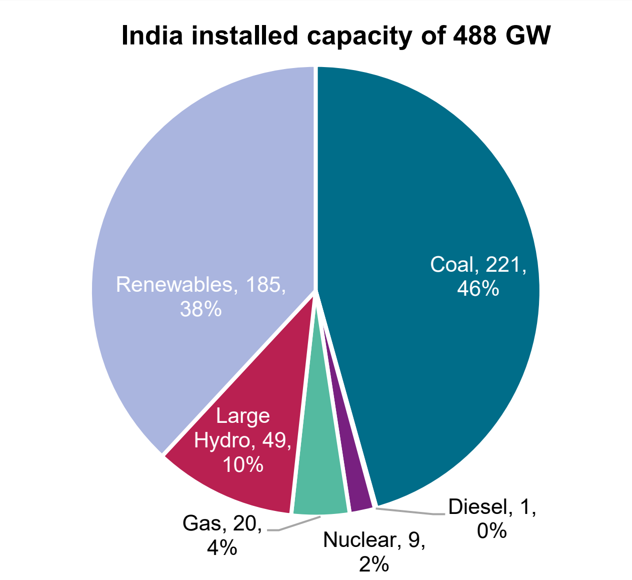
Figure 14: India Annual capacity additions and installed capacity

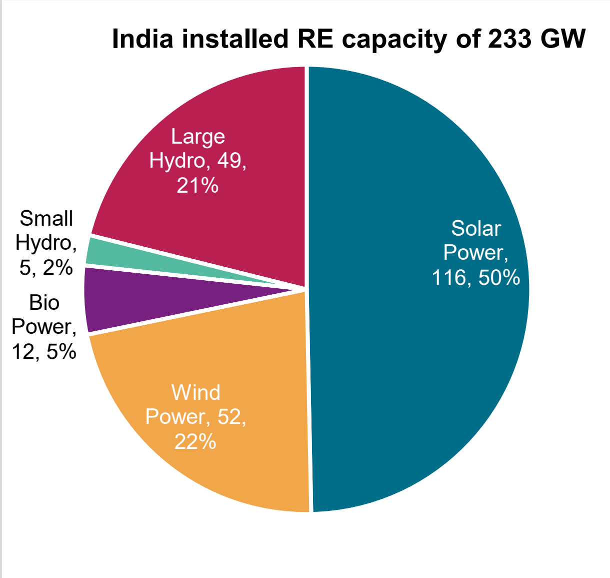


Other Renewable energy sources (RES) include biogas, bagasse, small hydro and waste-to-energy
**As of June 2025(Q1 FY 2026); Source: CEA, Crisil Intelligence*

The share of coal and lignite-based installed power generation capacity has reduced from ~56% in fiscal 2019 to ~45% as of June 2025. In the last few years, RE has been the focused area for capacity additions which is evident from the fact that RE installations (including large hydroelectric projects), have reached ~233 GW capacity as of June 2025, compared with 123 GW as of March 2019, constituting about ~ 48% of total installed generation capacity. This growth has been led by solar power, which rapidly rose to ~116 GW from 28 GW over the same period.

Figure 15: Breakup of installed capacity as of June 2025 (Q1 FY 2026) (GW, %)



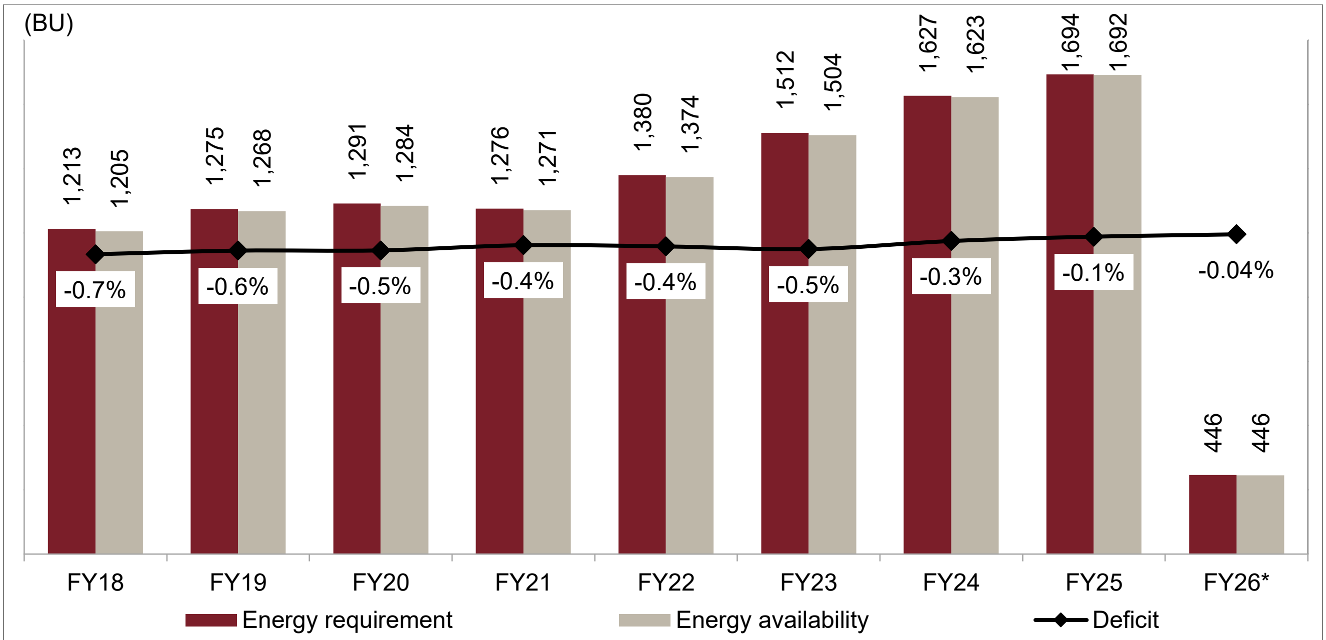


Source: CEA, Crisil Intelligence

2.1.2 Historical trends in power demand and energy requirement

India's electricity requirement and availability has risen at a CAGR of ~5.0% between fiscals 2019 and 2025. The energy deficit declined to 0.3% in fiscal 2024 and 0.1% in fiscal 2025 from 0.5% in fiscal 2019 due to an increase in capacity addition growth of ~5.0% over the same period. Strengthening of inter-regional power transmission capacity over the past five years has supported the rapid fall in deficit levels as it reduced supply constraints on account of congestion and lower transmission corridor availability, thereby lowering the deficit to 0.1% in fiscal 2025.

Figure 16: Aggregate power demand supply



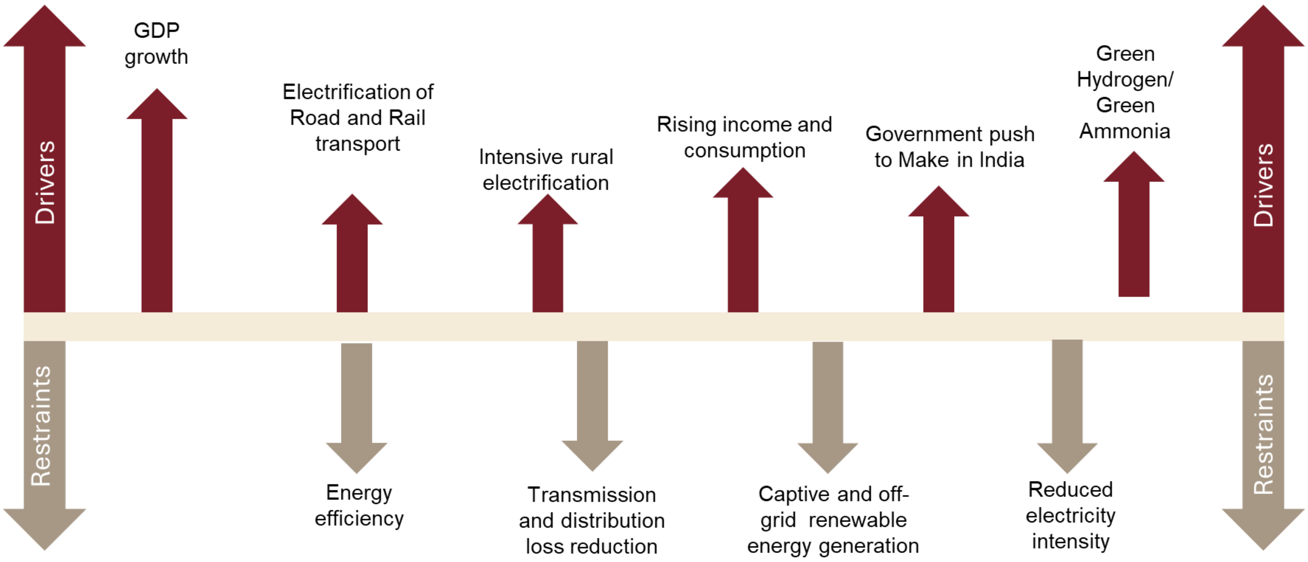
**As on June 2025 (Q1 FY 2026);Source: CEA, Crisil Intelligence*

2.2 Power demand supply outlook

2.2.1 Long term Demand drivers and constraints

Power demand is closely associated with a country's GDP. Healthy economic growth leads to growth in power demand. India is already the fastest-growing economy in the world, with an average GDP growth of 5.5% over the past decade. The trickle-down effect of government spending on infrastructure through the National Infrastructure Pipeline, expansion of the services industry, growing manufacturing industries, rapid urbanisation, data centres, Electric vehicles, and increased farm income from agriculture-related reforms are key macroeconomic factors that are expected to foster power demand. Significant policy initiatives such as 24x7 power for all, Sahaj Bijli Har Ghar Yojana (SAUBHAGYA) scheme provided electricity connections to all households, green energy corridor to facilitate evacuation of RE power, green city scheme to promote the development of sustainable and eco-friendly cities, PLI scheme and low corporate tax rates among others are expected to further support power demand in the country.

Figure 17: Factors influencing power demand



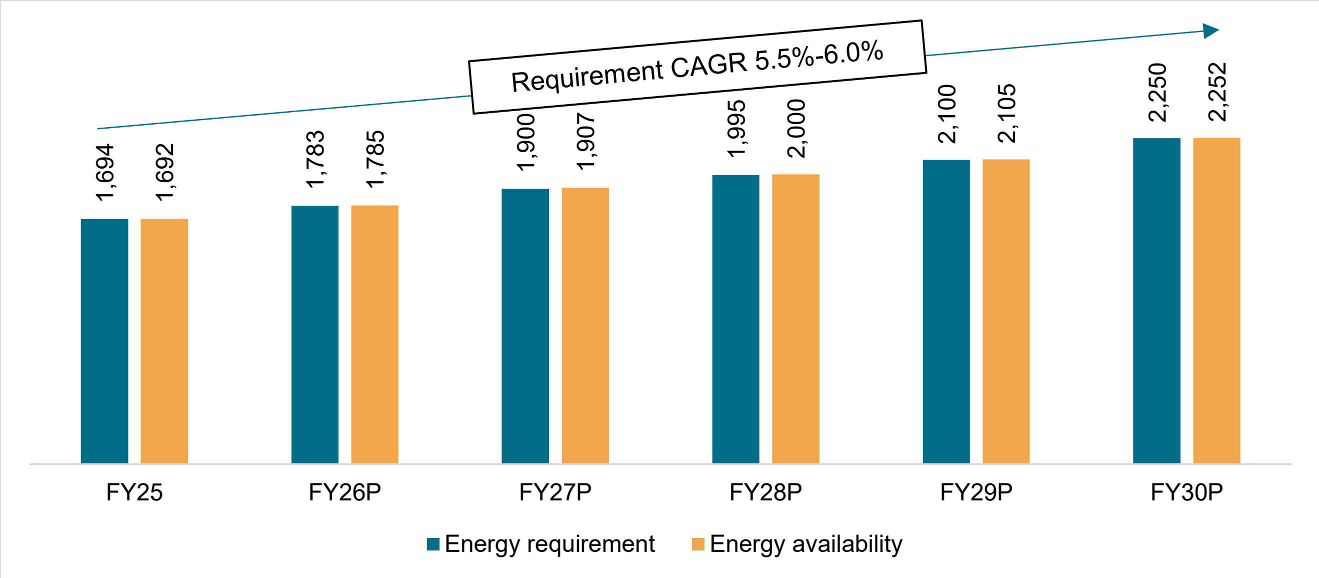
Source: Crisil Intelligence

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

2.2.2 Outlook on energy requirement and availability

Power demand maintained a strong growth momentum in fiscal 2023 logging a double-digit growth of ~10% albeit a moderate base of fiscal 2022 due to extreme seasonal vagaries, sustained buoyancy in economic activities along with robust industries activities accelerated power demand. In fiscal 2025, power demand surged 4.2% on year to 1,695 BU. This growth comes on the back of three consecutive high growth years starting from fiscal 2022 leading to an addition of 315 BU until 2025. Crisil Intelligence expects power demand to grow by 5.5-6.0% in the next five years which will be supported by infrastructure-linked capex, strong economic fundamentals along with expansion of the power footprint via strengthening of T&D infrastructure, coupled with major reforms initiated by the GoI for improving the overall health of the power sector, particularly that of state distribution utilities, are expected to improve the quality of power supply, thereby propelling power demand.

Figure 18: Energy demand outlook (fiscals 2026-30)



P: Projected, Source: CEA, Crisil Intelligence

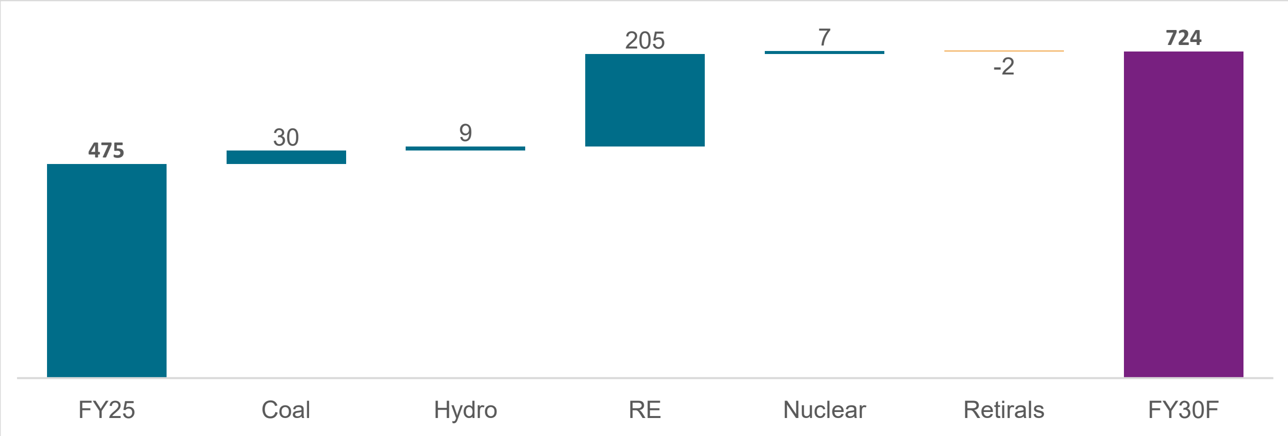
2.2.3 Capacity addition outlook

Capacity additions in the conventional power generation segment are projected to be around 28-31 GW from fiscals 2026 to 2030, driven by higher than decadal average power demand. Fresh project announcements are limited as players are opting for the inorganic route for expansion given the availability of assets at reasonable valuations. However, the need for generation capacity equipped for flexible operations to ramp up-down quickly is critical to meet peak demand as generation from renewable capacities is intermittent in nature. Crisil Intelligence expects 25-30 GW of coal-based power to be commissioned over fiscals 2026-30. Coal capacity additions are expected to be driven entirely by the central and state sectors, as major private gencos continue to focus on expanding RE capacity. Multiple outdated and inefficient coal plants, totaling ~ 10-15 GW, are due for retirement. However, as per notification from the Central Electricity Authority in January 2023 the power utilities are instructed to refrain from retiring any thermal units until 2030 and shall opt for renovation and maintenance to extend their lifespan.

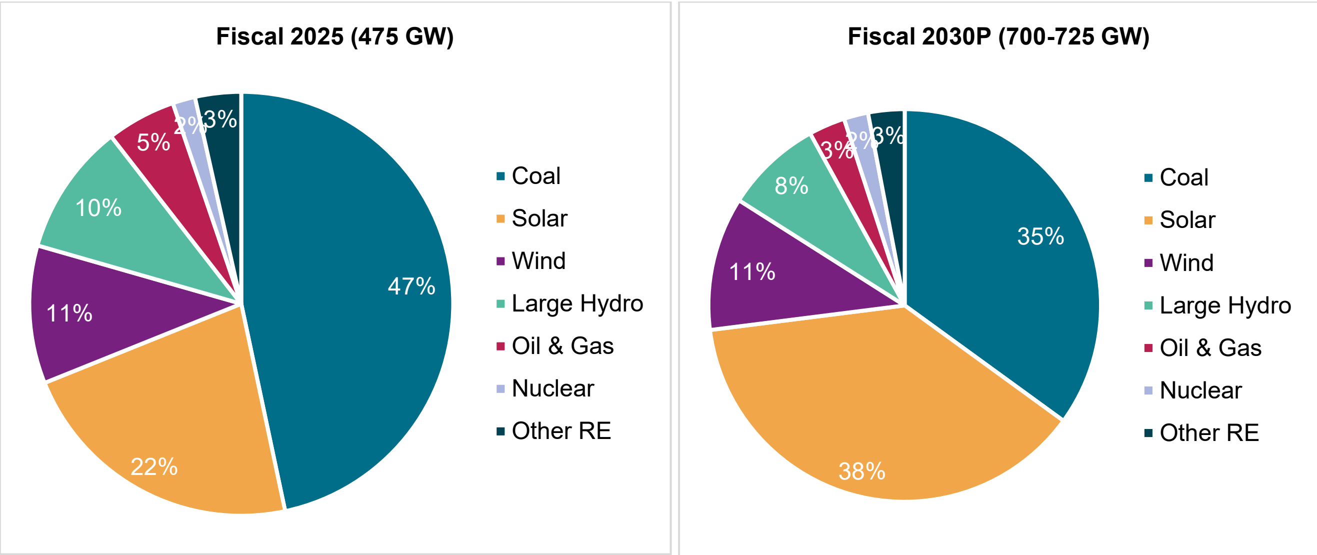
Nuclear power capacity additions of 5-7 GW are expected during the period as ongoing projects at Kakrapara, Kalpakkam, and Rajasthan are nearing completion. Nine reactors with a total capacity of 7.3 GW are under construction which are expected to be commissioned by 2030. Crisil Intelligence expects 16-18 GW of hydro power installations including 8.5-9.5 GW pumped hydro storage projects (PSP) capacity additions over fiscals 2025-2030.

The RE capacity addition of over 190-200 GW is expected to be installed between fiscal 2025-30 at a CAGR of 16-17% driven by various government initiatives, favourable policies, competitive tariffs, innovative tenders, development of solar parks and green energy corridors, etc. RE capacity is estimated to account for about 50% of the installed capacity of 700-710 GW by fiscal 2030. BESS capacity additions, aimed at storing renewable energy during off-peak hours of power demand to support peak supply, are expected to commission starting fiscal 2025, with 23-24 GW of BESS capacity likely to be added through fiscal 2030.

Figure 19: All India installed estimated capacity addition by fiscal 2030 (in GW)



F: Forecasted; RE includes solar, wind, small hydro, and other renewable sources
Source: CEA, Crisil Intelligence

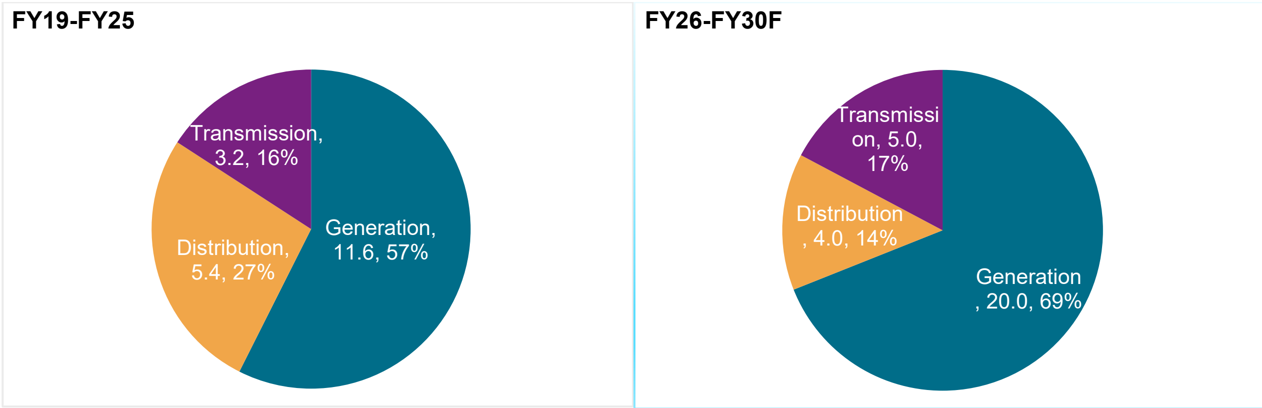


P: Projected; Source: CEA, Crisil Intelligence

2.3 Investments in generation, transmission, and distribution infrastructure

The total investments in the power sector between fiscal 2019-25 was about Rs. 20.2 trillion. Crisil Intelligence expects investments of Rs 29.0-30.0 trillion in the power sector over fiscal 2026-30. Generation segment investments are being driven by capacity additions with robust growth in RE installations followed by distribution investments led by the RDSS scheme.

Figure 20: Segment-wise break-up of total investments (Rs. Trillion, %)



F: Forecasted; Source: Crisil Intelligence

Investments in the generation segment are expected to be 1.7x from Rs ~11.6 trillion (over fiscals 2019-2025) to ~Rs 19-21 trillion (over fiscals 2026-30). Capacity addition from RE sources is expected to be 190-200 GW from fiscals 2026 to 2030 (including large hydro and ESS), and 25-30 GW from coal-based plants sources over the same period. Investments in RE capacity is expected to be Rs 13-15 trillion over the next five years, in line with capacity additions, which will constitute over 70% of overall generation investments. Investments in solar alone is expected to be approximately half of the RE investment, i.e., Rs. 9.0-10.0 trillion over the same period.

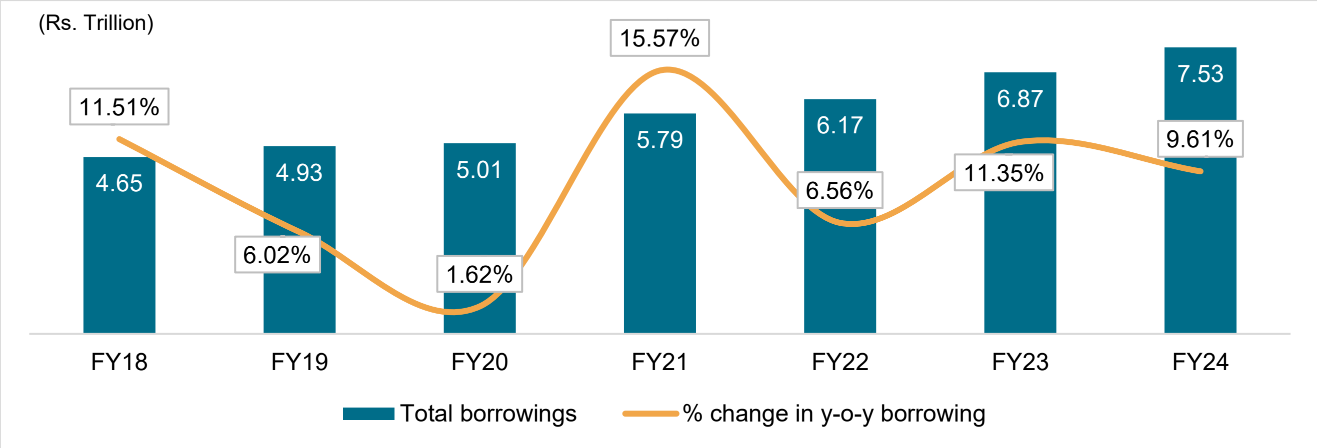
To achieve the RE generation target, strong transmission infrastructure is needed so as to integrate large scale RE capacities into the grid. This is expected to lead to transmission investments of Rs 4.5-5.5 trillion between fiscals 2026-2030 from ~Rs 3.2 trillion between fiscals 2019-2025 led by upcoming ISTS projects. The distribution segment is expected to attract investments worth Rs 3.5-4.5 trillion over fiscals 2026 to 2030 vis-à-vis ~Rs 5.4 trillion between fiscal 2019-2025. This is driven by the government's thrust on the RDSS scheme entailing an outlay of Rs 3.04 trillion for state discoms, to be allocated until fiscal 2026.

2.4 Financial position of transmission and distribution (T&D) sector entities

2.4.1 Current state of discom financial health

As per PFC's Report on Performance of Power Utilities for fiscal 2024, the aggregate losses for discoms decreased from Rs 594.97 billion in fiscal 2023 to Rs 255.53 billion in fiscal 2024. Total borrowings by distribution utilities increased from Rs 6,848.36 billion on March 31, 2023 to Rs 752.68 billion on March 31, 2024.

Figure 21: Total borrowings for discoms

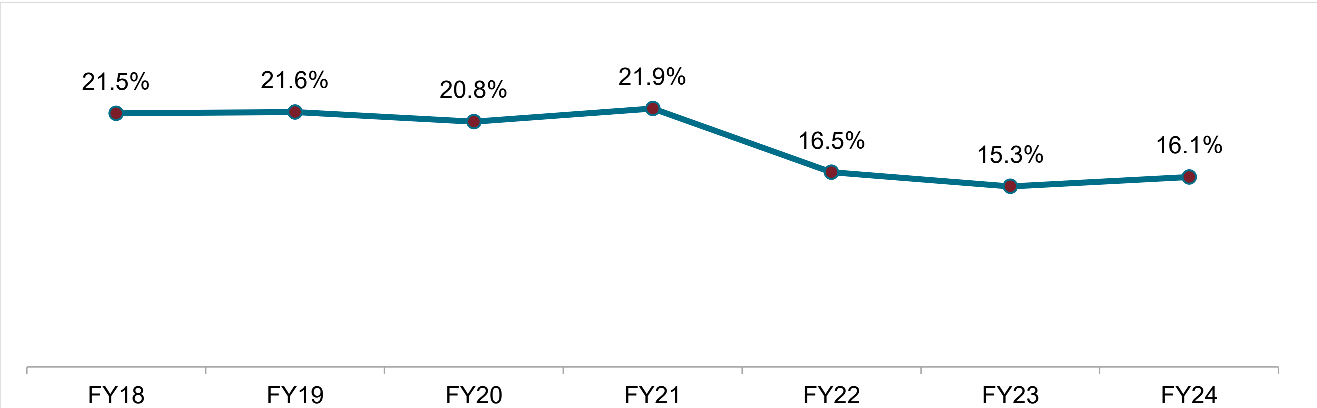


Source: MoP, PFC, Crisil Intelligence

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

The AT&C losses for distribution utilities improved from 21.9% in fiscal 2021 to 16.1% in fiscal 2024. Billing efficiency improved marginally from 86.8% to 86.9% in fiscal 2024. However, the collection efficiency decreased by 1.1% from 97.6% in fiscal 2023 to 96.5% in fiscal 2024 which has led to an increase in AT&C loss in fiscal 2024 to 16.1%.

