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Industry research report on renewable energy market in India

Rayzon Solar Ltd

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Module 1: Global macroeconomic overview

Amid global economic jitters, India to keep momentum

According to the International Monetary Fund (IMF), gross domestic product (GDP) growth is expected to be divergent across advanced and emerging economies in calendar years (CY) 2025 and 2026. Both categories are expected to see a marginal improvement next year — advanced economies (1.5% in CY26 vs 1.4% in CY25) and emerging economies (3.9% in CY26 compared with 3.7% in CY25). However, the trend will vary for the constituents. Among emerging market economies (EMEs), for instance, China's growth is likely to be subdued, while India's is expected to remain healthy.

Table 1: India is expected to emerge relatively stronger amid the global economic uncertainty

YoY (%)	CY18	CY19	CY20	CY21	CY22	CY23	CY24	CY25P	CY26P
World	3.6	2.9	-3.1	6.0	3.5	3.3	3.3	2.8	3.0
Advanced economies	2.3	1.7	-4.5	5.2	2.6	1.7	1.8	1.4	1.5
- Euro area	1.8	1.6	-6.1	5.2	3.4	0.4	0.9	0.8	1.2
- Germany	1.1	1.05	-4.6	2.6	1.8	-0.3	–0.2	0.0	0.9
- US	2.9	2.3	-3.4	5.7	1.9	2.9	2.8	1.8	1.7
- UK	1.7	1.7	-9.3	7.4	4.3	0.3	1.1	1.1	1.4
- Japan	0.6	-0.2	-4.5	1.7	1.0	1.5	0.1	0.6	0.6
Emerging and developing economies	4.6	3.7	-2.0	6.6	4.1	4.4	4.3	3.7	3.9
- China	6.7	6.0	2.2	8.1	3.0	5.2	5.0	4.0	4.0
- India*^	6.5	3.9	-5.8	9.7	7.0	7.6	9.2	6.5	6.5

*Note: *India's numbers are based on the fiscal year (FY) (April-March) where CY25 would correspond to fiscal 2026, on calendar year basis for other countries.*

^ Estimates for India are as per the Ministry of Statistics and Programme Implementation (MoSPI), Crisil Intelligence.

Euro area includes Germany, France, Italy and Spain.

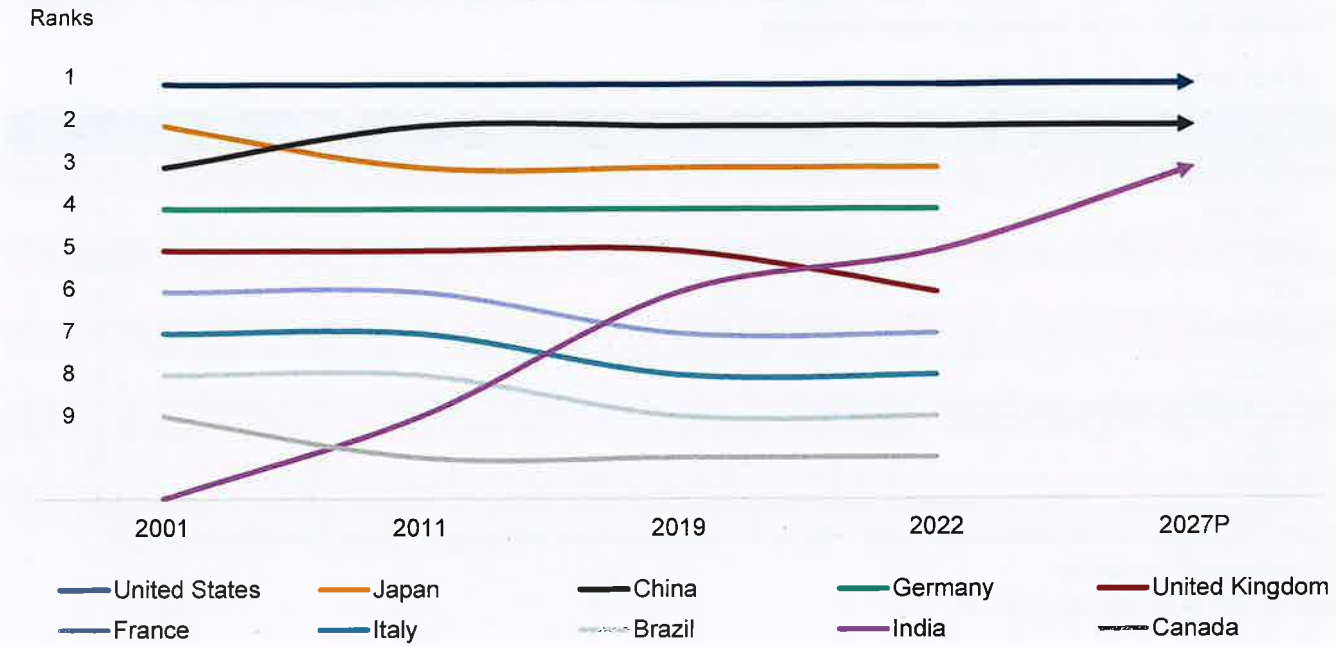
E: Estimate, P: Projected

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

In CY24, growth in China was impacted by a faster-than-expected slowdown in consumption, amid delayed stabilisation in the property market and persistently low consumer confidence, offsetting the positive impact of healthy net export growth. The euro area continued to see subdued growth, largely reflecting persistent weakness in manufacturing and goods exports, even as consumption picked up in line with the recovery in real income. Japan's output contracted mildly owing to temporary supply disruptions, while the United States (US) remained a bright spot, expanding 2.8% in CY24, powered by strong consumption in the second half of the year.

Amid the prevailing global uncertainties, India is poised to emerge relatively stronger, with GDP projected to grow 6.5% in FY26 (with a downside risk evolving from US actions tariffs), driven by a combination of factors, such as recovery in private consumption, investment and exports. Resilience and adaptability in the face of global challenges will be crucial in sustaining India's growth momentum, helping it remain one of the fastest-growing major economies in the world. Over the medium term, India is set to become a dominant player in the global economy, with the IMF projecting that it will overtake Japan and Germany to become the third-largest economy by CY27.

Figure 1: India to overtake Japan and Germany to become the third-largest economy



Note: The above graph is based on ranks of economies in nominal GDP.
P is Projected
Source: IMF

Monetary cycles seen easing in medium term, all eyes on tariff actions

Inflation has been falling since mid-2022 globally, supported by lower fuel and energy prices, especially in the US, the euro area and Latin America.

Since 2021, most central banks globally have been increasing interest rates to suppress demand and lower underlying (core) inflation. The latest series of rate increases has been more rapid and synchronous, compared with the previous global monetary tightening cycle just before the global financial crisis. The slowdown in new-home construction reflects the impact of the more-restrictive monetary policy.

Since mid-2022, inflation, excluding volatile food and energy prices, has been declining in most (but not all) major economies. Although the high-interest-rate approach adopted by central banks had a positive impact on moderating the inflation momentum, easing global commodity prices also contributed to this trend in 2023. Consequently, many economies faced lower inflation in 2023 compared with 2022. The inflation rate has begun to decrease, largely due to the measures implemented by central banks. From an Indian perspective, the repo rate exhibited a steady upward trend from 4.4% in May 2022 to 6.50% by December 2024. Subsequently, two rate cuts were implemented, leading to a decrease in the repo rate to 6.00% in April 2025. With inflation easing, the repo rate is now anticipated to moderate further. There has been a decline in food and energy prices, which have helped ease inflationary pressures domestically. It is now near the target level of 4% with demand pulls easing. That said, services-led inflation and employment remain strong, limiting the pace of decline.

These factors have now triggered the much-awaited policy-rate-cut cycle after a long period of waiting by central banks for the moderation of stubborn inflation. However, global tariff-related actions are an evolving dynamic, which can again lead to inflation flaring in key economies around the globe.

Table 2: Inflation movement across key economies

YoY (%)	CY22	CY23	CY24	CY25P
Advanced Economies				
- Euro area	8.4	5.4	2.4	2.1
- US	8.0	4.1	3.0	3.0
- UK	9.1	7.3	2.5	3.1
- Germany	8.7	6.0	2.5	2.1
- Japan	2.5	3.3	2.7	2.4
Emerging Market and Developing Economies				
- China	2.0	0.2	0.2	-0.02
- India	6.7	5.4	4.6	4.3

Note: The above table is on calendar year basis, while for India data is on fiscal year basis, with fiscal 2024-25 shown in 2024

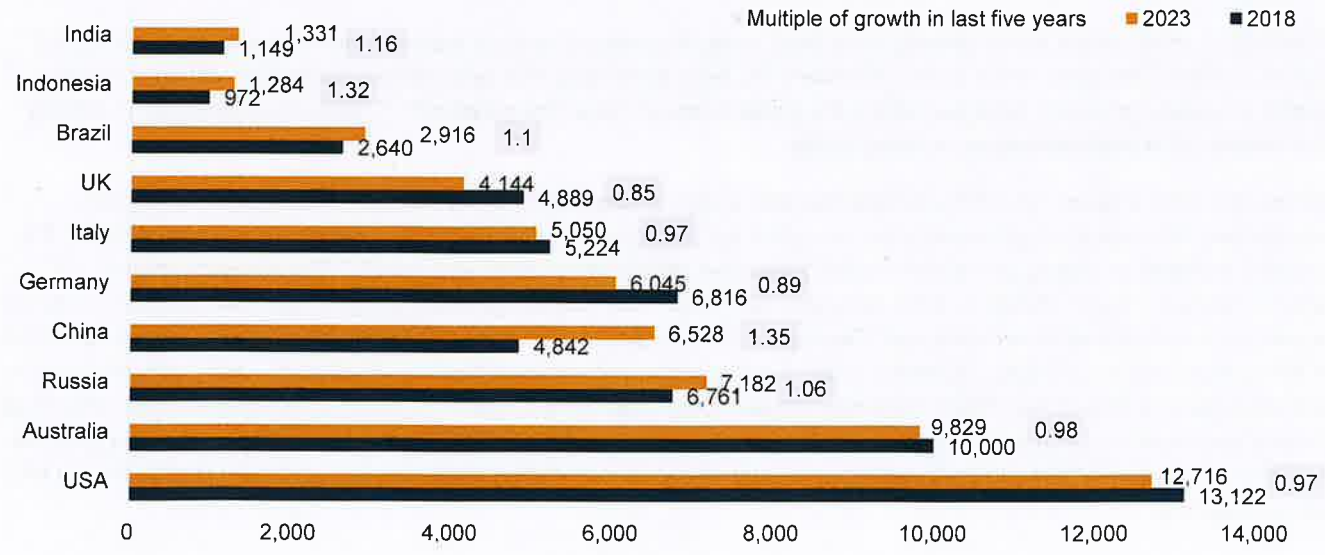
E – estimated; P – projected

Source: IMF World Outlook, April 2025

India ranks third in global electricity consumption

In terms of global power consumption, India ranks third with power consumption of 1,600 billion KWh—behind China and US—with the two countries reporting 9,210 billion KWh and 4,259 billion KWh of electricity use, respectively, in CY 2023. However, India's per capita power consumption is the lowest among the top 10 global power consuming countries, such as China, the US and Germany.

Figure 2: India has lower power consumption per capita as of 2023 (kWh)



Note: Multiple of growth in the past five years has been calculated as power consumption in 2023/power consumption in 2018

The above table is on calendar year basis, while for India, data is on fiscal year basis, with fiscal 2022-23 shown in 2023
Sources: CEA, World Bank, Crisil Intelligence

The relatively low per capita power consumption in India, coupled with its rapidly growing population, suggests that the country's full potential in terms of power demand remains untapped. In contrast to advanced economies, which have already experienced significant growth in power demand during the past economic cycles, emerging markets such as China, Indonesia and India are now poised to drive power demand growth despite prevailing global economic headwinds.

India's per capita electricity consumption has risen steadily in recent years, but it is much below the world average and has wide variations internally. While highly industrialised states are at the helm of per capita power consumption, states, which are largely domestic and agrarian in terms of power consumer base, occupy lower positions.

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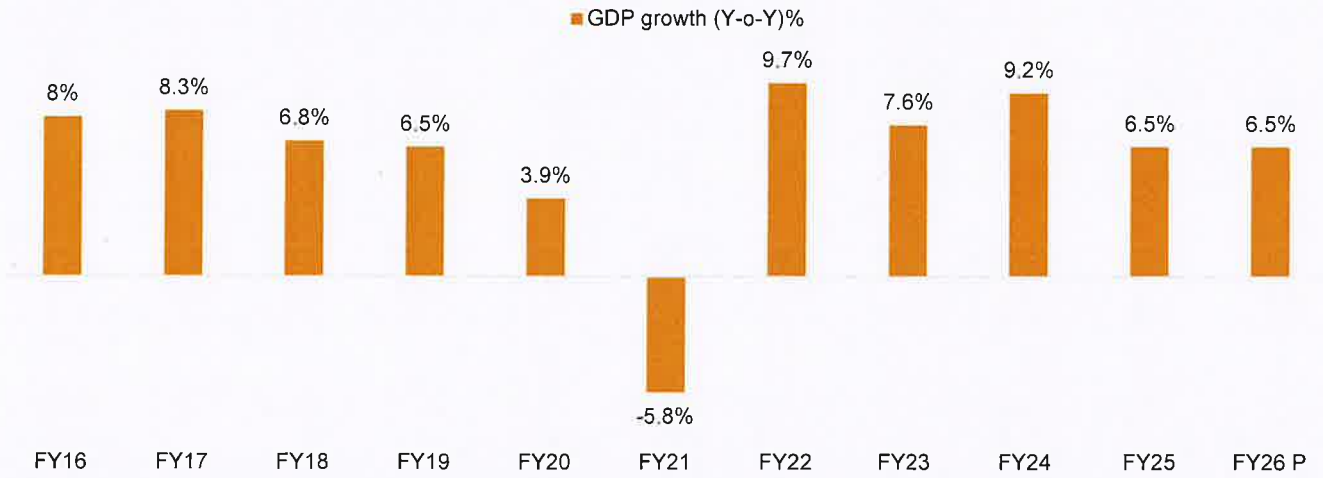
Module 2: Indian macroeconomic overview

India has a relatively balanced set of domestic drivers

Despite the prevailing geopolitical instability, India has managed to maintain its position as one of the fastest-growing economies globally, underscoring its resilience and adaptability in the face of adversity. India's GDP growth rate is expected to remain steady at 6.5% in FY26 (with a downside risk evolving from US actions tariffs), driven by recovery in private consumption. Cooling food inflation, tax benefits announced in Union Budget 2025-26, and lower borrowing costs are expected to drive discretionary consumption. Rural demand remains steady, fuelled by better agricultural prospects. An increase in government consumption expenditure is expected to play an important role in driving growth. In addition, lower crude oil prices and a normal monsoon also contribute to a favourable growth outlook.

Figure 3: India to grow 6.5% in fiscal 2026 despite challenges



Note: P Projected; GDP growth (in real terms) till FY24 is the actual number. GDP estimates for FY25 are based on the National Statistical Office's (NSO) Second Advance Estimates; for FY26, the numbers are projections by Crisil Intelligence.

Source: NSO, Crisil Intelligence

Table 3: Outlook for fiscal 2026

Macro variables	FY24	FY25P	FY26P	Rationale for outlook
Real GDP (y-o-y)	9.2%	6.5%	6.5%	Lower inflation and rate cuts by the Reserve Bank of India (RBI) are expected to maintain growth in FY26, assuming a normal monsoon and lower crude oil prices. The budget will be mildly supportive, but fiscal consolidation will moderate its impact. Private capex is key to investment growth, while exports face headwinds from US tariff hikes
Consumer Price Index (CPI) inflation (y-o-y)	5.4%	4.6%	4.3%	Inflation is expected to approach the RBI's 4% target due to a normal monsoon, high base effect, and softer global commodity prices, with a slight uptick in non-food inflation
10-year government security yield (Fiscal end)	7.1%	6.7%	6.5%	RBI rate cuts, lower inflation, and softer crude oil prices may lead to a mild softening of yields in FY26, although higher government borrowings will limit the decline

Macro variables	FY24	FY25P	FY26P	Rationale for outlook
Fiscal deficit (% of GDP) *	5.8%	4.8%	4.4%	The government aims to reduce the fiscal deficit to 4.4% next fiscal, by moderating revenue expenditure and maintaining capex, while relying on strong tax collections and dividends from the RBI and public sector undertakings (PSUs)
Current account balance (% of GDP)	-0.7%	1.0%	1.3%	The current account deficit is expected to rise due to US tariff headwinds on exports, but will be cushioned by lower crude oil prices, a strong services trade balance, and robust remittances growth
Exchange rate (March average, Rs/USD)	83.0	87.0	88.0	A manageable current account deficit (CAD) would mean not much pressure on the rupee, but geopolitical shocks could keep the rupee volatile

Note: P – Projected

Source: Crisil Intelligence

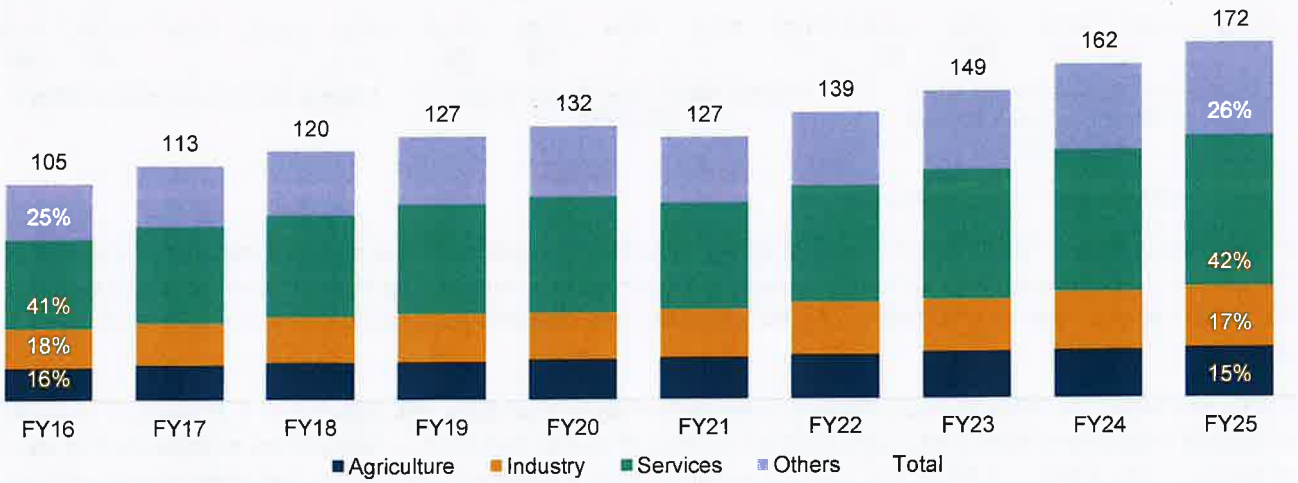
Contribution of key sectors to gross value added

An analysis of India's gross value added (GVA) shows it has grown consistently over the years except in fiscal 2021, when it was impacted by the pandemic-induced lockdown.

The growth in the manufacturing GVA (at a CAGR of 4.7% between fiscals 2016 and 2024) is attributable to various government initiatives, such as Atmanirbhar Bharat, Make in India and the Production Linked Incentive (PLI) scheme. Although the share of industry in the GVA has remained constant at 18%, a large percentage of PLI capex is yet to be commissioned, which is expected to aid growth in the share of both manufacturing and exports.

Figure 4: Contribution of key sectors (industry, agriculture and services) to GVA

(Rs trillion, % share)



Source: MoSPI, Crisil Intelligence

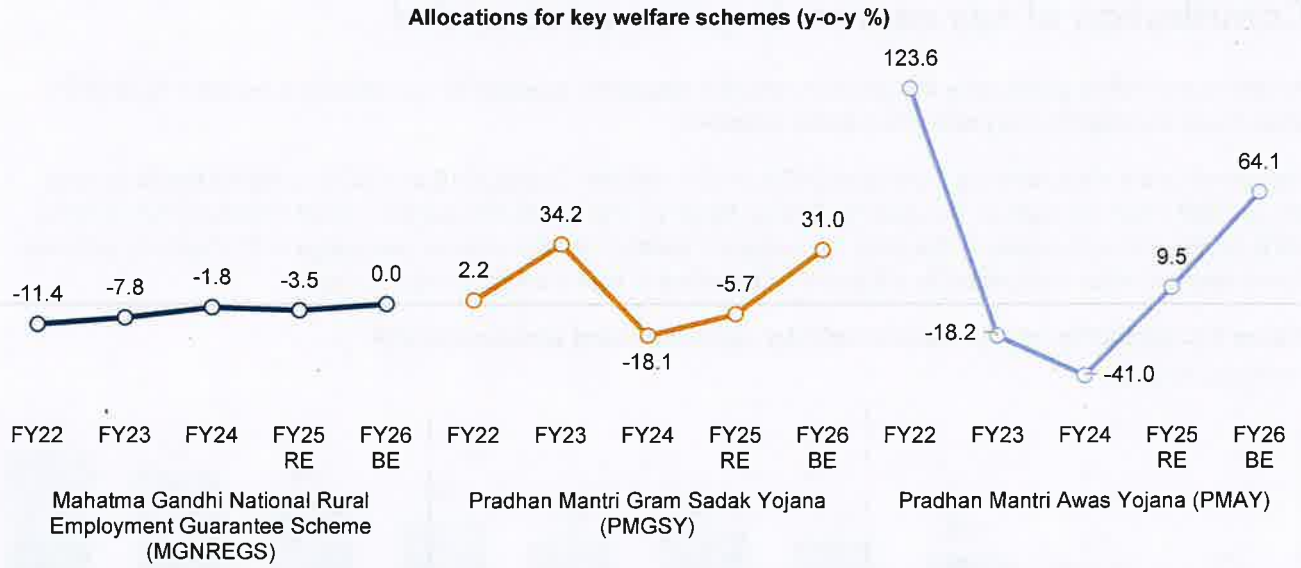
Private consumption expected to hold up in fiscal 2026

Accounting for more than 58% of GDP, private consumption remains the key driver of the economy. However, in fiscal 2025, middle-class consumption was subdued owing to high interest rates and food inflation. To address this, the Union Budget 2025-26 introduced measures aimed at providing a shot in the arm to consumer sectors.

Tax relief measures to prop up consumption: The government has reduced income tax rates under the new tax regime, increasing middle-class disposable income. The tax rebate limit is now Rs 1.2 million, up from Rs 0.7 million, saving an individual earning Rs 1.2 million about Rs 80,000 annually. The revised tax slabs will reduce the tax burden across income levels. These tax relief measures will support middle-class spending beyond fiscal 2026, though some income may go towards savings and debt repayment.

Support to consumption from key flagship schemes continues: Higher allocations for key infrastructure and employment-creating schemes such as Pradhan Mantri Awas Yojana (PMAY; up 64.1% on-year) and Pradhan Mantri Gram Sadak Yojana (PMGSY; up 31% on-year), as well as maintaining the allocation for the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS), should support incomes and consumption in fiscal 2026. The total allocation for these schemes has increased 23.7% on-year, after being stagnant in fiscal 2025. These schemes primarily benefit lower-income households, which tend to have a greater propensity to consume.

Figure 5: Higher allocations for key flagship programmes in fiscal 2026



Source: Budget documents, Crisil Intelligence

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

Policy rate cuts: The RBI's Monetary Policy Committee is likely to reduce the repo rate further in fiscal 2026 — following a cut of 25 basis points (bps) in February 2025 and another 25 bps in April 2025 — owing to the expected further easing of domestic retail inflation. A 50-75 bps reduction in repo rates is anticipated in fiscal 2026. The lower interest rates are expected to mildly support consumption, as they will gradually get transmitted to other interest rates in the economy, reducing borrowing costs.

Support from the rural economy: In addition to the budgetary support, favourable monsoon supported farm prospects in fiscal 2025. In terms of rural incomes, stable agricultural output is expected to provide some relief. Rural India remains largely agrarian, with 86% of land holdings belonging to small and marginal farmers, who dominate the country's agricultural landscape. Over the last five years, performance of the agriculture sector has been encouraging, in contrast to

the negative CAGR of 3.7% between fiscals 2013 and 2018. The sector has grown at a healthy pace, with GVA in agriculture logging a CAGR of 4.2% between fiscals 2019 and 2024.

Regulatory and policy developments that could drive the private capex cycle

In fiscal 2024, private consumption was a weak link, estimated to have grown just 4.0%, much below the GDP growth of 8.2%. A pickup in private capex is critical to sustaining the investment momentum.

Government push for infrastructure development: The National Infrastructure Pipeline (NIP) was launched with a projected infrastructure investment of Rs 111 trillion ($1.5 trillion) during fiscal 2020 to fiscal 2025. Sectors such as energy, roads, urban infrastructure and railways have a major share in the NIP. The focused infrastructure initiative will boost the economy, generate better employment opportunities and drive competitiveness of the economy. Roads, urban infrastructure, railways, power (conventional and unconventional) and irrigation departments have received the highest funds from the NIP, amounting to ~80% of the corpus.

Private sector participation: With the government normalising capex, the private sector is expected to take the lead in furthering the investment momentum. The ability of private corporates to invest is supported by their deleveraged balance sheets, the healthy balance sheets of lenders, and turning of the interest rate cycle. Private corporate investments have been sluggish so far. For a full-fledged and sustainable revival in overall capex, the private corporate sector will need to regain its position as a key driver of investments. The share of private corporate investment in total fixed investment saw a sustained decline to 34.4% in fiscal 2024 from a peak of 41% in fiscal 2016, following a steady climb from ~33% in fiscal 2012.

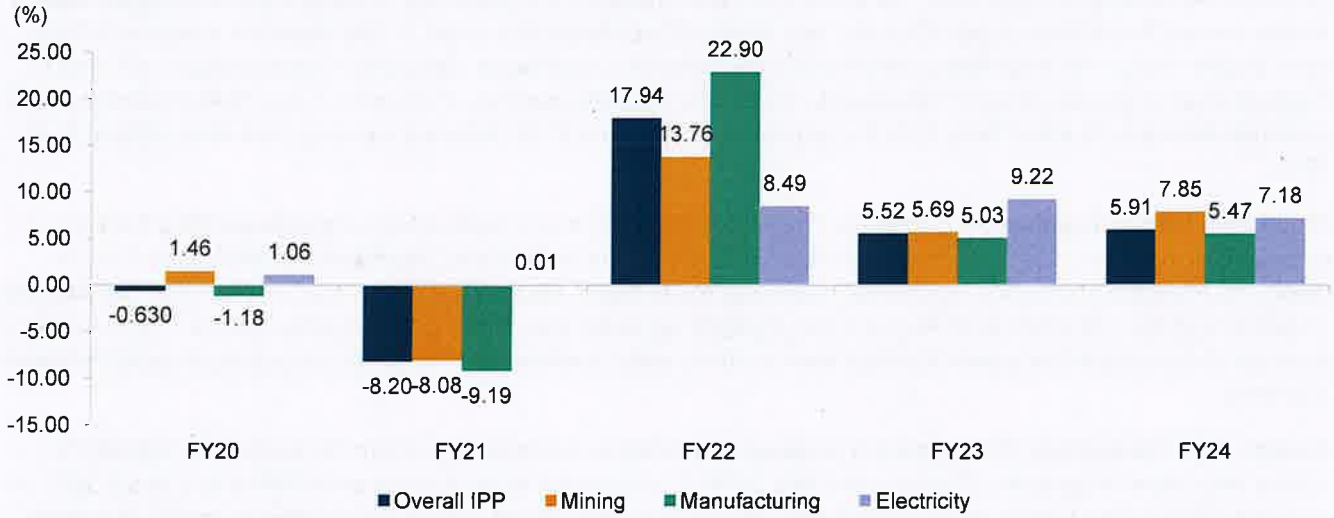
Production Linked Incentive (PLI) scheme: The PLI scheme, which aims to drive industrial capex of Rs 2.6-2.8 trillion during the scheme period, is projected to contribute ~5% to capex in key sectors. The incentives, totalling Rs 1.8-1.9 trillion, are expected to generate incremental revenue of Rs 30 trillion. Launched in March 2020, the scheme had attracted investments of Rs 1.46 trillion as of August 2024, highlighting healthy momentum in key targeted sectors. The PLI scheme is poised to drive significant growth in India's manufacturing sector over the next two years, particularly in capital-intensive segments.

Foreign direct investment (FDI): India has achieved a remarkable milestone in its economic journey, with gross FDI inflows reaching an impressive $1 trillion since April 2000. This landmark achievement was bolstered by a nearly 26% on-year rise in FDI to $42.1 billion during the first half of fiscal 2025. This growth reflects India's growing appeal as a global investment destination, driven by a proactive policy framework, a dynamic business environment and increasing focus on competitiveness.

Figure 6: Growth in India's FDI inflows

Source: Press Information Bureau (PIB)

Figure 7: Index of industrial production on-year growth trend



Source: MoSPI, CEIC, Crisil Intelligence

Power demand shows strong correlation with GDP per capita

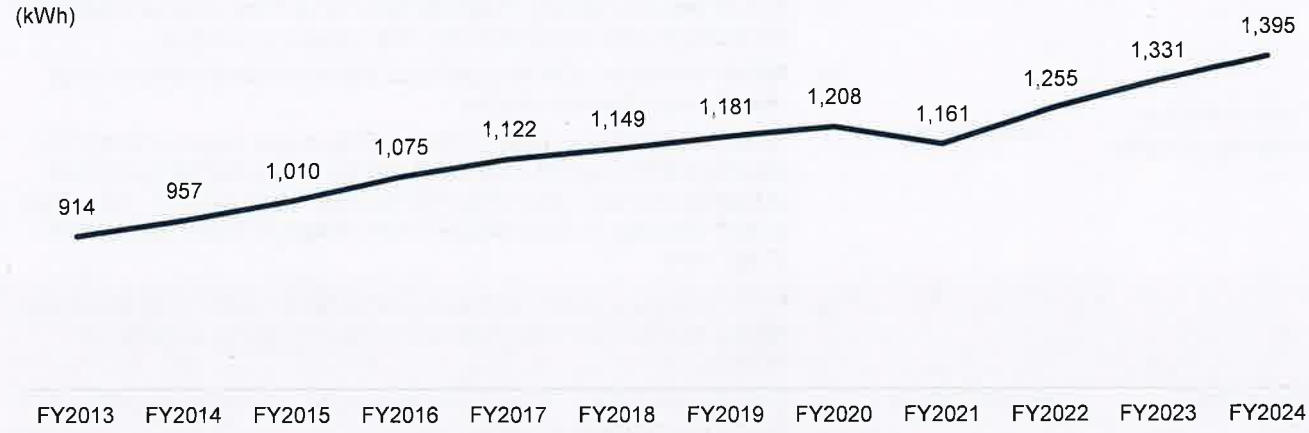
A 30-year data assessment indicates a strong correlation between power demand and overall GDP growth. Cross-country and cross-state comparisons also indicate the same. Hence, tracking GDP growth and its impact on per capita power demand is considered an established means of understanding the prospects of the power sector. The results of this analysis point to power demand tracking GDP by 100 bps on average over the past three decades.

Further, India's manufacturing GVA share of 17% as of fiscal 2024 (provisional estimate) is lower than that of its other Association of Southeast Asian Nations (ASEAN) peers, which play the role of factories to the world. That said, the ongoing supply-chain de-risking strategy of global players amid geopolitical disruptions, the Indian government's focus on initiatives such as Make in India and PLI, and the emergence of new-age sectors amid energy transition creating new

manufacturing needs are set to improve the contribution of manufacturing to India's GDP. This would further boost power demand prospects.

Alongside these developments, an efficient transmission and grid infrastructure would help reduce aggregate technical and commercial (AT&C) losses and improve energy efficiency in the power sector.

Figure 8: Per capita electricity consumption logged 3.8% CAGR between fiscals 2014 and 2024



Source: CEA, PIB, Crisil Intelligence

Atmanirbhar Bharat Abhiyan

PLIs in the 14 sectors for the Atmanirbhar Bharat vision received an outstanding response, with a potential to create 60 lakh new jobs (government estimates).
The PLI scheme for Solar PV modules was launched in April 2021 to promote domestic manufacturing of high efficiency

Table 4: Atmanirbhar Bharat vision for select sectors

Sector	Government spending	Key schemes
Renewable energy	~Rs 1,30,000 crore	• Rs 4,500 crore under PLI scheme for 'National Programme on High Efficiency Solar PV Modules', launched on 7th April 2021. The amount was increased further by Rs 19,500 crore in the budget for fiscal 2023, taking it to Rs 24,000 crore; 8.7 GW capacity in Tranche I and 39.6 GW capacity in Tranche II were allocated for domestic solar module manufacturing capacity under PLI • PM Surya Ghar Muft Bijli Yojana has a proposed outlay of Rs 75,000 crore and aims to light up 1 crore households (rooftop solar) by providing up to 300 units of free electricity every month • Implementation of Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM) scheme; the Ministry of New and Renewable Energy (MNRE), in November 2020, expanded the PM-KUSUM scheme to add 30.8 GW by 2022 with central financial support of Rs 34,422 crore. The scheme has been extended until March 31, 2026 • Approved Models and Manufacturers of Solar Photovoltaic Modules (Requirements for Compulsory Registration) Order, 2019

Sector	Government spending	Key schemes
		• List of manufacturers and models of solar PV modules and cells recommended under Approved List of Models and Manufacturers order • Scheme of grid-connected wind-solar hybrid power projects • Basic customs duty (BCD) of 25% on solar cells, 20% on solar invertors and 40% on modules, effective April 1, 2022
Power distribution companies (discoms)	~Rs 97,000 crore	• Rs 1.35 lakh crore liquidity infusion for discoms via Power Finance Corporation/ Rural Electrification Corporation (PFC/ REC) against receivables • Rebate for payment to be received by generation companies (gencos) to be passed on to industrial customers • Revamped Distribution Sector Scheme (RDSS) to help discoms improve their operational efficiencies and financial sustainability by providing result-linked financial assistance. Outlay of Rs 3,03,758 crore over 5 years, i.e., fiscals 2022 to 2026, including an estimated government budgetary support (GBS) of Rs 97,631 crore
New energy	~Rs 38,800 crore	• Rs 18,100 crore 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 for green hydrogen manufacturing, with an initial outlay of Rs 19,744 crore, to boost domestic production of green hydrogen

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

Supply chain diversification being adopted globally

Supply chain diversification 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. Numerous factors are encouraging supply chain diversification for solar, including the rising cost of labour in China, increasing complexity of the Chinese regulatory environment, growing political risk in the country, increasing demand for diversification from investors, and the emergence of several countries as potential destinations. Additionally, the US sanctions imposed on imports from the Xinjiang region in June 2022 had opened doorways for other exporting economies such as Vietnam, Malaysia, Thailand and India. These countries offer several advantages, including lower labour costs, favourable government policies and access to new markets. India is a potential destination for solar manufacturing due to its low labour cost as well as favourable political and regulatory environment for manufacturing. An expanding manufacturing base has enabled domestic manufacturers to tap the export potential, with nearly 97% of exports focused on the US alone. Businesses, particularly those in the metals and biofuels sectors, will face higher export costs, potentially reducing competitiveness and impacting global supply chains. This is likely to accelerate the adoption of supply chain diversification in the solar industry.

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

Global focus on energy transition and decarbonisation getting sharper

The urgent need to address climate change is driving the shift towards renewable energy, with international initiatives such as the Paris Agreement and RE100 promoting its adoption. To limit global warming, a transition to renewable energy

is critical. The global clean energy transition has been boosted by solar power, which has experienced remarkable growth – installed capacity almost tripled since 2018 to 1,418 GW by 2023, accounting for 37% of the world's total renewable energy capacity. Governments have supported the solar industry through policies such as feed-in tariffs, tax incentives and subsidies, accelerating global growth in solar PV and driving the sector's expansion. However, the progress of global climate initiatives has not been without setbacks, as evidenced by the US withdrawal from the Paris Agreement, which had significant consequences, including the abrupt end to climate finance. Notably, the Obama Administration's commitment to contributing to the Green Climate Fund (GCF), which helps developing countries mitigate and adapt to the impacts of climate change, was discontinued, highlighting the challenges that remain in securing international cooperation and funding to support the global transition to renewable energy.

The 26th United Nations Climate Change Conference of the Parties (COP26) was held in Glasgow, Scotland, in October-November 2021, and a draft agreement was circulated with respect to climate change action. The timeframe for NDCs were updated in August 2022, which are as follows:

- To reduce emissions intensity of its GDP by 45% by 2030 from the 2005 level
- To achieve about 50% cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030
- To achieve Net Zero by 2070

The Indian government has initiated efforts to combat climate change through multiple programmes and schemes, such as the National Action Plan on Climate Change (NAPCC), which comprises missions in specific areas of solar energy, energy efficiency, water, sustainable agriculture, Himalayan ecosystem, sustainable habitat, health, Green India, and strategic knowledge for climate change. The National Solar Mission under the NAPCC is a key initiative to promote sustainable growth while addressing India's energy security, with the total solar energy potential estimated at 748 GW peak by the National Institute of Solar Energy. Measures taken by the Centre to promote renewable power in India include the following:

a) Allowing FDI up to 100% under the automatic route

b) Declaration of trajectory for renewable purchase obligations (RPOs) until 2030

c) Introduction of schemes such as PM-KUSUM, PM Surya Ghar: Muft Bijli Yojana, Rooftop solar Phase II, and 12,000 MW Central Public Sector Undertaking (CPSU) Phase II

d) Laying of new transmission lines and creating new sub-station capacity under the Green Energy Corridor scheme for evacuation of renewable power

e) Standard bidding guidelines for tariff-based competitive bidding process for procurement of power from grid-connected solar PV system, wind and hybrid projects

f) Notification of promoting renewable energy through Green Energy Open Access Rules, 2022

g) Mandates that power shall be dispatched against letter of credit or advance payment to ensure timely payment by distribution licensees to renewable energy generators

The Indian government has implemented several initiatives to promote the use of renewable energy. One such initiative is the RPO, which requires distribution licensees to purchase a percentage of electricity from renewable sources. Further, the government has introduced the domestic content requirement (DCR) initiative, which mandates the use of domestically manufactured solar cells and solar modules in orders or projects under government schemes and grid-connected rooftop solar programmes, such as the CPSU scheme, PM-KUSUM scheme

The PM-KUSUM scheme, launched in 2019, aims to set up 10,000 MW of decentralised grid-connected renewable energy power plants and solarise 2.5 million agriculture pumps. The scheme has been expanded to support 2 million farmers with standalone solar-powered pump systems and 1.5 million farmers with solarisation of their grid-connected pump sets. The PLI scheme, introduced in 2021, aims to boost the manufacturing of high-efficiency solar PV modules and reduce import dependence for solar energy.

PM Surya Ghar Muft Bijli Yojana aims to provide up to 300 units of electricity generated from rooftop solar systems across 10 million households. Furthermore, India has contributed to the setting up of the International Solar Alliance (ISA), a global coalition of solar-resource-rich countries that aims to promote the use of solar energy and provide a platform for cooperation among member countries. These initiatives demonstrate India's commitment to increasing the use of renewable energy and reducing its dependence on fossil fuels.

Even in its National Electricity Plan for the generation segment, released in March 2023, the government projects solar and wind resources alone to form 54% of the installed base of ~900 GW expected by fiscal 2032. This will be driven by the robust pipeline created by government-led tenders, as well as the support to the rooftop segment, and other policy pillars provided to the clean energy sector.

India's competitiveness among leading manufacturing-based economies

Comparison of manufacturing ecosystem and relevant parameters

Recognising the significance of manufacturing in terms of contribution to GDP, exports, foreign exchange and job creation, and to realise the goal of a $30 trillion economy by 2047, the Indian government has introduced a number of initiatives, policies, programmes and schemes, such as Make in India, Atmanirbhar Bharat, PLI and India Semiconductor Mission (ISM) over the past decade. These measures aim to attract investments, promote domestic production and create employment opportunities for the growing population, thereby enhancing long-term growth prospects.

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Module 3: Overview of the power market

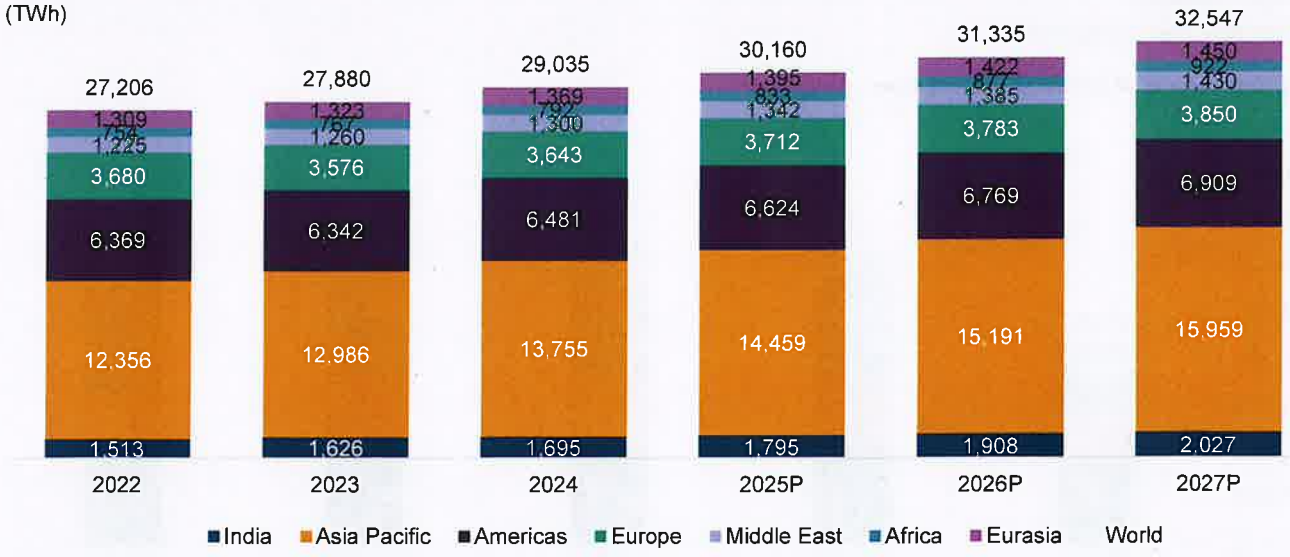
Global electricity demand outlook

Global power demand growth to sustain momentum

As per the International Energy Agency (IEA), global power demand grew 4.1% in calendar year 2024, faster than the 2.5% in 2023. More than 65% of global electricity demand growth came from Asia-Pacific, mainly China, India and Southeast Asia. Advanced economies, on the other hand, saw stable power demand in 2024, with the US and Europe experiencing marginal growth of 2% and 1.9%, respectively, led by increased use of heat pumps and electric vehicles (EVs) and higher demand from data centres. In the Middle East, power demand increased to 3.2% in 2024 from 2.8% in 2023, driven by an exceptionally hot summer season boosting air conditioning use. Africa's power demand increased 3.3% in 2024, driven by South Africa's recovery from a contraction in demand in 2023 to growth of 4.1% in 2024, as new capacity was brought online and the power sector limited load shedding. Meanwhile, Eurasia's power demand grew 3.5% in 2024, driven by economic stimuli and adverse weather.

According to IEA, Global power demand is projected to log a CAGR of 3.9% over 2024-2027, driven by rising industrial production, higher use of air conditioning, accelerating electrification and the expansion of data centres worldwide.

Figure 8: Global electricity demand to clock 3.9% CAGR between 2024 and 2027



Notes:

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

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

Crisil
Intelligence

Renewable energy to lead global electricity installed capacity and generation

As per the IEA, global power generation grew 4% to nearly 31,000 terawatt-hour (TWh) in 2024. Fossil fuels (coal, natural gas and oil) accounted for 60% of the global power supply, representing their lowest share in 50 years. Coal accounted for the largest share (35%) of the total, followed by natural gas (24%). Beyond fossil fuels, nuclear maintained a stable 9% share in total power generation. Renewables, led by solar and wind, accounted for 32%.

Global power generation is expected to log a 3-4% CAGR over 2024-2030, according to the IEA. Renewable energy is set to play a much larger role in power systems over these years. Solar PV and wind combined generation is expected to nearly triple by 2030, accounting for over 90% of the incremental electricity supply growth, overtaking coal in total incremental generation. Nuclear power generation is also expected to increase at the global level.

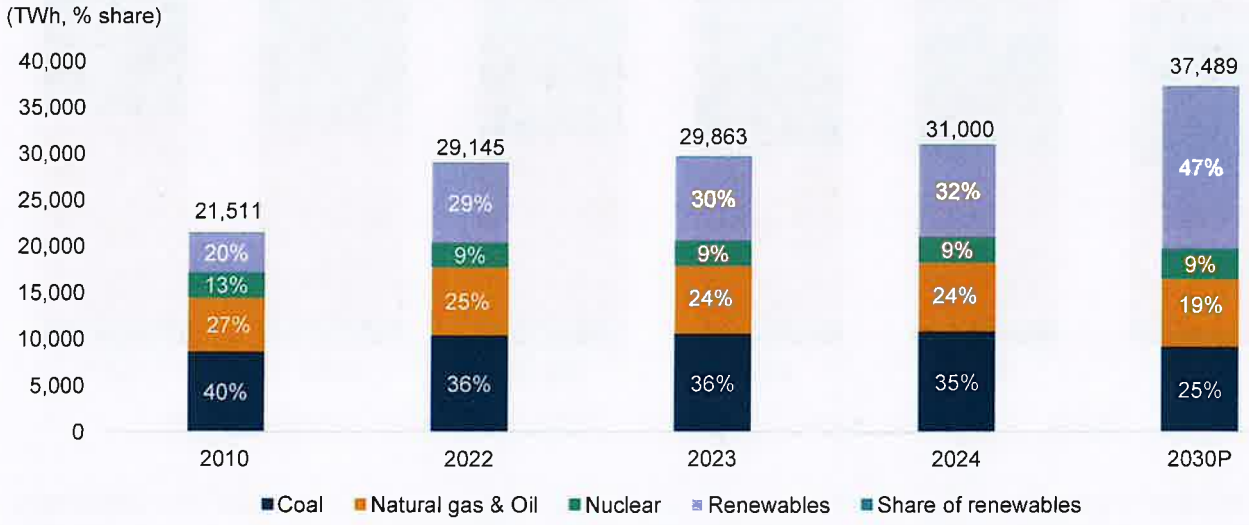
Table 5: Global power generation to clock 3-4% CAGR over 2024-2030

Electricity generation (TWh)	2010	2022	2023	2024	2030P	CAGR (2024-2030)
Coal	8,671	10,451	10,648	10,850	9,213	(2.6%)
Natural gas and oil	5,787	7,315	7,293	7,440	7,289	(0.34%)
Nuclear	2,756	2,684	2,765	2,790	3,266	2.6%
Renewables	4,209	8,567	9,029	9,920	17,577	10%
Total generation	**21,511**	**29,145**	**29,863**	**31,000**	**37,489**	**3.2%**

Note: P – Projected

Source: IEA, Crisil Intelligence

Figure 9: Share of renewables in power generation



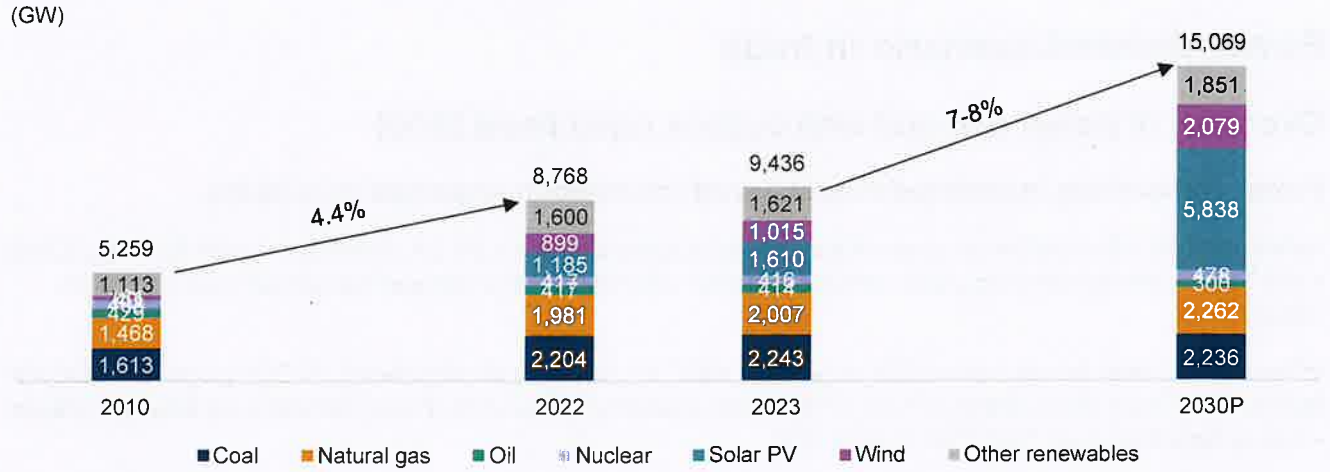
Note: P – Projected

Source: IEA, Crisil Intelligence

According to the IEA, the global installed electricity capacity increased 1.8x to 9.4 TW in 2023 from 5.3 TW in 2010. While fossil fuel capacity accounted for nearly 50% of the installed base in 2023, the addition over 2010-2023 was driven by renewable fuels, which accounted for a 70% share. Fossil fuels, on the other hand, accounted for 28%. Solar PV capacity increased 36% on-year to a new record of 1,610 GW in 2023.

The IEA expects the global installed electricity base to log a CAGR of 7-8% over 2023-2030. The growth is expected to be supported by a 13-15% CAGR in renewable energy, with a major contribution from solar PV, which is expected to log a CAGR of 21-23% during the period.

Figure 10: Global installed electricity base to clock 7-8% CAGR over 2023-2030



Note: P – Projected

Source: IEA, Crisil Intelligence

Asia-Pacific to continue to lead power generation

According to the IEA, global power generation is expected to log a CAGR of 3-4% over 2023-2026. Asia-Pacific led power generation in 2023 and is expected to maintain its dominance through 2026. Within Asia-Pacific, China led power generation in 2023, with renewables accounting for the majority share. China is followed by India, where due to a rapid increase in demand for electricity, the IEA expects renewable energy generation to accelerate, with an average annual growth rate of 13%. In the Americas, the IEA expects growth in renewable energy generation to displace the fossil-fired power generation. Power generation in the Americas is expected to log a CAGR of 1-2% over 2023-2026, with renewable generation forecast to clock a CAGR of 7-8% on average.

Table 6: Global electricity generation to clock 3-4% CAGR over 2023-2026

Electricity generation (TWh)	2022	2023	2024	2027P
Asia-Pacific	12,351	12,968	13,720	15,906
India	1489	1617	1732	2077
Americas	6369	6342	6481	6909
Europe	3680	3576	3643	3850
Middle East	1225	1260	1300	1430
Africa	754	767	792	922
Eurasia	1309	1323	1369	1450
World	**29,145**	**29,863**	**31,868**	**31,868**

Notes:

1. *P – Projected*
2. *For India, fiscal year is used*
3. *Asia-Pacific numbers exclude India's numbers*

Source: IEA, Crisil Intelligence

Power demand scenario in India

Overview of power demand with outlook (until fiscal 2030)

Power demand has maintained robust growth momentum, expected to continue

India's electricity consumption has grown at a steady pace, expanding at a 4.5% CAGR between fiscals 2014 and 2025 to 1,695 TWh, driven by economic growth, population growth, urbanisation, and improved transmission and distribution infrastructure.

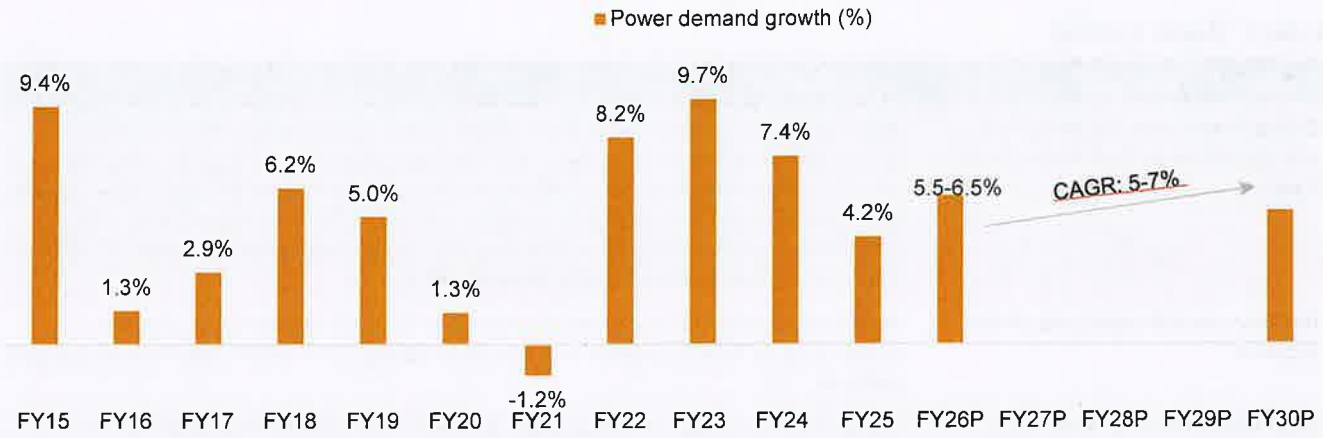
In fiscal 2025, power demand rose 4.23% on-year to 1,695 TWh, driven by an estimated 6.5% GDP growth and seasonal factors. This follows strong growth of 7.4% in fiscal 2024 and 9.6% in fiscal 2023. Power demand is expected to increase ~1.3x by fiscal 2030 from 1,695 TWh in fiscal 2025.

Base power demand logged a 5% CAGR between fiscals 2019 and 2025.

Power demand growth was cyclical in fiscal 2025. While above-normal maximum and minimum temperatures drove demand up 10.9% on-year in the first quarter, a favourable monsoon and slower industrial activity moderated the pace in the second quarter (0.3% on-year). Demand rebounded 2.6% on-year in the third quarter, driven by resumption in post-monsoon industrial activity, along with festive demand. In the fourth quarter, power demand grew a modest 3.6% on-year, led by warmer winters in the north, which reduced heating demand, and slower industrial growth (as indicated by a 2.9% increase in IIP in February 2025).

Between fiscals 2025 and 2030, power demand is expected to log a CAGR of 5-7%, driven by healthy economic growth and expansion of the electricity footprint via strengthening of the distribution infrastructure. The government's continued infrastructure and industrial manufacturing push is expected to drive power demand, with climate change-induced temperature fluctuations also a key reason for peak demand surges. The government's focus on rural electrification, railway electrification, EV transition and the '24x7 Power for All' policy will bolster energy consumption. Major reforms initiated by the central government to improve the health of the power sector, particularly that of state distribution utilities, are also expected to improve the quality of power supply, thereby boosting power penetration levels as well.