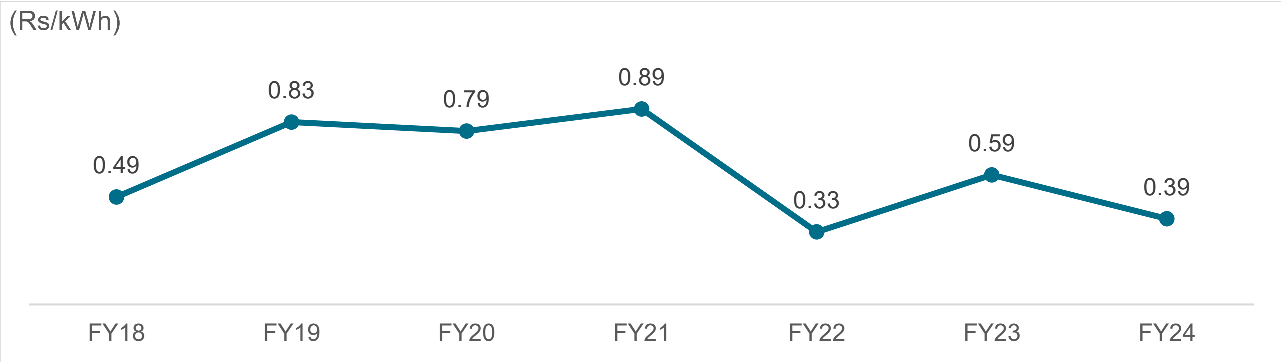
Figure 22: AT&C loss trajectory (%)



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 2023, the gap again increased to Rs 0.59/kWh due to an increase in power purchase cost. However, during fiscal 2024, the gap decreased by Rs. 0.20/kWh to Rs 0.39/kWh.

Figure 23: ACS-ARR gap



Source: PFC, Crisil Intelligence

2.4.3 LPS rules helped regularization of payment to IPPs by Discoms

MoP vide Gazette Notification dated 3rd June' 2022, notified "The Electricity (Late Payment Surcharge and Related Matters) Rules, 2022" (LPS Rules) to address cash flow challenges faced mainly by generation companies (gencos) and transmission companies (transcos) and to promote timely payments across the power sector. These rules provide a mechanism for settlement of outstanding dues of gencos, ISTS Licensees and Electricity Trading Licensees. The rules provisioned for converting discoms' outstanding dues to these companies into equated monthly instalments for gradual liquidation of these dues. Further, to promote timely payment of current power bills, the power supply would be regulated for discoms that fail to clear their bills one month after the due date of payment or two-and-a-half months after the presentation of the bill by the generating company.

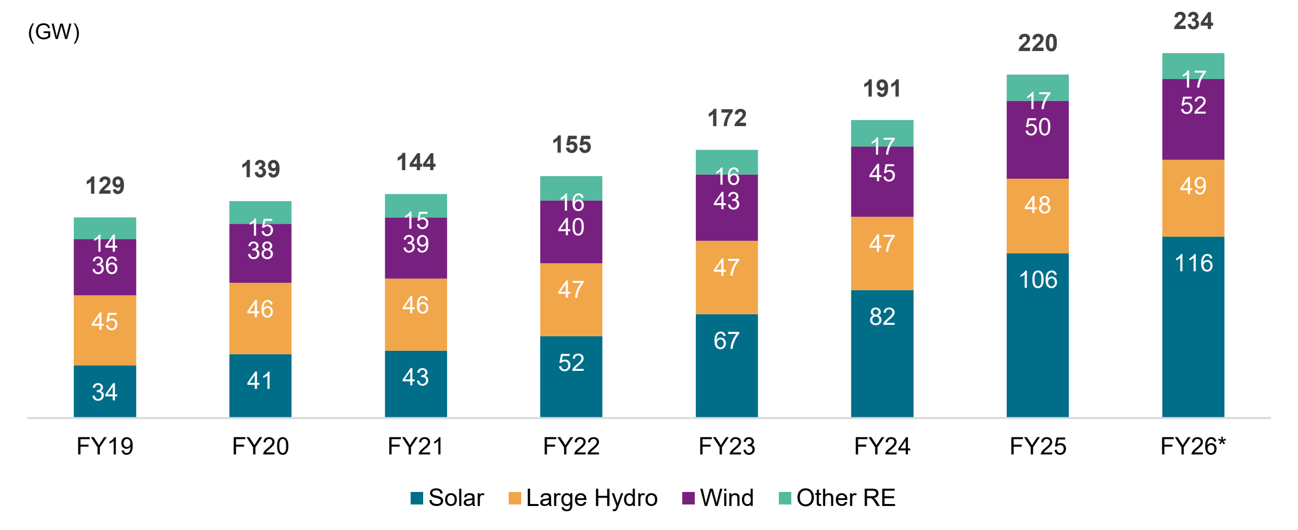
Since their notification, there has been significant progress in recovering outstanding dues, with most distribution companies now adhering to regular payment schedules. The total unpaid bills have reduced from around Rs. 1.4 trillion in June 2022 to around Rs. 586 billion in June 2025. As such the issue of nonpayment by discoms is largely resolved and provided with much required regulatory certainty. The LPS rule helped bring down days payable from 168 in fiscal 2022 to 132 in fiscal 2024.

3 Solar Power market

3.1 Overview of RE capacity additions

Renewable energy installations (incl. large hydro) was ~220 GW as of March 2025 and have increased to ~ 233 GW as of June 2025 (Q1 FY 2026), as compared with ~63 GW as of March 2012, led by various central and state-level incentives. As of June 2025, installed RE capacity (incl. large hydro) in India constituted ~48% of the total installed generation base. This growth has been led by solar power, which grew to ~116 GW as of June 2025 from merely ~0.09 GW in March 2012.

Figure 24: Historical growth of India's installed RE capacity



Other RE: Biomass, bagasse, small hydro, waste-to-energy
*As on June 2025 (Q1 FY 2026); *Source: MNRE; CEA, Crisil Intelligence*

The share of RE (including large hydro) in the total supply mix was ~12% in fiscal 2015, which has now increased to 22% in fiscal 2025 (as of March 2025) and ~ 23% in Q1 fiscal 2026 (as of May 2025). The RE generation has increased at a CAGR of ~17% in the last 10 years. The combined share of solar and wind energy was ~11% of the total energy supplied during fiscal 2024. The share of large hydro was ~8% and the remaining 2% from other RE sources. Going forward, in the next five years, the share of RE in terms of energy supply is expected to be about 35-40%. The share of solar energy supply is expected to be about 20-21% of the total RE supplied in fiscal 2029.

3.2 Government of India initiatives for RE growth

The Indian Government has undertaken multiple policy initiatives through various new and innovative schemes to boost renewable energy generation in the country. The list of some of the key schemes introduced/available is given below.

- Permitting **Foreign Direct Investment (FDI)** up to 100 percent under the automatic route for renewable energy projects
- **Scheme for the Development of Solar Parks and Ultra-mega Solar Power Projects** with a target of setting up 40,000 MW capacity. Under the scheme, infrastructure such as land, roads, power evacuation system water facilities are developed with all statutory clearances/approvals. Thus, the scheme helps

expeditious development of utility-scale solar projects in the country's central financial assistance (CFA) of:

- Upto 2.5 million per Solar Park, for preparation of Detailed Project Report (DPR).
- 2.0 million per MW or 30% of the project cost, whichever is lower, for development of infrastructure.

- **Central Public Sector Undertaking** (CPSU) Scheme Phase-II (Government Producer Scheme) for setting up 12 GW grid-connected Solar Photovoltaic (PV) Power Projects by Government Producers, using domestically manufactured solar PV cells and modules, with Viability Gap Funding (VGF) support, for self-use or use by Government/ Government entities, either directly or through Distribution Companies (DISCOMS). VGF support is provided up to Rs 5.5 Mn/MW to the CPSUs/Govt. Organizations entities selected through competitive bidding process.
- **PM-KUSUM** Scheme to promote small Grid Connected Solar Energy Power Plants, stand-alone solar powered agricultural pumps and solarisation of existing grid connected agricultural pumps. The scheme is not only beneficial to the farmers but also States and DISCOMs. States will save on subsidies being provided for electricity to agriculture consumers and DISCOMs get cheaper solar power at tail end saving transmission and distribution losses.
- **Rooftop Solar Programme Phase II** for grid connected solar rooftop power plants. Under this Programme, a subsidy is provided for the residential sector and performance linked incentives to DISCOMs for achieving capacity addition in rooftop solar above baseline.
- **Green Energy Corridors (GEC):** to create an intra-state transmission system for renewable energy projects. The CFA is provided to set up transmission infrastructure for evacuation of Power from Renewable Energy projects in a total of ten States (considering both the phases of GEC).
  - GEC Phase-I: CFA of 40 % of DPR cost or awarded cost whichever is lower.
  - GEC Phase-II: CFA of 33 % of DPR cost or awarded cost whichever is lower.
- Investment of Rs. 207 billion including central support of Rs. 83 billion for strengthening of interstate transmission system for evacuation and Grid Integration of 13 GW renewable energy from Ladakh.
- **National Green Hydrogen Mission** launched with an outlay of Rs. 197.44 billion with aim to make India a Global Hub for production, utilization and export of Green Hydrogen and its derivatives.
- **Viability gap funding** for 4,000 MWh battery energy storage systems and formulation of a detailed framework for pump storage projects.
- **Annual Bidding Trajectory:** MNRE has prescribed an annual bidding trajectory for RE power bids to be issued by Renewable Energy Implementation Agencies (REIAs). SECI, NTPC, NHPC & SJVN have been designated as REIAs. Bids for 50 GW per annum RE capacity, with at least 10 GW per annum Wind power capacity, are to be issued each year from 2023-24 to 2027-28.
- Waiver of Inter State Transmission System (ISTS) charges for inter-state sale of solar and wind power for projects to be commissioned by 30th June 2025
- Declaration of trajectory for **Renewable Purchase Obligation** (RPO) up to the year 2030
- The government has issued orders that power should be dispatched against Letter of Credit (LC) or advance payment to ensure timely payment by distribution licensees to RE generators.
- Notification of Promoting Renewable Energy through Green Energy Open Access Rules 2022.
- Notification of "The electricity (Late Payment Surcharge and related matters) Rules 2022 (LPS rules).
- Launch of Green Term Ahead Market to facilitate the sale of renewable energy power through exchanges.

3.3 Availability of finance and evolution of funding mechanisms

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

- *Funding from lending institutions such as PFC, IREDA, REC and PFS:* Government financial institutions such as PTC India Financial Services Limited (PFS), Rural Electrification Corporation (REC) and Indian Renewable Development Agency (IREDA) are also financing many solar projects. In fiscal 2025, REC sanctioned INR 1,052.59 billion loans to RE incl. large hydro. Further, for IREDA, the cumulative sanctions as of March 2025 stood at INR 762.5 billion for RE incl. large hydro.
- *Green bond / masala bonds market:* A green bond is like any other bond; however, it invests the proceeds to support green investments including renewable energy projects. The tenure of the bonds typically ranges from 18 months to 30 months. India is the second country after China to have national-level guidelines for green bonds; in India's case, they were published by SEBI. The green bonds may be issued by the national government; multilateral organisations such as Asian Development Bank, the World Bank or the Export-import (EXIM) bank of the country; financial institutions; and corporations.
- *Pension funds / endowment funds*: Pension / endowment funds are expected to play a key role in financing solar projects. Long-term 25-year PPAs with limited operational risk are very suitable to this investor category. Recently, Mahindra Group and Ontario Teachers' Pension plan has launched RE InvIT named Sustainable Energy Infra Trust (SEIT). Both Mahindra Group and Ontario Teachers' had committed to investing upto INR 30.50 billion and INR 35.50 billion respectively into Mahindra Susten and SEIT. Canada Pension Plan Investment Board (CPPIB) owns more than 50% stake in Renew Power. There are other InvITs also present in India such as IndiGrid backed by KKR, Virescent RE Trust backed by KKR, Anzen Trust backed by Edelweiss Real Assets Managers and Powergrid Infrastructure Investment Trust backed by PGCIL.
- *Private equity investments and debt investments:* In a quest to reduce the cost of capital for projects and further improve project economics, many players have increasingly resorted to private equity and debt investments to free up capital. The proceeds are used to invest in new projects. Developers have been exploring several diverse instruments / sources to raise finance such as green bond issuances, external borrowings, private placements (qualified institutional buyers), etc. This not only lowers the cost but also frees credit from domestic banks to be used again as initial capital for new projects.
- *Infrastructure investment trusts (InvITs):* InvITs own, operate and manage revenue generating infrastructure projects and operating assets. These are typically long-term investments since projects as well as assets have long term contracts and a life of 15-20 years providing steady cash flow over a long term. Since operating assets are largely strategic in nature, they are shielded from cost and time overruns as well as seasonal fluctuations of demand and supply. Further, SEBI mandates InvITs to invest a minimum 80% in revenue generating operating assets and limits under construction projects at 20% providing risk mitigation from delay in under construction projects. It is also pertinent to note that InvITs keep on adding to the operating assets thereby providing higher growth. Additionally, the sponsors provide ROFO / growth pipeline giving clarity on future.
- *Funding from multilateral banks and International Solar Alliance (ISA):* Further, the government channelises the funds available from multilateral banks and financing institutes such as World Bank and KfW. Funds are also provided to the Indian government under the Climate Investment Fund of the World Bank. For instance, SBI has received ~$625 million of soft loans with a long tenure of 20 years. 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.

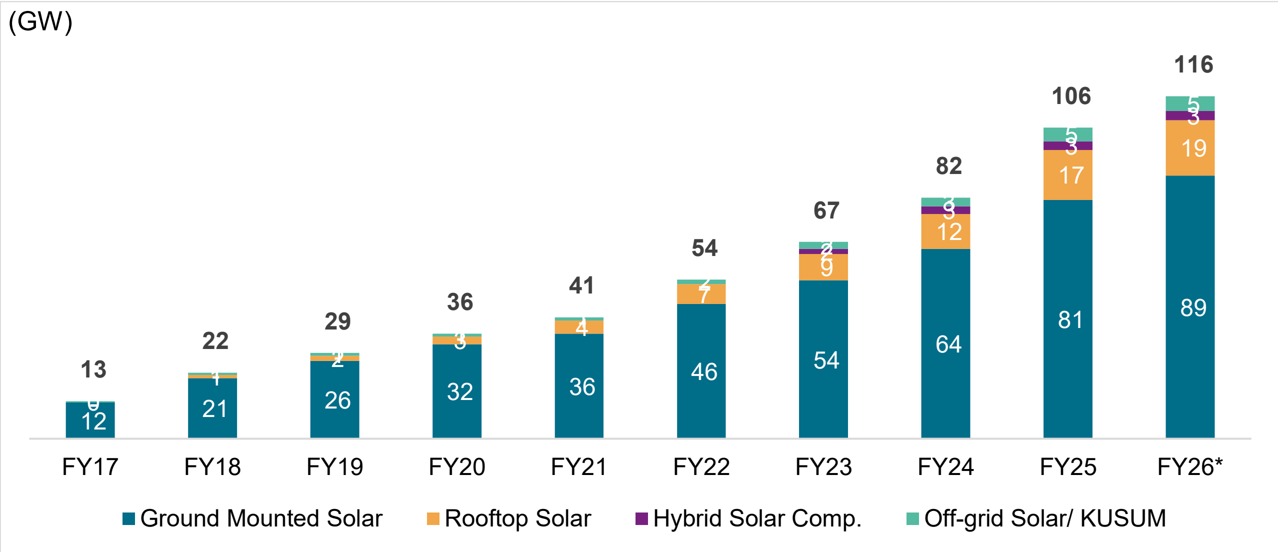
The ISA, an association of solar-resource-rich countries, launched by the governments of India and France, aims at mobilising $1 trillion funds by 2030. The alliance intends to make joint efforts through various policy measures, such as an international credit enhancement mechanism that is expected to derisk investments and reduce the cost of financing for solar projects. The ISA member countries, in collaboration with the United Nations, the Green

Climate Fund, multilateral development banks, investors, insurers, private financial institutions, and other interested stakeholders will finance solar projects.

3.4 Review of overall Grid connected solar energy capacity additions

In the renewable energy basket (including large hydro), solar energy accounted for a share of 46% as of March 2025. Growth in the solar power sector over the last five years has been robust. As much as ~84 GW capacity was added in the segment over fiscals 2018-25 YTD, registering a CAGR of ~26%. In fiscal 2023, solar capacity additions stood at ~13 GW, with ~2.2 GW from rooftop solar projects. In fiscal 2024, solar capacity additions stood at ~15 GW, with ~3 GW from grid connected rooftop solar projects. Similarly, in fiscal 2025, ~22 GW of solar capacity additions were registered and crossed 100 GW mark in total installed capacity.

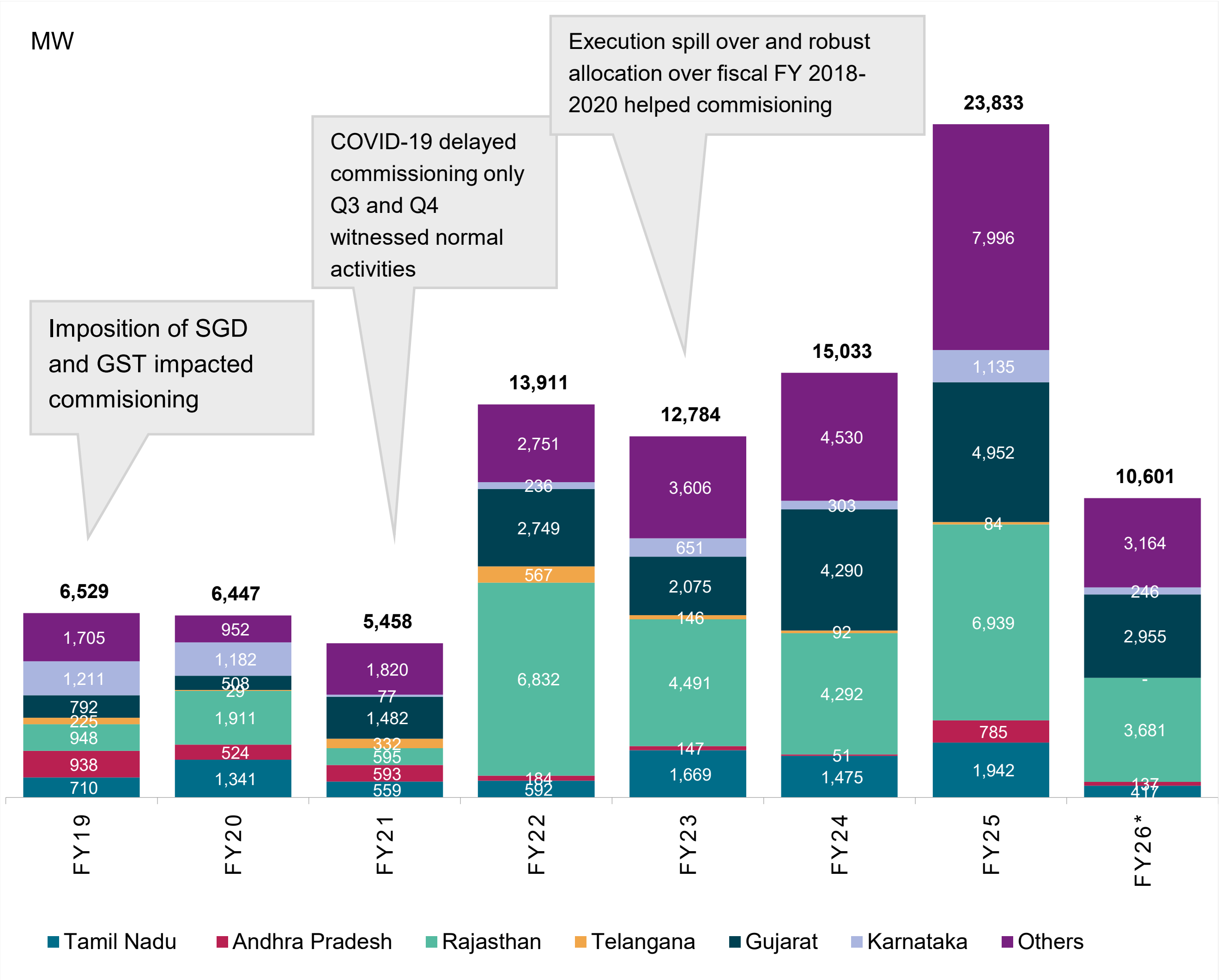
Figure 25: Trend in cumulative solar capacity installation in India



**As on June 2025(Q1 FY 2026); Source: MNRE, CEA, Crisil Intelligence*

India is committed to become carbon neutral by 2070. By 2030, India aims to achieve a total of 500 GW non-fossil-based capacity, with 280 GW of it coming from solar energy.

Figure 26: States that helped drive solar capacity addition in India



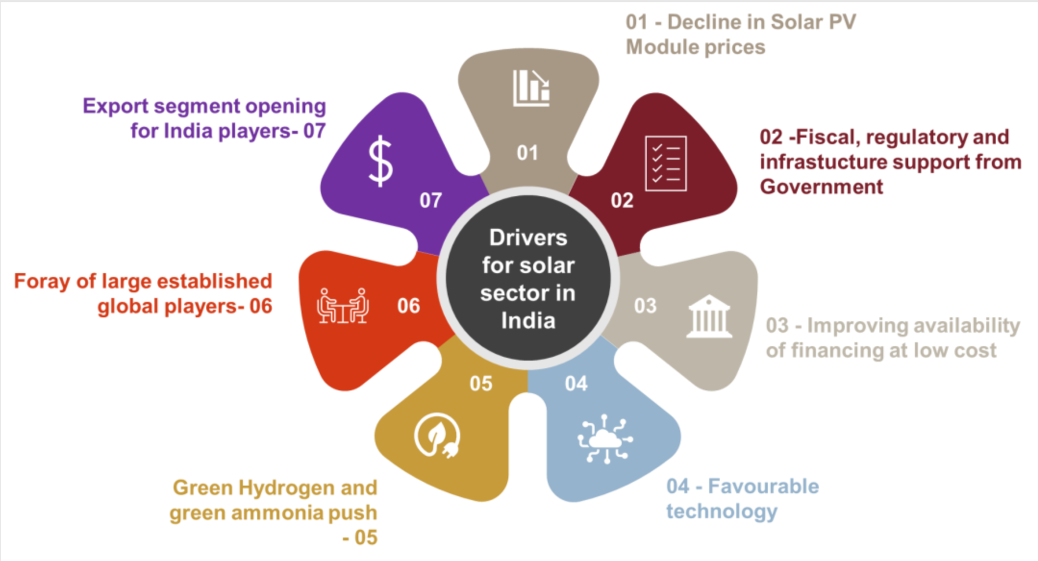
**As on June 2025(Q1 FY 2026); Source: MNRE, Crisil Intelligence*

Commissioning activity has been concentrated in the key states of Rajasthan, Gujarat, and Tamil Nadu, where of ~13.8 GW capacity was added in fiscal 2025 and ~8.8 GW capacity has been added till June 2025 (Q1 fiscal 2026); ~70% share was concentrated in these three states combined. In the previous fiscal as well, the installation trend was driven by the same states.

Despite such strong capacity addition, there is a huge untapped potential for RE installations in India, with solar energy having the highest potential of 750 GW, of which only about 15.4% of the potential has been tapped as of June 2025 (Q1 fiscal 2026).

3.5 Key drivers for solar capacity additions

Figure 27: Growth drivers for solar sector in India



Source: Crisil Intelligence

Some of these are discussed in detail in the following sections:

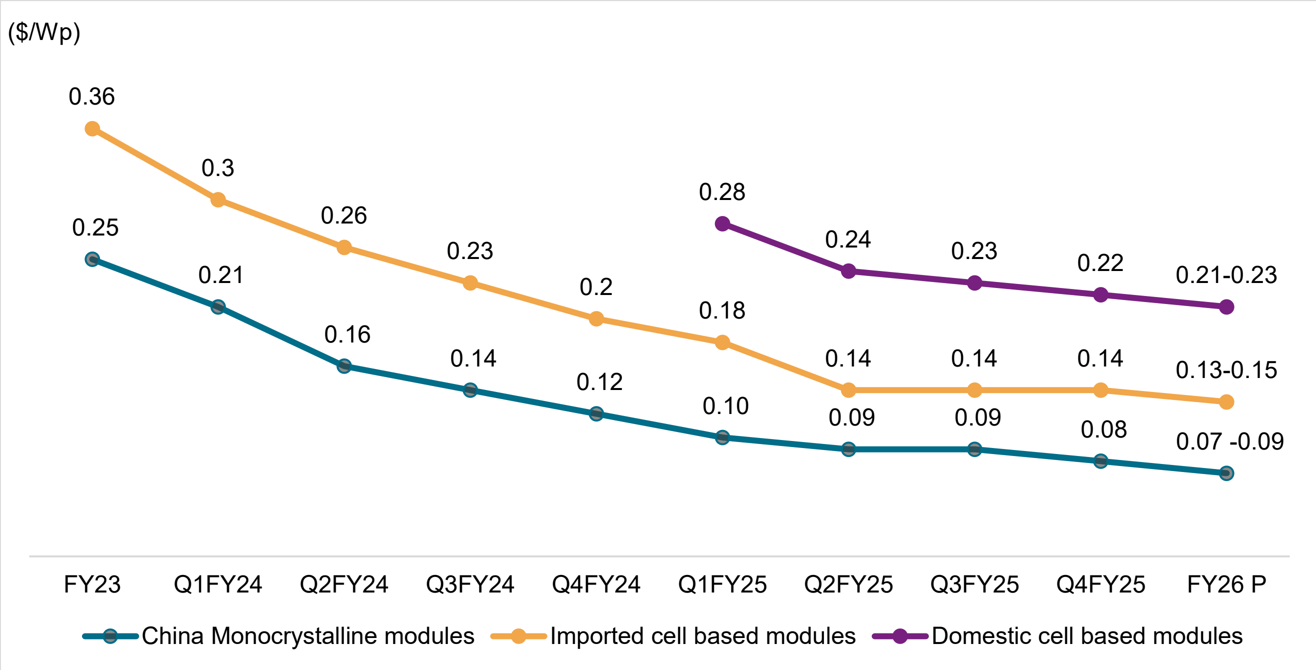
Declining module prices and tariffs

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

Module prices started to fall in 2023 owing to the ramp-up in the production of upstream components. Prices of modules fell to $0.15-0.20 per Wp in April-November 2023 from $0.23 per Wp in January 2023. This has eased some pressure on capital costs in fiscal 2024. The prices of Monofacial module had touched $0.20 per Wp by Q4 of fiscal 2024. The average module price for fiscal 2025 was estimated at $0.14/wp, down 42% on year, owing to sharp fall of 54% in cell prices on year.

Crisil Intelligence expects prices to be in the range of $0.13-0.15/wp for imported cell-based modules and $0.21-0.23/wp for domestic cell-based modules in fiscal 2026 as players are expected to clear inventory of old technology at low prices and seek premium for TOPCon technologies. Also, solar glass pricing, another key input to modules, was also lower on-year owing to falling prices of soda ash on account of low demand. MNRE has reinstated the applicability of the Approved List of Module Manufacturers (ALMM). As a result, only ALMM enlisted manufacturers can supply modules to government and government-assisted projects. Projects under open access and rooftop solar by private parties are also brought into the ambit of ALMM. Therefore, the fall in prices across the value chain is expected to be arrested in fiscal 2026. MNRE in December 2024, issued amendment to ALMM Order 2019 and introduced ALMM List-II for solar PV cells to be effective from 1st June 2026. All solar PV modules used in projects – including government-backed schemes, net-metering projects, and open access renewable energy initiatives – will be required to source their solar cells from ALMM List-II From 1st June 2026. All the government projects have to source domestic cells if the last date of bid submission is after the ALMM List II order date. For net-metering and open access projects, the cut-off date for commissioning is 1st June,2026, after which they must source cells locally.

Figure 28: Module prices (USD/Wp)

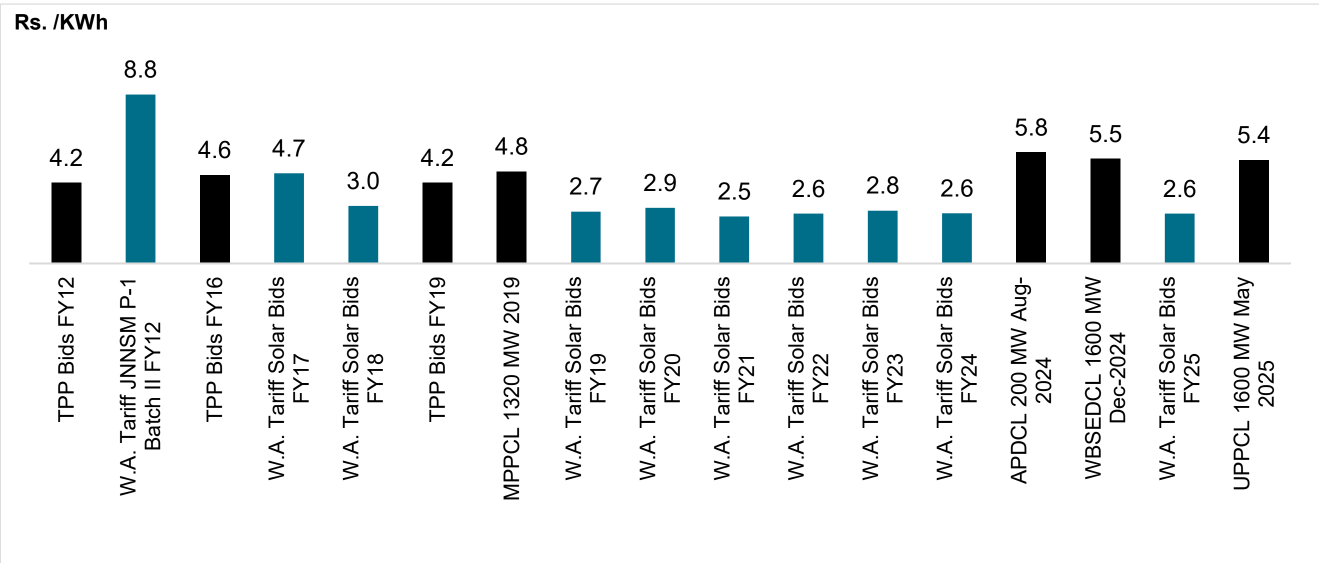


Source: Industry, Crisil Intelligence

- ***Solar power tariffs have been lower than coal-based power tariffs***

In recent years, there has not been any major development in the case of thermal power bidding. However, considering the previously bid prices of thermal power, solar power tariffs have been on the lower side. Tariffs recorded 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 as last year with a weighted average tariff of Rs. 2.6 per unit.

Figure 29: Competitively bid solar power tariffs are much lower than coal-based power tariffs



Note: TPP – Thermal power plant; JNNSM – Jawaharlal Nehru National Solar Mission; W.A. – Weighted average levelized tariffs

Source: Details of Case I bids, Bidding of power from stressed assets, CEA; Crisil Intelligence

Fiscal and regulatory incentives

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

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

Annual Bidding Trajectory:

The Government has decided to invite bids for 50 GW of renewable energy capacity annually for the next five years i.e., from fiscal 2024 till fiscal 2028. These annual bids of ISTS (Inter-State Transmission) connected renewable energy capacity will also include setting up of wind power capacity of at least 10 GW per annum.

Solar parks and ultra mega RE parks: One of the most important initiatives by GoI has been setting up of solar parks in the country. Such parks significantly reduce construction/ execution risk as they include a contiguous parcel of land, evacuation infrastructure (HV/EHV substation evacuating to state grid substation), and other ancillary infrastructure and utilities such as road, water, and drainage.

Under the Solar Park Policy released in September 2014, the government planned to prepare land banks for 20,000 MW of solar projects across 25 states. These states have started preparing land banks for solar parks, either through their own implementing agencies or through joint ventures with SECI. The capacity of the scheme was doubled from 20,000 MW to 40,000 MW in March 2017, to set up at least 50 solar parks by fiscal 2022.

Over 55 nos. Solar Parks / UMREPPs of aggregate capacity of 41,137 MW have been envisaged for development in the country as of January 2025. Out of 41,137 MW, 25,586 MW is awarded (Of these, the capacity of 13,054 MW has already been commissioned while 15,181 MW capacity is under construction), and 12,902 MW is under award/tendering process. The State-wise details are given below.

Figure 30: State wise solar park approved capacity (MW) as of January 2025

Sr. No.	State in which Solar Parks/UMREPPs are located	Total Capacity of Solar Park/ UMREPP (MW)	Capacity Under Award / Tendering (MW)	Capacity Awarded (MW)	Capacity under construction (MW)	Capacity Commissioned (MW)
1	Andhra Pradesh	4,300	300	4,300	950	3,050
2	Chhattisgarh	100	-	100	-	100
3	Gujarat	12,150	2,295	9,855	8,855	1,000
4	Himachal Pradesh	53	21	32	-	32
5	Jharkhand	1,089	679	410	410	-
6	Karnataka	2,500	500	2,000	-	2,000
7	Kerala	255	100	155	50	105
8	Madhya Pradesh	4,330	1,552	2,778	515	2,263
9	Maharashtra	1,105	855	250	250	-
10	Mizoram	20	-	20	-	20

Sr. No.	State in which Solar Parks/UMREPPs are located	Total Capacity of Solar Park/ UMREPP (MW)	Capacity Under Award / Tendering (MW)	Capacity Awarded (MW)	Capacity under construction (MW)	Capacity Commissioned (MW)
11	Odisha	40	0	40	40	-
12	Rajasthan	11,355	5,190	6,165	2,111	4,054
13	Uttar Pradesh	3,840	1,410	2,430	2,000	430
	Total	**41,137**	**12,902**	**28,235**	**15,181**	**13,054**

Source: CEA, MNRE, Crisil Intelligence

Favourable technology

Solar power is becoming increasingly attractive due falling module prices and improving efficiency resulting from excess manufacturing capacity in China and technology advancements respectively. On the project development front, developers are exhibiting heightened preference for bifacial modules that typically have higher efficiency relative to mono-facial modules and are compatible with tracker technology.

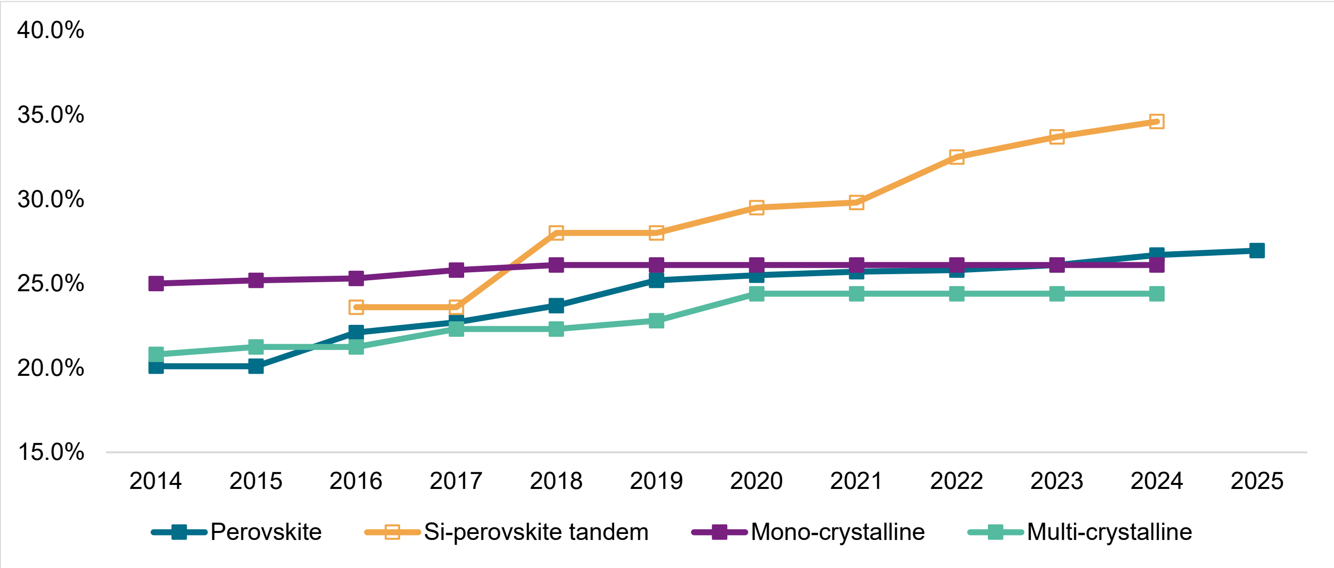
On the project development front, developers are exhibiting a heightened preference for bifacial modules that are compatible with tracker technology and typically have higher efficiency relative to mono-facial modules. The share of monocrystalline technology is now about 97% (compared with 66% in 2019) 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.

Currently, the solar PV market is dominated by monocrystalline silicon technology. TOPCon technology has also made inroads in India's solar module manufacturing sector with adoption and switching existing manufacturing lines to TOPCon. Within monocrystalline technology, Mono PERC is an advanced version that employs dielectric passivation film on the rear surface of the cells which increases the efficiency levels. These cells are currently leading the market due to higher efficiency, cover less space, higher output in low light conditions and are available at competitive pricing. 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. The p-type to n-type migration is currently underway and paving the way for new technologies, n-type technologies including TOPCon, heterojunction (HJT) and back contact represented 42% of China's total module manufacturing capacity (7% in 2022). These designs hold the potential for achieving additional efficiency gains in solar panels. Based on pilot tests conducted by leading global manufacturers, it is estimated that the TOPCon cell could provide an additional efficiency gain of upto 2-2.5% gain over mono PERC modules. While TOPCon is expected to be the dominant n-type technology over the next couple of years due to its lower cost over other new technologies, higher efficiency, and lower temperature sensitivity of HJT modules make it a better alternative to TOPCon modules in select locations. Additionally, China market share of HJT modules is expected to increase from an estimated 2% in 2023 to around 16% in 2027 due to decreasing production cost differential with TOPCon technology.

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

Figure 31: Cell efficiency comparison



Source: NREL, Crisil Intelligence

The developments in perovskite solar cells have resulted in a significant efficiency increase in laboratory conditions. Many of the Indian solar PV module manufacturers are also moving towards TOPCon technology. With the use of new technologies, the solar module efficiency is expected to increase by 2% to 2.5% over the next 2-3 years. However, Indian module manufacturers may still be behind their Chinese counterparts due to R&D as well as scale.

Green Hydrogen and green ammonia push

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

3.5.1.1 Foray of large established global players in India

The Indian solar energy sector has been spearheaded by major corporate entities such as Adani, Tata Power, ReNew, NTPC in India. In addition, global firms such as Engie, Sembcorp, Total Energies, Fortum, Eden have demonstrated considerable interest in the Indian solar market. They have entered the sector through partnerships or by acquiring stakes in the leading domestic players' assets. Furthermore, there are some of the large private equity groups such as KKR and Actis, who are actively investing in the RE firms, further fostering the development and expansion of the sector. Their financial support and strategic initiatives have played a pivotal role in propelling the Indian solar energy market towards greater sustainability and efficiency.

3.5.1.2 Export segment opening for India players

Even as Indian dependence on imported solar modules and cells continued, exports for fiscal 2020 increased to USD 213 million from USD 121 million (increase of 76%) from fiscal 2019. However, due to COVID-19 disruptions, exports declined to USD 77 million in fiscal 2021. Nevertheless, the exports grew in fiscal 2022 by ~45% due to the opening of economy and restoration of normalcy in most parts of the World.

During the fiscal 2023, India has experienced a significant surge in solar module exports. This increase can be attributed primarily to the restrictions imposed by other countries on Chinese goods, including solar modules. These restrictions have created opportunities for Indian manufacturers to fill the gap in the global market and meet the demand for solar modules. As a result, India has witnessed a notable boost in its solar module exports, contributing to the growth of its solar industry and strengthening its position as a global player in the renewable energy sector.

The US Inflation Reduction Act 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.

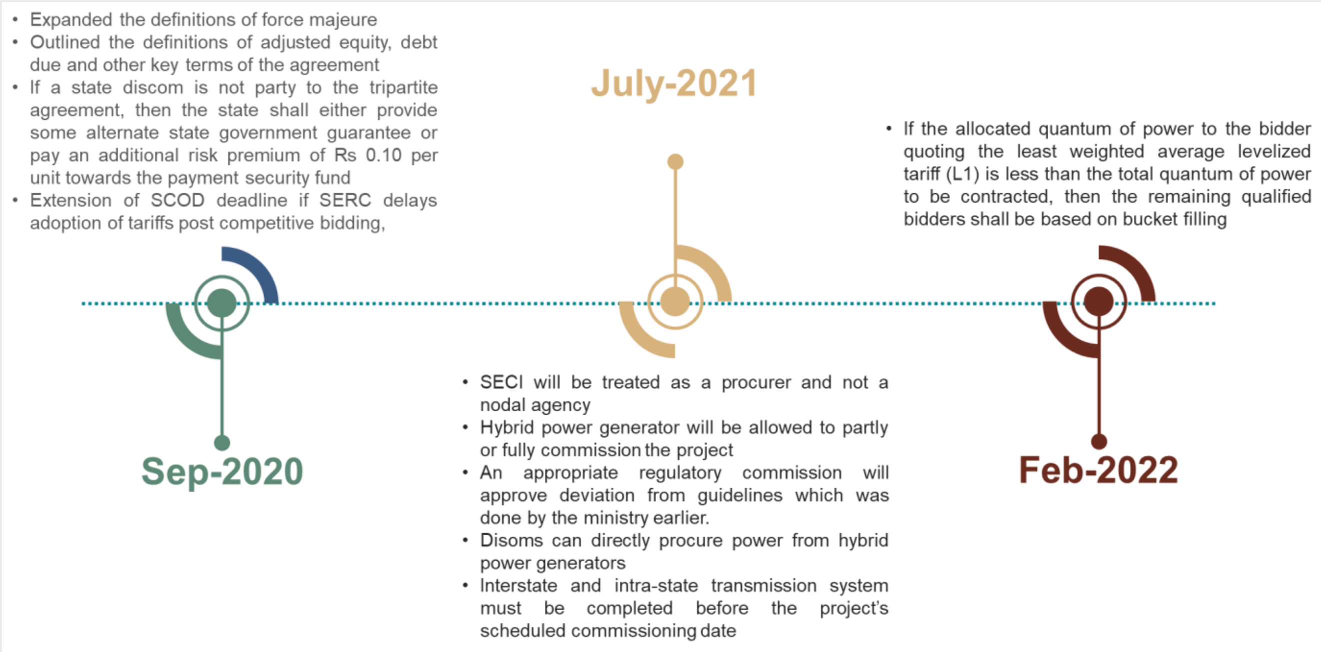
Limited domestic production of solar modules/cells in the USA has made it heavily reliant on international suppliers to meet its growing demand. This dependency presents a substantial opportunity for foreign manufacturers to penetrate the burgeoning US solar market. By either establishing operations in the US or exporting their products, foreign solar module/cell manufacturers can secure a significant share in this expanding industry. Several factors are contributing to India's emergence as a major exporter of solar module/cells to the US. Firstly, US policies such as the Inflation Reduction Act (IRA) incentivize domestic solar module production, which in turn drives up the demand for solar cells. This creates a prime opportunity for Indian manufacturers. Additionally, existing regulations, including Anti-Dumping Duties on Chinese imports, make Indian solar cells more appealing to US companies.

US enacted the Uyghur Forced Labor Prevention Act (UFLPA) in December 2021 with June 21, 2022, as effective date. Implementation of ULFA has supported India’s solar module exports. The ULFA 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.

3.6 Review of competitive bidding

For solar projects over 2009-2013, most states signed PPAs at FiTs determined by the state commission on the fixed regulated equity return of ~16%. While for wind energy projects, states followed the FiT mechanism till March 2017. However, from fiscal 2018, the sector veered towards competitive bidding.

Figure 32: Positive changes to bidding guidelines undertaken to support bidder interest

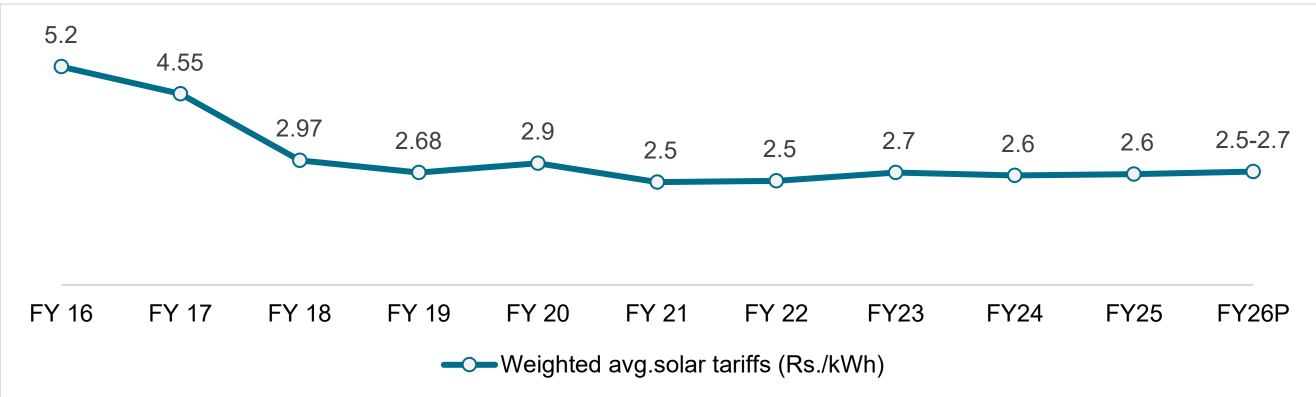


Source: MNRE, Crisil Intelligence

Overall, the above amendments are positive for the developers as these amendments grant 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, provide positive boost to the open access market and simplify procedures or provide provisions to stimulate bidder interest. However, the sector requires consistent positive regulatory support to spur capacity additions, despite a healthy pipeline.

After registering the lowest tariff of Rs. 1.99/kWh in December 2020, the solar tariffs have bounced back and witnessed more than 25% increase. This increase can be attributed to increased project cost, implementation of BCD, requirement of ALMM and domestic content requirement as well as regulatory and policy risks. Crisil Intelligence believes that a tariff of Rs 2.5-2.75/kWh will be required for a 10-15% equity IRR, owing to a sharp decline in module prices year-on-year in fiscal 2026, despite a basic customs duty in place.

Figure 33: Tariffs to remain flat in fiscal 2026 owing to fall in upstream component prices



Note: The above tariffs are for ground mounted solar only; Source: Industry, Crisil Intelligence

In February 2025, the MNRE issued revised guidelines for solar, wind, and hybrid projects and introduced several key changes. Procurers can now specify the sub-station for project connectivity. Generators that fail to maintain the minimum CUF for two consecutive years will be liable to pay damages. The guidelines also clarify the definition of "Change in Law" which now refers to any event related to the project that occurs from 7 days prior to the last date of Bid Submission. Additionally, the period for signing PPAs and power sale agreements can be extended to 12 months after receiving LoA, and tariffs discovered through bidding must be adopted by the appropriate Commission within 30 days. Other changes include the introduction of Insurance Surety Bonds, revised rules for Performance Bank Guarantees, and a requirement for procurers to seek approval from the appropriate Commission for any deviations from the guidelines.

3.6.1 New business models warrant higher tariffs

With a large quantum of the pipeline already in place for solar/ wind only projects, nodal authorities are now resorting to issuing tenders, which improve the quality of power supplied to off-takers. Some key changes were made to tender structures with respect to the generation profile available from RE plant and the ability to match demand requirements of the off-taker.

Three new tender structures have been issued so far to solve the above aspects – assured peak power supply (PPS), RTC, and the FDRE. A key feature across these tenders is the increase in the quantum of generation, which was required to be supplied and the PPS tender for stipulating the power to be provided during peak hours. The PPS tender also mandated the use of storage, as that would be essential to supply power during peak hours. The government has released four FDRE tenders of over 2.5 GW across Haryana, Madhya Pradesh, and Punjab since then.

Wind-Solar Hybrid Projects: In May 2018, the MoP issued the Wind-Solar Hybrid policy with an objective to provide a framework for promotion of large grid connected wind-solar PV hybrid system for optimal and efficient utilization of transmission infrastructure and land, reducing the variability in renewable power generation and achieving better grid stability. The Policy also aimed to encourage new technologies, methods and way-outs involving combined operation of wind and solar PV plants. Hybrid projects typically provide higher CUF than standalone solar or wind projects. This is due to the fact that the wind projects operate optimally during morning and night and thus complement solar projects which peak during daytime.

As per the revised bidding guidelines, the rated power capacity of one resource (wind or solar) in such projects should be at least 33% of the total contracted capacity. The guidelines also allowed the setting up of the solar and wind projects at the same or different locations. To meet the energy obligations under the power purchase agreements, developers generally install higher renewable energy capacity than the contracted capacity under the Hybrid Scheme.

Firm and dispatchable renewable energy projects: In June 2023, the MoP issues guidelines for procurement of firm and dispatchable power from grid connected renewable energy projects with energy storage systems. The guidelines explained the term ‘firm and dispatchable power’ as the power profile configuration that is defined in the request for selection that is sought to be met by RE power sources and will include configurations like assured peak power, Round the Clock RE with firm delivery of power at rated capacity at any hour of the day as per demand or load following power delivery as specified by DISCOM, RE projects with firm delivery of power for fixed hours of requirement by DISCOMs etc.

The guidelines also broadened the renewable energy to include solar power generating systems, wind power generating systems, wind solar hybrid; or any other renewable energy resource based generating system or a combination thereof, with energy storage system. Energy from solar and wind projects is intermittent and infirm in nature resulting in lower capacity utilization. However, FDRE addresses these challenges by providing following solutions.

- Firm power supply as per demand given by utilities; and

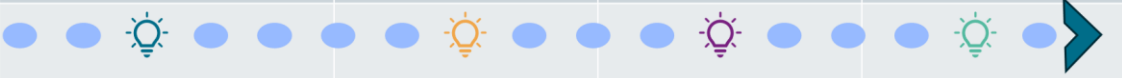
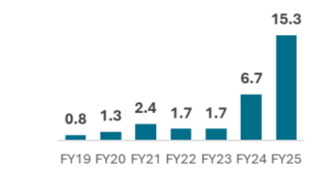
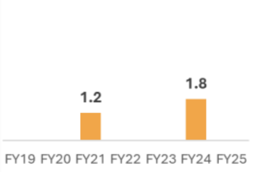
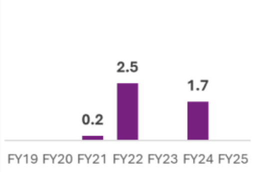
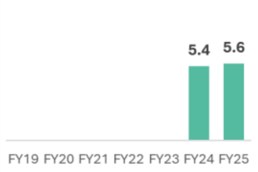
- Higher capacity utilization factor

Under FDRE, the project developer is required to supply RE power in a Firm and Dispatchable manner, matching the demand profile(s) provided by the Buying Entity. To provide firm power, developers are required to install mandatory energy storage system (either battery energy storage system or pumped hydro storage system) which are charged through renewable energy and discharged as per power requirement of buying entities. Further, To meet the energy obligations under the power purchase agreements developers generally install higher renewable energy capacity than the contracted capacity.

Modelling the above three tender structures with assumptions, coupled with industry interactions, we believe that the higher generation quantum mandated by these newer tenders could either be met using storage components or scaling up the plant capacity, i.e., setting up capacity larger than its rated capacity.

This has resulted in the expected tariff ranges being required to maintain the equity IRRs of 10-15%, which are currently seen in regular tenders, to be higher than the norm of Rs 2.50-2.75 per unit, approaching the range of Rs 3-5 per unit. This increase will mainly be driven by higher capital and operating costs resulting from either the inclusion of a storage element or the need for higher capacity. Some moderation was observed only in the RTC tender, where the stipulated escalation in tariff will lead to higher tariffs.