Figure 11: Snapshot of power demand (BU)



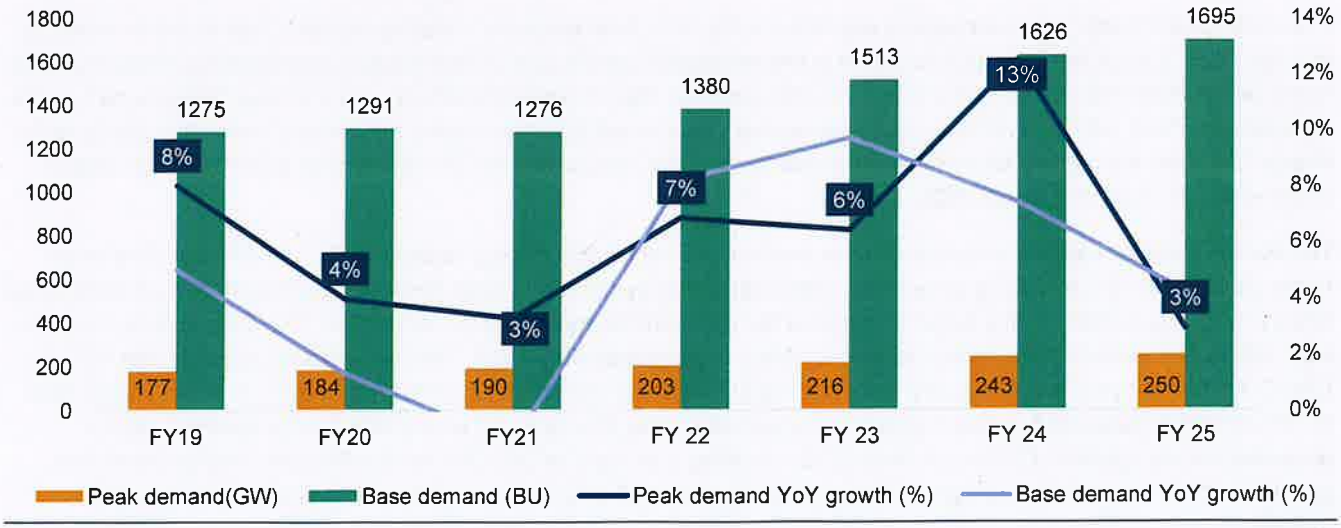
Note: P – Projected

Source: CEA, Crisil Intelligence

Peak demand has historically outpaced base demand growth

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

Figure 12: Peak demand growth outpaces base demand growth



Source: CEA, Crisil Intelligence

Power demand drivers in India

Table 7: Power demand

Power demand drivers	Description
Broad-based manufacturing and infrastructure push to boost power demand	India's power demand is expected to increase due to various factors, including GDP growth, industrial activity and government initiatives. Emerging areas such as data centres, green hydrogen and industrial expansion will contribute to this growth. Data centre capacity increased from 565 MW in CY 2021 to 1,300 MW in CY 2024, logging a CAGR of 32%. Additionally, the country's goal of producing 5 million tonne of green hydrogen by 2030 will require approximately 125 GW of renewable energy.
Railway electrification and metro projects	India's electricity demand is expected to rise with the 100% electrification of Indian Railways by 2025 and growth in metro projects, adding 22-27 billion units of power demand per year.
Gradual transition to EVs	The government's push for EV adoption, aiming for 30% of cars to be electric by 2030, is expected to add 6-7 billion units of power demand per year, totalling 40 billion units between 2025 and 2030.

Source: CEA, Government of India, Crisil Intelligence

Power supply

Power capacity base and fuel mix by fiscal 2030

Installed capacity to reach 730-780GW by fiscal 2030, renewables (ex-hydro) to account for 40-50%

The Indian power sector has witnessed a significant surge in its total electricity installed capacity, with an 8% increase as of fiscal 2025. A notable aspect of this growth is the substantial contribution of renewable energy sources, excluding large hydro, which accounted for 86% of the total capacity addition. Within renewable energy, solar energy has emerged as the dominant segment, with 83% of total renewable energy capacity additions (ex-hydro) attributed to solar. As a result, solar energy has been the primary driver of capacity addition in India, accounting for 72% of the total power capacity added between March 2024 and March 2025.

The current installed capacity statistics in India reveal a total renewable energy capacity of 220.10 GW including large hydro, and 172.26 GW excluding large hydro. Renewable energy (including large hydro) accounted for 22% of India's total energy mix in fiscal 2025, with a target to increase the non-fossil share to 50% by fiscal 2030. The solar installed capacity was 105.65 GW in fiscal 2025, while the wind installed capacity was 50.04 GW. The total installed capacity was 475.21 GW. Over the past year, solar capacity has exhibited significant growth of 29%, increasing from 81.81 GW in fiscal 2024 to 105.65 GW in fiscal 2025. According to government estimates, this upward trend is expected to continue, with a projected on-year growth of 22% until fiscal 2030, targeting a capacity of 280 GW. In contrast, wind energy witnessed growth of 9% in fiscal 2025, highlighting the varying trajectories of different renewable energy sources in the Indian market.

India's installed generation capacity increased to 475 GW in fiscal 2025 from 356 GW in fiscal 2019, driven by healthy renewable energy capacity additions (including solar, wind, hybrid and other sources) even as additions in coal and other fuels remained subdued. Renewables (ex-hydro) accounted for 36% of the total installed capacity in fiscal 2025, up from ~20% in fiscal 2018, whereas coal-based capacity tapered to 45% in fiscal 2025 from 55% in fiscal 2019.

Renewable energy capacity is expected to increase to 360-370 GW by fiscal 2030, on the back of strong capacity additions over fiscals 2026-2030 (ex-hydro and storage elements). Renewable energy capacity would account for 45-50% of the total capacity, which is expected to reach 730-780 GW by fiscal 2030. On the other hand, moderate coal-based capacity additions of 29-31 GW are expected to reduce coal's share to 30-35% by fiscal 2030. Other fossil fuels (including lignite, gas and diesel) are expected to remain stagnant due to negligible capacity additions. Inclusion of hydro and nuclear power in clean energy, is expected to provide a fillip to non-fossil capacity, taking it to 440-500 GW by fiscal 2030 (including storage). And it is expected to account for a staggering 55-65% of the total installed capacity.

The CEA released new guidelines in February 2025, mandating all standalone solar installations to incorporate energy storage systems (ESS). The ESS would be required to have a minimum backup of two hours and must be installed equal to at least at 10% of the solar capacity of the project. This policy is expected to boost growth in the solar segment, due to the growth of battery energy storage systems (BESS) which is anticipated to generate 140-160 GW of additional demand by fiscal 2030.

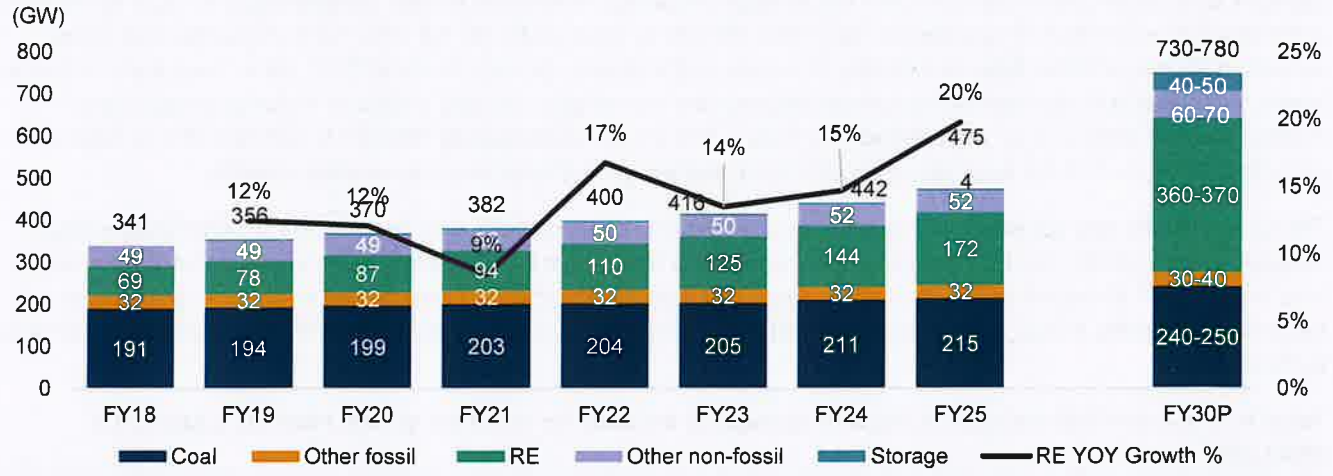
Table 8: Non-fossil fuel sources, along with storage, to account for over 55% of total installed capacity by fiscal 2030

	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY30P
Coal	55%	54%	53%	51%	50%	48%	45%	32%
Natural gas	7%	7%	7%	6%	6%	6%	5%	3%
Diesel	0%	0%	0%	0%	0%	0%	0%	0%
Hydro	12%	11%	11%	11%	10%	10%	9%	7%
Pumped hydro	1%	1%	1%	1%	1%	1%	1%	3%
Lignite	2%	2%	2%	2%	2%	1%	1%	1%
Nuclear	2%	2%	2%	2%	2%	2%	2%	2%
Solar	8%	9%	10%	14%	16%	18%	21%	33%
Wind	10%	10%	10%	10%	10%	10%	11%	12%
Hybrid	0%	0%	0%	0%	1%	1%	2%	5%
Other renewable energy sources (RES)	4%	4%	4%	4%	4%	4%	5%	3%
Battery	0%	0%	0%	0%	0%	0%	0%	3%

Note: P – Projected

Source: CEA, Crisil Intelligence

Figure 13: Share of renewable energy in installed capacity



Note: Renewable Energy (RE) includes solar, wind, hybrid and other renewable sources. Other fossil fuels include lignite, gas, and diesel. Other non-fossil fuels include hydro and nuclear. Storage includes Battery Energy Storage System (BESS) and pumped storage plants (PSPs); P – Projected

Source: CEA, Crisil Intelligence

Solar and wind capacity addition is expected to rise over the next five years, with most of the projects deploying efficient technologies to improve utilisation. Similarly, utilisation of PSPs is likely to improve in line with significant capacity addition during the period. Consequently, generation from renewable sources and storage capacities may rise significantly, lowering the requirement for coal supply. As a result, coal-based plant load factor (PLF) is expected to moderate amid higher renewable energy and storage-based utilisation.

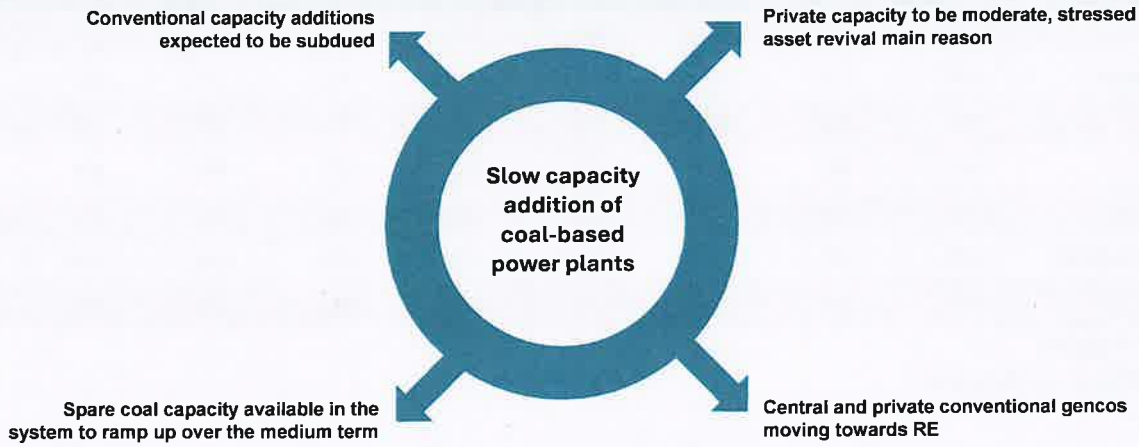
Figure 14: Solar projects fare better on cost and duration

Parameters	Coal	Solar	Wind
Capital cost (Rs mn per MW)	80-90	38-42	65-70
O&M cost (Rs mn per MW)	2-2.25	0.3-0.4	0.6-0.8
Construction time (Years)	4 to 6 years	1 to 2 years	1 to 2 years
Average PLF (%)	60-70	20-25	25-30
Ramp-up rate (% of capacity per minute)	1-3%	Cannot be controlled	Cannot be controlled
Tariff range of the fuel	5.0-6.0	2.6-2.8	3.8-4.0

Source: Crisil Intelligence

Key factors that are likely to slow the pace of coal-based capacity addition

Figure 15: Factors affecting capacity of coal-based power plants



Source: Crisil Intelligence

Power generation to clock 5-7% CAGR over fiscals 2025-2030

Power generation across fuels is expected to increase at a CAGR of 5-7% between fiscals 2025 and 2030. Crisil Intelligence expects generation to rise 5.5-6.5% to 1,950- 2,000 BU in fiscal 2026. Coal-based generation is expected to clock a 1.5-2.5% CAGR between fiscals 2025 and 2030 as India aims to achieve 50% of non-fossil-fuel-based electricity by 2030 under the Panchamrit climate action plan. The share of coal in overall power generation is expected to fall to 55-60% by fiscal 2030 from ~70% in fiscal 2025, indicating the fuel will remain a key part of the nation's energy supply mix even in the long term.

The contribution of renewable energy (ex-hydro) to total power generation increased to 15% in March 2025 and 15% in fiscal 2025 from 9% in fiscal 2019. Solar energy dominated this segment with a 57% share in renewable energy generation and 7.8% share in total energy generated in fiscal 2025.

Solar energy unit generation grew an impressive 24.3% over the last year. In contrast, wind energy unit generation declined 0.05% during the same period. This suggests that India's renewable energy sector is transforming, with solar energy emerging as a leading player. The growth of solar energy projects is expected to continue, driven by declining costs and favourable government policies.

Crisil Intelligence projects RE-based generation to surge at a CAGR of 20-21% between fiscals 2025 and 2030. Robust capacity addition and improving solar and wind capacity utilisation on the back of technological improvements are expected to help, along with an increased storage mix to aid RE's intermittent issues. RE sources are expected to account for 25-30% of the generation by fiscal 2030. Share of fossil fuels (coal, natural gas, diesel and lignite) in India's energy mix is expected to be in the range of 60-65% by fiscal 2030. With strong additions in RE sources, the share of non-fossil sources (RE, nuclear, hydro and storage) is expected to increase to 40-45% in fiscal 2030 from ~26% in fiscal 2025.

Storage-based capacities, which include BESS and PSP, are estimated to constitute ~1% of overall power generation in fiscal 2026. With steady growth in PSP capacity and healthy additions in BESS, storage is expected to contribute 3-4% of the overall power generation by fiscal 2030.

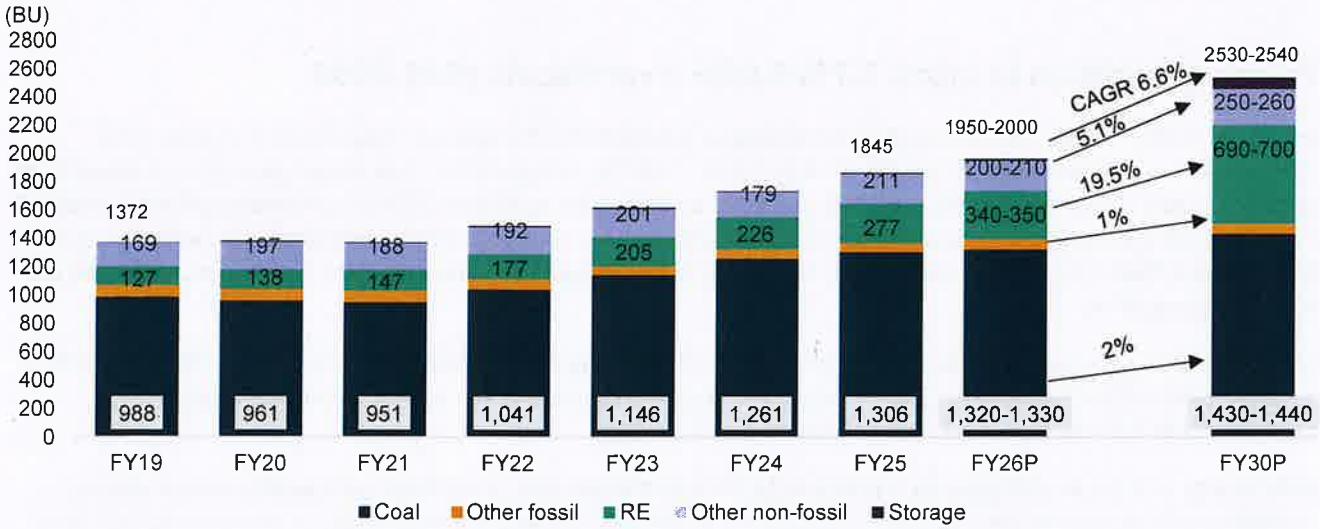
Table 9: Fuel-wise power generation in India

	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26 P	FY30 P
Coal	72%	69%	69%	70%	71%	73%	70%	67%	56%
Other fossil	6%	6%	6%	5%	4%	4%	4%	4%	3%
Solar	3%	3%	5%	5%	6%	6%	8%	11%	18%
Wind	4%	5%	4%	5%	5%	5%	5%	5%	8%
Other RES	2%	2%	2%	2%	2%	2%	2%	2%	2%
Other non-fossil	12%	14%	14%	13%	12%	10%	11%	11%	10%
Storage	0%	0%	0%	0%	0%	0%	0%	1%	3%

Note: P – Projected

Source: CEA, Crisil Intelligence

Figure 16: Fuel-wise power generation in India by fiscal 2030



Note: RE includes solar, wind, hybrid and other renewable sources such as biomass, small hydro, waste to energy. Other fossil fuels include lignite, gas, and diesel. Other non-fossil fuels include hydro and nuclear. Storage includes BESS and PSP; P – Projected

Source: CEA, Crisil Intelligence

Policy framework and watershed regulations

The Electricity Act, 2003, was key to the power sector reforms process as it consolidated previous policies, thereby streamlining the sector and improving efficiency. In 2008, the government introduced Open Access Regulations for establishment of power exchanges. In 2016, the government amended the National Tariff Policy with increased focus on renewable energy and the objectives of the Ujwal DISCOM Assurance Yojana (UDAY). In 2023, the Ministry of Power

issued the Electricity (Amendment) Rules that change the qualifying criteria for a captive generating plant and in 2024, the Electricity (Third Amendment) Rules which aimed at reducing dependence on non-renewable energy sources. In 2024, the Central Electricity Regulatory Commission (CERC) further notified the draft tariff regulations for the period from April 1, 2024, to March 31, 2029.The details of each legislation/policy are as follows:

- **Electricity Act, 2003:** De-licensed power generation, introduced open access in transmission and distribution, and unbundled state electricity boards to promote competition
- **Open Access Regulations, 2008:** Facilitated short-term bilateral trade in power and introduced power exchanges for anonymous trading
- **National Tariff Policy, 2016:** Aimed for 24/7 power supply, promoted use of renewable energy and encouraged energy efficiency
- **Electricity (Amendment) Rules, 2023:** Simplified rooftop solar installations, introduced connections for EV charging stations and expedited new electricity connections
- **Electricity (Third Amendment) Rules, 2024:** Promoted sustainability and reduced dependence on non-renewable energy sources
- **CERC Tariff Regulations, 2024:** Changed tariff calculations and introduced incentives for efficient thermal generation stations

Crisil Intelligence

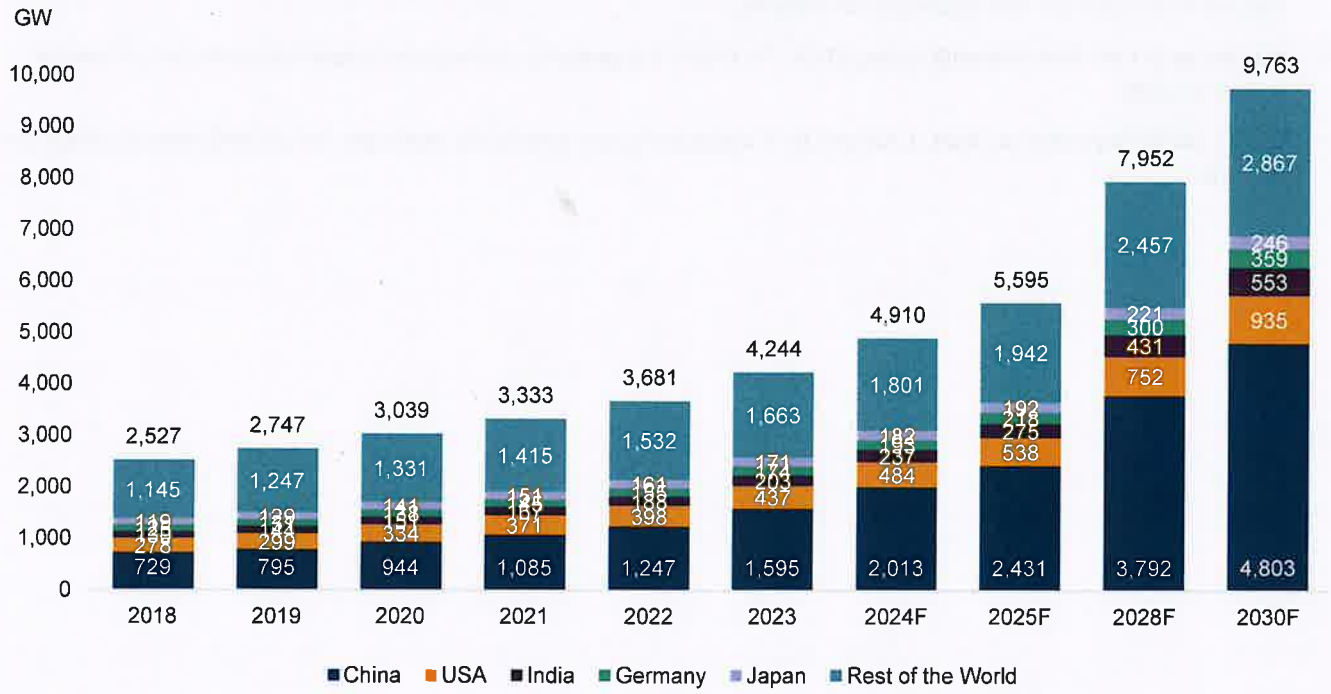
Module 4: Indian solar market

Industry overview

Renewables take centre stage

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

Figure 17: India had the third-largest renewable energy base in the world in 2024



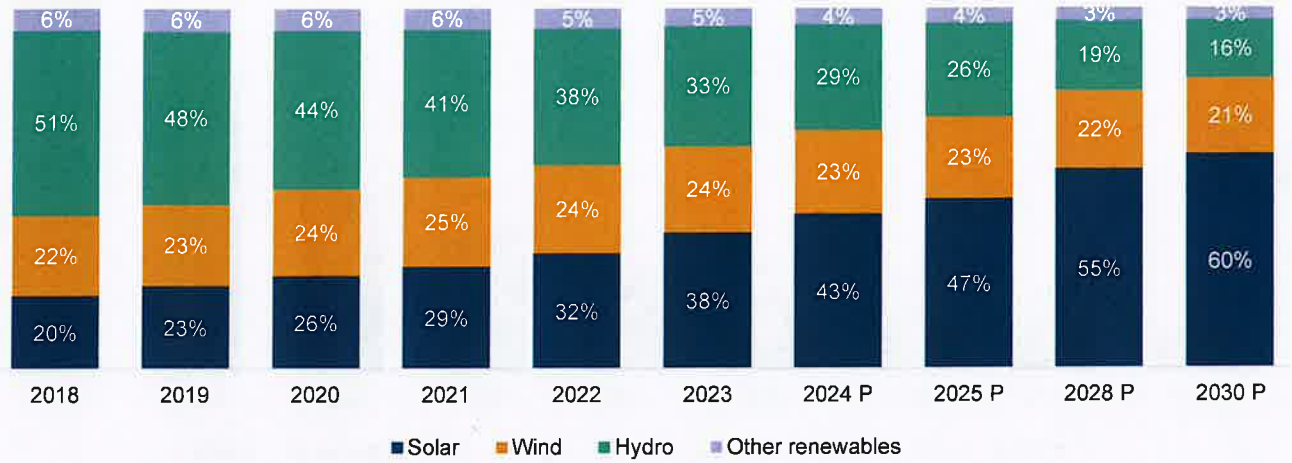
Source: IEA, Crisil Intelligence

As per the IEA, global renewable installed capacity increased at an 11% CAGR between 2018 and 2023 driven by the policy push across countries. China accounted for nearly 50% of the addition during the period with an installed base of 1.6 TW. US and India ranked second and third, respectively, with total installed base of 437 GW and 203 GW, respectively.

While India's renewable energy capacity has grown consistently over the years, its share in the global installed base remained stable at nearly 5% between 2018 and 2023.

Nearly 66% of the global renewable installed base by 2023 was solar and wind while the balance was driven by other renewable fuels.

Figure 18: Solar is the largest single fuel within the global RE installed base (GW) by 2023



Note: Other renewables include ocean, bioenergy and geothermal energy

Source: IEA World Energy Outlook Report October 2024, Crisil Intelligence

Solar leads RE capacity additions at a global level

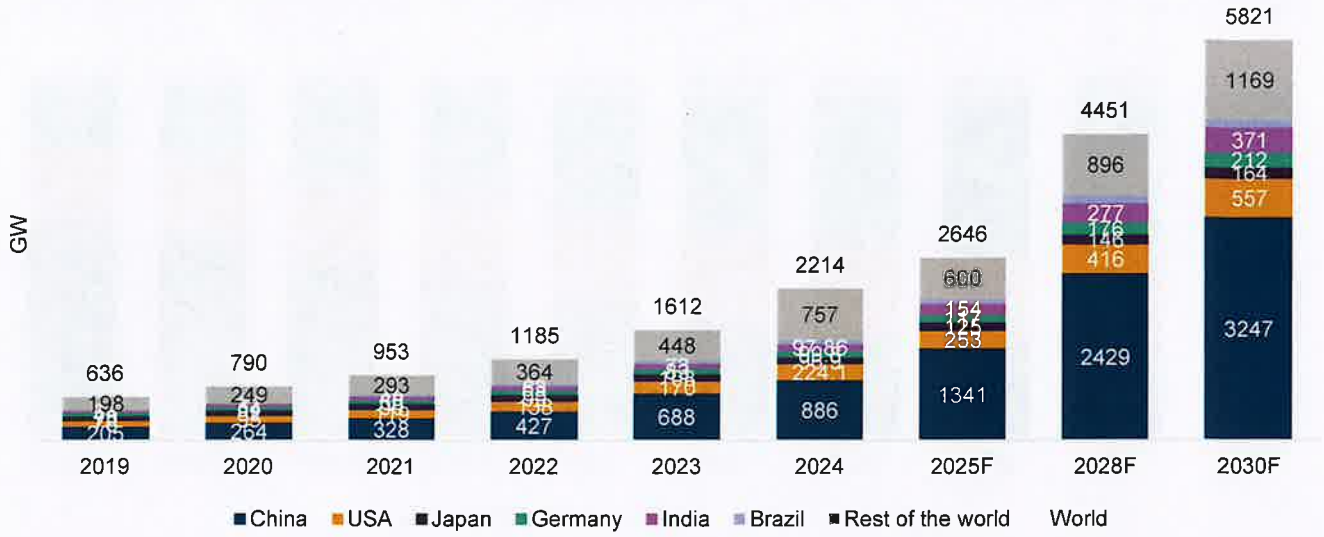
As solar PV becomes the preferred and most cost-effective option for electricity generation globally, investments are expected to increase. According to the IEA, average annual solar generation needs to grow by 25% between 2022 and 2030 to achieve the agency's Net Zero Emissions by 2050 Scenario, requiring a threefold increase in annual capacity deployment until 2030.

Globally, the solar PV installed capacity reached 2.2 TW in 2024, a 37% increase over the previous year. China leads the market with an installed base of 886 GW, followed by the US with 224 GW and Germany with 117 GW, according to the IEA. In India, the solar PV capacity installed base stood at 98 GW in 2024, clocking a CAGR of 23.6% between 2019 and 2024.

Capacity addition in 2024 was driven by the sharp fall in capital cost owing to oversupply of solar components globally, mainly from China. With 54 GW added in 2024 the US had 224 GW of solar PV capacity at the end of the year. India's additions were also supported by the ALMM kept in abeyance in fiscal 2024. Despite a BCD on imported modules, the sharp fall in prices of solar modules resulted in heavy commissioning. India had the fourth-largest solar PV installed base by the end of 2024.

The IEA expects the cumulative global solar PV installed base to reach ~5,800 GW by calendar year 2030, with China accounting for 56% of the total. Over 2025-2030, the US is expected to add 50-55 GW of utility-scale solar PV capacity annually.