Table 3: Higher tariff range at around Rs 3-5/kWh mark required to maintain returns similar to regular trend

	Plain Hybrid	Peak Power	RTC	Firm Power
Weighted avg. tariff	₹ 3.40 per unit	₹ 4.86 per unit	₹ 3.58 per unit	₹ 4.52 per unit
Year of first allocation under structure				
(GW)				
Total allocation	25.4 GW	3 GW	4.4 GW	10.7 GW
Key Players	Juniper, Adani, JSW, Avaada	Renew, Avaada, ACME, Hero Future	Greenko, Renew, NTPC	Juniper, Renew, JSW, Hero Future
Key distinctive features	Plain vanilla hybrid tenders require simple blending of solar and wind resources to achieve higher PLFs compared to those achieved on standalone basis	Peak power tenders demand injection of renewable energy during peak periods of power demand in the day, typically 4 hours per day	Round the clock tenders are designed to enable injection of renewable energy asking for higher availability from the energy sources	Firm power tenders require availability of firm and dispatchable renewable power with multiple requirements across availability, peak timing supply and/ or following of a particular load profile with battery

Note: Weighted average is calculated across all projects allocated under respective models till 31st March 2025.
Source: Crisil Intelligence

So far, all these tender models have seen successful allocations, with FDRE at 10.5 GW and RTC at 4.4 GW, mainly driven by central entities. Consequently, while the newer implementation models improve the dispatchability of power for off-takers, in the current scenario, they would still require a higher tariff to be executed. This would be monitored closely as the key off-takers, i.e., state discoms, may be hesitant to purchase renewable energy at significantly higher costs despite the improving quality.

The lowest tariff discovered in the FDRE tender is Rs. 4.38/kWh which is lower than that of many thermal plants and in fact below the APPC of many of the state utilities. The bid tariffs in the FDRE tenders are impacted by the tender conditions such as high availability requirement, supplying power during specific hours of the day, demand fulfilment ratio, etc. Hence, tenders with different conditions and complexities result in different tariffs. However, most of the good resource locations are already taken up for project development and limited availability of good resource locations may put upward pressure on tariffs.

The rising power demand force discoms to purchase electricity from power exchanges and through bilateral trading. The average prices at power exchanges for day ahead market hover around Rs 3.3 – 6 per kWh (average price during fiscal 2025 was ~ Rs. 4.5 per kWh) and for bilateral trading the prices have gone beyond Rs 8 per kWh in fiscal 2025. During fiscal 2024, states such as Uttar Pradesh, Madhya Pradesh, Chhattisgarh, Bihar, Haryana and Odisha were the major buyers from day ahead market of power exchanges which procured power at a weighted average price of about Rs 4.71/kWh. The price of exchanges is more than the price discovered under recent RTC and firm power tenders. These new age tenders not only provide competitive tariffs but are also an alternative sustainable source of power as compared to conventional power sources. Moreover, with the fall in BESS prices, the tariffs discovered under FDRE tenders would become more competitive in the medium term.

Since these projects are still relatively new and have been allocated recently, execution dynamics are yet to be clearly observed. Crisil Intelligence expects new business models to add 30-35 GW between fiscal 2024 and 2029. Furthermore, technological improvements, especially on the storage side, may further reduce cost requirements over the longer term, making implementation more feasible.

3.7 Outlook of overall grid connected solar energy capacity additions

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.

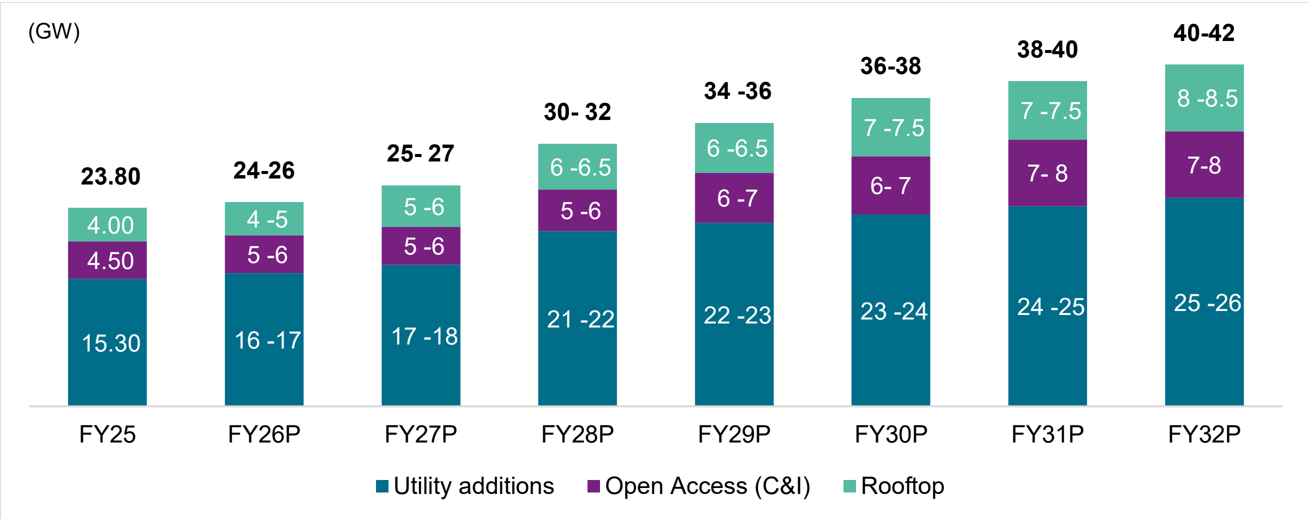
Crisil Intelligence expects 175-180 GW of solar capacity additions over fiscal 2025-2030. This will be driven by additions as follows:

- **NSM**: The entire NSM Phase II Batch II Tranche I of 3,000 MW has been commissioned. Under NSM Phase II, Batch III, and Batch IV, SECI through its state specific VGF has tendered out ~7 GW of capacities, most of which has been completed.
- **Other central schemes**: SECI has also started tendering projects outside the JNNSM Batch programme. It has initiated the ISTS scheme, wherein projects are planned for connection with the ISTS grid directly. Under this, SECI has already tendered and allocated ~35 GW (including hybrid).
- **State solar policies**: ~25-27 GW of projects are under construction and are expected to be commissioned over the fiscal 2025-2030. Based on tendered capacities by states at the end of June 2024, a further ~24 GW capacity of solar projects is expected to be up for bidding over the same duration.
- **PSUs**: The CPSU programme under JNNSM has been extended to 12 GW in February 2019. The government is also encouraging cash-rich PSUs to set up renewable energy projects. NTPC has already commissioned a total of over ~3.7 GW of capacities at the end of September 2024. It has a target of installing ~35 GW of renewable energy capacities by fiscal 2028. Similarly, NHPC had allocated 2 GW of projects in 2020, while the Indian Railways has committed to 20 GW of solar power by 2030. Other PSUs such as NLC, defence organizations, and governmental establishments are also expected to contribute to this addition.

- **Rooftop solar projects**: Crisil Intelligence expects 27-29 GW of rooftop solar projects (under the capex and opex mode) to be commissioned by fiscal 2030, led by PM Surya Ghar Yojana and industrial and commercial consumers under net/gross metering schemes of various state.
- **Open-access solar projects**: Crisil Intelligence expects 18-19 GW of open-access solar projects (under the capex and opex mode) to be commissioned by fiscal 2030, led by green energy open access rules 2022, sustainability initiatives/RE 100 targets of the corporate consumers, better tariff structures and policies of states such as Uttar Pradesh and Karnataka, which are more long term in nature.

Push for Green hydrogen: Production for green hydrogen is expected to start from fiscal 2026 with production of 0.5-1 million tonnes of production. The government has set the target production of 5 million tonnes of green hydrogen by 2030. As per announcement, we expect 2.0-3,0 MTPA of green hydrogen to commission which can lead to further upside of solar capacity of 30-32 GW, by fiscal 2030. However, developers may tie-up via grid / open access and not go to the captive route generation under this segment will remain a monitorable.

Figure 34: Year wise expected solar capacity addition



P: Projected; Source: Crisil Intelligence

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

Crisil Intelligence's outlook factors in the prevailing market dynamics, where regulatory/policy support is key. The renewable energy domain is highly dependent on policy support, and any uncertainty surrounding this could restrict capacity additions.

3.8 Review of C&I capacity addition in India

The C&I users consume ~51% of the electricity generated in India, but only a small percentage of their energy procurement comes from renewable energy sources. C&I users have emerged as an important standalone business segment in recent years in the renewable energy market, indicating their huge untapped potential. Although the present market size is small, specialised developers catering to C&I consumers have emerged with innovative business models and competitive prices. The C&I segment already accounts for 70-80% of the country's rooftop solar installed capacity and is making headway in the utility-scale solar space as well through open access and group captive routes.

3.8.1 Utility scale C&I solar capacity addition outlook

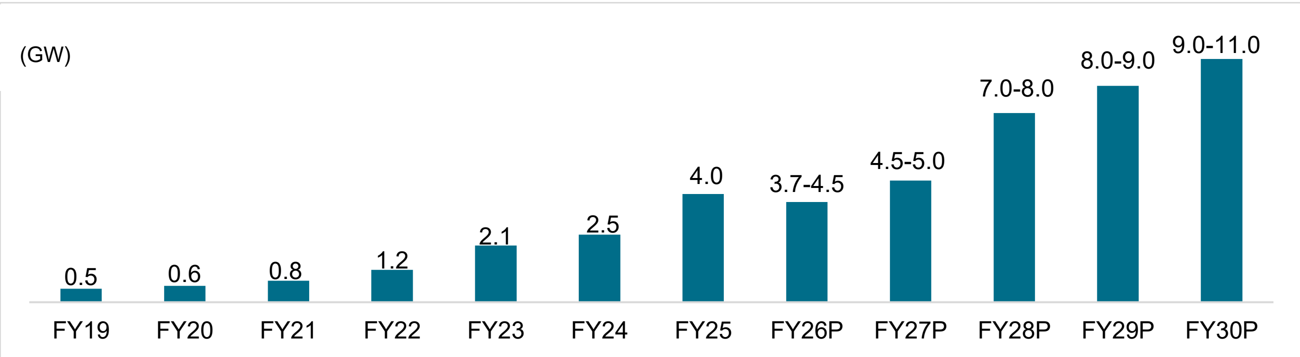
The Indian C&I solar sector added ~12+ GW over fiscals 2019 to 2024, with the total installed capacity as of fiscal 2024 at ~18.5 GW. Capacity additions picked up in the last two years in response to the easing of pandemic restrictions and increasing power demand. Further, the market has gained momentum over the last few years, with consumers keen on reducing their power bills, as well as carbon emissions. Increasingly, there is also very strong interest among investors with leading independent power producers, private equity funds, and other institutional investors committing huge sums to this market.

Solar power is preferred over other renewable energy sources by C&I consumers due to its ease of implementation, versatility, and negligible operating costs. Moreover, solar power prices have declined significantly over the past few years, making it more affordable for C&I consumers. In contrast, state discoms continue to charge C&I consumers very high tariffs compared with residential and public sector consumers to provide subsidies to agricultural and below poverty line consumers. Thus, large industries across segments and commercial consumers, including metro corporations, railways, airports, hotels, and multinational corporations, can generate substantial savings by meeting their electricity requirements through solar power-based captive, group captive, and open access projects.

Crisil Intelligence expects 30-32 GW of projects to be commissioned under the open access utility segment over the next five years through 2030, led by the go-green initiatives/sustainability targets of C&I consumers, effective long-term policies in key states such as Uttar Pradesh and Maharashtra, and lower offtake risk.

Additionally, in the proposed Draft Electricity Amendment Act 2022, several progressive measures have been proposed for the solar sector, including the introduction of a pan-India RPO with a strict penalty mechanism. Discoms and other large electricity customers are obligated to purchase a specific percentage of their power from solar energy sources under these RPOs. These measures will provide a significant boost to the uptake of rooftop solar in the C&I segment.

Figure 35: Open access in utility scale Solar annual capacity additions (FY26-FY30)



Note: Historical installed capacity is based on internal estimates. P: Projected

Source: Industry; Crisil Intelligence

3.8.2 Policy support in terms of incentives for C&I capacity addition

C&I capacity addition is largely influenced by the policy and regulatory framework governing open access. Some of the policies have helped in the C&I segment's growth, whereas certain provisions have acted as obstacles to capacity addition. State-wise variations, coupled with different interpretations of provisions, has constituted a major challenge. To avoid ambiguities, the MoP has issued a few rules to provide greater clarity in various OA-related provisions.

a. **Electricity (Promoting Renewable Energy Through Green Energy Open Access) Rules, 2022**

Highlights of Green OA Rules 2022:

- Multiple avenues (own generation, captive, open access, and from distribution licensee) provided to generate, purchase, and consume renewable energy
- Consumers having contracted demand or sanctioned load of 100 kW and above eligible to take power through green energy open access
- No limit on supply of power for captive consumers taking power under green energy open access
- A central nodal agency to operate a single-window green energy open access system for renewable energy
- Monthly banking allowed at least 30% of the total monthly consumption of electricity from the distribution licensee by consumers
- Charges to be levied on green energy open access consumers clearly defined
- CSS on a C&I consumer shall not be increased, during 12 years from the date of operating of the generating plant using RE sources, by more than 50% of the surcharge fixed for the year in which open access is granted
- Obligated entities can meet their RPO targets by purchasing green hydrogen or green ammonia
- CSS and additional surcharge shall not be applicable if green energy is utilised for the production of green hydrogen and green ammonia

b. **Waiver in ISTS transmission charges**

The MoP, in August 2020, waived the inter-state transmission system (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 off, and losses remained applicable. Subsequently, in November 2022, the waivers were amended as follows:

RE Source	ISTS Charge Waiver	Remarks
Solar	Yes	Waiver available for useful life of 25 years
Wind	Yes	Waiver available for useful life of 25 years
Pumped storage hydro plant	Yes	Waiver available for 25 years, provided minimum 51% of pumping energy from wind/solar sources
BESS	Yes	Waiver available for 12 years, provided minimum 51% of charging energy from wind/solar sources
GTAM/GDAM	Yes	Only for trading energy from solar/wind/PSP/BESS in GTAM/GDAM
Green hydrogen	Yes	Waiver available for 8 years for green hydrogen production using solar/wind/PSP/BESS sources

Waivers are available for projects commissioned by June 30, 2025. Hoverer, 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.

c. **Cross-subsidy and additional surcharge**

Captive power projects are exempt from paying CSS, as per Section 42(2) of the Electricity Act 2003.The Supreme Court, in its judgement dated December 10, 2021, ruled that captive power consumers are not liable to pay an additional surcharge under Section 42 (4) of the Electricity Act, 2003.

3.9 Outlook on rooftop solar PV capacity additions in India

3.9.1 Grid connected rooftop capacity stood at ~18.8 GW as of June 2025

The government had proposed to achieve 100 GW of solar energy by fiscal 2022, of which 40 GW was proposed to be added under rooftop-based solar systems. This was extended to fiscal 2026. However, it is estimated that ~ 18.8 GW of rooftop capacity has been installed till June 2025, with ~1.78 GW added in Q1 of fiscal 2026. Additions are seen across Gujarat (29%), Kerala (14%) and Maharashtra (17%). While additions in Gujarat and Maharashtra were driven through Surya Urja Yojana 2023 scheme, Kerala presents an opportunity for additions with large roofs per capita. The expansion of the market can be attributed to several factors, including increased consumer awareness, advancements in technology, and proactive subsidy initiatives implemented by both central and state governments. Additionally, global solar module prices have reached a historic low, standing at just USD 0.09 per watt-peak in June 2025, which is expected to stimulate growth in solar power capacity.

Crisil Intelligence expects that 25-30% of the installed base was residential while the balance was corporate. The residential segment, which lagged in the past, is now on the cusp of expansion. In January 2024, a boost was provided to residential rooftop segment with the launch of PM *Surya Yojana* that aims to solarise 10 Mn households.

PM Surya Ghar Yojna: In order to further sustainable development and people's well-being, Central Government in February 2024 launched the PM Surya Ghar: Muft Bijli Yojna. This project is expected to add Rs. 750 billion of investment and aims to light up 10 Mn households by providing up to 300 units of free electricity every month.

Subsidy for residential households
- Rs. 30,000/- per kW up to 2 kW
- Rs. 18,000/- per kW for additional capacity up to 3 kW
- Total Subsidy for systems larger than 3 kW capped at Rs 78,000

The MNRE on February 20, 2024, has declared that only applications received after February 13, 2024, will be considered for CFA under PM Surya Ghar Muft Bijli Yojana. Further, it was also clarified that this is a whole new scheme, and all previous schemes have been lapsed.

This scheme is expected to boost 20-25 GW of residential rooftop additions, taking the installed base to 22-27 GW from 2.65 GW in fiscal 2024. Crisil Intelligence expects 10-12 GW to be added between fiscal 2025 and 2030. The remaining 11-13 GW addition under the scheme presents a potential upside and remains monitorable.

3.9.2 Regulatory support required to drive the sector

In most state policies, net metering is allowed for residential and C&I consumers.

- All discoms are to utilise units generated from solar rooftop power plants to comply with their solar RPO targets if the consumer is not an obligated entity. Further, 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
- Discoms alone will meet their RPO targets from the units injected into the grid, if FiT are paid by discoms

Given lower capital cost, rooftop projects have become attractive for C&I consumers. In particular, the net-metering scheme – under which power generated can be consumed captively and the balance/excess sold to the grid – is attractive for consumers paying tariffs upwards of Rs 4.5 per unit to discoms. The cost of generating solar power from rooftop projects is estimated at Rs 3.5-4.0 per unit (without availing accelerated depreciation (AD).

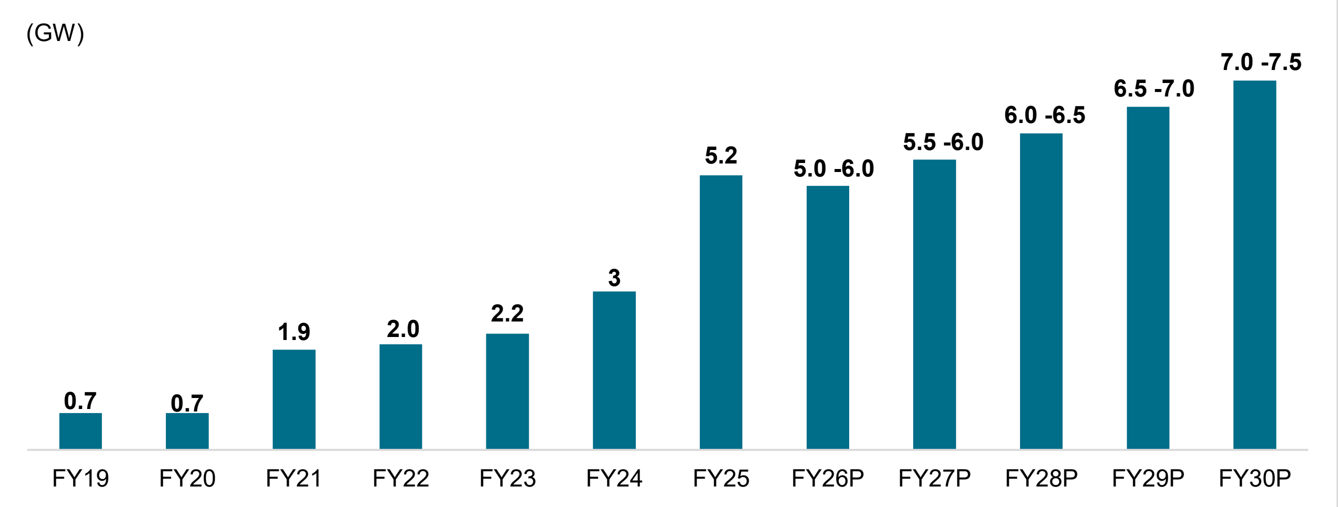
C&I consumers are best placed to claim the AD benefits and increase their project returns/reduce generation costs. This group includes all high-tension consumers and commercial consumers such as malls, hospitals, government establishments, and high-consumption group residential complexes.

3.9.3 Outlook on rooftop solar PV capacity additions in India

a. **Rooftop solar additions of 28-30 GW expected over fiscals 2026-2030**

Crisil Intelligence expects 28-30 GW of projects to be commissioned 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 36: Projected rooftop capacity additions over fiscals 2026-2030



P: Projected; Source: MNRE; Crisil Intelligence

3.9.4 Overview of Green Hydrogen Policy and its impact on capacity additions

Green hydrogen mission and policy

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

The initial outlay for the Mission will be Rs.197.44 billion, including an outlay of Rs.174.90 billion for the Strategic Interventions for Green Hydrogen Transition Programme (SIGHT) programme, Rs.14.66 billion for pilot projects, Rs. 4 billion for R&D, and Rs.3.88 billion towards other Mission components. Under the SIGHT, two distinct financial incentive mechanisms have been proposed, one is targeting domestic manufacturing of electrolysers and the other for production of Green Hydrogen. The Mission will also support pilot projects in emerging end-use sectors and production pathways.

The policy is expected to have a significant impact on the future renewable capacity addition in India. Green hydrogen is a key enabler of the clean energy transition, and the policy will help to accelerate the development of the green hydrogen sector in India.

The policy is expected to lead to increased investment in the green hydrogen sector, development of new green hydrogen technologies and increased demand for renewable energy.

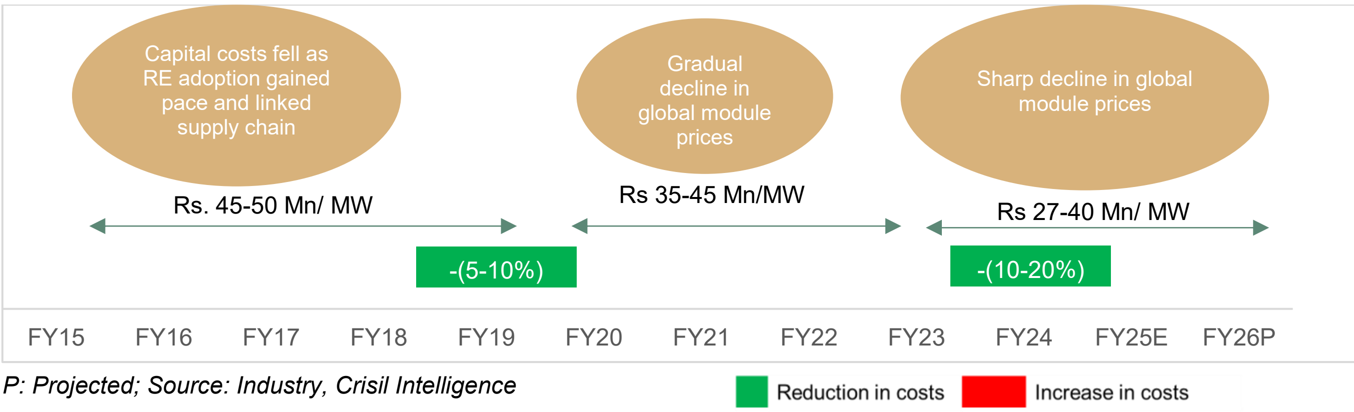
Overall, the Green Hydrogen Policy is a major step forward for the clean energy transition in India. The policy is expected to have a significant impact on the future renewable capacity addition in India and will help to make India a prominent player in the green hydrogen sector.

3.10 Movement of the project capital costs and Operations and Maintenance

Solar project CAPEX trend has largely followed global module price trends – between 2011 and 2021, EPC cost for utility-scale projects reduced by around 65% to Rs ~39 million/MWp due to falling module prices. While landed module cost increased temporarily in Q2 2022 due imposition of BCD on China modules, over H2 of 2022 and 2023, led by a massive supply glut in China, prices across the solar value chain declined sharply – China module prices decreased by around 57% in two-year period ended December 2023 to USD 0.12/Wp. As a result, EPC costs for utility-scale projects declined by around 33% in the two-year period ended December 2023 to Rs 27 million/ MWp. On the BoS front, while prices of commodities like copper and aluminium (used for building mounting structures and other key components) are volatile, the effect on overall EPC cost is marginal due to low share in CAPEX.

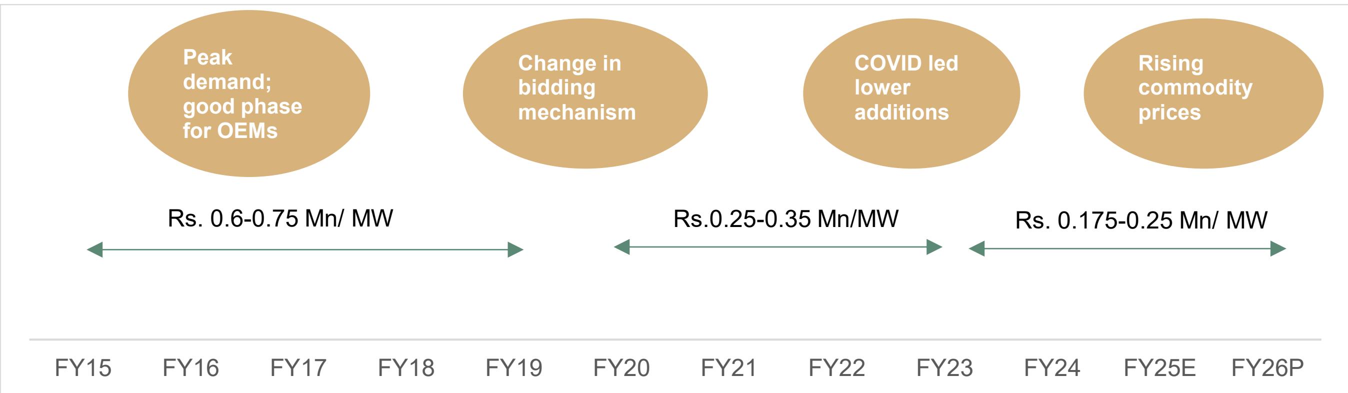
Going forward, while China module prices are expected to remain soft due to excess manufacturing capacity coupled with subdued international demand (mainly due to US aversion to China imports and high inventory levels in EU), domestic prices are expected to hover around USD 0.21-0.23/Wp in fiscal 2026 due to inadequate, albeit growing, domestic supply and ALMM implementation from April 2024 onwards. On the O&M front, costs have decreased by around 30% in the last 3-4 years to around Rs 0.18-0.25 Mn/MW/annum due to experience gained by service providers coupled with technology adoption including robotic cleaning. Robotic cleaning not only helps in achieving better efficiency but also is more environmentally friendly since they use less water and no chemical cleaners.

Figure 37: Declining Module prices leading to lower capital costs



P: Projected; Source: Industry, Crisil Intelligence

Figure 38: Demand, experience and technological improvement leading to lower annual O&M costs



P: Projected
Source: Industry, Crisil Intelligence

3.11 Overview on Indian wind solar hybrid market

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

India has introduced RTC generation tenders, including hybrid tenders to strengthen clean generation combining solar, wind and storage technologies. The MNRE introduced the National Wind-Solar Hybrid Policy on May 14, 2018. The main objective of the policy is to provide a framework for the promotion of large grid-connected wind-solar PV hybrid systems and efficient utilisation of transmission infrastructure and land. It also aims to reduce the variability in renewable power generation and achieve better grid stability. As on April 30, 2024, hybrid projects of aggregate capacity 35,787 MW are under construction in the country.

3.11.1 Key growth drivers

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

- **Potential:** India has around 696 GW (120 m hub height) wind potential and around 750 GW of solar potential. Currently only around 10% of the potential is developed and balance 90% of the potential yet to be exploited. This provides huge opportunities for wind and solar development.
- **Geographical advantages:** India's coastline provides high wind speed as well as excellent solar potential. State such as Gujarat, Maharashtra, Karnataka, Tamil Nadu, Andhra Pradesh have excellent wind as well solar potential. Such an advantage provides a great opportunity for hybridisation. Depending on the project requirements, the hybrid projects can be co-located or located in different locations, making it more flexible even if natural resources are located in different places.
- **Complementary resources:** Wind and solar sources complement each other. Due to their inherent characteristics, they generate power during different times of the day as well as seasons. Wind power is at its maximum during nighttime whereas solar power is available only during the day. Therefore, for 24X7 supply, they complement each other and hence WSH projects provide more reliable power and can be used for round-the-clock (RTC) supply.

Resource optimisation: Co-located WSH plants can help with resource optimisation. With optimum land utilisation and infrastructure sharing, the wind and solar resources can be optimally utilised leading to better CUF as well as cost optimisation. With energy storage facilities, the WSH plants help in better grid management and higher penetration of renewable energy into existing power systems.

Policy push: Government of India's policy push has also helped the WSH segment. With increased ROP targets, VGF funding, PLI schemes, solar park schemes, simplified land allocation has helped both the resources (wind and solar) to thrive.

3.11.2 Support policies for WSH plants

National Wind-Solar Hybrid Policy 2018

This policy aims to encourage new technologies, methods and way-outs involving combined operation of wind and solar PV plants. The aim is to reduce renewable energy variability and improve grid stability.

Capacity: A wind-solar plant will be recognised as hybrid if the rated power capacity of one resource is at least 25% of the rated power capacity of other resource.

Integration: The policy provides for integration of both energy sources, wind and solar, at alternating current (AC) and direct current (DC) level.

RPO: The power procured from the hybrid project can be used for fulfilment of solar RPO and non-solar RPO in the proportion of rated capacity of solar and wind power in the hybrid plant.

Hybridisation of existing wind/solar PV plants: Existing wind or solar power projects, willing to install solar PV plant or WTGs to avail benefit of hybrid project may be allowed to do so under certain conditions.

Incentives: All fiscal and financial incentives available to wind and solar power projects will also be made available to hybrid projects.

Battery storage: Battery storage may be added to the hybrid project to reduce the variability; providing higher energy output for a given capacity and ensuring availability of steady power during a particular period.

State level policies

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. 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 4: WSH policy comparison for select states

Parameter	MNRE	Gujarat*	Andhra Pradesh	Rajasthan	Karnataka
Issued in	May 2018	October 2023	January 2019	December 2019	April 2022
Capacity targets	-	-	5,000 MW	3,500 MW by fiscal 2025	-
RPO	RPO can be fulfilled separately for solar and non-solar	RPO can be fulfilled Separately as well as commonly depending on the project type	RPO can be fulfilled separately for solar and non-solar	Mandatory for discoms to purchase power equivalent to 5% of their RPO targets under this policy	RPO can be fulfilled separately for solar and non-solar
Banking	-	-	5% banking charges	10% banking charges	2% banking charges
CSS	-	Captive: 100% exemption Third-party sale: 25% concession	50% waived for third-party sale for projects set up within the state	-	-
Additional surcharge	-	Captive: 100% exemption Third-party sale: 25% concession	-	-	75% exemption

Parameter	MNRE	Gujarat*	Andhra Pradesh	Rajasthan	Karnataka
Transmission and wheeling charges	100% exemption for already existing plants	No waivers /concession for captive as well as for third-party sale	50% exemption in transmission and wheeling charges for new projects developed within the state	**Hybrid:** 50% concession for captive/ third party sale for 7 years from project commissioning. **Hybrid + storage:** 75% concession for captive/ third party for 7 years from the year of commissioning	Charges will be applicable for additional transmission capacity
Electricity duty	-	100% exemption for intrastate consumption	50% exemption for intrastate consumption	100% exemption for intrastate captive consumption	100% exemption for intrastate consumption applicable for third parties

**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

4 Assessment of solar equipment manufacturing in India and globally

4.1 Overview of solar module manufacturing value chain in India

Crystalline silicon (c-Si) technology is largely deployed in solar PV globally as well as in India. The technology is also expected to comprise the largest pie in India's ambitious target of 280 GW solar capacity addition by 2030. However, historically, 80-85% of the solar modules needed to be imported as domestic capacity was inadequate to meet demand. India does not have a manufacturing base for polysilicon ingots and wafer; hence, players import these components, incurring high cost.

Figure 39: Schematic of c-Si PV module supply chain

Source: Crisil Intelligence

Table 5: Overview of PV production process

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

Source: Crisil Intelligence

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

Only a few GW-scale companies are present in India. Many of the smaller companies have capacities in the 100-500 MW range, with very high operational costs.

Table 6: Key domestic solar module manufacturers with capacity (as of June 2025)

Sr. no.	Name	Installed capacity (MW)
1.	Waaree Energies Ltd.	13,300#
2.	Goldi Solar Pvt. Ltd.	10,700
3.	Emmvee Photovoltaic Power Pvt. Ltd.	7,800
4.	ReNew Photovoltaics Pvt. Ltd.	6,400
5.	Rayzon Solar Pvt. Ltd.	6,000
6.	Premier Energies Photovoltaic Ltd	5,100
7.	Tata Power Renewable Energy Ltd.	4,900
8.	Vikram Solar Ltd.	4,500
9.	Mundra Solar PV Ltd. (Adani)	4,000
10.	Saatvik Green Energy Ltd.	3,742
11.	First Solar	3,300
12.	Renewsys India Pvt. Ltd	3100

#including 1.3 GW of Indosolar,

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 ~91 GW in as per the ALMM list updated in 30th June 2025 and the cumulative cell manufacturing capacity is about ~25 GW till fiscal 2025. The nameplate module capacity in India is expected to touch 110-120 GW by March 2026. The difference in the manufacturing capacities of solar cell and module is partly due to the lack of vertical integration of domestic solar fabs. However, the operational capacity could be less than 50% of the nameplate capacity.

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 production capacities within the next two-three years through integrated factories.

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.

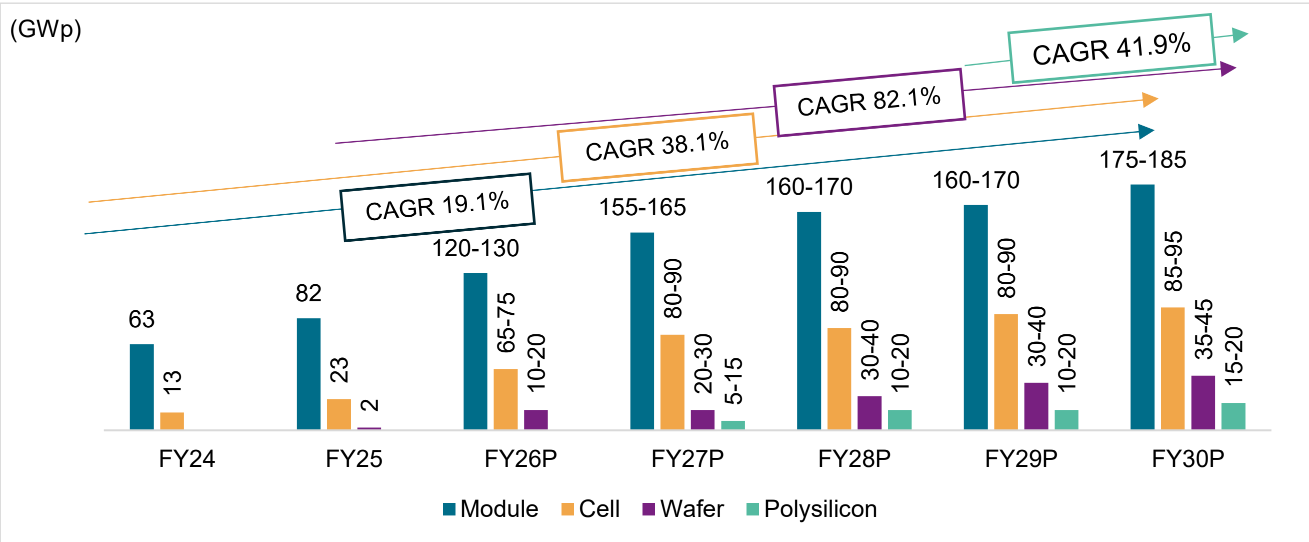
It is also noteworthy that the majority of solar module production is centred on a small number of states. Manufacturing of solar modules is concentrated in these states for a number of reasons, including easy access to ports (for international trade), affordable land, and readily available power close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

4.2 Outlook for 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 GoI 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 manufacturing Capacity to reach 175-185 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 only post fiscal 2025. Gujarat will be at the epicenter of additions with ~55-60% additions in the next 5 fiscals.

Figure 40 : India-Current and projected manufacturing capacity, GWp



P: Projected; Source: Industry, Crisil Intelligence

4.3 Scheme and incentives supporting solar module manufacturing in India

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:

a) *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.

b) *Safeguard duty and basic customs duty –*

Table 7: 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.

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.

c) *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.

d) *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 22021. The ceiling/usage charges was 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.

e) *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 (6W 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

f) *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 a total central financial support of Rs 344.22 bn.

g) 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 Viability Gap Funding (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 the Solar Energy Corporation of India (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.

h) *Introduction of ALMM List-II for Solar PV Cells-*

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

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

On 28th July 2025, MNRE issued amendments to implementation of ALMM for Solar PV cells wherein the last date of bid submission of 09.12.2024 in the earlier order will now shift to a cut-off date which is exactly 1 month after the publication of ALMM List-II. As per this amendment, solar projects bid until the cut-off date will be exempted from the requirement of solar PV cells from ALMM List-II.

On 31st July 2025, MNRE issued ALMM List-II (for Solar PV cells) listing 9 cell manufacturers with a cumulative annual production capacity of 13,067 MW.

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

4.4 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 ~91 GW in fiscal 2025 and further to an estimated 120-130 GW in fiscal 2026. This increase has been driven by government initiatives such as the Production Linked Incentive (PLI) scheme, the reimposition of the Approved List of Models and Manufacturers (ALMM) order, and a robust pipeline of solar projects.

Table 8: 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
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

Player	Polysilicon	Wafer	Cells	Modules
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

Current Status

First Solar has become the first company under the module PLI scheme to announce full commercial production ahead of the deadline – its 3.3 GW integrated thin-film plant commenced production in January 2024. Tata and AmpIn are the only other scheme winners expected to commission awarded capacity by the end of fiscal 2025. Reliance, awarded 10 GW polysilicon-module capacity, is due to commission a 5 GW HJT cell-module line December 2024 and another 5 GW line late 2025. Most other PLI winners are lagging completion deadlines. Waaree is due to commission 5.4 GW cell-module capacity in fiscal 2025. ReNew has already commissioned 4 GW module capacity and is due to commission 2 GW cell-module capacity by end of fiscal 2025. Grew and AmpIn (in partnership with Jupiter) are due to commission 2.8 GW and 1.3 GW cell-module units by the end of 2024. Shirdi Sai, Avaada and Vikram are further behind with a high degree of uncertainty about their plans. Shirdi Sai has made negligible progress while JSW has put the entire project on hold citing unviability of the business because of low module prices.

4.5 Odisha-Attractive State for Module Manufacturing

Odisha is becoming an important center for module manufacturing, particularly in the solar and electronics industries. The state is rich in natural resources, such as silicon and various minerals, which provide a strong base for manufacturing. Its strategic position along India's eastern coast offers convenient access to major markets and shipping routes with 5 major ports.

The Odisha government has introduced numerous incentives for manufacturing sectors, including tax relief and subsidies.

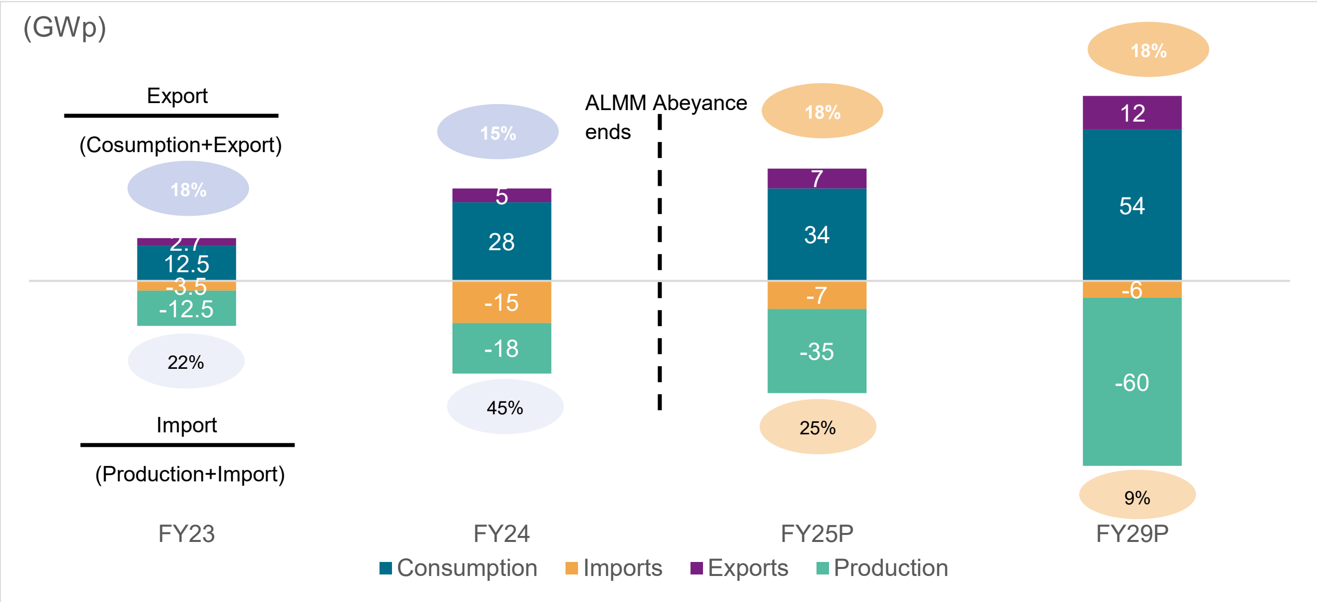
- **Stamp duty exemption**: 100% exemption on stamp duty for land acquisition and registration of deeds.
- **Electricity duty exemption**: 100% exemption on electricity duty for 7-10 years
- **Power tariff reimbursement:** Reimbursement of power tariff of Rs. 2 per unit consumed from local discom
- **Exemption in Open Access Charges:** 100% exempt from cross subsidy surcharge, additional surcharge, state transmission charges on renewable energy procured from plants based in Odisha
- **Capital Investment Subsidy**: 20% to 40% of the total investment
- **SGST Reimbursement**: Upto 100% reimbursement of SGST

Odisha provides number of advantages for solar PV module manufacturing such as supportive government policies, skilled labour force, proximity to markets, infrastructure, favourable business environment etc. Such benefits make it an attractive location for setting up solar PV module manufacturing facilities. Additionally, Odisha has number of ports which can be utilised for efficient logistics, reducing shipping costs and delivery times. Module manufacturers can also explore opportunities for exporting solar PV modules to international markets, making them competitive on the global stage. Odisha is also well connected logistically to entire southeast India to cover domestic market. This proximity to solar power projects can streamline the supply chain, reduce logistical complexities, and promote faster deployment of solar installations.

4.6 Share of domestic and imported modules in Indian market

The nameplate module capacity in India is expected to grow by 30-35% till March 2026, on year, to touch 120-130 GW, up from an estimated base of 96 GW as of March 2025. Even though India is one of the top ten solar module producers, it is far behind its biggest competitor China. Considering this, 80-85% of solar modules need to be imported due to inadequate capacity as well as technology. In fiscal 2024, imports increased by a staggering 11x on-year to 26,690 MW (from 2,098 MW in previous fiscal). The sudden and sharp surge in import was mainly due to ALMM waiver coupled with expiration of time extensions provided to projects under COVID-19 relief. Despite the price surge across the value chain for solar components, imports have been robust as sellers and developers availed duty free period after July 2021 and imported modules for commissioning planned even in fiscals 2022 and 2023 in advance. However, during fiscal 2023, the module import declined due to imposition of BCD on imported solar module, DCR and increased domestic production capacity.

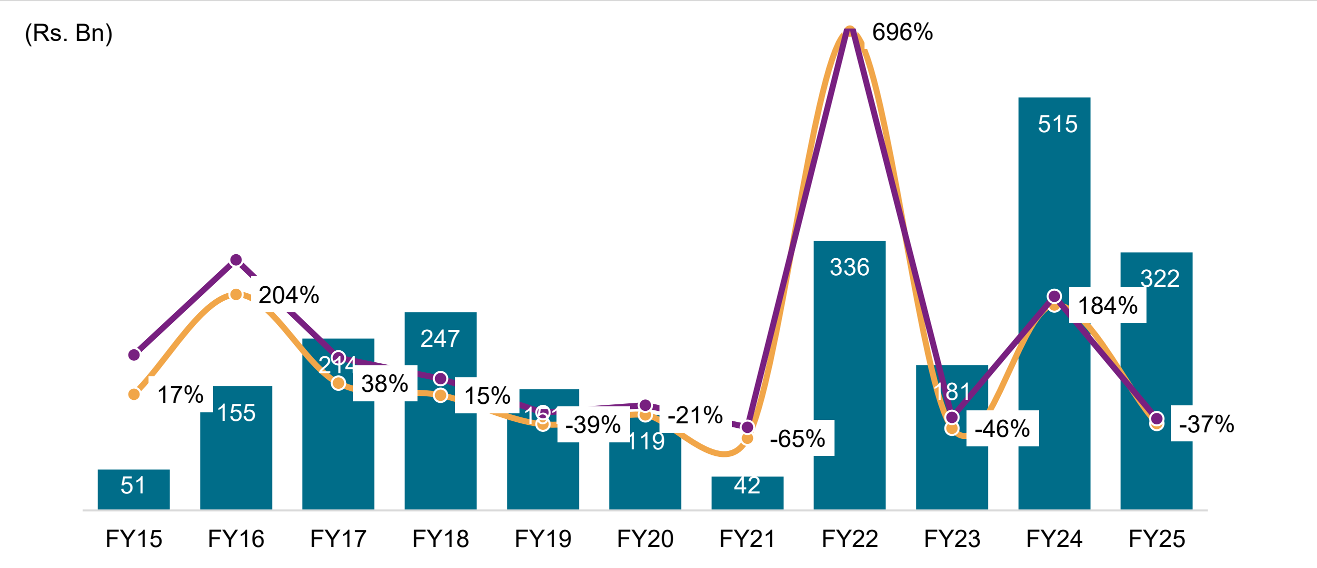
Figure 41: Domestic production to increase 6 times by FY2029 and reliance on imports to reduce



Note: The nos. are in W_p basis; DC Capacity with 150-160% overloading
Source: Crisil Intelligence

Average module production is expected to increase to 64-69 GW between FY26 and FY29 owing to PLI capacities. Nearly Rs 97.3 bn worth solar cells and modules have been exported in fiscal 2025. It is expected to remain flat on year. The average exports between fiscals 2026 and 2029 are expected to be ~2.4 times than of fiscal 2024. 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 25-30% in fiscal 2025 and fall to 5-10% by fiscal 2029 owing to increase in domestic capacity of technologically progressive solar modules and upstream manufacturing. Demand from solar energy remains robust with 150-170 GW of addition expected between FY26-FY30. Further, the application of BCD creates level playing field for manufacturers.

Figure 42: Solar module imports (INR billion)



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

Source: Ministry of Commerce, Crisil Intelligence

China continues to be the largest module exporter to India, followed by Germany and 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 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 8-10% by fiscal 2029. Nevertheless, India will continue to depend on imports for upstream components such as polysilicon, wafers, and cells.

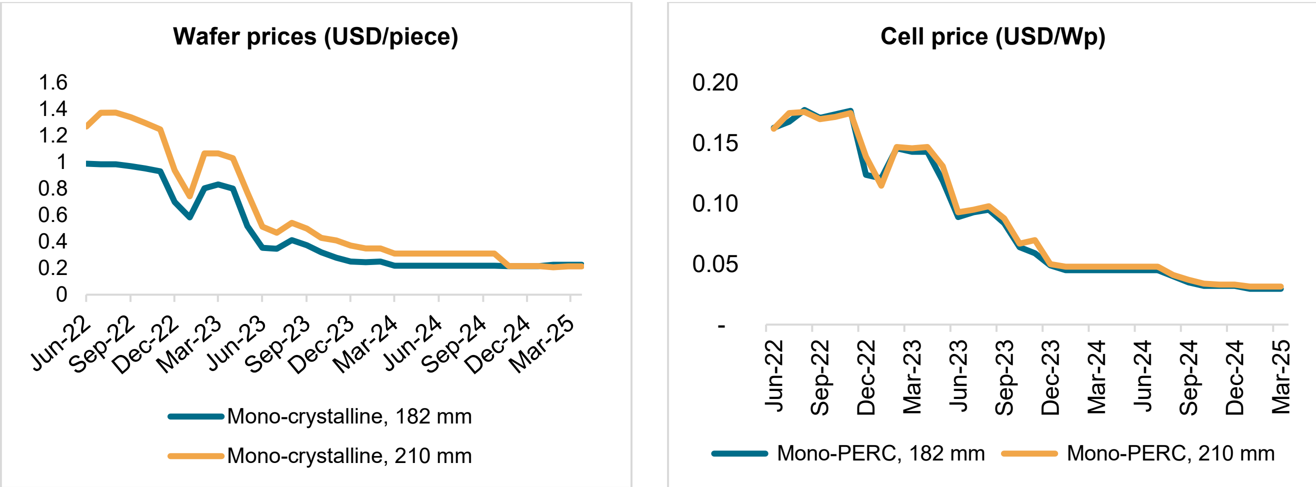
4.7 Price trend of solar PV cells and modules

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% to $ 0.12-0.15/piece as of March 2025.

The oversupply of polysilicon also prompted the world's largest monocrystalline solar wafer supplier to cut the prices of its photovoltaic wafers twice between April and May 2023, reducing prices by 33% as cell manufacturers sought to fulfill their order requirements. Cell prices were also down 76% over December 2022 levels, reaching $0.036 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 43 : Wafer and cell prices

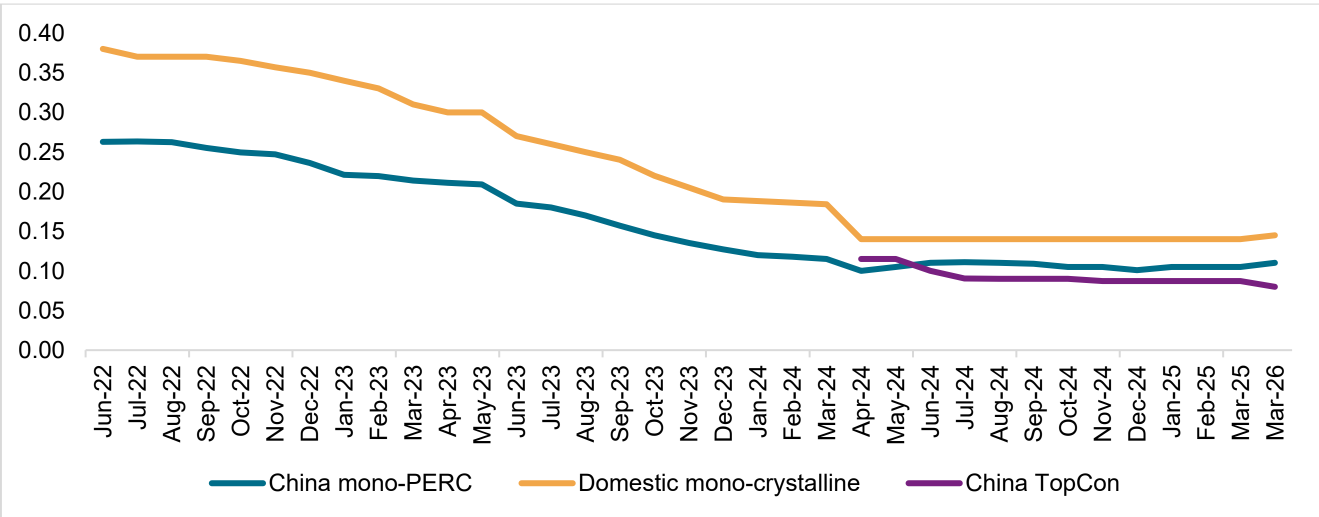


Note: Prices are free-on-board (FOB) China basis as applicable at the end of each quarter.
Source: Crisil Intelligence

Declining module prices

Module prices experienced a remarkable surge of 22% in fiscal 2022 and a subsequent 7% increase in fiscal 2023. In fiscal 2025, module prices remained stable, standing at $0.11 per Wp in March 2025. However, in Fiscal 2024, module prices underwent a significant decline, standing at $ 0.11 per Wp in March 2024 and 2025, down 43% YoY The sharp decline observed in previous years can be attributed mainly to the supply glut in China and low upstream components including polysilicon. Domestic module prices declined in line with China prices to $0.14 per Wp in March 2024 and 2025 but maintained a sizeable premium over China prices. As of March 2025, India had approximately 89 GW module capacity, in contrast to only around 25 GW of cell capacity.

Figure 44 : 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

4.8 Domestic vs Export demand potential

Module exports experienced a significant uptick in fiscal 2024 reaching a record high of 6,077 MW, up 87% Y-o-Y due to higher prices in the international market – export price of domestic modules ranged from USD 0.29-0.37

per Wp, a significant premium over domestic prices. International aversion to Chinese imports following implementation of Uyghur Forced Labour Prevention Act in 2022 has been a key catalyst. The recently initiated antidumping investigation in the US against SEA imports is expected to be another key catalyst for Indian module manufacturers. Exports are expected to remain high between fiscal 2024 and 2028, reaching 25 GW, driven by domestic capacity additions of 60-65 GW. Export demand will also be supported by other key renewable energy markets, such as the Middle East, the European Union, and Latin American nations.