Figure 19: Global solar global capacity to cross 5 TW by 2030

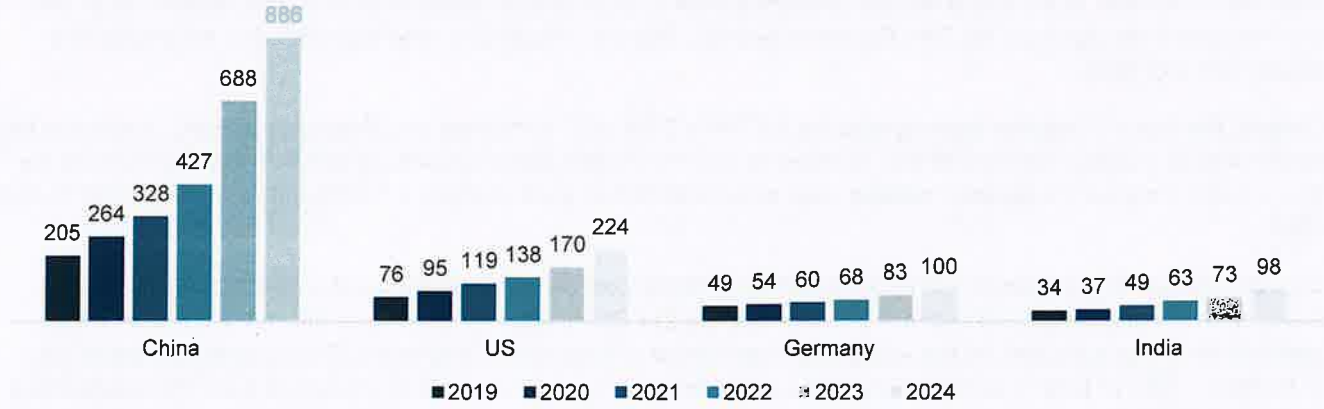


Note: India's installed capacity data has been taken from the CEA. For other countries, data till 2023 has been taken from the IEA. Data for 2024 has been taken from the IEA PVPS

Source: IEA, IEA PVPS, CEA, Crisil Intelligence

Figure 20: Top four countries constituted 66% of the solar installed base in 2024, with an uptrend for all

(GW)



Source: IEA, IEA PVPS, CEA, Crisil Intelligence

Technology improvements have aided solar energy adoption

Technological advancement in solar and wind energy has significantly reduced the costs, making them more economically viable than fossil fuels in many regions.

Technological innovations have led to significant improvements in conversion efficiency, material usage and energy efficiency per module. Over the past decade, solar PV cells have become more efficient and generation costs have decreased substantially.

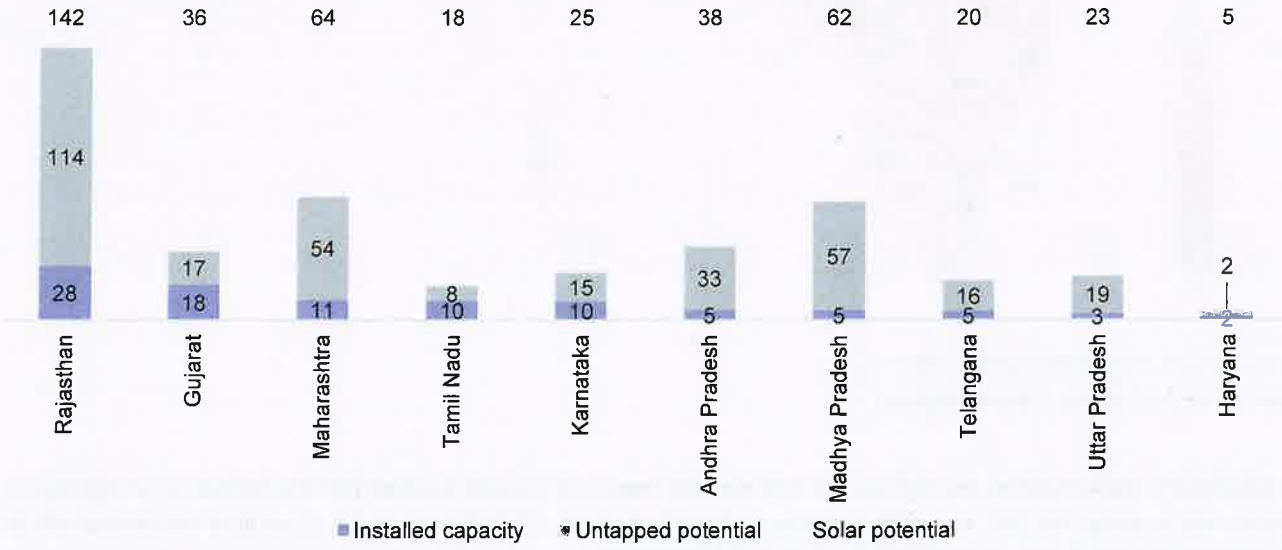
Bifacial modules are the latest technology to gain widespread commercial scale, especially in utility-scale projects, because of their improved efficiency. From a cell perspective, the industry has a wide installed base of monocrystalline cell technology, which accounted for over 50% of the market share as of 2023, according to Fraunhofer Society for the Advancement of Applied Research. This shift is driven by the high efficiency and long lifespan of monocrystalline solar panels. Moreover, newer technologies, such as tunnel oxide passivated contact (TOPCon) and heterojunction (HJT), are now on the horizon of commercial application. Ongoing investments in research and development (R&D) will further innovation, cost reduction and efficiency gains in the solar PV sector, reduce material intensity, particularly for critical minerals like silver and copper, and minimise supply chain vulnerabilities. Preference for TOPCon has already surged, while HJT is yet to find wide commercial adoption.

In India, mirroring the global trend, most manufacturers have transitioned to mono passive emitter rear contact (mono-PERC) technology, which is expected to remain dominant for the next 2-3 years. While TOPCon's share remains low at 4%, adoption is increasing, with leading players already offering it and others planning an upgrade from mono-PERC or parallel operations of the two given the easy fungibility across the technologies.

India has solar potential of 748 GW and wind potential of 1,164 GW at 150 meters above ground level

India enjoys rich solar potential on account of the tropical geography

Figure 21: Top 10 states utilised only 23% of their solar potential in fiscal 2025



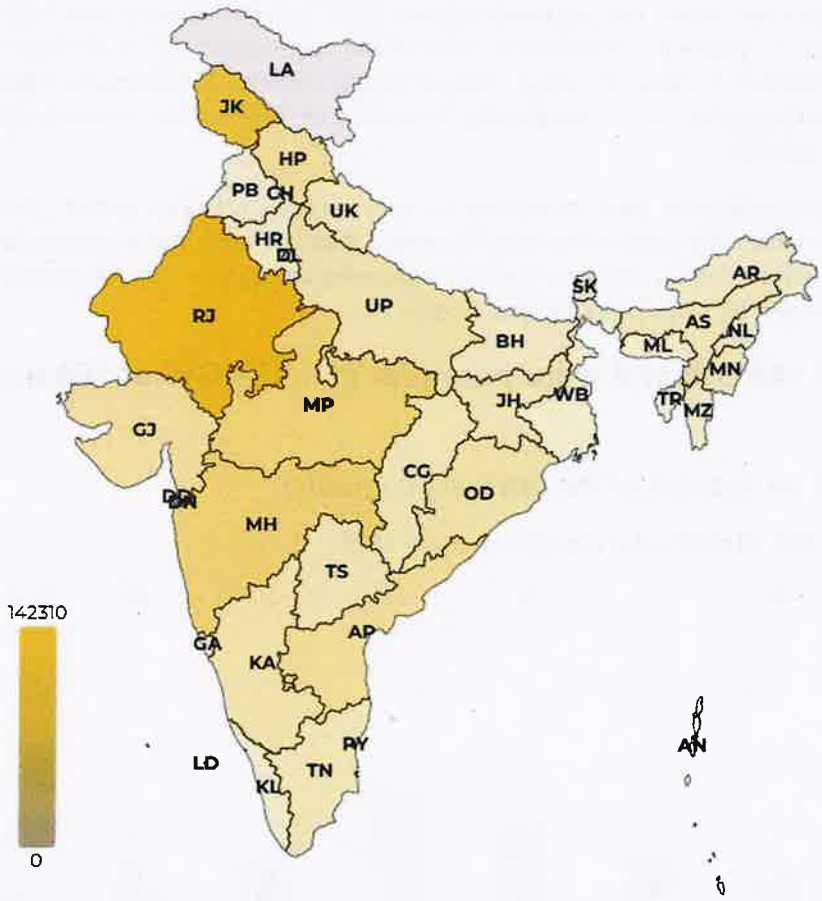
Source: NITI Ayog, MNRE, Crisil Intelligence

India has immense solar energy potential, with the National Institute of Solar Energy estimating it at ~748 GW, assuming just 3% of the country's waste land is covered with solar PV modules. The country's location receives 300 days of sunshine annually, which makes it an ideal spot for harnessing solar energy, with 300 days of India's immense solar sunshine annually..

The Global Horizontal Irradiance (GHI) in India ranges from 3.77-5.64 kWh/m2. The GHI varies across the north-eastern hilly regions and the western cold desert areas. Certain states such as Gujarat, Rajasthan, Madhya Pradesh,

Maharashtra, Andhra Pradesh, Karnataka, and Tamil Nadu receive more solar irradiance than others, which makes them prime locations for solar projects.

Figure 22: Solar potential fairly distributed across India



Note: The unit of gradient scale is in MW
Source: ICED Niti Aayog, Crisil Intelligence

In fiscal 2025, Rajasthan has the highest installed capacity base of 28.3 GW, coupled with the highest solar potential in the country at about 142 GW. However, the state has only achieved ~20% of its potential. Gujarat ranks second with an installed base of 18.5 GW, achieving 52% of its 35.7 GW potential.

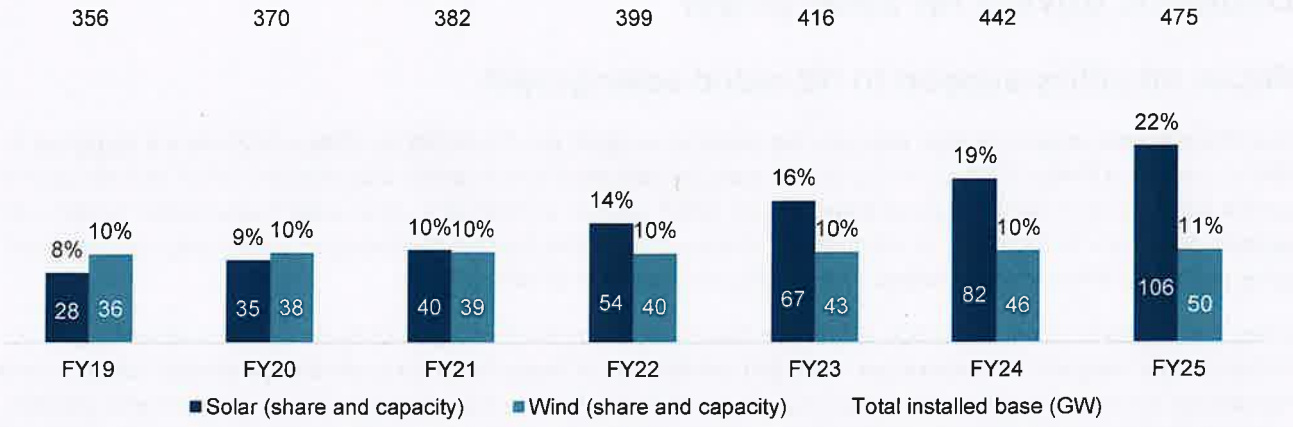
Maharashtra, with its third-highest installed base of 10.7 GW, has achieved a mere 17% of its 64 GW potential. Tamil Nadu has fulfilled 57% of its potential, installing 10.2 GW out of 17.6 GW potential. Madhya Pradesh, with an installed base of 5 GW, has only realised 8% of its 61.6 GW potential.

Solar overtakes wind as India's leading renewable source

The installed capacity of solar and wind formed ~33% of the total power installed base, as of fiscal 2025, up from 29% in 2024. Solar accounted for 22% of the installed base in fiscal 2025 up from 8% seen in 2019. Clocking a CAGR of ~37%, the solar installed base rose to 105.6 GW in fiscal 2025 from 21.8 GW in 2019. While the installed base of wind accounted

for 10% in fiscal 2019, it increased slightly to 11% in fiscal 2025. The installed base of wind clocked a CAGR of 7% over fiscals 2019-2025 rising to 50 GW in fiscal 2025 from 35.6 GW in 2019.

Figure 23: Share of solar in total installed base grew ~2.4 times in five years



Note: Installed base is total power installed base for the corresponding fiscal year. Numbers mentioned inside the columns pertain to installed base of respective segment in GW.

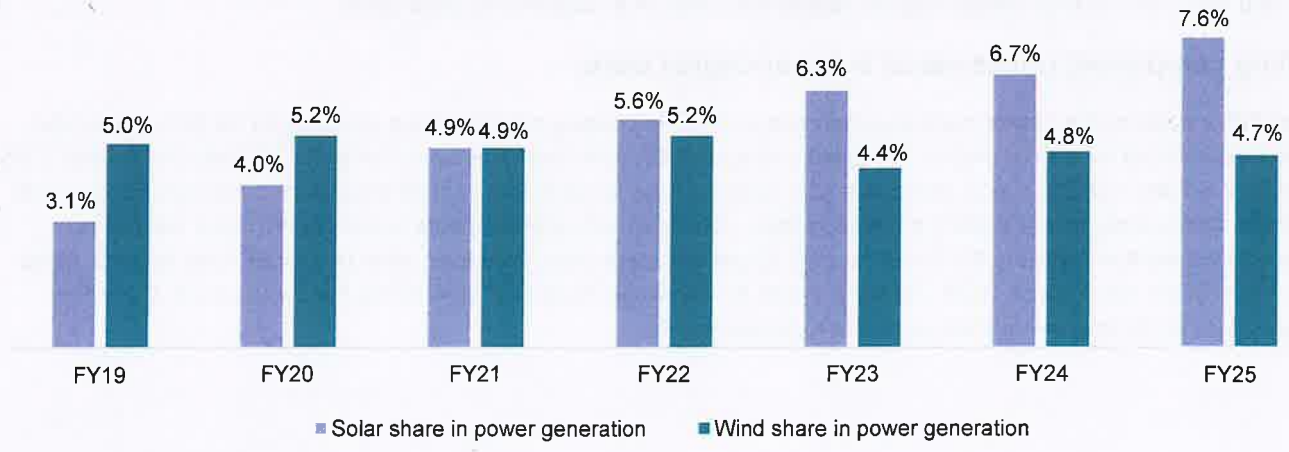
Source: CEA, Crisil Intelligence

In fiscal 2025, India installed about ~24 GW of solar capacity—a near 60% increase over the same period last year.

Despite the growth in capacity, the share of solar and wind energy in total power generation remains low, with both accounting for 12.3% share in power generation as of fiscal 2025. This is still a rapid increase of 420 bps from 8.1% in fiscal 2019. The share of solar in power generation rose to 7.6% in fiscal 2025 from 3.1% in 2019, while wind power generation stood at 4.7% in fiscal 2025 as against 5.0% in 2019.

Conventional sources still dominate power generation on account of lower wind and solar utilisation rates.

Figure 24: Increasing capacity share of solar energy reflects in in generation share



Source: CEA, Crisil Intelligence

While the share of solar and wind in generation has improved, power supply from these sources, by nature, is intermittent. To tackle this, the government is focusing on energy integration using a multi-fuel and storage model to provide round-the-clock power supply and mitigate standalone renewable energy intermittency.

Domestic drivers for solar power

Focus on policy support to RE-aided solar growth

The total installed capacity of solar energy in the country increased to ~105.6 GW as of fiscal 2025 from a negligible 1 MW at the end of March 2011, driven by various state policies as well as a central solar mission. Large allocations under central schemes such as the National Solar Mission (NSM; phase I and phase II), Inter-state Transmission System (ISTS) projects from Solar Energy Corp of India(SECI), projects from REIAs (Renewable Energy Implementing Agencies) and other state-level schemes have helped increase the installed base of solar in India.

Policy wise, India is committed to 500 GW of non-fossil capacity by 2030 as a part of its climate commitment goals. To further ensure integration of renewables in the grid, the Ministry of Power has introduced energy storage obligation and has waived transmission charges for solar projects, to promote interstate sale of power. The government also provides various benefits such as 40% Accelerated depreciation (AD) benefit, capital subsidy for rooftop projects, net metering for solar PV roof top projects etc., which will drive capacity additions in India.

Jawaharlal Nehru National Solar Mission (JNNSM)

The JNNSM, launched in 2010, initially aimed to establish 20 GW of grid-connected solar power by 2022, which was later increased to 100 GW in 2015.

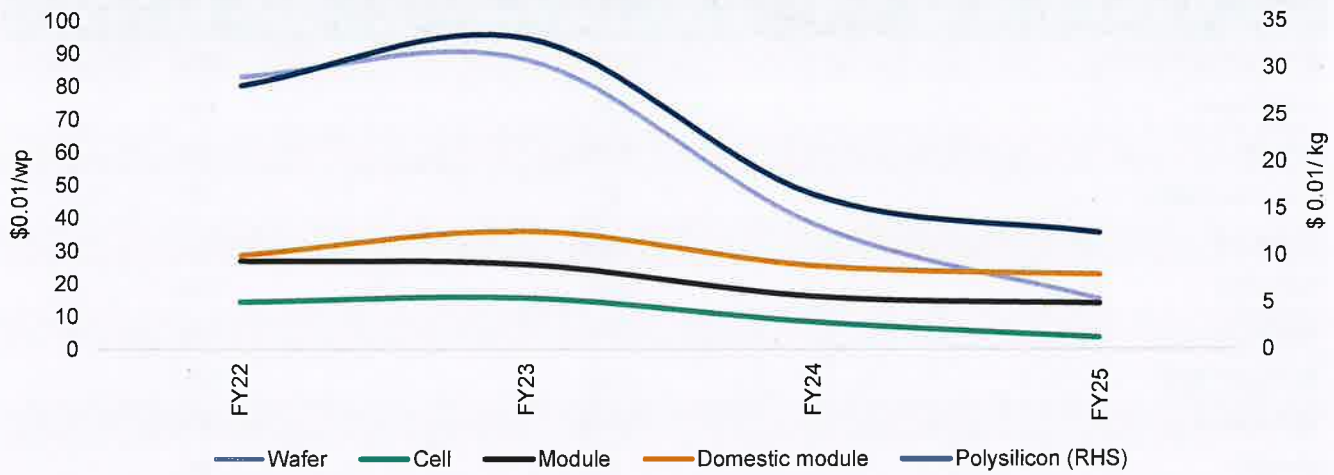
The first phase of JNNSM tendered 450 MW in two batches, with an additional 470 MW offered under solar thermal technology. Most of these projects are operational. The second phase introduced viability gap funding (VGF) to lower costs and established SECI as the executing agency. Phase II Batch-1 involved 750 MW of grid-connected solar PV projects, with a fixed tariff of Rs 5.45 per unit for 25 years.

Batch-II of phase II aimed to implement 15,000 MW of grid-connected solar PV plants in three tranches but was curtailed to only tranche I due to declining solar tariffs. Subsequent batches, including batch III and IV, involved setting up 2,000 MW and 5,000 MW of solar power projects, respectively, with VGF support and fixed tariffs.

Falling component prices result in lower capital costs

A key factor determining capital costs is component pricing. Purchasing solar modules accounts for 55-60% of the total capital expenditure for a solar project. Weighted-average tariffs for solar energy tariffs fell to Rs 2.63 per unit in fiscal 2025 from Rs 2.9 a unit in 2020, mainly on account of a drop in prices for upstream components. Solar component prices have declined continuously due to a rising production base, combined with improvements in technology. Solar cell prices reached their peak in February 2023, reaching $0.23 per watt peak (Wp). However, solar cell prices have fallen by close to 0.03 cents per wp in March 2025. Similarly, prices for wafers declined over 80% during the same period. Currently, prices are at an all-time low and are expected to remain stable.

Figure 25: Prices plunge as world sees a supply glut



Note: The units of kg above correspond to polysilicon, while wp is applicable for all other components.

Source: Crisil Intelligence

Solar energy tariffs also fall

The falling component prices attributed to large scale manufacturing capacity additions and R&D resulted in a fall in solar tariffs as well. The solar tariffs fell to Rs 2.63 per unit in fiscal 2025 from Rs 5.2 a unit in 2016. The oversupply in photovoltaic value chain moderated tariffs over the years. The resultant effect of the fall in prices over the years has made solar a cheaper source of energy compared with wind (Rs 3.8-4 per unit) and coal (Rs 5-6 per unit).

Payment security mechanisms in-built into utility market

The power purchase agreements (PPAs) for projects signed between the developer and SECI, NTPC Ltd, and NTPC Vidyut Vyapar Nigam Ltd (NVVN) considerably mitigate the risk associated with off-taker credibility, making it more bankable. SECI, NTPC and NVVN better credibility and payment track records compared with distribution companies and are also a part of the tripartite payment security agreement (between certain public sector undertakings [PSUs], government and RBI) which ensures payment from state budget allocations in case these entities default on payments. Also, some central-scheme PPAs also ensure the setting up of a payment security fund covering two to three months of payments to generators.

Ultra-mega solar parks

In December 2014, the MNRE introduced a scheme to establish minimum 25 solar parks and ultra mega solar power projects, adding over 20 GW of installed solar capacity. This was later increased to 40 GW and to develop a minimum of 50 solar parks of 500 MW and above capacity each by fiscal 2020. In July 2018, the MNRE extended the timeline to develop solar parks and ultra-mega solar projects totalling 40 GW from 2019-20 to 2021-22.

The scheme was extended to March 2026. According to the MNRE, as of February 2025, 50 solar parks/Ultra mega renewable energy power parks (UMREPPs) of 40.7 GW aggregate capacity were envisaged for development in the country. Within these parks, ~25 GW has been awarded (of which ~12 GW has been commissioned, while another ~12 GW is under construction), and 15 GW is under award/tendering process.

Table 10: Status of solar parks in India as of February 2025

State in which Solar Parks are located	Sanctioned capacity (MW)	Commissioned capacity (MW)
Andhra Pradesh	4,300	3,050
Chhattisgarh	100	100
Gujarat	12,150	1,000
Himachal Pradesh	53	32
Jharkhand	1,089	-
Karnataka	2,500	2,000
Kerala	255	105
Madhya Pradesh	4,780	2,263
Maharashtra	1,105	0
Mizoram	20	20
Odisha	340	0
Rajasthan	10,341	3,306
Uttar Pradesh	3,730	430
All India (Total)	**40,763**	**12,306**

Source: CEA, Crisil Intelligence

Push to states in the form of renewable purchase obligation also a factor

The renewable purchase obligation (RPO) is a regulatory requirement set by the State Electricity Regulatory Commission, mandating entities to procure a minimum percentage of their energy from renewable sources, as outlined by the Ministry of Power. In 2016, the Indian government modified the National Tariff Policy to encourage solar power adoption, setting a solar RPO target. States established their own targets based on their renewable energy potential, and in 2018, the ministry introduced a revised trajectory to achieve these goals.

In October 2023, the central government introduced the distributed renewable energy (DRE) and revised RPO targets, allowing projects under 10 MW to meet RPO requirements for distribution companies and open-access consumers.

Table 11: Revised RPO trajectory

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

Source: Ministry of Power, Crisil Intelligence

On April 1, 2024, the revised RPO trajectory came into effect, allowing excess energy from "other" sources to offset wind or hydro shortfalls. Compliance may not increase due to steeply rising RPOs, unless states purchase required RECs or intra-state power. Some states such as Telangana, Karnataka, and Gujarat may comply due to rapid solar additions, while others like Delhi, Uttar Pradesh, and Punjab may struggle.

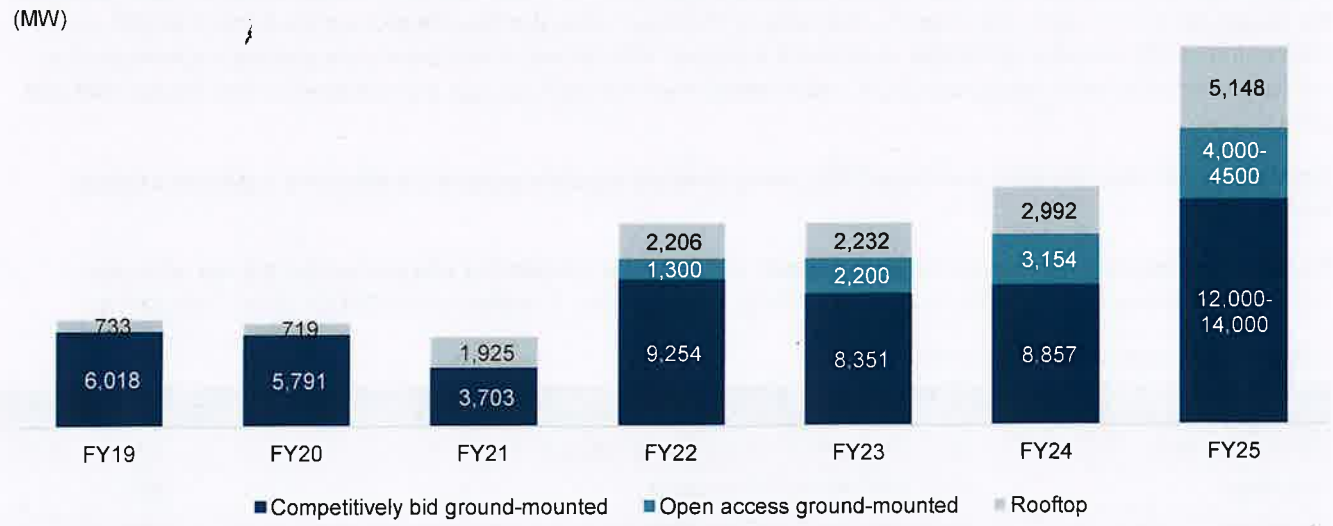
Despite non-compliance, enforcement of RPO targets has been limited due to weak discom finances. Lower solar Renewable energy certificates (REC) prices may increase compliance, as discoms can buy more renewable energy certificates. Strict enforcement is needed, but the proposed amendment to the Electricity Act, which imposes a penalty on non-compliance, is pending. The MNRE's RPO Compliance Cell, set up in May 2018, has not ensured strict enforcement, which remains a concern.

Solar power market

Capacity of 77 GW added between fiscals 2019 and 2025

The solar PV generation segment, which added a record ~15 GW of capacity in fiscal 2024, added ~24 GW in fiscal 2025, increasing yearly addition by ~59%. At this pace, it is projected that solar capacity will surpass 200 GW by the end of the current decade. The growth is being driven by environmental concerns and the consequent transition towards renewable power generation, supported by favourable government policies for domestic equipment manufacturing and renewable power offtake. Also, government and private companies are participating more in the renewable energy sector. Spurred by policy, the rooftop solar market is set to see rapid growth till fiscal 2030.

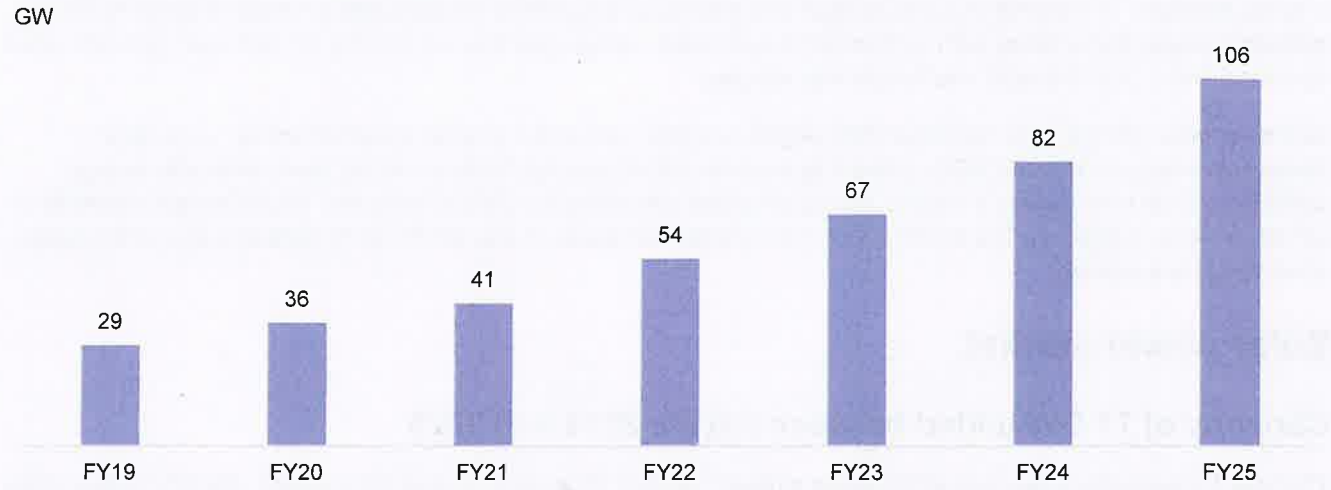
Figure 26: Incremental capacity addition led by competitively bid ground-mounted segment



Note: The split of open access and competitively bid capacities are Crisil Intelligence estimates

Source: MNRE, Crisil Intelligence

Figure 27: Installed Solar capacity grew at a CAGR of 24% from fiscal 2019 to fiscal 2025



Source: MNRE

Capacity additions in fiscal 2025 were primarily driven by the competitively bid segment (50-55% of additions), followed by rooftop solar (22% of additions). Additions in fiscal 2024 were also driven by competitively bid utility solar (58%), followed by open access (22%) and rooftop (21%), as supply-chain pressures eased on-year.