Ban on modules linked to Xinjiang due to notification of the UFLP Act in June 2022 by US could ideally provide Indian manufacturers with an opportunity to increase market share in US, however, withdrawal of tariffs on non-Xinjiang Chinese modules in February 2022 could prove to be roadblock and this continues to remain a monitorable. USA continues to be top consumer of Indian made modules 60% of FY 23 exports to US already achieved in Q1 FY 24 owing to ban on Chinese module imports The European Union is also expected to contribute to future demand. Post BCD levy, domestic project developers may tie up with domestic module manufacturer to import cell at 20% duty (27.50% with AIDC) for local assembly of modules to avoid 20% duty (40% with AIDC) levied on panels. Also, on February 4, 2022, the Biden administration extended the Section 201 tariffs imposed on the import of solar modules from China for four years. This is a growth driver for domestic module exports. Ban on Chinese region and ALMM abeyance to surge Indian exports in fiscal 2024 and domestic usage to be largely preferred till 2028.

With the ban on imports from Xinjiang region and PV grade polysilicon being designated “high priority” item to enforce ban, ~ 45% of global PV grade polysilicon facilities could come under scrutiny. USA imported 54 GW of modules in 2024, with SEA representing around 84% share. Module manufacturers like Longi, Jinko, JA and their ties with Xinjiang based polysilicon providers have come under special scrutiny for use of forced labour and could look for an alternative market like India to off load surplus panels. However, off late module shipments worth 600 MW of Trina was cleared. Indian manufacturers on other hand could be looking to capitalise on this and increase their market share in USA by exporting more and supplying less locally.

USA: As per IRENA, at the end of CY2023, the USA has installed base of ~137 GW of solar PV capacity. During last 7 years (2017-2024), on an average basis, the USA added around 17 GW solar PV capacity annually. The extension of production tax credit (PTC) and investment tax credit (ITC) proposed by US government is envisaged to promote capacity additions. During the next 5 years, the USA is expected to add around 40-45 GW of Utility scale solar PV capacity annually. However, the planned phase out of tariffs on solar imports from China and full restrictions on imports from Xinjiang region, remain monitorable. The IRA aims to reduce domestic inflation and established an Advanced Manufacturing Production Credit to promote domestic manufacture of solar modules and its components offering solar tax credit of 30% till 2032. However, the 30% Residential Clean Energy Credit would be terminated from midnight of 31 December 2025; Wind and solar facilities that begin construction after 1 year from enactment would be required to be placed in service by 31 December 2027 to receive tax credit for commercial and utility-scale projects under Section 48E. To promote the local manufacturing, USA imposed 50% import tariff on solar cells and modules from China. There have been various barriers on import from China in USA including antidumping or countervailing duty tariffs, Section 201 and 301 tariffs, and restrictions under the Uyghur Forced Labor Prevention Act (UFLPA).

European Union: The European Union had a cumulative solar PV capacity of ~302 GW as of 2024. During the last 8 years, the EU added around 26 GW of solar capacity annually. During the next 5 years, the EU is expected to add around 30-32 GW of Utility scale solar PV capacity annually. The EU has plans to increase the solar capacity to 600 GW by 2030. Local module manufacturing has been a concern in Europe. Large scale dependence on China for module manufacturing has been a concern due economic security and geopolitical vulnerabilities. European Union has targeted minimum of 45% of self-sufficiency in module manufacturing across value chain. The large production cost gap between regions is the biggest challenge to overcome to spur local module supply chain manufacturing. Recent developments including additional funding from the European Investment Bank (EIB) and the use of State aid to support manufacturing investments could trigger more announcements or contribute to the realization of the new manufacturing capacity announced. It is estimated that during the next 3-4 years, more than 30-35 GW of solar PV module manufacturing capacity will come in Europe.

In recent years, the EU has adopted the forced labour regulation, created the International Procurement Instrument, introduced the foreign subsidies regulation, revised its foreign direct investment screening process, opened anti-subsidy probes, passed the Critical Raw Materials Act, and agreed the Green Deal Industrial Plan with the newly passed Net Zero Industry Act at its core.

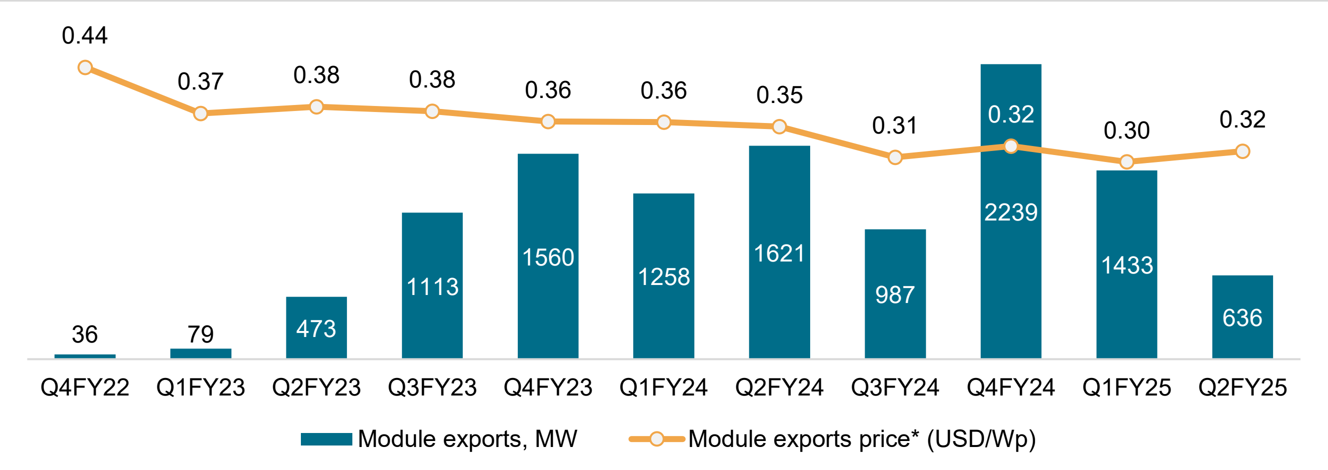
Middle East: The Middle East is a transcontinental region centered in Western Africa. Saudi Arabia is the largest nation in the group, while Bahrain is the smallest. The Middle East's economic performance has been skewed over the years.

The OPEC+ alliance had announced oil output cuts, meaning that major MENA energy producers would sell less oil in the near term than during a large part of 2022. Brent oil prices are expected to drop from about USD102 per barrel in 2022 to USD87-88 per barrel in 2023 and 2024, reducing the petrodollar inflows into MENA oil-exporting countries when compared to 2022. With solar power tariffs reaching grid parity, solar power has been gaining significance in the Middle East region. Considerable population growth and increased industrialisation and developments have put stress on the existing power network, which has helped affordable renewable solutions find a comfortable place in the region. Various government policy supports as well as the requirement of use of maximum RE sources, will drive the solar market in the region.

Oman is working to increase its use of renewable energy. The country's Vision 2040 plan aims to increase the share of renewable energy in the country's electricity generation mix from 1% today to 20% by 2030 and to 35-39% by 2040.

The UAE has set a target of achieving net-zero emissions by 2050. To support this goal, the UAE aims to install 14 GW of clean energy capacity by 2030. Saudi Arabia has set a similar target of reaching net-zero emissions by 2060. To support its transition towards cleaner energy sources, Saudi Arabia plans to install 58 GW of renewable energy capacity by 2030. Bahrain has also committed to achieving net-zero emissions by 2060. As part of its efforts, Bahrain aims to have renewables account for 10% of its power generation by 2035. Qatar aims to reduce its emissions by 25% by 2030. To contribute to this goal, Qatar plans to have renewables responsible for 20% of its power generation by 2030.

Figure 45: Module exports and prices



**Weighted avg. price*
Source: Crisil Intelligence

Around 98% of module exports from India has been to the USA. Implementation of the Uyghur Forced Labor Prevention Act has provided impetus to India's solar module exports. However, tariffs on imported solar panels and modules under Section 201 of the Trade Act of 1974, chances of imposition of anti-dumping and countervailing duties, competition from other countries and US government incentives to module manufacturers in USA can impact the export to US. Module exports grew 5% on year during April to December 2024 as domestic manufacturers continued to focus on the US market. Supply chain diversification, owing to geopolitical tensions between China and the US, continues to favour the export market for growing PV economies such as India, Thailand, Vietnam, and Malaysia. The re-emergence of ALMM in fiscal 2025 is not expected to hinder exports, as the rising capacity of module and upstream components is expected to be sufficient to cater to both.

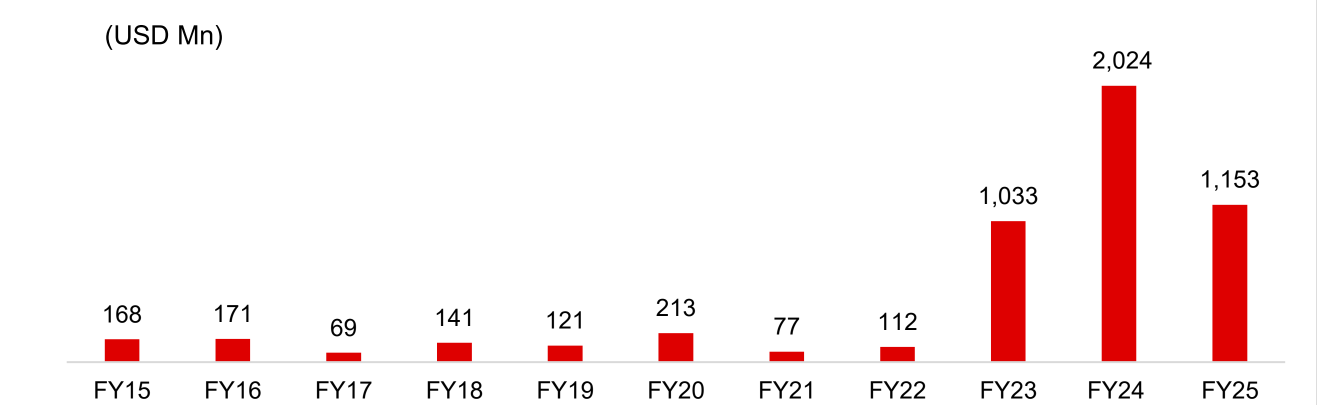
4.9 Major export destinations for Indian solar modules

Although India has 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 ULFA has supported India's solar module exports. The ULFA 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 ULFA 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 ULFA and exports to US have seen substantial increases in fiscal 2022.With more focus on sustainability and its plans for expansion of solar capacity, the trend of export to US is expected to continue.

Figure 46: Export of modules and cells from India in value terms



Source: Ministry of Commerce; Data for HS Code 85414011; FY 21-22 (HS Code 85414011+85414012): FY 23 onwards (HS Code 85414300 +85414200); Crisil Intelligence

During fiscal 2024, USA accounted for ~98% of the exports of solar modules (in value terms), followed by Thailand, Somalia, Indonesia and South Africa. Also, during fiscal 2025 US accounted for ~97% of the total exports of solar module followed by Canada and Thailand.

Table 9: % Share of export of solar modules (in value terms USD Mn)

Country	2023-2024 (in $ Million)	Export Share (%)	2024-2025 (in $ Million)	Export Share (%)
U S A	1,972.69	97.50%	1119.12	97.08%
Thailand	12.39	0.60%	0.47	0.04%
Somalia	9.86	0.50%	-	0.00%
Indonesia	7.85	0.40%	-	0.00%

South Africa	4.73	0.20%	0.12	0.01%
Canada	2.07	0.10%	1.76	0.15%
UAE	2	0.10%	0.37	0.03%
Tanzania	1.24	0.10%	0.17	0.01%
Cambodia	0.95	0.00%	-	0.00%
Afghanistan	0.91	0.00%	-	0.00%
Others	9.11	0.50%	30.77	2.67%
Total	**2,023.80**	**100**	**1152.78**	**100.00%**

Source: Ministry of Commerce; FY 22-23-22 (HS Code 85414011+85414012); FY 23-24: (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 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 (IRA) in 2022. US PV module production stood at ~50 GW in February 2025. The US Inflation Reduction Act (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.

The European Union is another key destination for module manufacturers with a target to reach 30 GW solar module production by 2025, from its current capacity of 9.4 GW. As per announcements by key manufacturers, 15-20 GW of expansion is expected for modules, cells and wafers/ingots each, in addition to 30 GW of polysilicon manufacture by 2025. Expansion plans for cell and module manufacture by major players are given below:

Global solar capacity additions will be largely policy driven across key markets:

China: NEA’s “Guideline on Energy Work In 2023” targets to increase China’s installed capacity of wind power and photovoltaic power by 160 GW over the year. Capacity additions will further be driven by $140,000 allocated to support feed-in-tariff (FiT) based projects, R&D programs & fiscal incentives.

USA: The extension of production tax credit (PTC) and investment tax credit (ITC) proposed by US government is envisaged to promote capacity additions. However, the planned phase out of tariffs on solar imports from China and full restrictions on imports from Xinjiang region, remain monitorable. The IRA aims to reduce domestic inflation and established an Advanced Manufacturing Production Credit to promote domestic manufacture of solar modules and its components offering solar tax credit of 30% till 2032. However, the 30% Residential Clean Energy Credit would be terminated from midnight of 31 December 2025; Wind and solar facilities that begin construction after 1 year from enactment would be required to be placed in service by 31 December 2027 to receive tax credit for commercial and utility-scale projects under Section 48E.

Japan: METI in 2025 introduced support scheme for the initial investment in the second half of FY2025. Starting in October 2025, the support price will increase for homes as well businesses. The new scheme will be effective for 1.5 years from October 2025 through FY2026, with no decision yet made for FY2027 onwards. This increase in incentives is expected to boost commercial and residential adoption with higher initial support prices starting October 2025.

Germany: It is expected to record 4-5 GW of capacity additions annually, which may increase as the government is looking to move away from gas-based generation owing to geopolitical factors. Additionally, removal of cap on solar subsidies may also bolster capacity additions.

Spain: Spain has targeted to add ~81 GW of solar energy installed capacity by 2030. The Spanish PV market is predominantly focused on the utility sector, which holds 60% of the market share, followed by the commercial and industrial (C&I) sector at 27%, and the residential sector at 13%. Spain has been a leader in renewable energy adoption, and its ongoing investments in solar infrastructure are likely to continue driving rapid capacity additions.

4.10 China Plus One strategy

China Plus One strategy encourages companies to diversify their operations by expanding outside of China while still maintaining a presence in the country. This strategy is becoming increasingly popular in the solar industry, as companies look to reduce their dependence on China and diversify their supply chains. There are a number of factors encouraging the China Plus One strategy for solar. Some of them are: The rising cost of labor in China; the increasing complexity of the Chinese regulatory environment; the growing political risk in China; the increasing demand for diversification from investors; number of other countries that are emerging as potential destinations. Countries like India, Vietnam, Malaysia, and Thailand offer a number of advantages, including lower labor costs, favorable government policies, and access to new markets. India is one of the potential destinations for solar manufacturing due to its low labor cost as well as favorable political and regulatory environment for manufacturing.

4.11 India’s Export opportunity

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 ~125 GW by fiscal 2029. Domestic demand for solar modules is estimated to be around 38-42 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.

4.12 Competitive mapping Solar Module manufacturers in India

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 FS India (First Solar) account for about ~ 33% of the total domestic ALMM enlisted module manufacturing capacity of ~29.7 GW (excl. co-branding) as of 30th June 2025.

Table 10: Comparative summary of domestic module manufacturers

Parameter	Saatvik	Waaree Energies	Vikram Solar	Adani Mundra Solar PV	Premier Energies	RenewSys India
Number of manufacturing factories	3 in Haryana	4 in Gujarat	1 each in West Bengal and Tamil Nadu	1 in Gujarat	2 in Telangana	1 each in Karnataka, Telangana and Maharashtra
Experience in PV module manufacturing	9 Years	16 years	17 years	8 years	26 years	12 years
Operational capacity (as on April-25)	~3.7 GW Modules	13.3 GW modules (incl. 1.3 GW of Indosolar)	4.5 GW modules	4 GW cells and modules	4.1 GW modules, 2 GW Cells	2.5 GW modules, ~0.1 GW cells
Under-construction capacity	5 GW module In Phase 1 4.8 GW Cells In Phase 2	6 GW Modules 5.4 GW Cells **Proposed-** 6 GW modules, 6 GW cells, 6 GW Ingot-Wafer capacity	Proposed 6 GW & 3 GW Cell integrated cells & modules	10 GW cell and module	2 GW Wafer 5 GW Cell 5 GW Module	3 GW Modules
PLI Capacity	NA	6 GW (W+C+M)	2.4 GW (C+M)	0.737 (Group) (integrated)	NA	NA
NABL Accredited Lab	-	For modules	For modules	-	-	For encapsulants and backsheets
Enlisted Capacity as ALMM List 30th June-25	1,740 MW	11,961 MW	2,855 MW	3,919 MW	3,646 MW	2,949 MW

Parameter	Saatvik	Waaree Energies	Vikram Solar	Adani Mundra Solar PV	Premier Energies	RenewSys India
% Share in total enlisted capacity as per ALMM List Feb-25	1.91%	13.16%	3.14%	4.31%	4.01%	3.24%
Key Products and services	Solar PV modules, EPC services, O&M Service, Solar Pumps	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, EPC services, O&M services, and water pumps	Solar PV modules and cells
Cumulative Installed capacity in EPC	150 MW	1000+ MW	1,420 MW	NA	650+ MW	NA
Key Technologies offered	Bifacial N-TOPCon, Bifacial Half Cut, Mono Half Cut, Monocrystalline, Polycrystalline	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	TOPCon, Polycrystalline Si cells, mono PERC, poly Si modules	TOPCon, Mono/Multi PERC, Bi-facial
Efficiency (%)	Upto 22.84	21 - 23	20.22 – 23.02	20 - 22	Upto 22	Upto 25.3
PE Investments	NA	Rs. 10 Bn (Value quest)	Rs. 7.04 Bn (Multiple Investors incl Viney Equity Market)	USD 394 Mn from Barclays PLC and Deutsch Banks	Rs. 2 Bn from GEF Capital	NA

NA: Not available

Source: Company, Company websites, MNRE ALMM 30th June-2025, 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 11 :Existing and planned capacity additions of leading players

Players		Existing Capacity (GW)	Planned Capacity (GW)	State where capacity is planned
Waaree Energies	Module	13.3	6	Gujarat
	Cell	5.4	6	Gujarat
Adani Solar	Module	4	6	Gujarat
	Cell	4	6	Gujarat
Reliance New Energy	Module	-	10	Gujarat
	Cell	-	20	Gujarat
Shirdi Sai Electricals	Module	0.5	30	Andhra Pradesh
	Cell	-	30	Andhra Pradesh
Vikram Solar	Module	4.5	17	Tamil Nadu
	Cell	-	12	Tamil Nadu
Premier Energies	Module	5.1	8	Telangana
	Cell	2	8	Telangana
Saatvik Green	Module	3.7	5	Odisha
	Cell	-	4.8	Odisha
Goldi Solar	Module	10.7	4	Gujarat
	Cell	-	4	Gujarat
ReNew	Module	6.4	-	NA
	Cell	2.5	4.0	Gujarat
Grew Energy	Module	2.9	3.5	Jammu & Kashmir
	Cell	-	2.8	Jammu & Kashmir
Solex Energy	Module	1.5	13.5	Gujarat
	Cell	-	5	Gujarat
RenewSys	Module	2.5	3	Maharashtra
	Cell	0.1	1	Andhra Pradesh
TP Solar Ltd.	Module	4.9	-	NA
	Cell	4.9	-	NA
Rayzon	Module	6	6	Gujarat
	Cell	-	3.5	Gujarat

Source: Industry, Company websites, Crisil Intelligence

4.13 Overview of Global PV Module and Cell manufacturing

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.

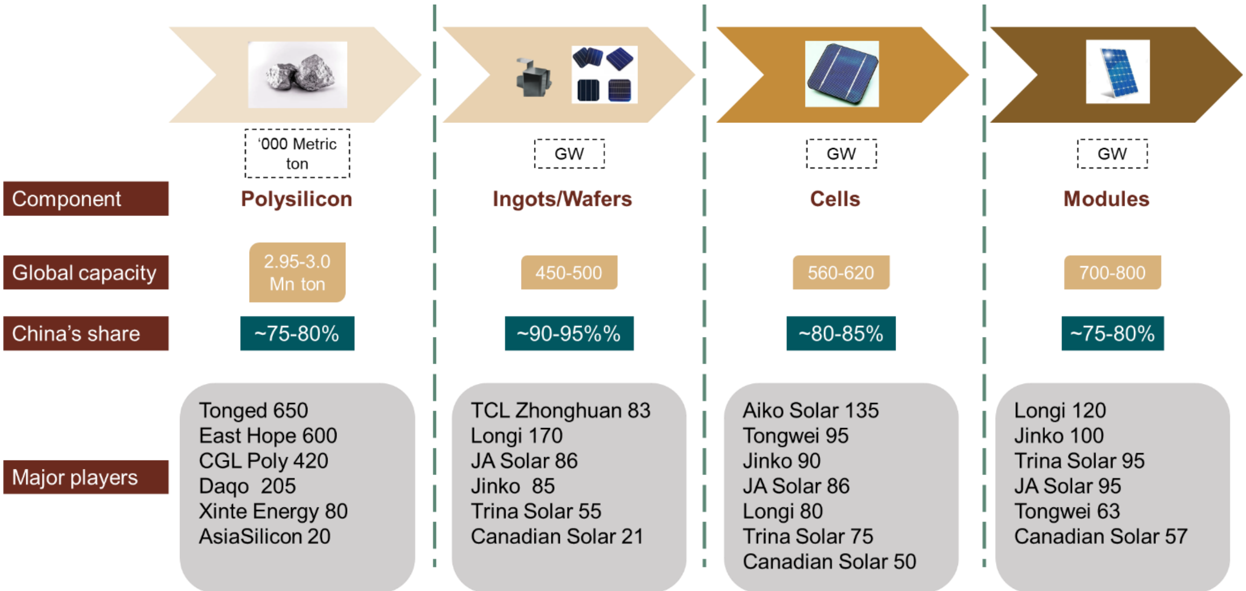
In terms of wafers, China faces minimal competition as it dominates the manufacturing sector. However, when it comes to cells and modules, Southeast Asia, particularly countries like Vietnam, Malaysia, and Thailand, possesses significant manufacturing capacity. These countries have emerged as key players 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 47 : China's share in solar value chain



As on end of CY 2023; 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 2023, global PV shipments were approximately 564 GW—an increase of 100% from 2022. In 2023, 98% of PV shipments were mono c-Si technology, 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 IRA provides tax credits for various PV segments, leading to mostly segment-specific project announcements.

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 2023 crossed 500 GW, of which the top 10 players, including LONGi Solar, Trina Solar, Jinko Solar, accounted for a share of ~ 75% in shipments.

Table 12: Comparative summary of global module manufacturers

Parameter	LONGi Solar	Trina Solar	Jinko Solar	JA Solar	Canadian Solar	Risen Energy
Number of manufacturing factories	8 in China, 1 each in Malaysia and Vietnam	4 in China, 1 each in USA, UAE, Thailand, Indonesia and Vietnam	14 in China, Vietnam, Malaysia and USA	12 in China, Vietnam and Malaysia	20 in Canada, China, Brazil, Thailand and Vietnam	4 in China, 1 in Malaysia
Experience in PV module manufacturing	25 years	28 years	19 years	20 years	24 years	23 years
Operational Capacity 2015	NA	5.1 GW Modules 3.7 GW Cells	4.7 GW Modules 3.0 GW Cells	4.0 GW Modules 4.0 GW Cells	4.3 GW Modules 2.7 GW Cells	NA
Operational capacity (As on Dec-24)	120 GW modules 80 GW cells 170 GW wafers	120 GW modules 105 GW cells 60 GW wafers 10 GW trackers	130 GW modules 95 GW cells 120 GW wafers	100+ GW modules 70+ GW cells 80+ GW wafers	61 GW modules 48 GW cells 31 GW wafers 25 GW ingot	35 GW modules 27 GW cells
Under-construction capacity	150 GW modules 100 GW cells 200 GW wafers	30 GW modules 25 GW cells 6.5 GW wafers	20 GW modules 40 GW cells 35 GW wafers	10 GW modules 30 GW cells 30 GW wafers	42.2 GW modules 40.2 GW cells 30 GW wafers 30 GW ingots	16 GW modules 19 GW cells
Product shipments (CY 24)	108.5 GW wafers 82.32 GW cells & modules	34 GW modules*	93 GW modules, 6.7 GW cells and wafers	74.2 GW modules and cells	31.1 GW modules	24.5 GW modules
Key Products and services	Solar PV modules, wafers, solutions for C&I, utility, and rooftop use	Solar PV modules, solar trackers, utility solutions, EPCM services	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

Key Technologies offered		TOPCon, Mono PERC, bi-facial module, half-cut cells, HPBC	Bi-facial PERC, TOPCon, HJT, 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,	Mono PERC, bi-facial PERC, bi-facial HJT modules, TOPCon
Key Financials (CY 24)	**Revenue**	$11.49 bn	$6.07 bn*	$12.6 bn	$9.7 bn	$6.0 bn	$2.8 bn
	Net profit	($1.2 bn)	$0.74 bn*	$1.4 bn	NA	NA	NA

**As of H1 2024; Source: Company websites, Crisil Intelligence*

Table 13: 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 USA, UAE, Thailand, Indonesia 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 (As on Dec-24)	~ 2 GW cells	105 GW cells	95 GW cells	70+ GW cells	48 GW cells	~ 12 GW
Product shipments (CY 24)	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

Parameter		Sunlike Solar	Trina Solar	Jinko Solar	JA Solar	Canadian Solar	Hanwha Q Energy
Key Financials (CY 23)	Revenue	NA	$6.07 bn*	$12.6 bn	$9.7 bn	$6.0 bn	NA
	Net profit	NA	$0.74 bn*	$1.4 bn	NA	NA	NA

NA: Not available

**As of H1 2024; Canadian, Trina Solar, Jinko and JA Solar shipment for the FY23 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.

4.14 Global technology trends and its adoption

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.