Gujarat, Karnataka, Maharashtra, Rajasthan and Tamil Nadu dominated the list of states with installed capacity base. These states accounted for more than 79% of capacity additions in fiscal 2024 and 67% in fiscal 2025. A major reason for the record additions in fiscal 2024 was the abeyance of the Approved List of Models and Manufacturers (ALMM), which relaxed the ALMM provision applicable to domestic additions. With no restrictions on imports, developers witnessed an increase in imported modules in fiscal 2024, which helped them commission their pent-up pipeline from fiscals 2023 and 2024.

While the ALMM was reapplied from fiscal 2025, rising domestic supply is expected to offset any impact on capacity addition.

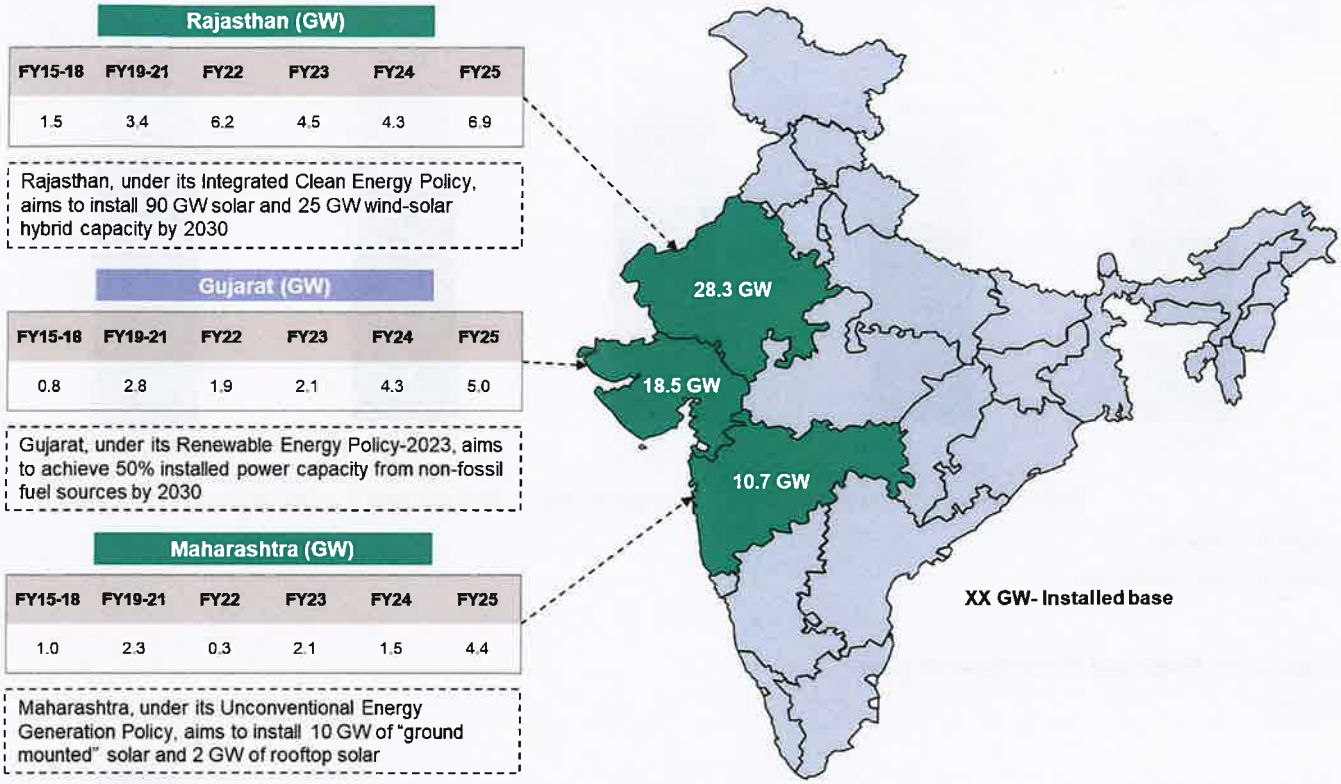
Rajasthan witnessed a high concentration in capacity additions. Commissioning was seen under the key schemes of SECI ISTS Tranche-V, SECI ISTS Tranche-IX, RUMSL Floating Solar Tranche-I and MSEDCL Solar Tranche-VIII.

Table 12: Key commissioning in fiscal 2025

Project location	Scheme	MW
Madhya Pradesh	SECI 1,200 MW ISTS Connected Projects (ISTS-VI)	300
Rajasthan	SECI 2,000 MW ISTS Tranche-IX	400
Rajasthan	SECI 2,000 MW ISTS Tranche-IX	100
Rajasthan	SECI 2,000 MW ISTS Tranche-IX	97
Rajasthan & Gujarat	CPSU Scheme (Tranche-II, 1,500 MW)	100
Rajasthan	SECI 1,070 MW Rajasthan Tranche-III	150
Rajasthan	SECI 1,200 MW ISTS Connected Projects (ISTS-V)	215

Source: Industry, Crisil Intelligence

Figure 28: Top three states comprised ~54% of national solar installed base as of fiscal 2025



Source: MNRE, Crisil Intelligence

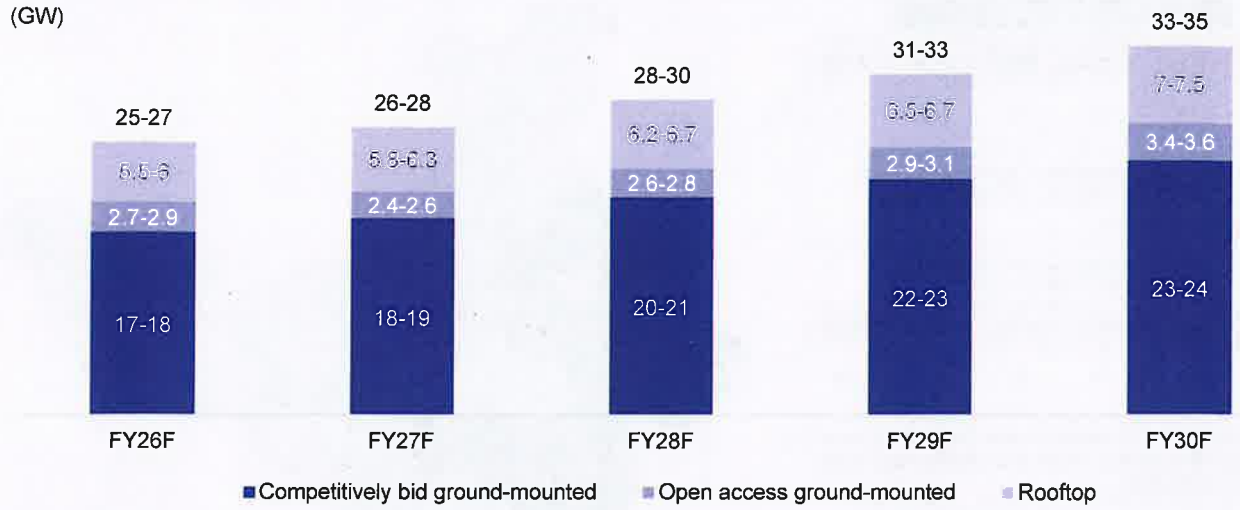
As illustrated in the chart, solar projects in fiscal 2025 are concentrated in Rajasthan and Gujarat, with the two pocketing a ~44% share of additions. This was mainly because of attractive solar policies by the state governments concerned, as well as high irradiance and ample land availability. The states have also set renewable energy targets of 90 GW and 100 GW, respectively, by fiscal 2030.

Solar additions of 140-160 GW expected by fiscal 2030

Crisil Intelligence expects 140-160 GW of solar capacity to be added over fiscals 2025-2030 through:

- Schemes launched by SECI (ISTS, floating solar tenders, newer structure tenders, state-specific schemes, etc)
- Capacities tendered by discoms in various states to fulfil RPO
- Capacities tendered by cash-rich public sector undertakings (PSUs) such as NTPC, NLC (formerly Neyveli Lignite Corporation) and Coal India Ltd (CIL)
- Rooftop solar
- Open-access solar

Figure 29: Majority of solar additions till fiscal 2030 will come from the competitively bid segment



Note: F is forecast
Source: Crisil Intelligence

Figure 30: Projected solar installed base

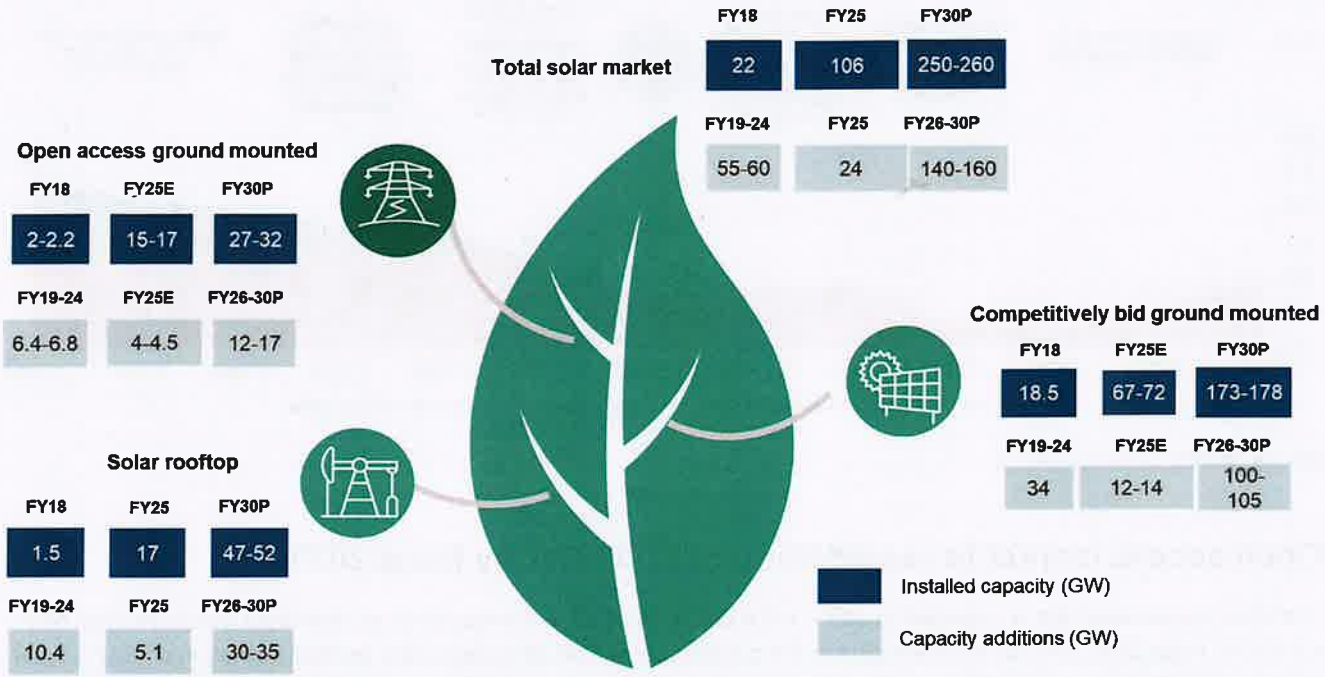
Source: Crisil Intelligence

Additionally, public sector undertakings (PSUs) are also expected to drive solar capacity additions. The CPSU programme under Jawaharlal Nehru National Solar Mission (JNNSM) was extended from 1 GW to 12 GW in February 2019. The government is also encouraging cash-rich PSUs to set up renewable energy projects. NTPC, for example, has already commissioned over ~4 GW of capacities at the end of 2025 under various schemes. 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 organisations and government establishments are also expected to contribute to this drive.

Solar capacity is anticipated to approach 250-260 GW by fiscal 2030, with the market projected to grow at a CAGR of 19-20% from fiscal 2025 to fiscal 2030. This growth is driven by decreasing costs of solar energy generation and favourable government incentives.

To arrive at capacity additions, Crisil Intelligence has considered the progress of capacity allocations from the schemes mentioned above. Crisil Intelligence has also factored in the economic feasibility of tariffs, the extent of payment security, the financial health of state discoms, RPO targets as well as execution risks.

Figure 31: Capacity addition avenues for Indian solar market



Note: The split of open access and competitively bid capacities are Crisil Intelligence estimates
Source: Crisil Intelligence

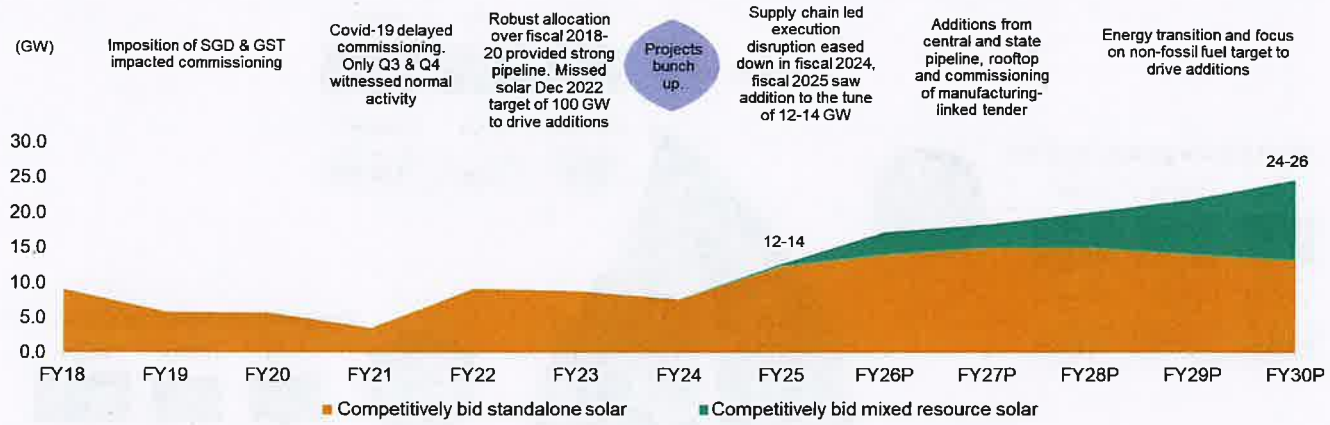
Policies that have been factored into Crisil Intelligence's outlook on capacity additions:

- SECI has tendered capacity under various schemes, where ~42.7 GW has been allocated, ~22 GW is under construction and ~3.2 GW has been tendered
- Under the state schemes, ~27 GW of projects are under construction and are expected to be commissioned over fiscals 2026-2030. Based on tendered capacities by states at the end of fiscal 2025, a further ~12 GW worth of solar projects is expected to be up for bidding soon
- The government has expanded the 1 GW CPSU programme to 12 GW to encourage cash-rich central PSUs to set up renewable energy projects. About 922 MW, 1,104 MW and 5,000 MW was allocated under tranche I, II and III, respectively, of this scheme, respectively. Crisil Intelligence expects 5-6 GW from this scheme to be commissioned by fiscal 2028
- Crisil Intelligence expects 12-17 GW of projects to be commissioned under the open access ground-mounted window between fiscals 2026 and 2030, driven by the go-green initiatives/sustainability targets of commercial and industrial

(C&I) consumers; effective long-term policies in key states such as Karnataka, Uttar Pradesh and Maharashtra; lower offtake risk; and conducive policies such as the Green Open Access Regulations

- Crisil Intelligence expects 30-35 GW of projects to be commissioned under the rooftop solar segment between fiscals 2026 and 2030, led by capacities added under PM Surya Ghar Yojana; capacities allocated by the state governments; and commissioning of capacities by government institutions such as metro, railways and airports. Capacities will also be added by industrial and commercial consumers

Figure 32: Solar capacity additions under competitively bid ground-mounted to triple by fiscal 2030

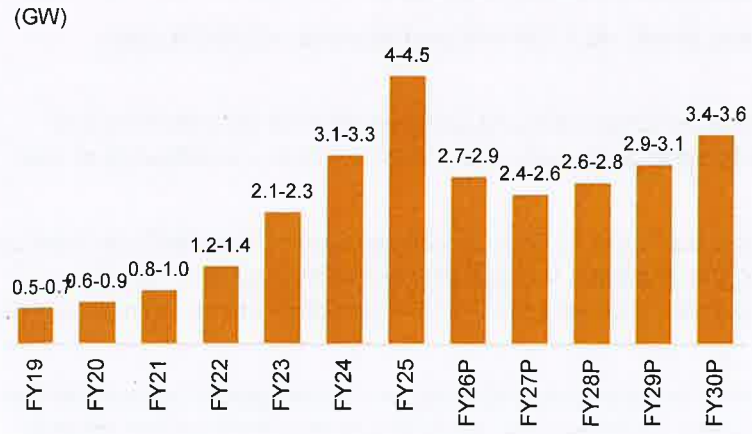


Source: MNRE, Crisil Intelligence

Open access market to see addition of 12-17 GW by fiscal 2030

The open access segment is expected to add 2.7-2.9 GW in fiscal 2026, compared to an estimated record addition of 4-4.5 GW in fiscal 2025. The fall in momentum in the current year will be attributed to the gradual cessation of ISTS waiver from June 2025. This waiver, following the estimate record addition of 4-4.5 GW in fiscal 2025, is expected to enable consumers to enter into long-term contracts or buy power from the spot market as well as from various market segments such as GTAM and GDAM that cater to green power requirements.

Figure 33: Open access additions to continue with micro-shock expected from withdrawal of ISTS waiver



FY24 - Capacity additions soared as developers hastened project commissioning prior to ALMM abeyance expiration in March 2024

FY25- Capacity addition continued its upward trajectory in lieu of impending waiver of ISTS charges

FY26 to FY30 - Green Energy Open Access Rules, go-green initiatives, and long-term policies in key states to drive capacity additions. ALMM exemption for green hydrogen projects may lead to growth in the segment.

Withdrawal of ISTS charges waiver after June 2025 may pose a micro-shock to open access addition, this however, would be absorbed as the waiver would be removed in a phased manner, thus not impacting the additions sharply

Note: P is projected
Source: Crisil Intelligence

Rooftop solar additions of 30-35 GW over fiscals 2026-30; 2x over fiscals 2019-25

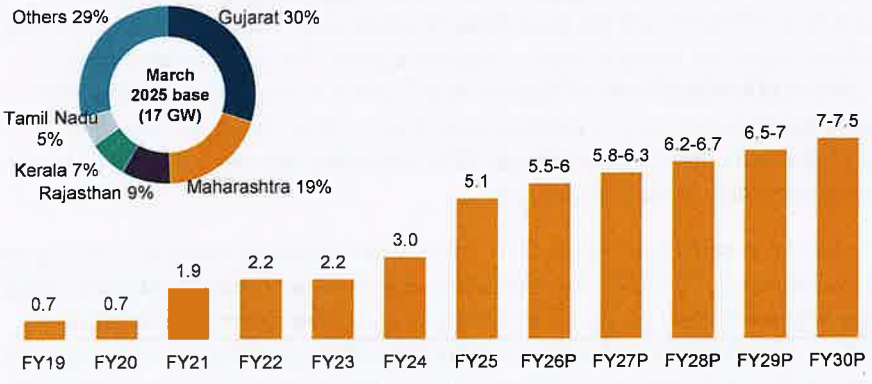
Rooftop projects are small-scale solar PV installations on rooftops of buildings that may or may not be connected to the grid. The Indian rooftop solar market has grown ~9.5 times between fiscal 2019 and fiscal 2025. While the number of installations has grown, the pace is still not enough to meet the government's target of 40 GW by fiscal 2026.

Rooftop solar installed capacity was 17 GW in March 2025, with 5.1 GW added in fiscal 2025. Gujarat (32%), Maharashtra (24%) and Rajasthan (7%) accounted for 63% of these additions. Several factors such as increased consumer awareness, advancements in technology and proactive subsidy initiatives implemented by central and state governments drove the additions.

In January 2024, the residential rooftop segment received a boost from the launch of PM Surya Ghar Yojna, which aims to solarise 1 crore households. State-level rooftop schemes, such as the Gujarat Surya Urja Rooftop Yojana, are also key drivers to rooftop solar additions. The scheme provided 40% and 20% state subsidy for installations up to 3 kW and 3-10 kW, respectively. Further, the state also allowed consumers to rent their premises or roofs to third parties for electricity generation, encouraging solar installations. Additionally, the micro, small and medium enterprise (MSME) policy that Gujarat released in September 2019 enabled the installation of solar projects with more than 100% of sanctioned load or contract demand. Under the scheme, MSMEs can sell excess power to the state government at Rs 3.5 per unit, leading to an increase in installations.

Rooftop additions in fiscal 2024 and in fiscal 2023 were fuelled by robust additions under the residential rooftop segment. Gujarat added 687 MW in fiscal 2023 and 740 MW in fiscal 2024, driven by Surya Urja Rooftop Yojana; Maharashtra added 547 MW in fiscal 2023 and 417 MW in fiscal 2024, driven by a rooftop subsidy scheme. These two states accounted for 58% of the 2.2 GW additions in fiscal 2023, while their share in fiscal 2024 stood at 57% of rooftop additions. Total capacity additions in fiscal 2024 were 34% higher when compared with fiscal 2023. The majority of additions were under the capex model, with states empanelling vendors and commissioning the allocated capacities under MNRE Phase II of the Rooftop Solar Programme.

Figure 34: Rooftop market to see rapid growth until fiscal 2030 spurred by policy



Gujarat and Maharashtra accounted for 59% of additions in fiscal 2025 driven by PM Surya Ghar Yojana

The PM Surya Ghar Yojana, which targets the installation of 10 million rooftop solar plants in residential areas, is anticipated to be a major catalyst for growth in the sector over the next decade.

The C&I segment's growing demand, driven by sustainability goals, combined with the MNREs streamlined guidelines for residential consumers, is expected to propel capacity additions from fiscal 2026 to 2030

Note: P is projected
Source: MNRE, Crisil Intelligence

From a pan-India perspective, roadblocks to the segment's growth include the higher cost of rooftop projects compared with utility-scale projects, limited availability of finance for rooftop projects, lack of uniform policies across states, weak infrastructure of power discoms and divergence between state policies and implementations.

During fiscals 2026-2030, rooftop solar installations in India are expected to accelerate at double the momentum seen over fiscals 2021-2025, supported by robust policies and the Union government's focus on the residential segment through PM Surya Ghar Muft Bijli yojana scheme introduced in January 2024.

We expect ~30-35 GW of projects to be commissioned under the rooftop solar segment over the next five years. Additions to the tune of 15-17 GW each is expected from the commercial and industrial segment under net/gross metering schemes as well as residential rooftop consumers. The addition is influenced by various factors such as consumer awareness, availability of cheap source of funding and grid availability. Overall, the rooftop segment is expected to witness an investment of Rs 1.8-2.0 trillion during fiscals 2026-2030.

Further, the ministry's approval to allow net metering up to 1 MW gives a much-needed fillip to the sector, leading to an increase in demand for rooftop installations. To promote quicker adoption of residential rooftop solar systems, MNRE has issued a simplified procedure for consumers. The following are the highlights of the move:

- A national portal for registering applications from beneficiaries has been developed
- Rooftop solar plants can be installed by consumers themselves or through any vendor of their choice
- The new process allows household beneficiaries to apply online for rooftop solar installation subsidies, which can be claimed once the application is approved through the national portal.

Solar power can act as an alternative for states with high loadshedding such as Tamil Nadu, Uttar Pradesh and Punjab, which are also served by diesel generator sets, and for rural areas with poor grid connectivity. To this end, states such as Maharashtra and Rajasthan have announced rooftop solar targets. Maharashtra aims to solarise residential roofs under the PM Surya Ghar Muft Bijli Yojana, while Rajasthan aims to reach rooftop install base of 6,000 MW by 2027, of which 4,500 MW is expected to be in the residential space.

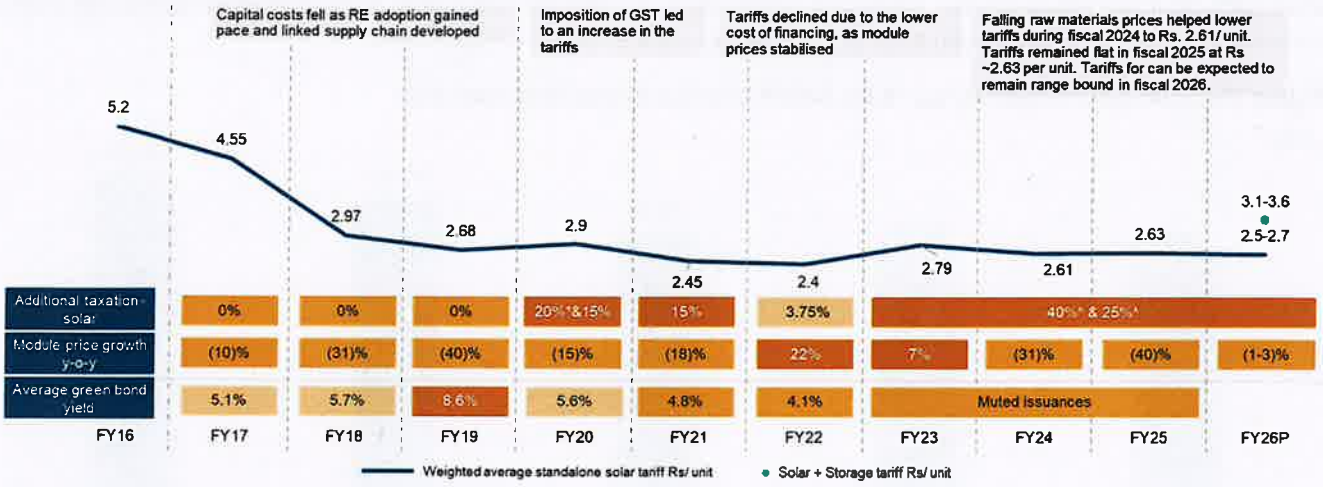
Module pricing, financing cost impact solar tariffs

Solar tariffs saw a rapid decline after the implementation of the competitive bidding process, along with a rapid fall in component prices, technological improvements in efficiency and the government's policy push. However, there was a blip in fiscal 2023 when the tariffs rose 16% to Rs 2.8 per unit owing to supply-side disruptions. The global energy crisis, geopolitical tensions and supply-side disruptions at key locations in China led to a reversal in module price trend, with prices climbing to $0.35 per watt-peak during the fiscal for mono-crystalline bifacial technology. However, after the normalisation of supply and a fall in prices of upstream components in fiscal 2024, the tariffs declined to Rs 2.61 per unit, a drop of ~7%. In fiscal 2025, the tariffs remained stable at Rs 2.63 per unit.

Declining module prices contributed to a reduction in tariffs over fiscals 2017-2019, while access to low-cost financing was the primary driver for the decline in tariffs over fiscals 2020-2022. Over the said period between fiscals 2020-2022, global investments in the Indian renewable energy segment picked up via green bond issuances and external commercial borrowings, helping lower the cost of debt for the space. The participation of global players and entities with strong credit profiles (CPSUs) retained tariffs in the range of Rs 2.4-2.6 per unit until fiscal 2022. A key point to note is that historically, the tariffs have not risen or fallen at the same pace as the rise or fall in module prices.

In February 2025, CEA released new guidelines, advising mandatory incorporation of storage with standalone solar. As per the new norms, energy storage systems (ESS) must have a minimum backup of two-hour equivalent and must be equal to 10% of solar capacity of the project. Auctions previously conducted under this format had seen tariffs range between Rs 3.1 and Rs 3.6 per unit. The tariff trend for such tenders is expected to remain in the same range in fiscal 2026 as well.

Figure 35: Weighted average solar tariff trend



*Note: *Safeguard duty for six months this fiscal*

^Imposition of BCD on cells and modules; the above tariffs are for ground-mounted solar only

Source: Crisil Intelligence

At the tariff of Rs 2.5 per unit and above, developers are estimated to be able to generate an equity internal rate of return of more than 12%. Our base-case analysis is for an independent power producer (IPP) undertaking EPC in-house and using domestic modules as per the ALMM in fiscal 2025. Additionally, because of variations in land prices, the model has been based on a leased land scenario. We have not assumed any other source of income, such as income from carbon credits, etc.

A key factor driving tariffs is capital cost for a solar project. Previously, component prices were mainly dependent on imports from China. The cost of solar modules accounts for 55-60% of a project's total capital cost, making it the key component of the project cost.

MNRE and the Ministry of Finance have approved a BCD of 40% on photovoltaic modules and 25% on photovoltaic cells.

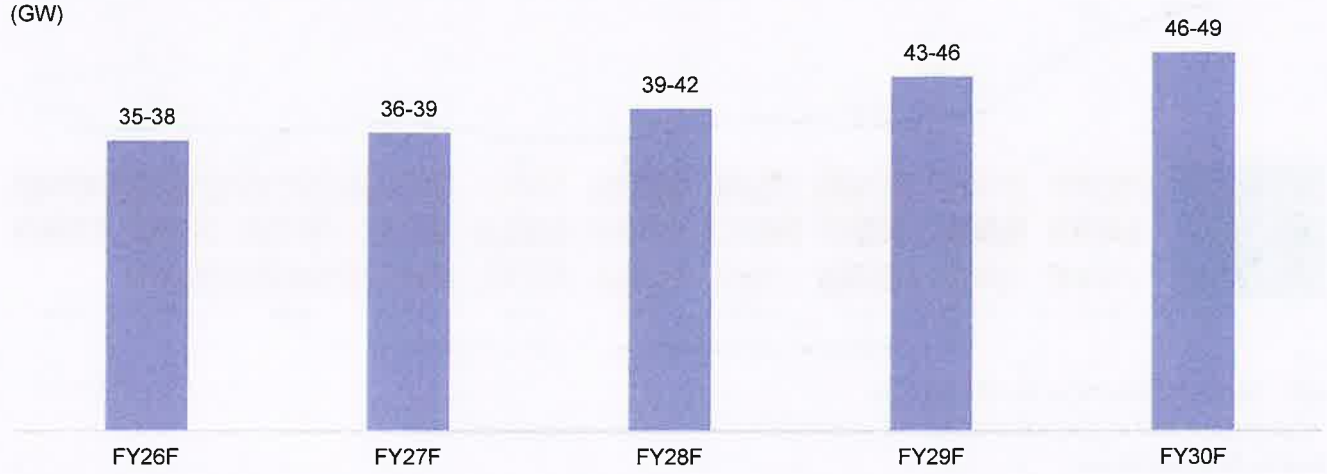
In July 2018, the Directorate General of Trade Remedies (DGTR) had imposed a safeguard duty of 25% on all imported cells/ modules (including those imported from China and Malaysia). The duty raised capital costs by 10-15%, despite module prices falling from $0.30 per Wp in March 2018 to $0.25 per Wp by September 2018.

However, the duty rate declined in subsequent years. The declining duty trajectory provided relief, as after June 2019 procurement for all new bids could be made at a duty of 15%. DGTR further cut the safeguard duty to 14.9% from July 30, 2020, and then to 14.5% from January 30, 2021, for another six months. The decline in duty eased cost pressures and tariffs also started to fall. However, with the imposition of BCD from April 1, 2022, capital costs increased to Rs 5.5-6.0 crore/MW for imported mono-crystalline modules and corresponding tariffs rose accordingly, depending on module procurement.

However, the decline in prices of polysilicon and commodities such as copper and aluminium (used in mounting structures and other components) reduced capital costs to Rs 3.5-4.0 crore/MW in fiscal 2025, after accounting for the 25% BCD on imported cells used in domestic modules. The price decline was because of the demand-supply mismatch in the global market.

As India largely relies on imported cells for module manufacturing, a steep fall in upstream component prices also brought down the module prices. In fiscal 2025, the average price was estimated at $0.14/Wp, down 42% on year, owing to a sharp 54% fall in cell prices on year. We expect module prices to be in the range of $0.13-0.15/Wp for imported cell-based modules this fiscal. This is expected to bring down capital costs to Rs 3.2-3.6 crore/MW.

Figure 36: Solar cell demand to log ~6.8% CAGR between fiscals 2026 and 2030



Note: Demand for solar cells is calculated based on 40% overloading on the expected capacity additions
Source: Crisil Intelligence

However, in June 2026, ALMM-II, which mandates use of domestically made solar cells, will become applicable and is expected to boost the usage of domestically produced cells for module manufacture. Overall, the domestic demand for solar cells is estimated to log a 6.8% CAGR between fiscals 2026 and 2030.

For modules based on domestically made cells, we expect prices to be in the range of $0.21-0.23/Wp this fiscal as players are expected to clear inventory of old technology at low prices and seek premium for TopCon technologies. This is based on an estimated capital cost of Rs 40-45 million per MW (including DC side overloading of 40%).

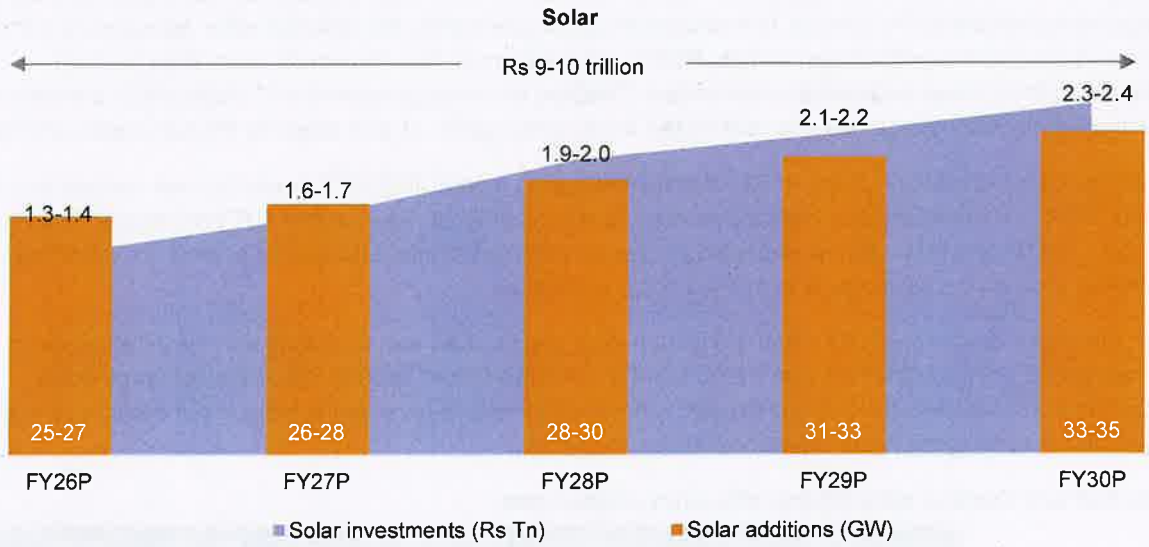
Solar glass is another key input for modules. The central government has imposed a 10% BCD on solar glass imports, effective October 1, 2024, to promote domestic manufacturing. The duty decision came after an anti-dumping investigation against Chinese and Vietnamese suppliers and is expected to reduce imports.

Solar investments over fiscals 2026-2030 seen at Rs 9-10 trillion

We expect an investment of Rs 9-10 trillion in solar energy over fiscals 2026-2030. Developers are expected to opt for solar owing to low upfront investment requirement and operating costs. Solar investments will also be driven by expected upcoming capacity of 140-160 GW between fiscals 2026 and 2030. The utility segment is expected to experience significant growth through multiple channels, including pipeline projects, tenders, and a renewed focus on integrating renewable energy sources into the grid. This will be achieved by introducing innovative tender

models and incorporating energy storage solutions, ultimately driving the expansion of solar capacity. Disparity between prices in the private power market and discom tariffs is expected to drive the open-access market, furthering installations of solar power to cater to commercial and industrial consumers. Moreover, the national aim to increase the reach of rooftop solar under the PM Surya Ghar Yojana will drive addition of solar capacity in the residential segment.

Figure 37: Solar investments to be driven by built-up pipeline



Source: Crisil Intelligence

Module 5: Solar PV cells

Evolution of cell technology

The rapid growth of the sector, accompanied by intense competition in the supply chain, has increased the focus on enhancing product efficiency. As a result, technology has undergone significant advancements, transitioning from multi-crystalline to mono passive emitter rear contact (PERC) cell-based modules, and now to more advanced cell technologies, such as tunnel oxide passivated contact (TopCon) and heterojunction (HJT). Additionally, consistent increase in solar module wattage has also contributed to the conservation of land space for the same electricity output.

From a technological standpoint, mono PERC cells dominated the market in 2019, followed by back surface field (BSF). While mono PERC remained the dominant technology globally as of 2023, TopCon and HJT have started to gain traction. On average, TopCon and HJT cells are expected to offer an incremental efficiency gain of at least 1% over mono PERC cells. This has enabled the possibility of higher electricity generation.

However, the capital cost intensity for establishing manufacturing facilities also increases with the initial capex for HJT estimated to be 2.5-3.0 times that of mono PERC and 1.5-2.0 times that of TopCon. Nevertheless, large-scale manufacturing, combined with the ongoing research and development, is expected to bring about economies of scale benefits in the future for these higher-efficiency cell technologies.

Table 13: HJT and TopCon cells: Higher efficiency, higher cost

	Mono PERC	TopCon	HJT
Cell efficiency	Up to 22%	22.5-24%	23-25%
Module efficiency	Up to 22%	22-24%	22-24%
Losses and damages	P-type mono PERC cells are prone to LID and PID losses, which are the highest in the group	PID and LID losses in TopCon are lower that mono PERC, but a bit higher than HJT	Not prone to PID and LID losses since general cell construction is n-type
Complexity	Moderately complex	Less than HJT	Most complex

Note: PID is potential induced degradation and LID is light induced degradation

Source: Industry, Crisil Intelligence

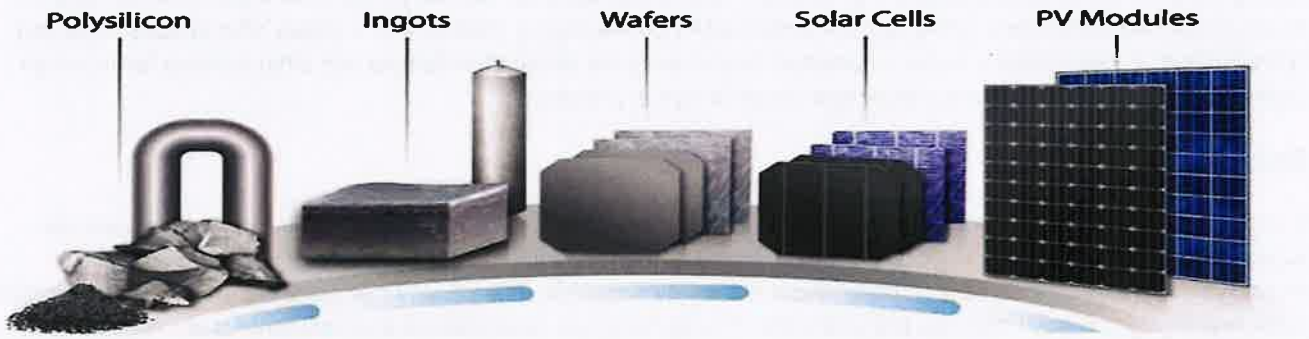
The solar PV industry is constantly at the risk of technological disruption. According to the Fraunhofer Institute for Solar Energy Systems ISE, emerging technologies, such as Perovskite, III-V on Si (2-terminal), and III-V-Multi Junction Concentrator solar cells, had achieved efficiencies of ~34%, ~36% and ~48%, respectively, in laboratory settings in the first half 2024.

Overview of solar PV module value chain

The solar PV module manufacturing value chain encompasses five critical processes for transforming raw materials into the final product, i.e., polysilicon into solar modules that are ready for electricity generation. It is a complex and globalised network, with each step contributing to the final product's cost, performance and sustainability.

The industry standard for testing solar modules includes a series of stringent procedures such as thermal cycling, humidity freeze damp heat testing, hail testing and mechanical load testing. These tests are designed to simulate extreme environmental conditions and mechanical stresses that the modules might encounter during their operational life.

Figure 38: PV manufacturing value chain



Silica (SiO2) is refined to metallurgical grade silicon (MG-Si) using a carbothermic process in an electric arc furnace. MG-Si is then purified through a chemical vapor deposition process converting it to trichlorosilane gas which is decomposed to produce ultra-pure solar-grade polysilicon.	Solar polysilicon is melted in a crucible to form a cylindrical ingot using crystal pulling or float zone method. The ingot is then sliced into thin wafers using wire saws. These wafers serve as the base material for manufacturing solar cells.	Solar wafers are processed to form solar cells by adding dopants to create a p-n junction, which enables electricity generation. An anti-reflective coating is applied, and metal contacts are added for electrical connections. The cells are then tested for efficiency before being assembled into solar panels.	Solar cells are connected in series and parallel, laminated between layers of protective materials, and sealed with tempered glass and a back sheet. The assembly is framed for structural support with a junction box added for electrical connections. This creates a durable weather resistant solar module ready for installation.

Note: Value chain and components used can differ based on the technology of solar cells; the above process is the most widely used cell technology (monocrystalline) in the world as of 2024

Source: Crisil Intelligence

Brief descriptions of solar cell and module components

Solar cells

Solar cells are electrical devices that convert the energy of light directly into electricity by the photovoltaic effect, which is a physical and chemical phenomenon. It is a form of photoelectric cell, defined as a device whose electrical characteristics, such as current, voltage or resistance, vary when exposed to light. Individual solar cell devices are often the electrical building blocks of photovoltaic modules. The following key raw materials and components are used in the manufacture of solar cells:

Silicon wafers: Sliced from ingots made of ultra-pure silicon, these form the foundation of solar cells. The exceptional quality and purity of this silicon material is essential to ensure the optimal performance of solar cells.

Silver paste: This is a crucial component in solar cell manufacture. It is used to create the conductive contacts on the front side of the cells. Applied through a screen-printing process, this paste plays a vital role in facilitating the collection and transfer of electrical current generated by silicon wafers, enabling the efficient flow of energy.

Aluminium paste: A layer of aluminium paste is applied to the rear of the solar cell. When heated in a furnace, it creates a reflective surface that bounces electrons back into the silicon, allowing them to be harnessed as electrical current, thereby boosting the cell's overall efficiency.

Other gases and chemicals: The manufacturing process of solar cells relies on a range of gases and chemicals, each playing a critical role at various stages. For example, specialised dopants, such as phosphorus oxychloride, are used to create n-type semiconductors, while boron is employed for p-type doping. Additionally, a variety of chemicals, including hydrofluoric acid, are utilised in wafer preparation to strip away the silicon dioxide layer and other solvents for thorough cleaning, ensuring the wafers are pristine and ready for further processing.

Solar modules

A solar module is an assembly of solar or photovoltaic cells mounted in a framework for installation. Solar panels use sunlight as a source of energy to generate direct electricity. In India, solar modules are currently assembled using monocrystalline and TopCon cells (imported from third-party suppliers). The primary raw materials and components used in the manufacture of solar modules are solar cells. The following key raw materials and components are used in the process:

Backsheet: This is a critical component of a solar module, serving multiple purposes to ensure optimal performance and longevity. It provides mechanical strength, electrical isolation and moisture resistance, while also acting as a reflective layer to redirect photons back towards the solar cell, enhancing energy generation. Additionally, the backsheet forms a protective barrier against external factors such as ultraviolet rays, temperature fluctuations and humidity changes, which could otherwise compromise the module's performance. Its inner surface also ensures a secure bond with the encapsulant, holding the entire cell assembly in place for extended periods, while its outer surface provides a safe and shock-resistant interface for installers.

Encapsulants: These play a vital role in a solar module's performance, serving three primary functions: transmitting light, holding the cell assembly together and adhering to the glass and backsheet. Their high light transmittance ensures that the cell assembly receives adequate supply of photons to generate maximum power output. Encapsulants also act as a mechanical bonding agent, keeping the solar cells separated, preventing short circuits through its gel content, which provides intermolecular strength. Additionally, they help minimise shrinkage, which is critical to prevent misalignments and short circuits. Further, encapsulants must form a strong and durable bond with the glass on the front side and backsheet on the back side of the module, while withstanding elevated temperatures and high UV exposure over extended periods.

Glass and other auxiliary products: The glass component in solar modules is crucial for optimising energy output by minimising reflection and maximising light transmission. As the first point of contact for incoming light, the glass surface must be optimised to reduce reflection, which can result in significant power losses. To address this, an anti-reflective coating is applied to the front surface, reducing reflection to as low as 1% in many cases. Additionally, the glass is tempered to provide mechanical strength and rigidity, protecting the solar module from weather conditions, shocks and other environmental factors. It is essential to use specialised solar glass with specific components to ensure long-term stability and performance. Beyond solar cells and the mentioned components, other critical inputs required for solar module manufacturing include aluminium frames, ribbon and junction box, all of which work together to create a high-performing and durable solar module.

Cell manufacturing is more complex than module manufacturing

The fabrication of solar cells relies on several high-purity semiconductor-grade gases and chemicals, which are critical inputs at each stage of the manufacturing process. To ensure safe, efficient and high-yielding solar cell production, the effective management of utilities is paramount.

Table 14: Complexities in solar cells and modules

Complexity	Solar cell	Solar module
Raw materials processing	The manufacture of solar cells requires the use of ultra-high-purity silicon, which in turn demands complex and precise refining and processing procedures to achieve the necessary level of quality.	The manufacturing of solar modules is facilitated by the use of pretreated silicon cells, which simplifies the manufacturing process by reducing the complexity of subsequent processing steps.
Technological requirements	The manufacture of solar cells involves the deployment of advanced technologies designed to optimise cell efficiency and perfect complex production methodologies.	The production of solar modules is primarily driven by advancements in assembly technologies, with relatively less attention devoted to innovative breakthroughs at the individual cell level.
Skilled labour	The fabrication of solar cells requires a highly skilled workforce with expertise in chemical processing and semiconductor manufacturing methodologies, ensuring precision and quality in the production process.	The assembly of solar modules demands a skilled workforce, although with a broader range of skills compared to cell fabrication, as it involves a combination of assembly and quality control expertise.
Production scale	The production of solar cells is typically carried out on a smaller scale due to precise and delicate handling requirements, which limit production capacity and throughput.	In contrast, solar module manufacturing can be scaled up to larger production volume, owing to the implementation of efficient assembly processes and relatively simpler design, which reduces complexity and enables high-volume production.
Technological advancement	The rapid pace of technological innovation in the solar industry poses a significant threat to solar-cell manufacturers, as it can quickly make current production methods outdated, necessitating continuous adaptation to stay competitive.	In contrast, the solar module manufacturing industry undergoes a more gradual pace of technological progress, with innovations typically leading to incremental enhancements rather than revolutionary changes that would suddenly make existing production processes obsolete.
Supply chain management	The production of solar cells involves an intricate supply chain management process, necessitated by the wide range of raw materials and specialised chemicals required for fabrication, which can pose logistical challenges and increase operational complexity.	In contrast, the supply chain for solar module manufacturing is relatively straightforward, primarily focusing on the sourcing of solar cells and auxiliary components, with fewer complexities and dependencies compared to solar cell production.

Source: Industry, Crisil Intelligence

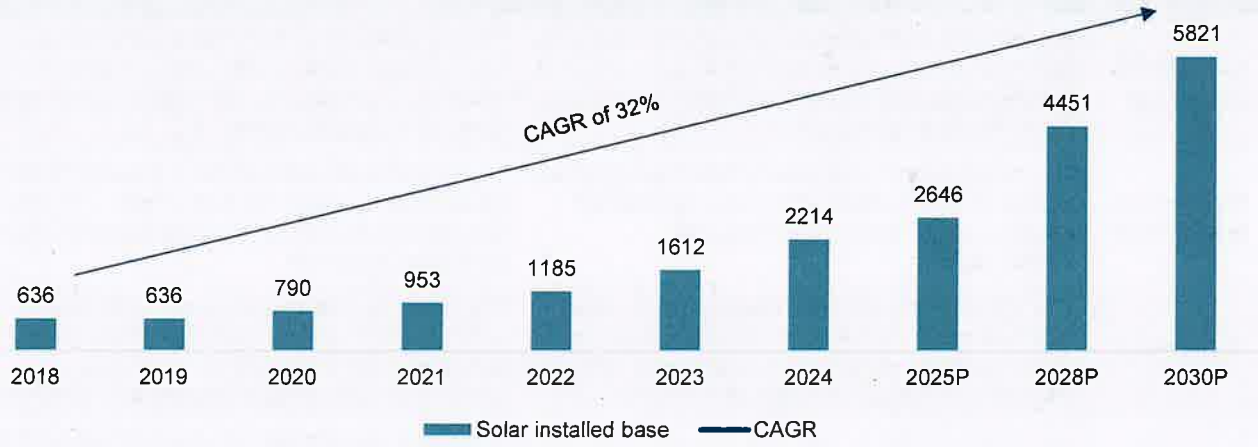
Going forward, with increased cell manufacturing capacities in India, especially after its inclusion under ALMM, the domestic ecosystem required for development such as skilled manpower and availability of technology are also expected to improve.

Crisil
Intelligence

Global solar energy installation rising

According to the IEA, the global solar energy installed capacity is estimated to have grown to 2,214 GW by end-2024 from 636 GW in 2019, i.e. a CAGR of 28%. By 2030, the installed base is expected at 5,821 GW, i.e. a CAGR of 17% from 2024. China is expected to account for 60% of the additions, followed by the US (9%) and India (7%).

Figure 39: Global solar generation installed capacity to nearly triple in three years



Source: IEA outlook

Meanwhile, the total global installed solar generation module capacity, which expanded at a CAGR of 28% between 2019 and 2024, is forecast to accelerate at a CAGR of 17.5% between 2024 to 2030.

Global solar cell and module demand rising

Global cell and solar module demand was estimated at ~1,600 GW in 2024, with demand at 506 GW in 2024, as per the IEA. Going by installation rates, 50% of the demand was driven by China, followed by the US (8%), India (5%) and Germany (3%). In 2024, factors such as cost reduction resulting from the fall in prices and technological advancements are major factors that drove additions.

PV module demand driven by policy and renewable push

China

PV module demand in China has been driven by installations, propelled by government targets announced in 2020, under which Beijing plans to achieve peak emissions by 2030 and carbon neutrality by 2060. In 2024, the installed base for solar was 886 GW, with 198 GW added in 2024.

USA

Demand from the US has been driven by the government's Energy Efficiency and Renewable Mission, which aims to add an average of 30 GW of solar capacity until 2025 and 60 GW annually between 2025 and 2030. This resulted in a demand of 100-150 GW of solar modules between 2019 and 2024. And in 2024, the US added 54 GW of solar capacities, taking the total installed base to 224 GW.

Germany

Demand for solar modules in Germany has been driven by the Renewable Energy Sources Act, through which the government hiked its solar PV tariff ceiling prices by 25% in January 2023 over December 2022 prices, which boosted the subscription rate for utility-scale ground-mounted solar to 100% in January 2023 from 68% in December 2022. In 2024, the country added 17 GW new solar capacities, taking the installed base to 100 GW.

India

India's solar module demand has been driven by solar energy additions of 83 GW during fiscal 2019-2025. After a subdued trend in 2020, additions picked up pace, driven by the government's Panchamrit pledge at COP26 in 2021, under which the country aims to install 500 GW of non-fossil fuel capacity by fiscal 2030. Furthermore, according to the CEA's national electricity plan for generation, non-fossil capacity is expected to be driven by a solar installed base of 364 GW by 2032.

Table 15: Solar installed capacity additions in select countries

Country	2024 additions (GW)	2024 Installed base (GW)
China	198	886
USA	54	224
Germany	17	100
India	25	98

Source: CEA, IEA

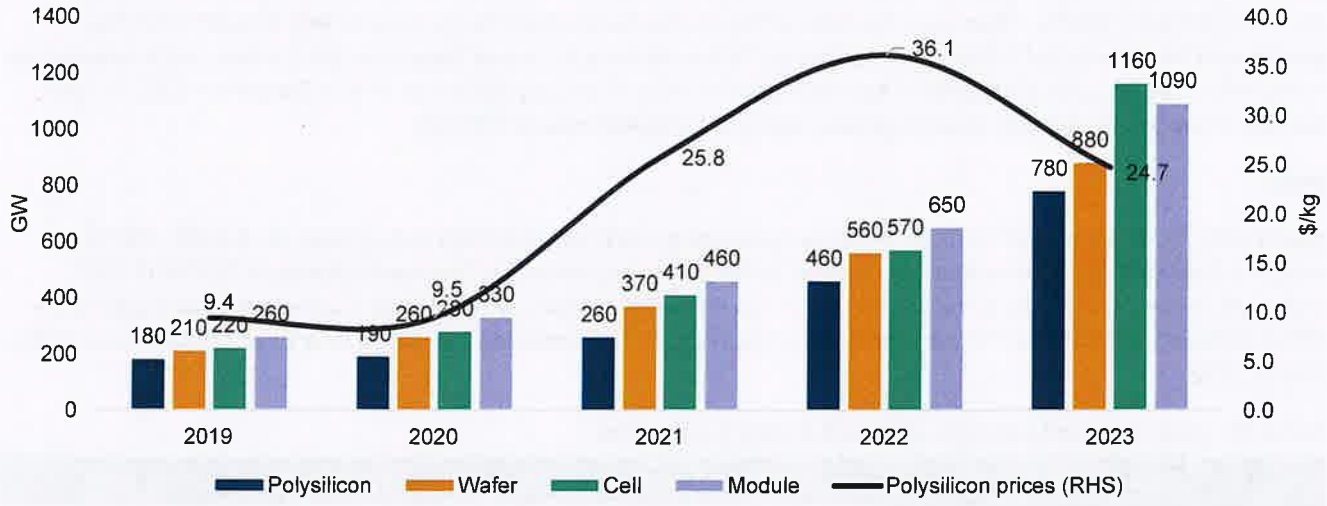
Overall

But while the mentioned countries have driven demand for solar modules through a cumulative solar target of over 1,000 GW of the installed base by 2030, their ability to meet demand through domestic PV manufacturing is limited. In fact, only China had a robust integrated manufacturing base to cater to domestic as well as global demand, resulting in the world relying on imports from China.

Global solar module manufacturing outpaces demand

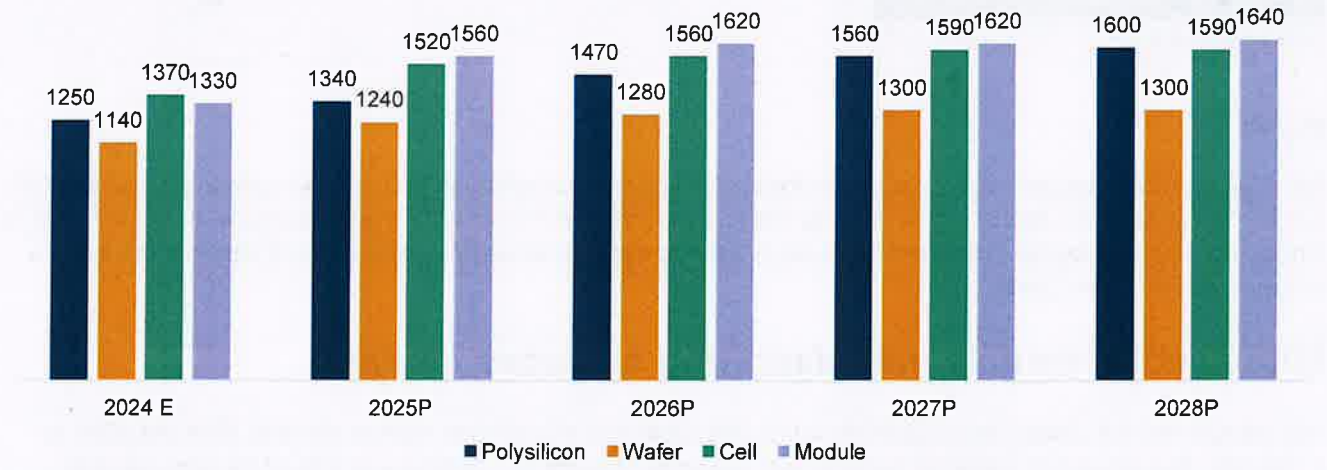
According to the IEA, global solar module manufacturing capacity is estimated to risen 4x between 2019 and 2024, to 1,330 GW. This growth has outpaced demand, with solar module demand in 2024 at only 60% of the total available module manufacturing capacity. In tandem, the production of upstream components also saw significant expansion over the past five years, with a notable surge in growth since 2023, particularly that of polysilicon.