Table 14: Existing vs upcoming technologies

Parameters	Mono PERC	TOPCon	HJT
Initial Capex	$ 31-38 mn./GW	$ 38-46 mn./GW	$ 69-75 mn./GW
Cell Efficiency	23.2% - 23.7%	24.5% - 25.2%	24.5% - 25.2%
Module Efficiency	20.0% – 21.5%	22.0% - 23.0%	22.0% - 23.0%
Bi-faciality	70% - 75%	80% - 85%	80% - 90%
Complexity	Moderately complex	Less than HJT. Existing Mono PERC production facility can be upgraded to TOPCon	Most complex

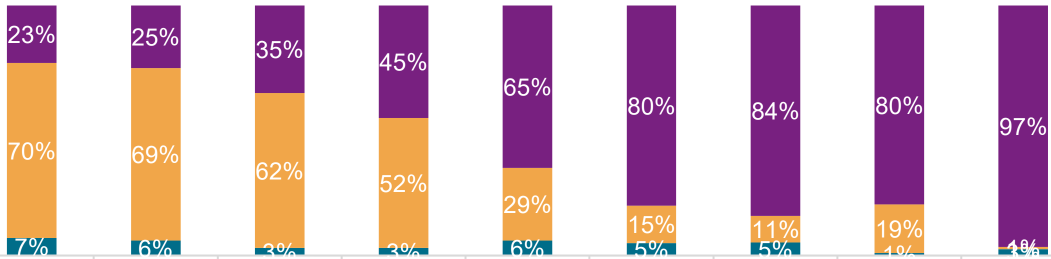
[2] Fraunhofer ISE: Photovoltaics Report, updated: 29 May 2025

Parameters	Mono PERC	TOPCon	HJT
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 Intelligence

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

Figure 48: Module technology share



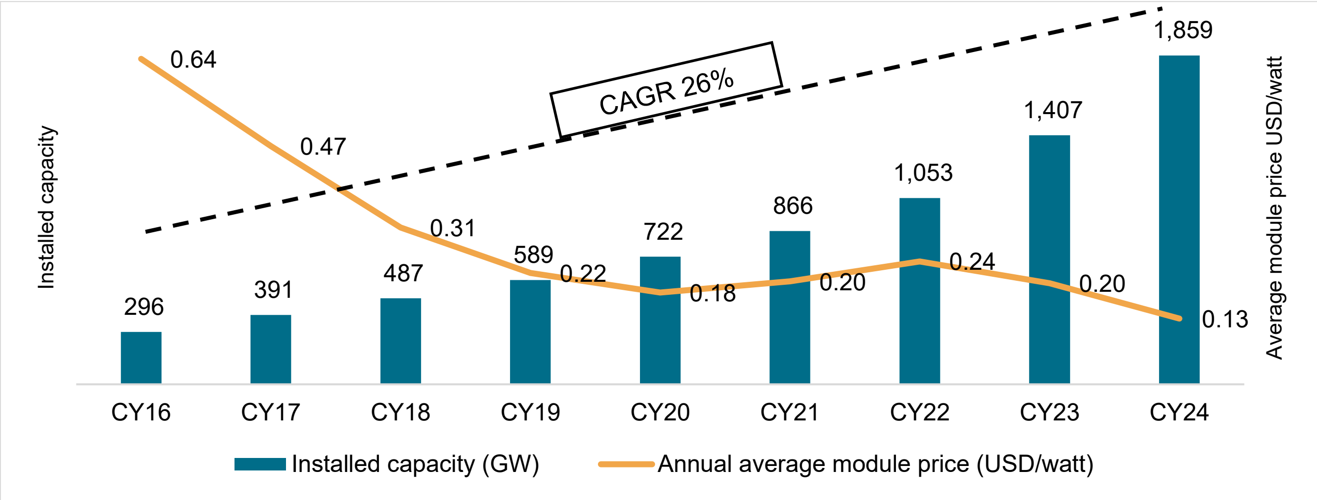
	CY15	CY16	CY17	CY18	CY19	CY20	CY21	CY22	CY23
Mono Si	23%	25%	35%	45%	65%	80%	84%	80%	97%
Poly Si	70%	69%	62%	52%	29%	15%	11%	19%	1%
Thin Film	7%	6%	3%	3%	6%	5%	5%	1%	3%

E: Estimated; Source: Industry, Crisil Intelligence

4.15 Total Global Market Opportunity in GW Installations

Continuous innovation and economies of scale have helped drop in Module prices. With significant fall in module prices, solar PV became one of the most preferred electricity generation technology leading to substantial capacity additions.

Figure 49 : Global solar PV installed capacity registered ~25% CAGR between 2016 and 2024



Source: IRENA, Crisil Intelligence

Table 15: Annual solar capacity additions in major economies (in GW)

Region	CY17	CY18	CY19	CY20	CY21	CY22	CY23	CY24
China	53	44	30	49	53	86	217	278
EU	5	8	16	18	26	33	53	58
USA	8	8	10	15	19	18	15	38
Japan	7	7	7	9	7	5	4	3
Australia	1	4	5	5	5	4	4	5
India	8	9	8	4	10	13	9	25
Africa	2	2	1	1	1	1	1	2
Middle East	1	1	3	1	2	3	5	3
Canada	0	0	0	0	1	1	0	0
RoW	10	11	24	30	21	25	39	41
World	95	95	103	132	144	189	352	452

Note: The annual capacity addition numbers pertain to calendar year (January-December)

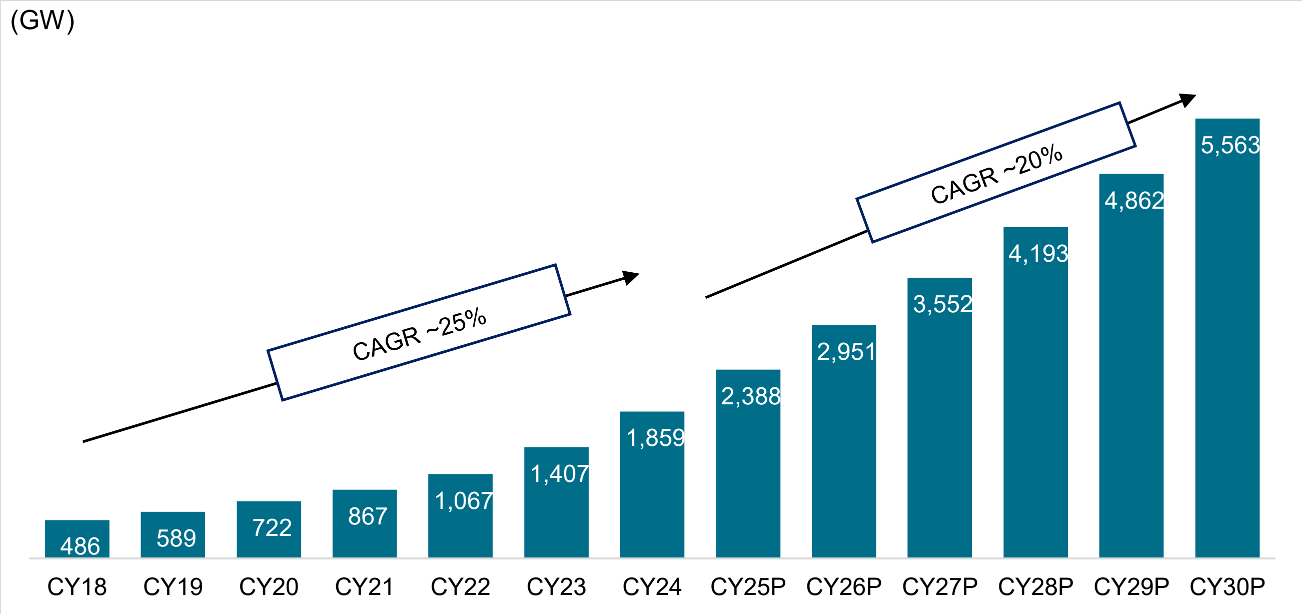
Source: IRENA, Crisil Intelligence

China continues to dominate the solar PV market, accounting for about ~61% of the global installed capacity, while key European countries control about ~13% of the total solar PV installed capacity.

4.15.1 Global solar outlook (CY2025-2030)

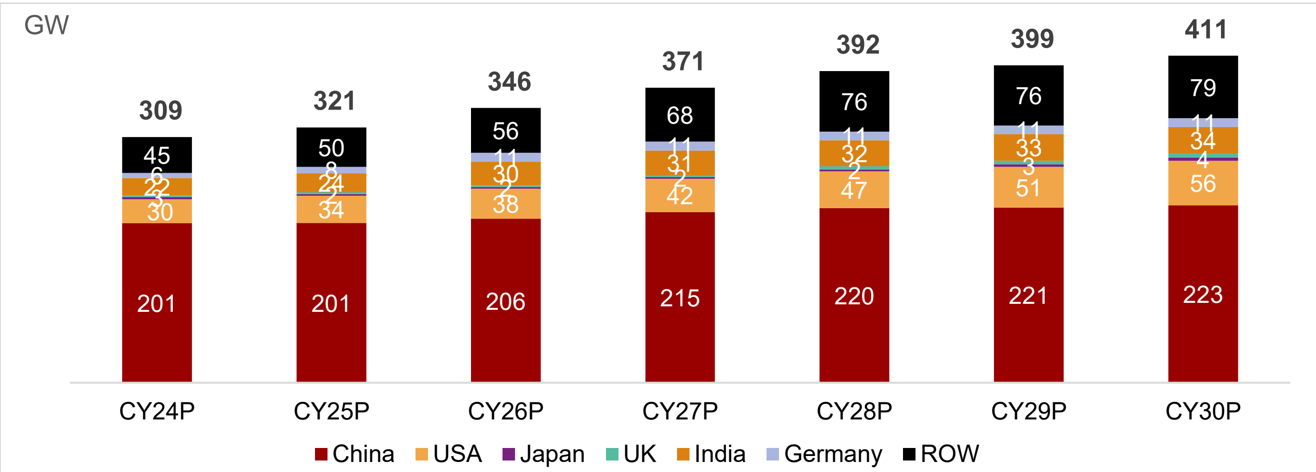
As per IEA- Renewables 2024, global annual renewable capacity additions rise from 666 GW in 2024 to almost 935 GW in 2030. Solar PV and wind are forecast to account for 95% of all renewable capacity additions through 2030 because their generation costs are lower than for both fossil and non-fossil alternatives in most countries, and policies continue to support them. Global renewable capacity is expected to increase over 5 520 GW during 2024-2030, 2.6 times more than deployment of the last six years (2017-2023). Utility-scale and distributed solar PV growth more than triples, accounting for almost 80% of renewable electricity expansion worldwide. Solar PV adoption accelerates thanks to declining equipment costs, relatively rapid permitting and widespread social acceptance.

Figure 50: Historical and Projected growth in global installed capacity base in solar PV over CY18-30P



**Solar PV Utility scale as well as distributed systems*
(P): Projected
Source: IRENA, IEA Renewables 2024, Crisil Intelligence

Figure 51: Projected annual solar capacity additions in major economies



(P): Projected; Source: IEA Renewables 2024, Crisil Intelligence

The International Solar Alliance has committed to invest $1 trillion by 2030 in solar industry. This will result into installation of 1,000 GW of solar energy capacity. The market is driven by various positive influences such as falling costs of solar energy technologies, the increasing awareness of the risks of climate change, and the growing demand for energy security. Increasing adoption of rooftop/decentralised solar applications, growth of utility scale solar coupled with energy storage solutions and advancements in solar and energy storage technologies will drive investments in the sector.

Due to supportive policies and favourable economics, the world's renewable power capacity is expected to surge over the rest of this decade, with global additions on course to roughly equal the current power capacity of China, the European Union, India and the United States combined, according to IEA Report Renewables 2024.

The Renewables 2024 report by the IEA finds that the world is set to add more than 5500 GW of new renewable energy capacity between 2024 and 2030 – almost three times the increase seen between 2017 and 2023.

According to the report, China is set to account for almost 60% of all renewable capacity installed worldwide between now and 2030, based on current market trends and today's policy settings by governments. That would make China home to almost half of the world's total renewable power capacity by the end of this decade, up from a share of a third in 2010. While China is adding the biggest volumes of renewables, India is growing at the fastest rate among major economies.

In terms of technologies, solar PV alone is forecast to account for a massive 80% of the growth in global renewable capacity between now and 2030 – the result of the construction of new large solar power plants as well as an increase in rooftop solar installations by companies and households.

4.16 US module demand supply situation

Demand Situation

The U.S. solar industry has witnessed exponential growth in recent years, with solar energy becoming one of the fastest-growing segments of the energy market. However, as solar adoption accelerated, the demand for solar energy has grown exponentially due to which the supply of solar modules has faced both opportunities and challenges. The demand-supply dynamics of solar modules is crucial for all the stakeholders including policymakers, manufacturers, and project developers.

The demand for solar modules in the U.S. market has experienced significant growth which are driven by multiple factors, majorly the federal and state policies, such as the Investment Tax Credit (ITC) and renewable portfolio standards, have played a pivotal role in encouraging the adoption of solar energy. Additionally, the decreasing costs of solar technologies and an increased focus on sustainability/transitioning to renewable energy sources have further boosted demand.

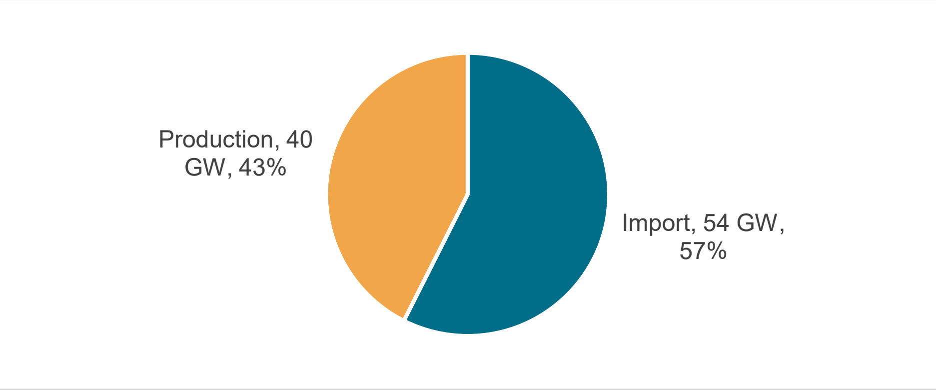
Corporate demand has been a key factor in driving the increasing need for solar modules. A growing number of large corporations are aiming to meet sustainability goals by powering their operations with renewable energy. Leading companies, such as Amazon, Apple, and Google, have made substantial investments in solar energy, contributing to the development of large-scale solar farms and corporate power purchase agreements (PPAs). Moreover, the residential solar sector has experienced strong growth, with consumers installing rooftop solar systems to lower energy costs and reduce their carbon emissions.

Supply Challenges

Despite the rapid increase in demand for solar modules, supply has faced significant challenges due to both global and domestic factors. The U.S. remains heavily dependent on imported solar modules, primarily from Asia, with China as the leading supplier. However, ongoing trade tensions between the U.S. and China, coupled with tariffs on Chinese solar products, have led to supply disruptions. The imposition of Section 201 tariffs and anti-dumping duties on solar cells and modules from China has resulted in higher costs for developers and delays in module imports, impacting project timelines.

The U.S. government has focused on promoting domestic solar module manufacturing. Measures such as the Solar Energy Manufacturing for America Act (SEMA) and provisions within the Inflation Reduction Act (IRA), are intended to incentivize companies to establish or expand production facilities within the United States. While these efforts are important steps toward reducing dependence on imports, increasing domestic production capacity will take time. U.S. manufacturers face significant competition from lower-cost international producers, posing challenges to scaling up production at the required pace.

Figure 52: Solar module status in USA, 2023



Source: EIA, S&P Global market intelligence, Crisil Intelligence

5 Assessment of EPC Solar market in India

5.1 Introduction

A typical EPC solar project covers design, civil works, equipment purchase and installation, and commissioning. However, with constrained returns, the scope of an EPC solar project has been 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, rooftop installations by C&I Consumers have provided impetus to solar 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.

Large players such as TATA Power, L&T, Vikram Solar are also offering EPC services along with some of the key players such as Waaree renewable technologies, Saatvik Green, Sterling & Wilson, BHEL, Solarworld, Prozeal Green energy, Oriana power and Jakson green etc. Most of these players are also present in rooftop solar installation’s EPC.

The development of solar power projects in India requires a detailed and extensive process, from conceptualization to commissioning and regulatory approvals. The regulatory framework in India is administered by the Ministry of New and Renewable Energy (MNRE), Central Electricity Regulatory Commission (CERC), 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 approximately 12-18 months, 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 works 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 covering around 75-80% of the project cost, such as modules, transformers, inverters, and cables, 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 solar module manufacturers insist on buying the entire package and not just solar modules, since they also provide EPC services.

5.2 EPC project: Turnkey versus 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 solar plants.

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 down 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 appoint the principal contractor for holistic project management and act as an interface between subcontractors.

5.3 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.

Figure 53: Initial selection using the checklist

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 contractor:

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.

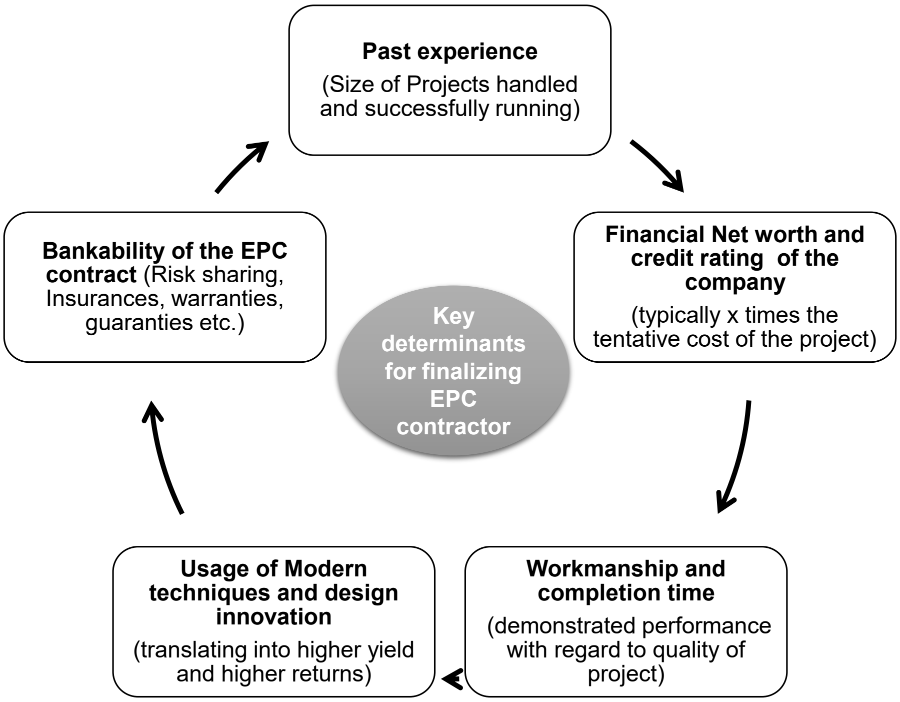
C. **Least-cost selection (LCS):** The winning submission is determined based on lowest-priced financial proposal. The technical proposals are evaluated only to the extent of assessing the minimum technical score.

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).

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 54: Key Determinants for selecting EPC contractor



Source: Crisil Intelligence

5.4 Execution of projects using 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 is 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.	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.

Factor	In-house EPC	Outsourcing to large, specialised EPC contractors
	Hence, in the case of in-house EPC projects, O&M contractors are appointed.	
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.
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.

5.5 Global EPC Opportunities

With increased thrust on clean energy, rising environmental concerns, stringent regulatory mandates to curb GHG emissions, encouraging policies and favourable economics, solar energy capacity is expected to surge in the next 5 years. As per “The Renewables 2024 report”, by IEA, the World is set to add more than 5 500 gigawatts (GW) of new renewable energy capacity between 2024 and 2030 – almost three times the increase seen between 2017 and 2023. Solar PV alone is forecast to account for a ~80% of the growth in global RE capacity additions by 2030 – the result of the construction of new large solar power plants as well as an increase in rooftop solar installations by companies and households.

China is expected to add more than 3200 GW RE capacity over 2024-2030. Solar PV will be the key component accounting for 80% of the increase. The United States is expected to add ~500 GW RE capacity over 2024-2030. Implementation of the IRA is expected to drive the Solar PV expansion. Similarly, Asia Pacific (excluding China) is expected to add more than 680 GW in 2024-2030 with more than 70% from Solar PV. Furthermore, Europe is expected to add ~700 GW RE capacity with more than 70% from Solar PV. ~ 90 GW of new RE capacity expected to be added in sub-Saharan Africa from 2024 to 2030. Solar PV and wind additions make up nearly 80% of new capacity in the region. RE capacity in MENA region is expected to add ~100 GW RE capacity wherein solar PV will account for over 85%.

Various regions have emerged as a significant market for solar EPC in recent years due to declining solar costs, policy push for adoption of RE, government initiatives etc. Indian solar EPC players have a significant opportunity to tap into the growing solar market, leveraging their expertise and experience in executing large-scale solar projects in India. There are various opportunities available through partnerships and collaborations, export of technical design and project development services, technology transfer, competitive advantage of lower cost and government support. However, there could be some challenges in terms of global competition, local content requirements, logistical challenges and cultural and language barriers (in some regions) etc.

The Indian EPC Players have certain advantages over their global counterpart. Cost competitiveness, expertise in execution of large scale solar PV projects, skilled workforce, large no. of English speaking people, proximity to emerging markets (Africa and MENA), technical prowess, good supply chain, flexibility and adaptability and wider brand recognition can help the Indian EPC players to successfully compete in the global solar EPC market.

6 Overview of Solar pump market

Solar pumps are versatile and can be used for various requirements such as drinking water, industrial applications, agricultural irrigation etc. Solar pumps are eco-friendly alternatives to polluting diesel or electricity grid connected pumps. They can be a valuable solution in providing energy access to remote areas with their efficiency, ease of installation and eco-friendly operations. With availability of abundant sunlight for more than 300 days, they can be used across the country. Currently, they are being used for various applications in agricultural, industrial, commercial and even residential purposes.

India is an agrarian economy and large part of Indian agriculture sector relies on rains (specifically monsoons) for irrigating crops. Farmers use pumps running on diesel gen sets or grid electricity as an external means to irrigate the crops. However, unreliable grid electricity, inefficient and expensive diesel gensets result in delays and economic stress. Solar water pumps are a great help for farmers for irrigation purposes since it uses sunlight to produce energy. There is no dependency on grid electricity for irrigation purposes. Use of solar water pumps can help farmers in increasing crop yield with a reliable and economical supply of water for irrigation purposes.

A solar water pump system is essentially an electrical pump system in which electricity is provided by one or several Solar PV panels. A typical solar powered pumping system consists of a solar panel array that powers an electric motor, which in turn powers a bore or surface pump. These are environmentally friendly equipment which replaces erratic grid supply and harmful diesel gen sets.

6.1 Types of solar pumps

6.1.1 Motor type

Electric motors are of two types- one is an AC motor (powered by alternating current) and the other is a DC motor (powered by direct current).

6.1.2 Application

- **Agriculture:** Can help to provide a reliable water source for livestock and irrigation in remote areas.
- **Community water supply:** Can be used by municipalities for water treatment facilities and distribution networks to provide clean water to communities; also for accessing water for use in remote areas or regions with no or unstable power supply solar water pumps can be a great help.
- **Industrial and commercial:** Can be used for providing water for commercial use, for instance, in hotels, airports, corporate offices, malls, universities/colleges etc., moving wastewater in sewage treatment plants, firefighting, heating and cooling systems, washing etc. in Industries, supplying water to construction sites or dewatering if water collects on the construction field etc.
- **Domestic:** Can be used for pumping water from surface or underground sources for domestic use, bungalows, high-rise buildings, housing complexes, apartments etc.

6.1.3 Type

There are different types of water pumps, each with their own unique features and capabilities.

- Surface pump: A pump used for drawing water from nearby water sources like lakes, ponds, canals or rivers.
- Submersible pump: A pump that is completely submerged into water or any fluid to move it from one place to another.
- Centrifugal pump**:** A pump that uses the principle of centrifugal force to transfer water from one location to another.
- Positive displacement pump**:** A mechanical device which displaces a known quantity of liquid for every revolution or cycle that the pump completes.

- Jet pump: A pump that uses the principle of jet propulsion to transfer water from one location to another.

6.1.4 Power ratings

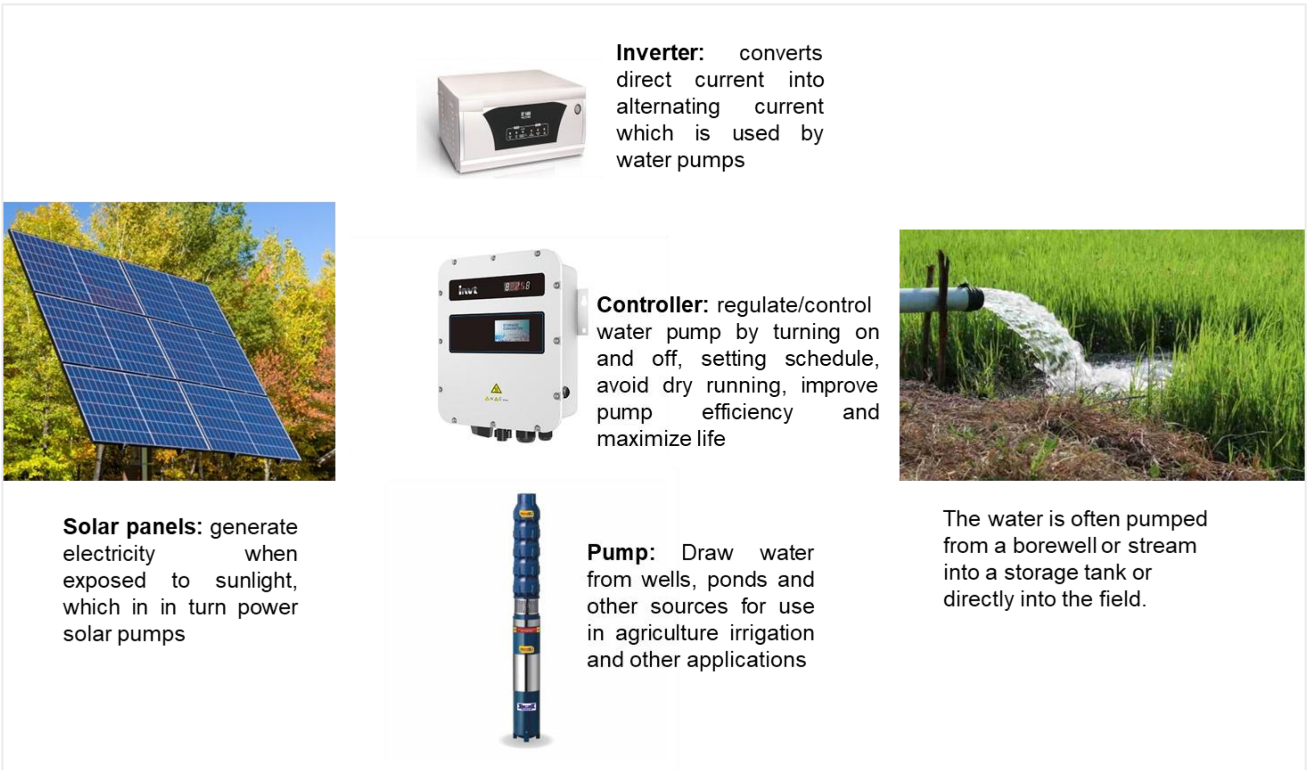
Water pumps can be classified based on their power ratings such as < 5 HP, 5 to 10 HP, 10 to 20 Hp and above.