Figure 40: PV manufacturing capacity reached 1,000 GW on average by 2023



Source: IEA, Crisil Intelligence

Figure 41: PV manufacturing capacity to reach 1,500 GW on average by 2028



E – estimated; P – projected

Source: IEA, Crisil Intelligence

From 2017 onwards, the limited availability of PV-grade polysilicon manufacturing capacity emerged as a significant constraint in the PV supply chain. This bottleneck became apparent in 2021, when a combination of underinvestment and a fire at a major manufacturing facility led to a global polysilicon shortage, causing prices to triple. However, by 2024, China had significantly expanded its polysilicon production capacity, increasing it 5x vs 2021 levels. China's dominance in the PV value chain continued to grow, with the country estimated to account for over 80% of the installed base on an average across the value chain at end-2024, as per the IEA.

By 2028, module manufacturing capacity is expected to reach 1,640 GW, as per IEA. This will be accompanied by backstream components of 1,590 GW of cells, 1,300 GW of wafers and 1,600 GW of polysilicon.

Policy support key for solar cells and module manufacturing

Supply chain diversification has played a major role for Indian cell and module manufacturers.

Table 16: Government policies and Acts having a bearing on PV manufacturing

Country/Association	Policy/Act/Agreement	Impact
US	Inflation Reduction Act	Renewable energy projects receive a 30% tax credit for solar and wind installations. Additional incentives include production tax credits, bonus credits for projects in low-income areas and extra credits for using domestic materials, aiming for a carbon free grid by 2025. However, US President Donald Trump issued an Executive Order on January 20, 2025, pausing Inflation Reduction Act of 2022 (IRA) fund disbursements. The move has created uncertainty, as it is unclear which aspects of the IRA funding will be halted.
US	Uyghur Forced Labour Prevention Act 2022	The ban on module imports linked to Xinjiang has enabled Indian module manufacturers to fill part of the vacuum. Nearly 98% of India's module exports in 2024 were destined for the US. The country's share in the US import basket, therefore, increased to 11% in 2024 from 1% in 2021.
US	Antidumping duty on Southeast Asian imports	The commerce department initiated antidumping and countervailing duty investigations of crystalline silicon photovoltaic cells from Cambodia, Malaysia, Thailand and Vietnam. The dumping margins vary from 70.35% to 271.28%. Collectively, these countries accounted for 77% of the solar cells and modules in the US import basket in 2024.
India	Approved List of Models and Manufacturers I	ALMM I mandate requires the usage of modules as enlisted in the ALMM I List issued by the government. As per March 2025 ALMM, it stood at nearly 77 GW, with no international players.
India	Approved List of Models and Manufacturers II	ALMM II mandates the procurement of cells from the corresponding list, effective from June 2026. This will give a necessary boost to backward integration. While the supply of over 55 GW of cell manufacturing capacities announced should be enough, there could be a transient shortfall till manufacturing ramps up. Furthermore, while prices of Indian cells are 1.5-2.0x higher than Chinese cells, ALMM II can create a level playing field for domestic cell and module manufacturers.
India	Rajasthan - Rajasthan Investment Promotion Scheme 2019 and Solar Energy Policy	It provides a 7-year land tax exemption and a 10-year electricity duty exemption for solar power equipment manufacturers. It also provides land allotment at a 50% concessional rate with 100% stamp duty exemption. Additionally, an investment subsidy of 90% of State Goods and Services Tax due and deposited is offered for 7 years.
India	Gujarat – Gujarat Industrial Policy (2020-25)	It provides a 6-12% capital subsidy based on location, disbursed annually, capped at Rs 400 million per year. Additionally, it offers a long-term lease of government land up to 50 years at 6% of the market rate.
India	Tamil Nadu – Tamil Nadu Solar Policy 2019 and TN Industrial Policy 2021	It provides land provision for solar system component manufacturing with incentives for co-utilisation of land. The Industry Policy 2021 provides for a Structured Package of Incentives.
India	West Bengal – West Bengal New and Renewable Energy Manufacturing Promotion Policy 2023	It provides 100% exemption from land conversion fees, stamp duty and electricity duty for expansion and new units for 5 years. Additionally, it offers exemption from water cess.

Source: Gujarat, Rajasthan, Tamil Nadu and West Bengal governments, MNRE, US *government, Crisil Intelligence*

Global competitive landscape (2023)

Over the past decade, China has emerged as the top solar PV manufacturer owing to favourable government policies, continuous innovation and accelerated investments in the segment, surpassing Europe, Japan and the US. Global PV module shipments between 2023 and the nine months of 2024 crossed 250 GW for LONGi Solar, Trina Solar, Jinko Solar, JA Solar and Canadian Solar, which are significant global PV manufacturers. Collectively, their installed base is estimated to have accounted for over 50% of the global module manufacturing base at end-2023.

Table 17: Comparative summary of global manufacturers

Parameter	LONGi Solar	Trina Solar	Jinko Solar	JA Solar	Canadian Solar
Experience in PV manufacturing	24 years	27 years	18 years	19 years	23 years
Operational capacity	Module – 120 GW Cell – 80 GW Wafer – 170 GW	Module – 95 GW Cell – 75 GW Wafer – 55 GW	Module – 120 GW Cell – 95 GW Wafer – 130 GW	Module – 95 GW Cell – 86 GW Wafer – 86 GW	Module – 61 GW Cell – 48 GW Wafer – 5 GW
Product shipments	Module & Cell– 82.3 GW Wafer – 108.4 GW	Module - 65 GW	Module – 92.9 GW Cell and wafer – 6.7 GW	Module – 57 GW	Module – 31.1 GW
Key products and services	Solar PV modules, wafers, solutions for C&I utility, and rooftop	Solar PV modules, solar trackers, utility solutions, and engineering, procurement, construction, and management services	Solar PV modules, energy storage systems, and C&I and rooftop solutions	Solar PV modules, and energy storage systems for domestic and C&I use	Solar PV modules, energy storage systems, inverters, and EPC services
Key technologies offered	TOPCon, Mono PERC	PERC, TOPCon, HJT	Tilling ribbon technologies, PERC and TOPCon	TOPCon, Mono PERC	TOPCon, HJT modules, dual cell PERC

Note: Jinko Solar and Canadian Solar capacities and shipments are as of December 2024. LONGi Solar shipments are as of December 2024 while operational capacity is as of December 2023. JA Solar and Trina capacities and shipments are as of December 2023.

Source: Company websites, Crisil Intelligence

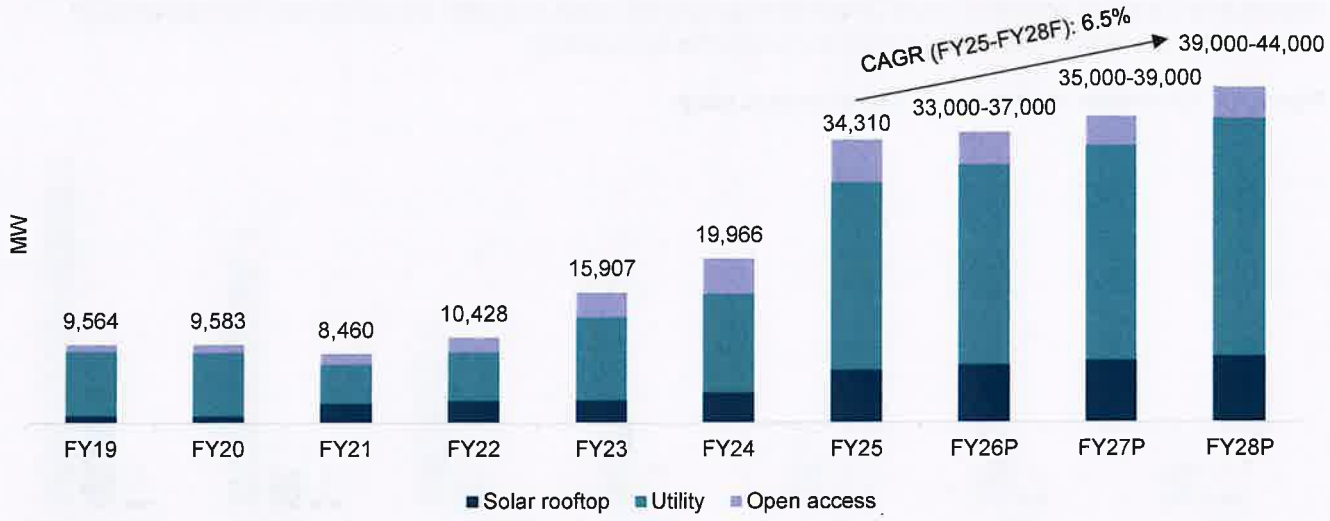
Domestic solar PV manufacturing in expansion phase

The domestic PV segment has been driven by domestic demand for solar modules form various segments, such as rooftop, utility scale and open access. From the beginning of fiscal 2019 to the end of fiscal 2025, India has seen estimated cumulative solar module demand of 108 GW.

Domestic demand for solar modules to grow robustly as power goes green

Over fiscals 2019-2025, domestic demand for solar modules was driven by the competitively bid utility segment, with 66% share, followed by the rooftop (18%) and open access (16%) segments. Average demand per annum is expected to rise at 7% CAGR between fiscals 2026 and 2028.

Figure 42: India to experience module demand of 35-40 GW p.a. between fiscals 2026 and 2028



Note: Demand includes DC overloading

Source: Crisil Intelligence

Demand drivers include declining module prices, supportive government policies and increasing awareness of the benefits of solar energy.

The competitively bid segment saw significant growth, with installed solar capacity more than doubling to 80 GW by the end of fiscal 2025 over fiscal 2019, driven by initiatives under the National Solar Mission, solar parks, renewable purchase obligations and the Panchamrit target pledged under COP26. Central tender allocations, led by SECI, accounted for at least 13% of these additions, while other central and state allocations contributed the remainder. States with high irradiance, such as Rajasthan and Gujarat, witnessed the most significant additions.

The rooftop solar segment also experienced material growth, with installed capacity increasing nearly ninefold by the end of fiscal 2025 over fiscal 2019, driven by subsidies under the national rooftop mission, PM Suryaghar Yojana, and state-specific initiatives such as Gujarat's Surya Urja Yojana. Favourable policies, including net metering in some states, further incentivised adoption. The top three states - Gujarat, Maharashtra and Rajasthan - accounted for 59% of the installed base by fiscal 2025. The rooftop segment is poised to add 18-20 GW of capacity during fiscals 2026-2028, up 1.2x over fiscals 2019-2025.

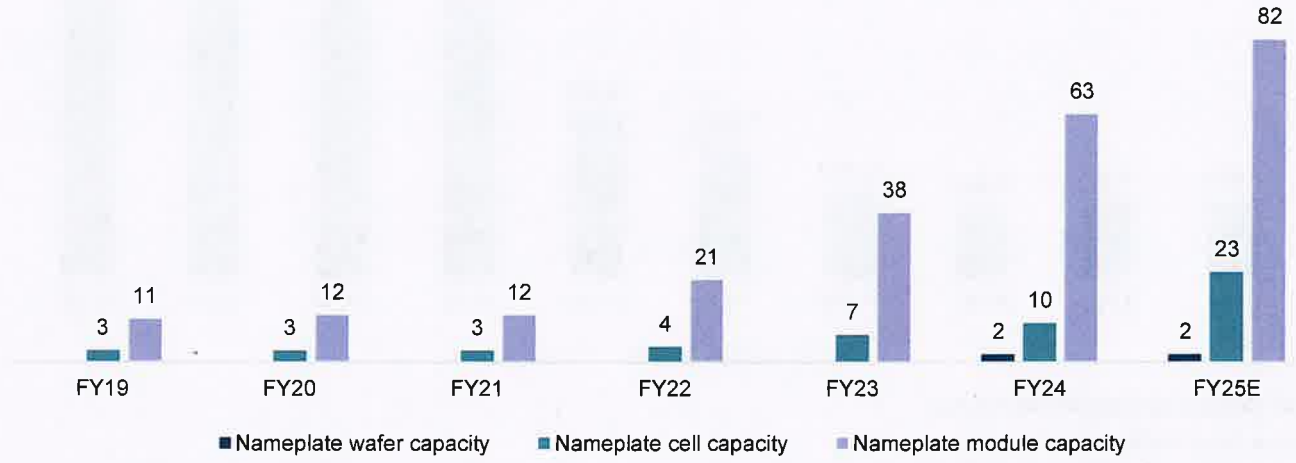
Open access solar, which allows consumers to purchase solar energy directly from producers, strengthened the demand for solar modules. This segment attracted large commercial and industrial consumers seeking cost savings and sustainability benefits. The Green Energy Open Access Rules of 2022 stimulated growth by reducing the minimum load requirement, making open access projects more attractive and financially viable. The open access solar segment is expected to witness 5-10 GW of capacity additions during fiscals 2026-2028, registering 66% growth over capacity added during fiscals 2019-2025.

Domestic manufacturing capabilities have grown rapidly in the past 5 years

India's solar PV module and cell manufacturing capacity expanded from 21 GW and 3.2 GW in March 2022 to an estimated 82 GW and 23 GW, respectively, by March 2025. This growth was driven by a strategic combination of government policies, market dynamics and a growing commitment to renewable energy.

Despite robust demand for solar modules, India's manufacturers have remained focused on the downstream component stage due to the capital-intensive nature of upstream components such as wafers and polysilicon. The availability of cheaper alternatives from China has also contributed to this concentration.

Figure 43: Expansion of capacity in cell to module stage



Source: Company reports, Crisil Intelligence

Between fiscals 2022 and 2025, India's module and cell manufacturing capacities expanded significantly, by ~61 GW and ~19 GW, respectively. This expansion was driven by the government's efforts to reduce dependence on imported solar components, particularly from China.

Hence, while there has been significant expansion in module manufacturing capacity, cell expansion is happening at a slower pace.

To support local manufacturing, the Indian government introduced a range of protective measures, including a safeguard duty on imported solar cells and modules from July 2018 to 2021. In fiscal 2023, a BCD of 40% on modules and 25% on cells was introduced to enhance the competitiveness of India-made products. The government simplified the duty structure in the Union Budget 2025-26 with a change in duty calculations on inclusion of Agriculture Infrastructure and Development Cess (AIDC). Duties on solar modules were split into BCD and AIDC at 20%, while that in cell was restructured to 20% and 7.5% of BCD and AIDC, respectively. Additionally, a domestic content requirement was imposed on certain schemes, such as the CPSU scheme phase-II, PM Surya Ghar Yojna and PM KUSUM.

The government also implemented measures such as the ALMM to ensure quality control and encourage capacity additions in the downstream stages. Furthermore, the PLI scheme for high-efficiency solar modules, launched in 2021, provided financial incentives to manufacturers based on their incremental production. This scheme played a crucial role in encouraging manufacturers to expand capacity, invest in new technologies and pursue backward integration.

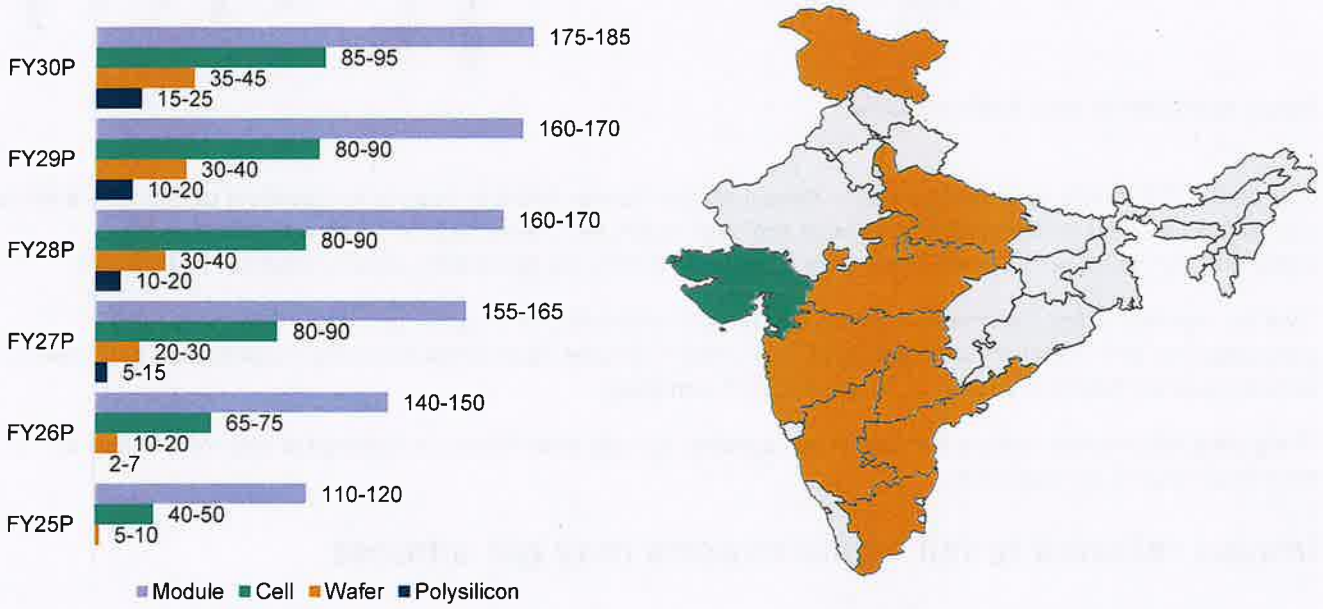
Domestic PV manufacturing to continue expanding

By the end of fiscal 2030, India's domestic module and cell manufacturing industries are projected to experience significant growth, with nameplate capacities (rated capacity or maximum manufacturing capability) expected to increase by ~2 times and ~4 times, respectively, from fiscal 2025. Overall, the module manufacturing space has witnessed announcements of over 100 GW owing to rising demand. In India, cell manufacturing capacity is estimated to be 23 GW

as of fiscal 2025, which is expected to grow to 80-90 GW by fiscal 2027. In an effort to boost domestic manufacturing and enhance the competitiveness of Indian-made products, ALMM-II will be implemented from June 2026 as per MNRE Notification dated December 9, 2024, which mandates use of domestically made solar cells for manufacturing of solar PV modules, applicable from June 1, 2026 and is expected to boost the usage of domestically produced cells for module manufacturing. On the other hand, the country is expected to see the establishment of large-scale wafer and polysilicon facilities, with capacities reaching 35-45 GW and 15-25 GW, respectively, by fiscal 2030. Increase in manufacturing capacity provides an opportunity for India to expand its production and establish its position in export markets such as the US. Hence, expansion in supply chain will cater to both domestic demand as well as exports.

The substantial expansion in capacity, particularly in the upstream components, is expected to be driven by a combination of trade, non-trade interventions and the PLI scheme, which aims to encourage investment and growth in the domestic solar manufacturing industry.

Figure 44: Upstream supply chain announcements to be driven by PLI, Gujarat a favourite for PV

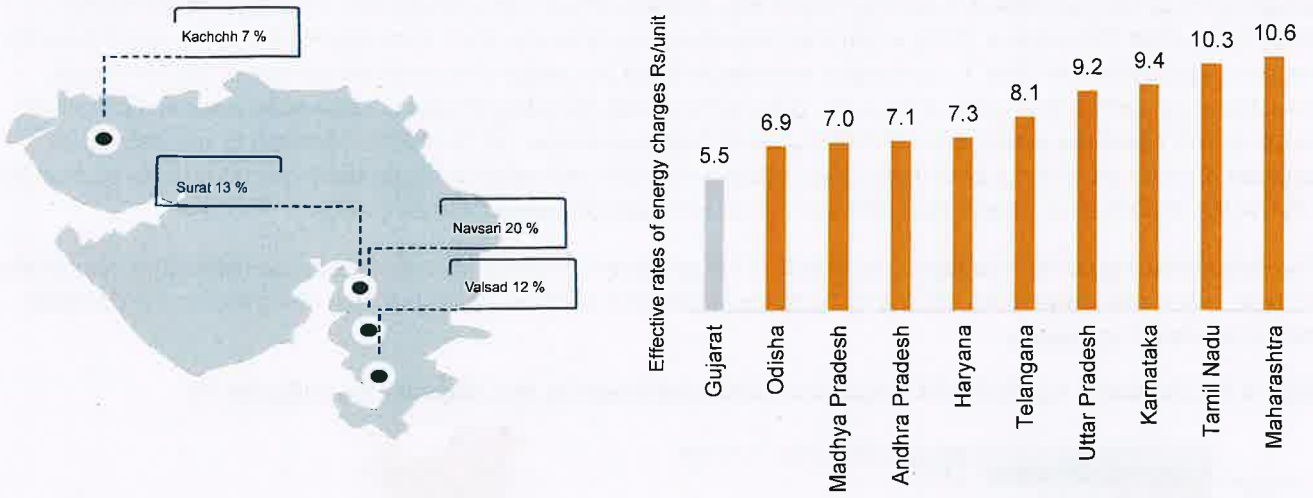


Note: The above capacity is based on market announcements available in the public domain.
Source: Company reports, Crisil Intelligence

Integrating solar PV manufacturing plants that produce wafers, cells and modules under one roof has certain advantages such as improved efficiency and cost reduction. With reduced transportation costs and economies of scale, these plants can optimise their production flow and have better quality control. Integrated solar PV manufacturing plants also provide greater flexibility and supply chain security. Manufacturers can respond to changes in demand efficiently, reduce the dependence on external suppliers by getting access to advanced technologies, and gain competitive advantage in terms of quality and price.

Gujarat is expected to be the epicentre of PV manufacturing capacity additions because it has one of the lowest effective power rates for the industrial sector in India. In fact, nearly 42% of the enlisted capacity of ~77 GW in the ALMM by March 2025 was in Gujarat.

Figure 45: High concentration in Gujarat, with nearly 52% of capacity located in four districts



Source: ALMM, MNRE, REC, Crisil Intelligence

Until fiscal 2025, India's solar industry was in its early stages, heavily reliant on imports for upstream components such as cells and wafers. Hence, the availability of ports and trade routes also makes Gujarat an attractive location for manufacturing. Based on the pipeline, the state is expected to continue dominating capacity additions in the future.

Over the next four years, the industry's technology setup is expected to undergo an upgrade. While mono PERC technology has been dominant until fiscal 2025, more than 10 players have announced capacity additions using TopCon technology and a few have chosen to expand into HJT technology.

The growth in nameplate module manufacturing capacities for cells and modules is expected to help India reduce its reliance on imports by fiscal 2029.

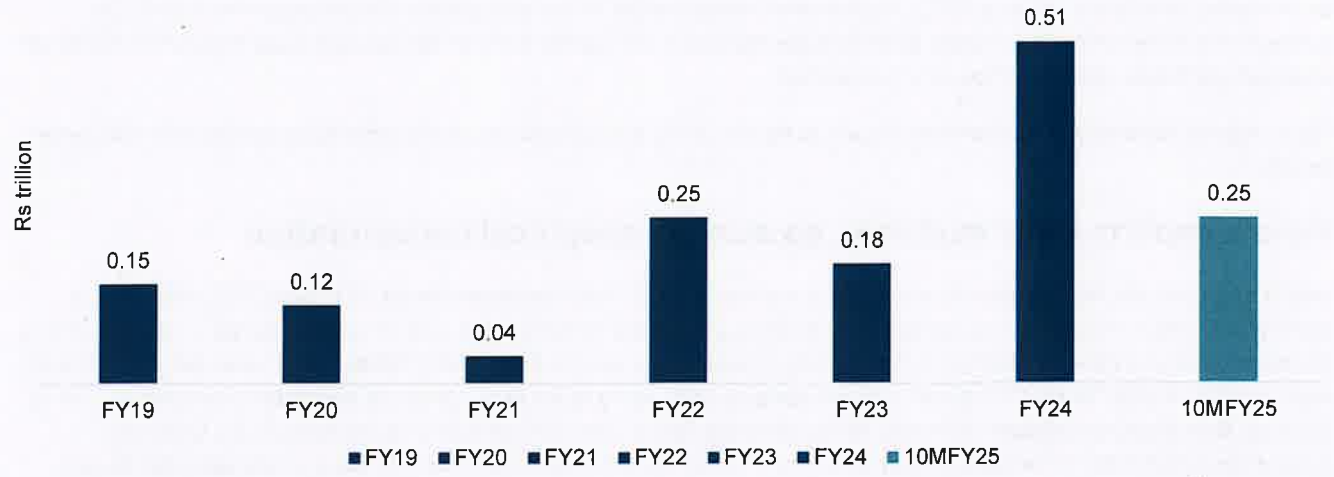
Import reliance to fall, while exports may get a boost

Share of Chinese imports falls

Between fiscals 2019 and 2025, the Indian companies invested significantly in solar cell and module manufacturing. However, domestic manufacturers relied on export revenue due to Indian solar developers' preference for cheaper imports and catered more to the domestic content requirement in certain Indian market segments, which were smaller verticals of the overall RE sector. As a result, more than 55% of solar modules installed in India during this period were imported due to inadequate domestic capacity, competitive pricing and technology preference.

As of March 2025, India had ~23 GW installed capacity of solar cells and ~82 GW of modules. Even though India is one of the top 10 solar module producers, it is far behind its biggest competitor, China. In fiscal 2022, imports increased by a staggering 494% on-year to Rs 0.25 trillion (from Rs 0.04 trillion). This sudden and sharp surge in imports was due to ease in restrictions coupled with expiration of time extensions provided to projects under the Covid-19 relief. After falling 28% on-year in fiscal 2023, imports jumped 184% on-year in fiscal 2024 owing to ALMM abeyance to meet rising solar power demand in the country. Imports fell in the first 10 months of fiscal 2025 to Rs 0.25 trillion owing to the reimposition of ALMM from April 2024, with case-to-case exemptions on projects at an advanced stage of construction.

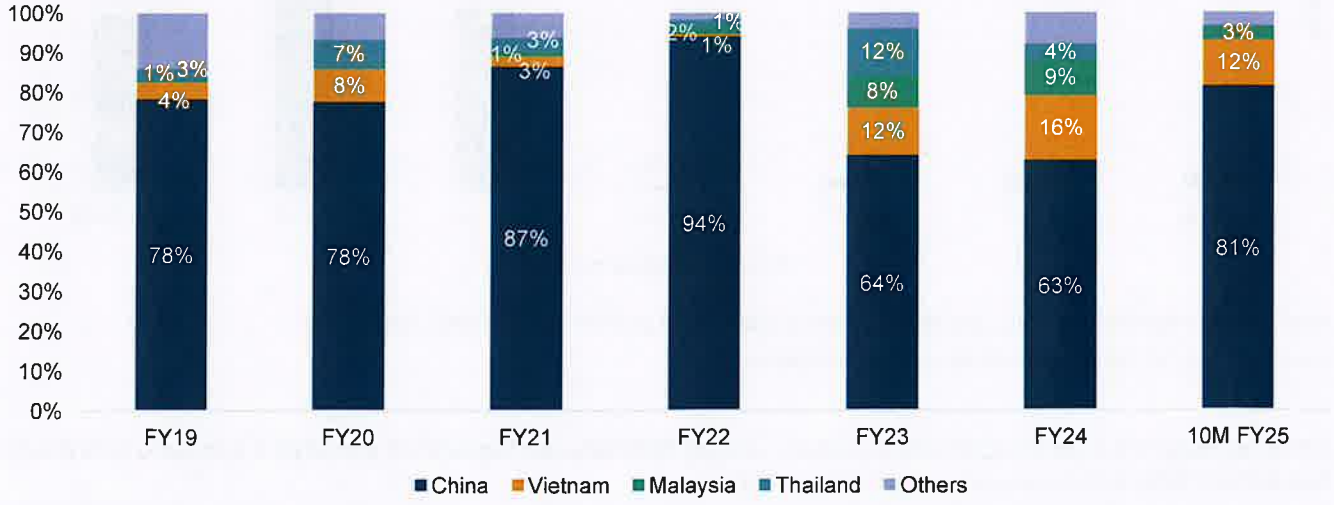
Figure 46: ALMM reimposition curbs imports in 10 months of fiscal 2025



Note: HS Code 85414011 and 12 used till fiscal 2022 and 85414200 and 300 used from fiscal 2023.
Source: Ministry of Trade and Commerce, Crisil Intelligence

The share of China in India's import basket has varied over fiscals 2019-2025, averaging 78%. Furthermore, with increase in manufacturing capacities in the ASEAN nations, the share of Vietnam, Malaysia and Thailand has averaged 5% during the same period.