6.2 Advantages of solar pumps

- **Reduced dependence on grid supply:** With off-grid, autonomous operations, solar pumps are independent of power grid which is not a reliable source specially for farmers. This also helps in reducing use of fossil fuel and contributing to a sustainable future.
- **Environment friendly:** Solar pumps run on solar energy, which is a clean, renewable source of energy without any harmful emissions making it a sustainable environmentally friendly option.
- **Economical and efficient:** Even though the initial investment is relatively high, with almost zero fuel or electricity expenses, the long-term operating costs are low, making it a viable option.
- **Reliable and low maintenance:** Fewer moving parts provide reliability and reduced maintenance, with regular cleaning of solar panels optimal efficiency can be achieved

A solar pumping system provides an environmentally friendly, economical and sustainable solution for irrigation as well as water supply in remote areas where grid access is not yet reached or costs more. Key components of a solar-powered pumping system is shown in the following figure.

Figure 55: Key components of solar water pump system



Source: Industry, Crisil Intelligence

6.3 Government policies

The Central government has initiated multiple programs to boost RE adoption and by 2030, India aims to achieve a total of 500 GW of non-fossil-based capacity, with 280 GW of it coming from solar energy. Some of the key government schemes supporting this goal include both off-grid and grid-connected initiatives.

Installation of solar power pumps was covered under the Off-grid and Decentralised Solar PV Applications scheme until FY 2017. In FY 2018, MNRE launched PM-KUSUM (Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan) scheme to increase adoption of cheaper solar power in the agricultural sector with a view to reducing DISCOM losses from sale of power to farmers at highly subsidised rates. The Scheme has three components targeted to achieve solar power capacity addition of 34.8 GW by 31.3.2026 with total central financial support of Rs. 34,422 Cr. The other salient features of the Scheme are given below.

Table 16: Salient features of the KUSUM Scheme

Components, Targets & Criteria	Financial Assistance available
The Scheme is demand driven and open for all farmers of the country for implementation as per guidelines issued for the Scheme **Component A:** Setting up of 10,000 MW of Decentralized Ground/Stilt Mounted Solar Power Plants on barren/fallow/pasture/marshy/ cultivable land of farmers. Such plants can be installed by individual farmer, Solar Power Developer, Cooperatives, Panchayats and Farmers Producer Organisations. **Component B**: Installation of 14 Lakh Stand-alone Solar Pumps in off-grid areas. **Component C:** Solarisation of 35 Lakh Grid Connected Agriculture Pumps through (i) Individual Pump Solarisation (IPS) and (ii) Feeder Level Solarisation (FLS). The beneficiaries under Component-B and Component-C could be individual farmers, Water User Associations, Primary Agriculture Credit Societies and Communities/Cluster Based Irrigation Systems.	Procurement Based Incentive (PBI) to the DISCOMs @ 40 paise/kWh or Rs.6.60 lakhs/MW/year, whichever is lower, for buying solar/ other renewable power under this scheme. The PBI is given to the DISCOMs for a period of five years from the Commercial Operation Date of the plant. Therefore, the total PBI payable to DISCOMs is Rs. 33 Lakh per MW. For Component-B and individual pump solarisation under Component-C: CFA of 30% of the benchmark cost issued by MNRE or the prices of the systems discovered in the tender, whichever is lower is provided. However, in Northeastern States including Sikkim, Jammu & Kashmir, Ladakh, Himachal Pradesh and Uttarakhand, Lakshadweep and A&N Islands, CFA of 50% of the benchmark cost issued by MNRE or the prices of the systems discovered in the tender, whichever is lower, is provided. In addition, the respective state/UT has to provide at least 30% financial support. Balance cost is to be contributed by beneficiary. Component B and Component C - (IPS) of PM KUSUM scheme can also be implemented without State share of 30%. The Central Financial Assistance will continue to remain 30% and the remaining 70% will be borne by the farmer. For agriculture feeder solarization, CFA of Rs 1.05 Crore per MW is provided. There is no mandatory requirement of financial support from the participating State/UT. The feeder solarisation can be implemented in CAPEX or RESCO mode.

Source: MNRE, Crisil Intelligence

6.4 PM KUSUM Status

State-wise targets or fund allocation is not made under PM-KUSUM as it is a demand driven scheme. Further, the funds are released to States/UTs on achieving certain milestones. State/UT wise solar pumps allocated, and installations achieved so far are shown in the following table.

Table 17: Progress under PM-KUSUM

State	Component-A (MW)		Component-B (Nos)		Component-C (Nos)			
	Sanctioned	Installed	Sanctioned	Installed	Sanctioned (IPS)	Installed (IPS)	Sanctioned (FLS)	Installed (FLS)
Andaman and Nicobar	-	-	34	-	436	-	-	-
Andhra Pradesh	-	-	-	-	-	-	1,00,000	
Arunachal Pradesh	-	-	700	577	-	-	-	-
Assam	2	-	4,000	-	-	-	-	-
Bihar	-	-	-	-	-	-	90,000	-
Chhattisgarh	330	7	10,000	-	-	-	-	-
Goa	50	-	900	100	-	-	11,000	700
Gujarat	500	-	18,212	11,813	-	-	7,25,000	1,83,728
Haryana	158	15	2,27,655	1,57,073	-	-	12,899	-
Himachal Pradesh	100	100	1,270	959	-	-	-	-
Jammu and Kashmir	-	-	5,000	2,890	-	-	-	-
Jharkhand	-	-	52,985	35,459	-	-	-	-
Karnataka	-	-	41,365	2,334	-	-	6,28,588	21,427
Kerala	-	-	8	8	3,796	2,199	25,387	10,964
Ladakh	-	-	1,400	-	-	-	-	-
Madhya Pradesh	1,790	52	59,400	7,325	-	-	3,45,000	16,316
Maharashtra	260	4	5,55,000	4,19,825	-	-	7,75,000	3,07,194
Manipur	-	-	1,150	78	-	-	-	-
Meghalaya	-	-	3,035	98	-	-	-	-
Mizoram	-	-	1,700	40	-	-	-	-
Nagaland	-	-	265	65	-	-	-	-
Odisha	90	-	16,441	5,716	-	-	10,000	-
Punjab	-	-	28,000	15,025	186	-	-	-
Rajasthan	5250	457	1,62,914	1,04,574	2,035	2,138	4,00,000	49,197
Tamil Nadu	14	3	5,200	4,187	5,000	-	6,000	-
Telangana	1,450	-	-	-	28,000	-	-	-
Tripura	5	-	10,895	4,971	3,600	285	-	-
Uttar Pradesh	1	-	1,10,948	66,463	12,000	3,945	3,70,000	-
Uttarakhand	-	-	3,685	1,367	-	-	-	-
West Bengal	-	-	-	-	20	20	-	-
Total	**10,000**	**639**	**13,32,234**	**8,40,947**	**55,073**	**8,587**	**35,08,874**	**5,89,526**

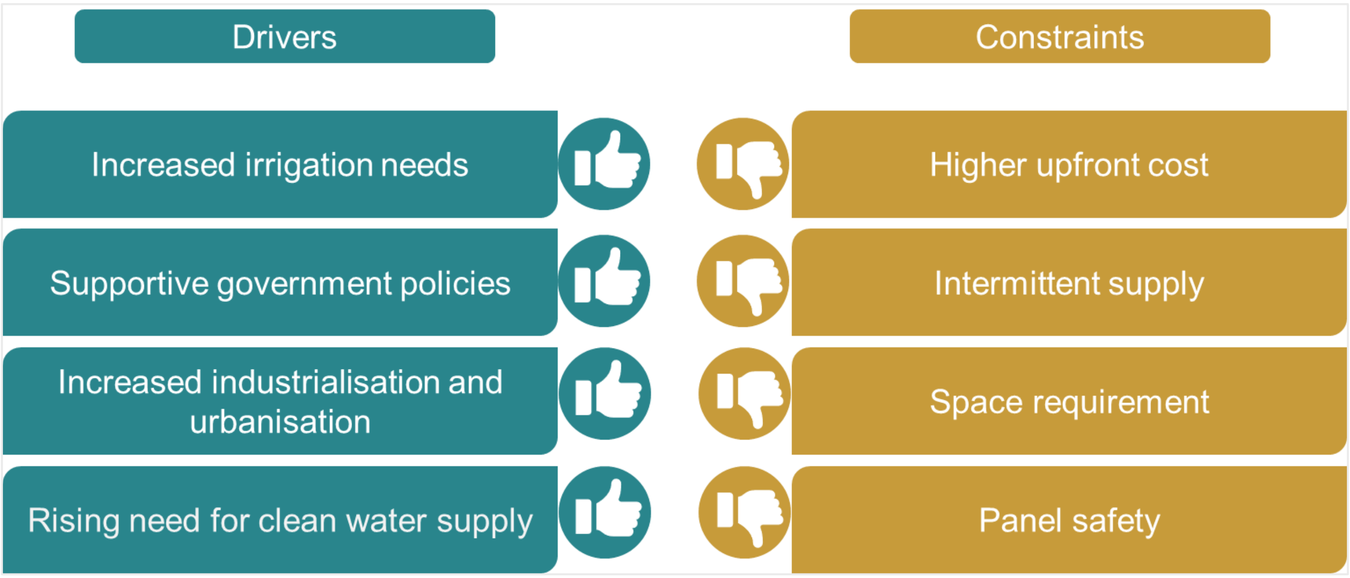
As of 28th July 2025; IPS: Individual pump solarisation, FLS: Feeder level solarisation
Source: Source: MNRE PM KUSUM portal, Crisil Intelligence

6.5 Key demand drivers and constraints

Governments of India has been encouraging the use of RE sources, such as solar power, to reduce dependence on fossil fuels and mitigate climate change. PM KUSUM Scheme is specifically developed for increase in penetration of solar pumps. There is a sustained demand for agriculture and irrigation needs and solar pumps is a cost-effective and sustainable solution for irrigation. The government is offering incentives and subsidies to encourage the adoption of solar pumps. India's projected GDP growth and urbanization driving the pump demand. Solar pumps are being used to supply clean water in rural and remote areas, where access to electricity is limited.

However, there are certain challenges for large scale adoption of solar pumps. The initial capital cost for solar pumps can be more expensive than the conventional pumps. Even with subsidies, farmers may be reluctant to pay upfront costs. Water level and sunlight availability also remain concerns, with some farmers dissatisfied with water output during cloudy days. The installation of panels requires space which can be a deterrent for farmers, especially if they are losing cultivable land. There is always a fear of solar panels getting stolen specifically in remote areas. Additionally, availability of spare parts or technicians also discourage farmers from adopting solar pumps.

Figure 56: Key demand drivers and constraints for solar pumps



Source: Industry; Crisil Intelligence

Tata Power, Shakti Pumps, Rotomag, Saatvik Green Energy, CRI Pumps, and Premier Solar are the key solar pump installers. These four companies have participated in all three EESL tenders and are empanelled across all major agricultural states. But the market is heavily fragmented with hundreds of small players bidding in smaller regional tenders.

There are multiple key success factors in the business:

- **Access to in-house module manufacturing capacity** eliminates reliance on external suppliers
- **In-house EPC and manufacturing capability** provides economies of scale in procurement and execution
- **Local channel partner network** speeds up customer acquisition and execution
- **Strong brand image** helps in customer acquisition

6.6 Market outlook

The Indian solar pumps market has witnessed significant growth in last 5-7 years due to supportive government policies and push for sustainable renewable energy additions. The agriculture sector contributes ~18% in India's GDP and therefore use of solar pumps is key for economic and sustainable agriculture. Some of the areas where eco-friendly solar pumps can be used include rainwater harvesting, water for livestock, drip irrigation, aquaculture and irrigation of the fields.

As pe the Census 2011, ~263 million people are involved in farming activities. Out of these ~119 million people are land-owning farmers and 144 million are landless workers and peasants. There are about 30 million irrigation systems in India that use electricity, diesel, or solar energy to pump water. Thus, there is untapped potential of ~89 million. further, approximately 70% of the million irrigation systems in India use electricity, about 29% use diesel and around 1% use solar pumps. Therefore, ~8-8.5 million diesel pumps provide the opportunity of replacing them with solar pumps. Altogether, ~95-100 million farmers provide opportunities for solar pumps. However, considering the farmers having more than one hectare of land, the untapped opportunity or market potential to provide pumps can be anywhere from Rs. 3500 to 5000 billion.

However, considering the water availability, ability to pay, geographical conditions and other challenges, the no. of farmers opting for pumps will be substantially low. The solar pumps market in India has seen dramatic growth. From a market size of Rs.1.5 to 2 billion in fiscal 2019, it grew to Rs. 45-50 billion by fiscal 2024, witnessing a staggering growth at CAGR of ~90%. Crisil Intelligence expects the solar pumps market in India is expected to reach to Rs. 220-240 billion by 2030 growing at a CAGR of ~30% over fiscal 2025-2030. It is also expected that by fiscal 2030, the solar pumps will constitute about 50%-55% of the total pumps market.

PM-KUSUM scheme will largely drive the market expansion wherein the farmers are eligible to get subsidised solar pumps. Some of the other parameters which are likely to drive the solar pumps market include strong thrust on sustainability, increasing prices of diesel, favorable economics, proactive subsidy initiatives by government, advancements in technology, increased consumer awareness, increased emphasis on GHG emission reductions, unreliable and poor-quality grid supply, concerns over pumps getting damaged due to voltage fluctuations etc.

7 Leading players in module manufacturing

Following table summarises the competitive analysis of Saatvik Green with leading Indian module manufacturers.

Table 18: Competitive analysis with leading Indian module manufacturers

INR Mn	Saatvik Green Energy Ltd.			Premier Energies Ltd.		
Particulars	FY 25 (A)	FY 24 (A)	FY 23 (A)	FY 25 (A)	FY 24 (A)	FY 23 (A)
Installed Capacity (MW)	3,742.00	1,154.00	550	5,100.00	3,360.00	1,370.00
Effective Installed Capacity (MW)	1,743.66	566	510	NA	1,670.00	1,140.00
Actual Production Solar Module (MW)	1,459.39	501	248.61	NA	1,010.00	490
Capacity Utilisation (%)	83.70%	88.52%	48.75%	NA	60.29%	42.81%
Total Order book (in Rs. million)	50,768.50	5,599.73	6,861.87	84,456.00	54,332.37	9,860.46
Total Order book (MW)	3,522.05	300.13	223.36	5,303.00	NA	NA
Total Sales (MW)	1,388.40	458.76	242.5	NA	960.12	469.08
Revenue from Operations	21,583.94	10,879.65	6,085.88	65,187.50	31,437.93	14,285.34
Domestic (Module sale)	21,311.53	9,663.00	6,034.09	NA	27,040.60	14,210.38
Export (Module sale)	272.41	177.91	46.86	NA	4,397.33	74.96
EPC and O&M	737.55	1,601.55	-	-	-	-
Exports %	1.26	1.64%	0.77%	NA	13.99%	0.52%
Revenue growth, CAGR (%) (FY23 to FY25)	88.32%			113.62%		
EBITDA	3,539.32	1,568.44	238.66	19,142.16	5,053.18	1,128.81
EBITDA growth, CAGR (%) (FY23 to FY25)	285%			312%		
EBITDA Margins	16.40%	14.42%	3.92%	29.36%	16.07%	7.90%
PAT	2,139.30	1,004.72	47.45	9,371.32	2,313.60	-133.36
PAT margins % (as % of Total Revenue)	9.76%	9.16%	0.77%	14.09%	7.30%	-0.91%
Total debt/Equity(x)	1.36	2.18	7.13	0.67	2.11	1.8

INR Mn	Saatvik Green Energy Ltd.			Premier Energies Ltd.		
Particulars	FY 25 (A)	FY 24 (A)	FY 23 (A)	FY 25 (A)	FY 24 (A)	FY 23 (A)
ROE	63.41%	83.21%	23.40%	33.21%	35.77%	-3.11%
ROCE	60.45%	64.07%	24.80%	34.93%	24.61%	-0.74%
Asset Turnover ratio	1.86	2.29	2.53	1.25	1.11	0.83
Current Ratio	1.14	1.11	1.07	1.88	1.16	1.02
Net working capital	1,594.86	484.38	126.26	24,495.21	2,959.48	183.1
Net Working capital days	26.97	16.25	7.57	137.15	34.36	4.68
Gross Debt (Rs. Million)	4,580.96	2,634.20	1,444.92	18,934.58	13,922.40	7,635.42
Net worth (Rs. Million)	3,376.59	1,206.73	202.73	28,221.06	6,468.51	4,112.15

INR Mn	Vikram Solar Ltd.			Waaree Energies Ltd.		
Particulars	FY 25 (A)	FY 24 (A)	FY 23 (A)	FY 25 (A)	FY 24 (A)	FY 23 (A)
Installed Capacity (MW)		3,500.00	3,500.00	13,300.00#	12,000.00	9,000.00
Effective Installed Capacity (MW)	NA	NA	NA	NA	11,010.00	6,500.00
Actual Production Solar Module (MW)	NA	NA	NA	NA	4,780.00	2,630.00
Capacity Utilisation (%)	NA	NA	NA	NA	43.37%	40.46%
Total Order book (in Rs. million)	NA	NA	NA	4,70,000.00	NA	NA
Total Order book (MW)	NA	NA	NA	25,000.00	19,930.00	18,060.00
Total Sales (MW)	NA	NA	879.2	NA	NA	NA
Revenue from Operations	NA	25,109.90	20,732.30	1,44,445.00	1,13,976.09	67,508.73
Domestic (Module sale)	NA	8,978.59	5,226.61	NA	48,021.32	19,914.75
Export (Module sale)	NA	15,462.55	4,484.87	NA	65,690.96*	46,165.39*
EPC and O&M	NA	668.76	11,020.82	-	-	-

INR Mn	Vikram Solar Ltd.			Waaree Energies Ltd.		
Particulars	FY 25 (A)	FY 24 (A)	FY 23 (A)	FY 25 (A)	FY 24 (A)	FY 23 (A)
Exports %	NA	61.58%	21.63%	NA	57.64%	68.38%
Revenue growth, CAGR (%) (FY23 to FY25)	NA			46.28%		
EBITDA	NA	4,115.51	2,048.59	31,250.00	18,095.77	9,441.34
EBITDA growth, CAGR (%) (FY23 to FY25)	NA		140%		82%	
EBITDA Margins	NA	16.39%	9.88%	21.63%	15.88%	13.99%
PAT	NA	797.18	144.91	19,281.30	12,743.77	5,002.77
PAT margins % (as % of Total Revenue)	NA	3.16%	0.69%	12.99%	10.96%	7.29%
Total debt/Equity(x)	NA	1.81	2.02	0.1	0.08	0.15
ROE	NA	17.90%	3.97%	19.70%	30.26%	26.26%
ROCE	NA	22.52%	11.94%	24.78%	31.82%	30.49%
Asset Turnover ratio	NA	0.99	0.88	0.73	1.54	1.4
Current Ratio	NA	1.39	1.35	1.5	1.48	1.11
Net working capital	NA	5,559.78	4,567.34	43,706.80	25,899.41	5,228.43
Net Working capital days	NA	80.82	80.41	110.44	82.94	28.27
Gross Debt (Rs. Million)	NA	8,083.33	7,377.87	9,394.60	3,173.19	2,734.80
Net worth (Rs. Million)	NA	4,454.17	3,651.95	94,792.00	40,878.13	18,384.10

**Export revenue includes EPC revenue also; (A): Audited, #Including 1.3 GW of Indosolar*
Source: Company (Saatvik restated financial statements), Company websites, Annual Reports, RHP Filings, Crisil Intelligence
Notes: NA-Not available;

Formulae used:

Capacity Utilisation=Actual Production Solar Module/Effective Installed Capacity
Effective Installed Capacity=The effective installed capacity of a manufacturing plant is the actual amount of production that a company can achieve in a year, assuming that all machines are running at full speed, 330 days a year.
EBITDA: Earnings before interest, tax, depreciation, and amortization (Restated profit before tax + Finance cost + Depreciation and amortization expense)
EBITDA margin: EBITDA / Revenue from operations for the period
PAT: Restated profit after tax for the period

PAT margin: PAT / total revenue
Total Debt/Equity: (Long term borrowing + Short term borrowing)/ Equity including non-controlling interest
ROE=PAT attributable to owners for the period /Equity excluding NCI
ROCE: EBIT/ Capital employed
EBIT=PAT + Tax+ Depreciation
Capital Employed = Total Assets – Current Liabilities
Asset turnover ratio=Revenue from operations/average total assets
Current ratio=current assets/current liabilities
Net working capital=Current assets-current liabilities
*Net Working capital days= Net working capital/Revenue from operations*no. of days during the period*
Gross debt=Long term borrowing + Short term borrowing
Net Worth=Total Equity attributable to the parent company

- The revenue of Saatvik Green (the Company) has grown at a CAGR of 88.32% between Fiscal 2023 to Fiscal 2025, backed by a strong recovery in volumes and change in product mix
- The operating margin of the Company has increased to ~16% in fiscal 2025 from ~14% in fiscal 2024.
- With a debt: equity ratio of 1.36 for fiscal 2025, the Company is a moderately leveraged module manufacturer in India
- The Company has witnessed a healthy return on capital employed (ROCE) of 60.45% in FY2025.
- The Company is one of India's leading module manufacturers, in terms of operational solar PV module manufacturing capacity, with an operational capacity of ~3.7 GW modules as of March 31, 2025.
- The Company currently operates three module manufacturing facilities in Ambala, Haryana spread across a total land area of 724,225 square feet, which together form one of the largest single location module manufacturing facilities in India.
- The Company is one of the fastest growing module manufacturing companies in India and has established itself as one of the key player in India's solar energy market.
- The Company offers modules based on polycrystalline cell technology, monocrystalline cell technology, bifacial technology, M12 technology and advanced Tunnel Oxide Passivated Contact ("TopCon") technology which helps reduce energy loss and enhances overall efficiency.
- The Company is one of the early adopters of new technology like N-type Topcon and Mono PERC in India
- The Company recently launched G12R based Topcon modules and has started commercial production from January 2024. The Company is one of the first mover in the industry.
- The Company also offers end-to-end solutions through its Engineering, Procurement, and Construction (EPC) arm.
- The Company is one of the first companies in India to commence the commercial production of G12R based TopCon solar modules.

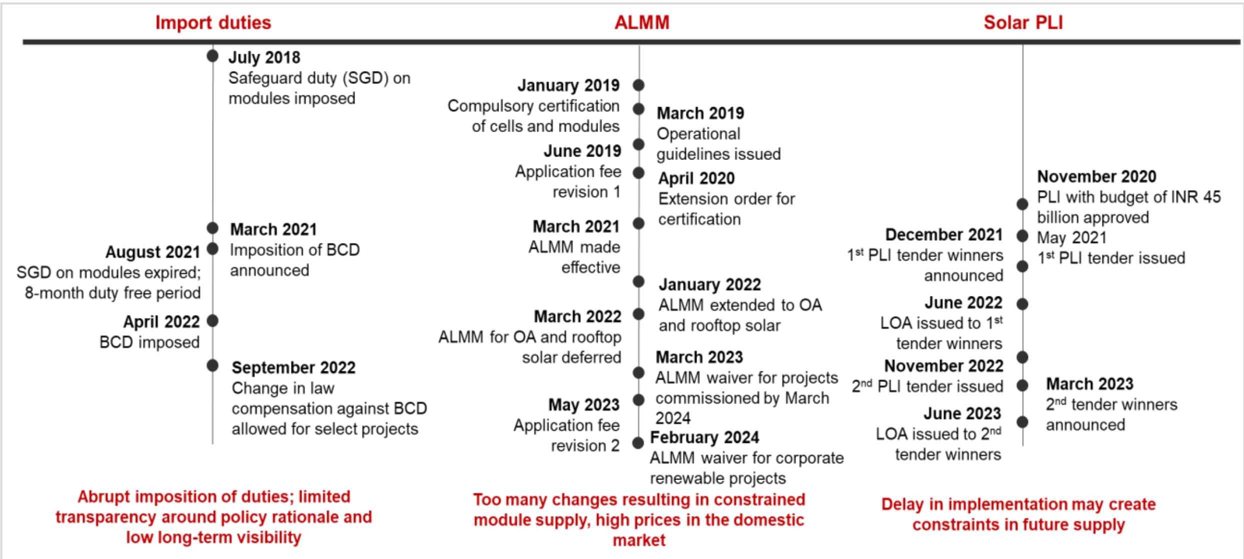
- The Company also offers EPC services in India with 69.12 MW of installed EPC base as of March 31, 2025.
- The Company is one of the few integrated players with capabilities in O&M, EPC, module manufacturing and now planning to set up a cell manufacturing facility and solar pump manufacturing facility. This strategic move [towards backward integration] will help the Company to reduce dependency on external suppliers, particular in regions such as China and Taiwan, where the majority of the global cell supply is currently concentrated.
- It offers PV modules with efficiencies upto 22.84%.
- The Company commissioned a 61.42 MW floating solar power project at Ramagundam, Telangana in Fiscal 2023, which was one of India's largest floating solar power plants.
- The Company also commissioned a 12 MW installation for the Jindal Group under its EPC wing in Fiscal 2024, which was one of the largest single rooftop solar project.
- The Company supplied 40.00 MW of solar modules for the DVC floating solar project in Fiscal 2025.
- The Company has diversified client base with presence in various segments (large utility, C&I, Open access, residential rooftop, solar pump) and across geographies (selling in all parts of India, North America, Africa and South Asia)
- The Company is one of the largest module manufacturers in North India, which is a lucrative market having high solar incidence area and proximity to states like Rajasthan and Madhya Pradesh. The North India also has proliferation of Industries in NCR, Uttarakhand, Western UP, Haryana and Madhya Pradesh etc.
- The Company had a high capacity utilisation of 83.70% in Fiscal 2025.
- The Company is one of the key solar pump installers in India and have participated in all three Energy Efficiency Services Limited (EESL) tenders and is empaneled across all major agricultural states.

8 Threats and Challenges

8.1 Threats

8.1.1 Policy and regulatory uncertainty

The solar energy segment 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.



8.1.2 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 tendering 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.

8.1.3 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.

8.2 Challenges

8.2.1 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.

8.2.2 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.

8.2.3 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. The water consumption is also significant, especially for the production of silicon wafers, which need to be purified, cut, and polished with large amounts of water. These challenges can impact costs, operational efficiency and the overall feasibility of the project.

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