Figure 47: Share of China volatile in India's import basket



Note: HS Code 85414011 and 12 used till fiscal 2022 and 85414200 and 300 used from fiscal 2023.
Source: Ministry of Trade and Commerce, Crisil Intelligence

While supply chain diversification resulted in 28% loss of share for Chinese cells and modules in India's import basket in fiscal 2024 over fiscal 2022, the share increased to 81% with increase in cell imports. Countries such as Vietnam,

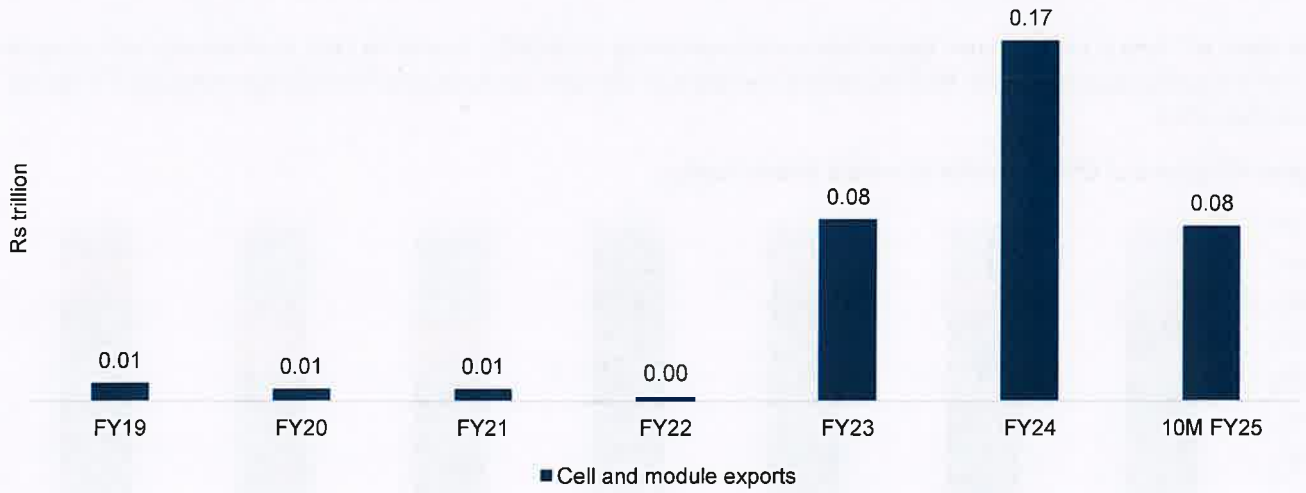
Malaysia and Thailand have gained 12%, 3% and 0.2% market share, respectively, in the first 10 months of fiscal 2025. While lack of domestic capacity prompted the need for imports, the pricing of international modules also proved beneficial for domestic developers. In fiscal 2025, imports were concentrated to the exemptions offered under the ALMM. On average, the traded price of imported solar modules remained at least Rs 4-6/Wp (excluding duties) lower than that of an imported cell based domestic module in fiscal 2025.

While imports remained ~55% between fiscals 2019 and 2025, exports also recorded remarkable growth over the same period.

India's exports grow multifold, so also geographical concentration

India's solar cell and module exports averaged a modest Rs 0.01 trillion between fiscals 2019 and 2022. However, a significant boost in manufacturing capacity and shifting geopolitical dynamics led to a remarkable surge in exports, with a 39-fold on-year increase in fiscal 2023, followed by a twofold increase in fiscal 2024. While export value fell in the first 10 months of fiscal 2025 to Rs 0.08 trillion, volume remained flat owing to fall in the prices of upstream components. This is because manufacturers allocate domestic cell-based modules to cater to local demand arising from the DCR and government segments, while exports may be a mix of imported cell-based domestic module and domestic cell-based modules.

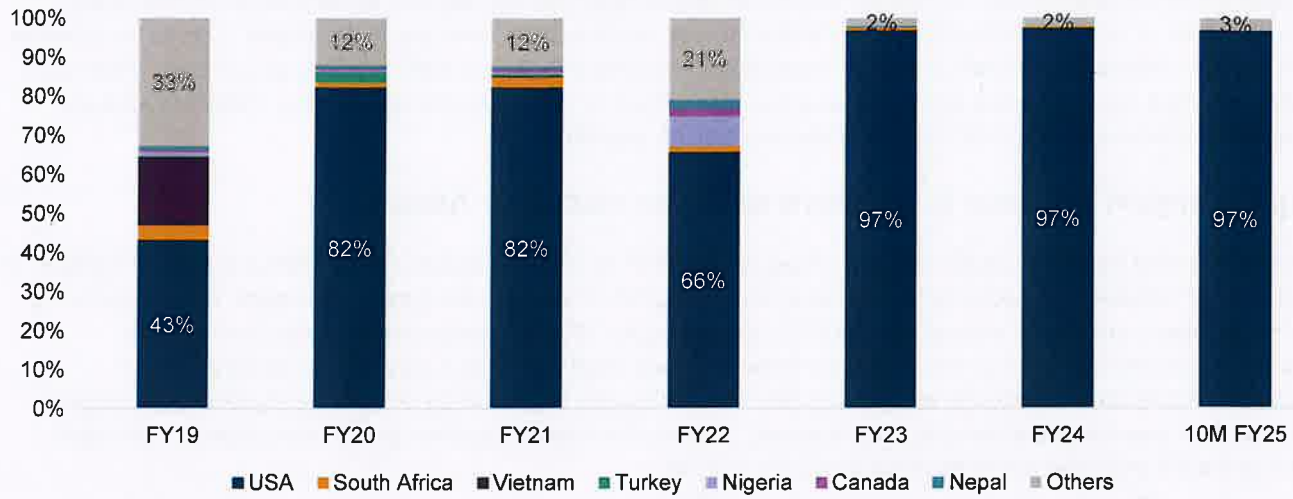
Figure 48: Geopolitical dynamics boosts Indian exports



Note: HS Code 85414011 and 12 used till fiscal 2022 and 85414200 and 300 used from fiscal 2023.
Source: Ministry of Trade and Commerce, Crisil Intelligence

While the share of the US in India's export basket averaged 60% between fiscals 2019 and 2022, it jumped to 97% during fiscals 2023, 2024 and the first 10 months of fiscal 2025.

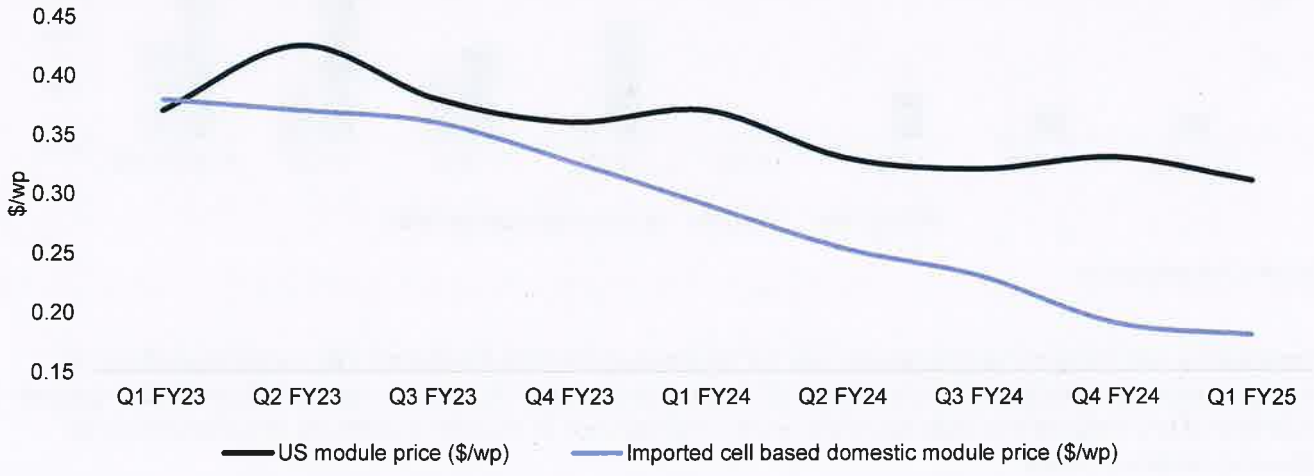
Figure 49: The US accounts for 97% of India's solar exports



Note: HS Code 85414011 and 12 used till fiscal 2022 and 85414200 and 300 used from fiscal 2023.
Source: Ministry of Trade and Commerce, Crisil Intelligence

A major reason for increased exports to the US is its sanction on imports from Xinjiang region imposed in June 2022 that opened doorways for other Asian exporting economies, including India. While India's prices remained uncompetitive to Chinese suppliers, they still offered a lower price compared with those manufactured in the US. This is because of higher labour cost and infrastructure capex requirement in the US vs India.

Figure 50: Gap between the US and India rates enables premium sales for domestic module makers



Note: Price for monocrystalline technology-based modules.
Source: EIA, Crisil Intelligence

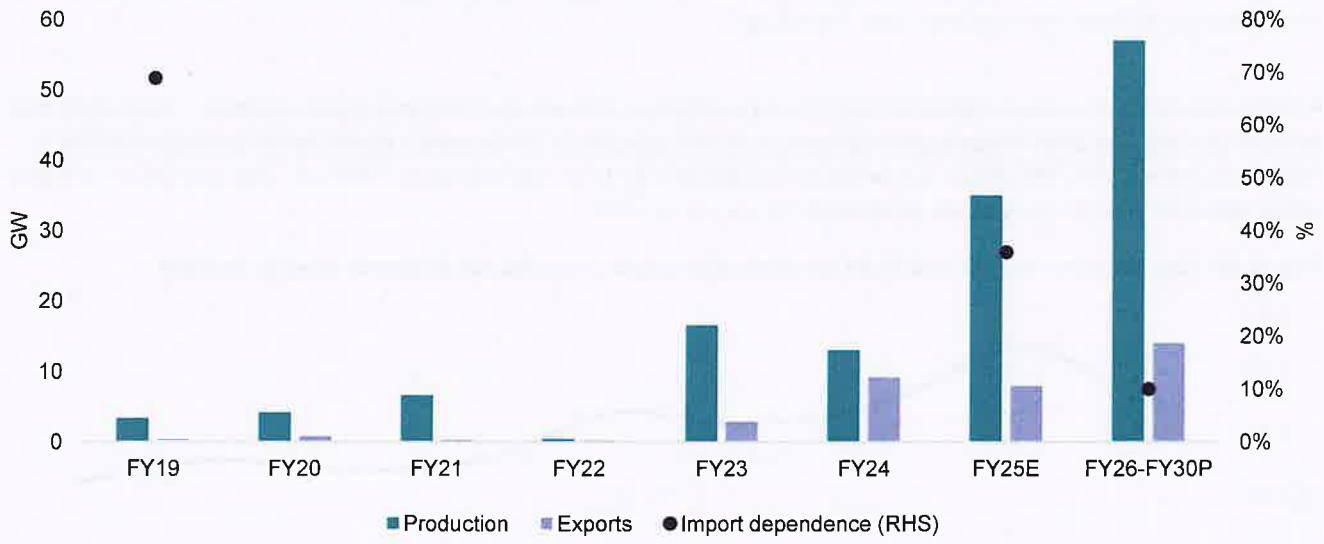
On average, the difference between the module price of US and Indian produce was ~$0.06/Wp between fiscal 2023 and Q1 of fiscal 2025. Also, considering tariff and non-tariff barriers levied by the US on China and ASEAN countries, India

remains in a favourable position to export to the US thanks to lower rates vis-à-vis competing peers. In April 2025, the US imposed a 26% ad-valorem duty on India as a part of its large-scale trade negotiations, which was put on hold till July 2025. However, a 10% baseline tariff on imports of solar modules from India continues in the interim. Despite the baseline tariff, the price differential between global cell-based Indian modules and the US make remains favourable to India. Crisil Intelligence does not anticipate a significant volume-based impact on India's exports to the US as Indian products are competitive against other exporters (mainly China and ASEAN countries).

Export-import balance to improve over the next four fiscals

While the demand for solar modules remains robust, projected at 38-43 GW between fiscals 2026 and 2030, the growth in production of modules is expected to be sufficient from fiscal 2025 onwards, making room for exports. India exported ~6 GW of modules in the first 10 months of fiscal 2025, accounting for 20-40% of the domestic production. Module manufacturing compared with domestic demand between fiscals 2026 and 2030 is expected to create an export opportunity. While absolute exports will increase, the share of exports in production is expected to moderate between 25% and 32% over the years owing to rising domestic consumption needs. However, global trade dynamics and tariffs between the US and other countries remain key monitorables.

Figure 51: Import dependence to fall 10-15% by fiscal 2029



Source: Crisil Intelligence

Consequently, with rising nameplate capacity and the reimposition of ALMM from fiscal 2026, import dependency for modules is expected to fall from 65-75% in fiscal 2019 to an average of 5-10% between fiscals 2026 and 2030. However, a low base of fully integrated capacity would still result in high reliance on imports for upstream components such as polysilicon, wafers and cells.

Sharp fall in the prices of PV components due to supply glut

The prices of upstream components such as polysilicon shot up to $0.39 per kg in the second quarter of fiscal 2023 owing to power rationing in China's solar provinces, followed by the Chinese energy crisis due to low coal stocks and a surge in demand. However, on a global scale, the polysilicon base expanded 68% on-year by the end of December 2022, reaching

a range of 1,000-1,100 tonnes from 600-650 tonnes. Despite strong demand from China, the increased installed base by December 2022 resulted in oversupply, causing a dramatic drop in price to $0.19 per kg by fiscal 2025, nearly half of the peak of the second quarter of fiscal 2023.

Consequently, downstream components also witnessed significant price reductions, with wafer prices plummeting over 70% to $0.15 per piece in fiscal 2025 from $0.98 per piece in the second quarter of fiscal 2023. The oversupply of polysilicon also prompted the world's largest monocrystalline solar wafer supplier to cut the prices of its PV wafers twice between April and May 2023 by 33% as cell manufacturers sought to fulfil their order requirements. Cell prices also saw a decrease in fiscal 2025 compared with the second quarter of fiscal 2023, reaching $0.03 per Wp, while module prices fell 68% during the same period.

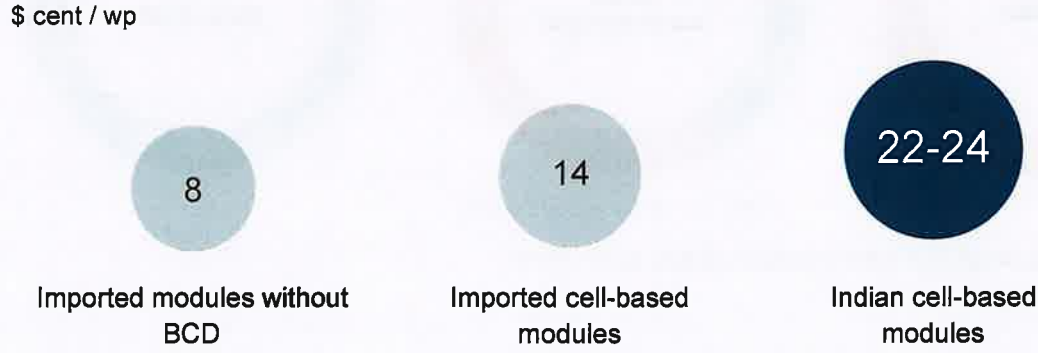
The combination of weak European demand and an accumulation of Chinese module inventory kept global module prices subdued in 2024.

The oversupply is expected to continue this fiscal, resulting in the prices of imported solar modules ranging between $0.08-0.1 per Wp and $0.14-0.19 per Wp for the locally assembled ones. However, the prices of modules assembled using Indian cells remained at least 1.2 times higher than those assembled using imported cells.

Pricing of Indian cell-based modules minimum 1.5 times higher than that of imported cell-based modules

The need for economies of scale is essential to achieve competitive pricing for domestically manufactured modules. Domestic content requirement ensures that projects utilise solar cells and modules produced in India. Although the current approved list of models and manufacturers (ALMM) provides price resilience to domestic manufacturers, the absence of large-scale cell capacity has resulted in modules assembled using local cells being at least 1.5 times more expensive than the modules utilising imported cells and ~2.8 times more expensive than a traded Chinese module.

Figure 52: Indian cell-based module prices 1.5-2 times higher than traded Chinese modules in fiscal 2025



Note: Prices are as at March 2025 and reflects prices of Mono-PERC based cell technology and are exclusive of GST.
Source: Crisil Intelligence

As a result, a comprehensive policy initiative has been instrumental in driving significant expansion of domestic module manufacturing capacity, with a positive impact on the module segment of the value chain. This policy push is also expected to support the expansion of cell manufacturing capacity. However, the industry's reliance on imported upstream components is likely to remain in the long term, which may lead to a shift towards Chinese component imports.

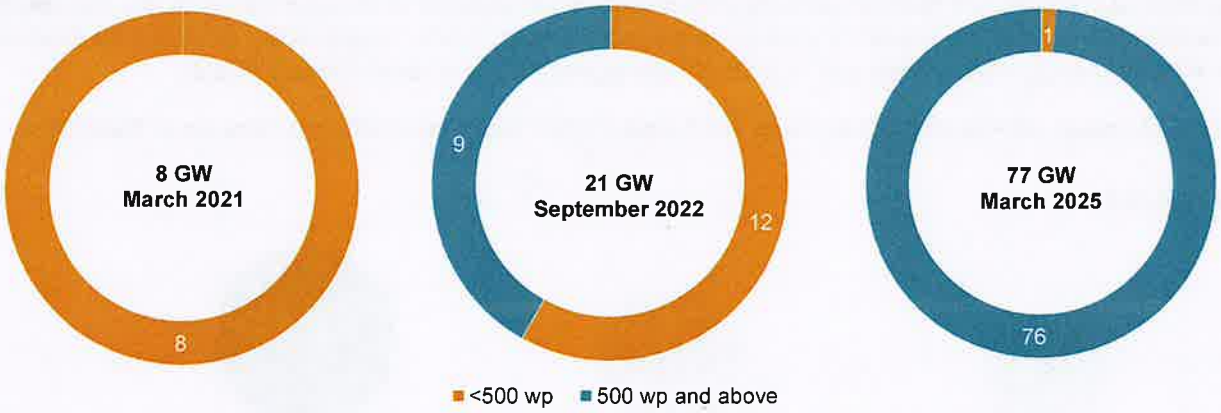
Furthermore, the export market is expected to be driven by policy-led diversification strategies, where Indian products will stand to gain if competitively priced against domestic alternatives. Despite the high price differential, the demand for domestically made modules is expected to increase because of the mandate of using domestic-made cells with the implementation of ALMM-II.

Policy support key for photovoltaic manufacturing expansion

The PV manufacturing industry has received both demand and supply incentives during fiscals 2019-2025. The fruits of these benefits are expected to materialise over the years.

1. 50 GW annual tendering capacity: The government has decided to invite bids for 50 GW of renewable energy capacity annually for the next five years (fiscal 2024 to fiscal 2028). Since RE projects take 18-24 months for commissioning, the bid plan is to help add 250 GW of renewable energy and ensure 500 GW of installed capacity by 2030.
2. ALMM: The approved list of models and manufacturers is an initiative by the Ministry of New and Renewable Energy of India to ensure that only high-quality solar models are used, and high-quality manufacturers are engaged in projects supported by the government. The initiative introduced in 2021 has acted as a non-tariff barrier for global manufacturers to enter the Indian market. The list has been updated several times between March 2021 and December 2024 with increasing enlistments. The capacity enlisted touched 77 GW in March 2025, ~10 times more than that listed in March 2021.

Figure 53: Enlisted capacity grows ~10 times



Note: Capacity inside the doughnut is the total enlisted capacity as per ALMM
Source: MNRE, Crisil Intelligence

The initiative does not involve any foreign manufacturer's plant globally as of March 2025, providing price resilience to domestic manufacturers.

3. ALMM-II: The ministry has also announced the induction of cells in the ALMM ecosystem, to be imposed from June 2026. With over 55 GW cell manufacturing capacity announced, the ALMM-II is expected to help expand manufacturing in this value-chain stage as well. Thus, timely commissioning of the cell capacity is crucial.
4. Supply chain diversification: This strategy encourages companies to diversify their operations by expanding outside of China while still maintaining a presence in the country. India is one of the potential destinations for solar

manufacturing due to its low labour cost, as well as a favourable political and regulatory environment for manufacturing. A rise in the manufacturing base has enabled domestic manufacturers to tap the export potential, with nearly 97% of exports focused on the US alone.

5. PLI scheme: In April 2021, MNRE launched tranche I of the PLI scheme for high-efficiency solar modules, allocating 8.7 GW to three manufacturers with an outlay of Rs 45 billion. However, this was later increased, and a second round of allocation was conducted based on an oversubscription witnessed in tranche I. MNRE then announced tranche II of the PLI scheme in September 2022, to allocate 36 GW of fully integrated/partially integrated solar manufacturing with an outlay of Rs 195 billion, and 13 unique manufacturers were chosen across various stages of the value chain.

6. Basic custom duty (BCD): From time to time, the government of India has intervened to reduce the price disparity between Indian and international modules in the form of safeguard duties and basic custom duty. Rising imports had discouraged manufacturing capacity expansion in the past, and thus various players from the Indian domestic solar component manufacturing industry (mainly modules) filed additional duty petitions against imports.

   Despite the safeguard duty, imports dominated module supplies. Indian producers sought an extension, and the duty was extended for a year, then removed after July 2021. However, the Ministry of Power alternatively levied a BCD effective 1 April 2022. Although the imposition of ~40% BCD on modules and 25% on cells led to an increase in the capital cost, the price disparity between a domestic-assembled module and an imported one reduced to $1-2 cents /Wp from $7-8 cents/Wp, resulting in the demand for domestic modules.

   The recent simplification of duty structure in the budget for fiscal 2026 changed the duty structure.

Table 18: New and simplified duty structure

Solar module	Old duty structure	New duty structure
BCD	40%	20%
SWS	4%	-
AIDC	-	20%

Solar cell	Old duty structure	New duty structure
BCD	25%	20%
SWS	2.5%	-
AIDC	-	7.5%

Source: Crisil Intelligence

   Although the landed price of imported cells and modules are estimated to decrease marginally, the implementation of ALMM and ALMM II is likely to protect the demand for domestic produce.

7. Domestic tariff area (DTA): The DTA refers to the geographical region within a country where goods and services are freely available for trade, subject to domestic duties and taxes, as opposed to Export Oriented Units (EOUs) or Special Economic Zones (SEZs), where special exemptions apply. For solar cells and module manufacturers in India, the DTA policy framework plays a pivotal role in fostering domestic production. By ensuring that imported goods, such as solar cells or modules, incur tariffs under the BCD or other trade protections, the DTA helps create a level-playing field for domestic manufacturers. This measure is particularly relevant, given India's target of 500 GW of renewable energy capacity by 2030, with solar energy constituting a significant proportion. The imposition of duties on imported solar cells and modules, particularly from countries such as China, helps reduce dependency on imports and provides a competitive edge to local manufacturers.

Risks and monitorables

Although the growth drivers are expected to propel the industry, module manufacturers are vulnerable to multiple risks such as change in government regulations, exchange-rate volatility, input-price volatility, and market and competition risk, among others.

Figure 54: Government regulations, commissioning capability and technological progress key for the industry

Risks and monitorable	Impact meter	Impact
Change in import-export regulations		India's limited upstream component base is expected to result in continued imports. Thus, change in global trade policies, particularly in formulation of duties, could significantly impact manufacturers
Fluctuation in foreign currency		The impact of INR depreciation on imports of upstream components is anticipated to be offset by a surge in exports of downstream components
Change in government policy		Heavy reliance on government interventions, in the form of tax and non-tax barriers, helps the industry remain resilient in the domestic market. However, any shifts in government policy could severely impact the industry
Rise in competition from domestic market and imports		Increased investment from Chinese players in Vietnam, Thailand and Malaysia is expected to intensify export competition for Indian manufacturers. The timely commissioning of large-scale vertically integrated capacities will be crucial to maintaining competitiveness
Technology upgradation		The end-use industry is likely to face challenges related to land availability. The ability to pivot from existing technologies to higher-performing alternatives will be a key factor to monitor
Price volatility and market risk		The limited upstream component base, such as polysilicon, wafers, and cells, is expected to leave India vulnerable to supply and price shocks from the international market. However, rising upstream domestic capacity over the longer term will mitigate this risk
Business concentration		Diversification of the export basket will remain crucial to monitor in the future, as major importing economies develop their own manufacturing setups

Note: Red zone denotes high risk, amber denotes moderate risk and green denotes low risk

Source: Crisil Intelligence

Manufacturing base widens, with several mature players in the fray

As of April 2025, the top seven players in the industry other than Rayzon Solar Ltd, namely Waaree Energies, Emmvee Photovoltaic, Goldi Solar, Vikram Solar, Saatvik Green Energy, Premier Energies and Solex Energy, accounted for about 37% of the total domestic ALMM enlisted module manufacturing capacity of ~30 GW.

Comparative summary of domestic module manufacturers

Table 19: Comparative summary of domestic module manufacturers

Parameter	Waaree Energies Ltd	Goldi Solar Private Ltd	Vikram Solar Ltd	Rayzon Solar Ltd	Emmvee Photovoltaic Power Private Ltd	Saatvik Green Energy Ltd	Solex Energy Ltd	Premier Energies
Geographical presence	Gujarat, USA	Gujarat	West Bengal and Tamil Nadu	Gujarat	Karnataka	Haryana	Gujarat	Telangana

Parameter	Waaree Energies Ltd	Goldi Solar Private Ltd	Vikram Solar Ltd	Rayzon Solar Ltd	Emmvee Photovoltaic Power Private Ltd	Saatvik Green Energy Ltd	Solex Energy Ltd	Premier Energies
within India/outside								
Enlisted capacity in ALMM as of April 2025 (GW)	11.9	5.8	2.9	3.0	4.5	1.7	0.6	2.6
Market share as per ALMM	15%	7%	4%	4%	6%	2%	1%	3%
Order book (GW)	25 as of FY25	NA	4.4 for FY24	3 GW as of 9MFY25	NA	3.4 as of 9M FY25	NA	5.3GW as of FY25
Order book (Rs crore)	47,000 as of FY25	6819 as of Feb 2025	NA	4,652 (4,152) as of 9MFY25	5,994 as of 15 Oct 2024	4,732 as of 9M FY25	131 as of Q1 FY25	8446 as of FY25
Installed module capacity (GW)	15 as of FY25*	10.7 as of Mar 2025	3.5 for FY24	6 GW as of FY25	4.25 for FY25	1.5 as of FY25	1.5 as of 9MFY25	5.1 as of FY25
Effective annual capacity (GW)	11 for FY24	NA	1.8 for FY24	1.9 GW for 9MFY25	NA	0.6 for FY24	NA	0.62 as of Q1 FY25
Actual production (GW)	5.07 as of 9M FY25	NA	0.8 for FY24	1.4 GW for 9MFY2025	NA	0.5 for FY24	NA	0.51 as of Q1 FY25
Capacity utilisation (%)	43.4% for FY24	NA	48.1% for FY24	73.4% for 9MFY25	NA	88.5% for FY24	NA	75% as of FY25
Type of products and services	Solar PV modules, inverters, batteries, EPC services, rooftop solutions, O&M services and solar water pumps	Solar modules, EPC services, solar pumps	Modules, EPC, rooftop solutions, and solar water heater solutions	Solar PV modules	Modules, EPC, rooftop solutions, and solar water heater solutions	Solar PV modules and EPC services	Solar PV modules and EPC services	p-Type and n-Type mono and bifacial solar modules
Primary technology of manufacturing	TOPCon, Mono and poly crystalline PV modules, Mono PERC	Mono-crystalline, poly-crystalline PV modules	TOPCon, Mono PERC, polycrystalline modules	Mono PERC and TOPCon	TOPCon, Mono PERC, polycrystalline modules	Mono PERC and TOPCon	Mono PERC and TOPCon	Mono PERC and TOPCon

*Note: *Installed module capacity of Waaree includes 1.3 GW from Indosolar and 1.6 GW from USA; order book of Rayzon as indicated in brackets is the net order book as of 9MFY25*

Source: Company reports, rating rationales, ALMM and Crisil Intelligence

Financial analysis

Table 20: Financial comparative analysis of manufacturers in India

Particulars	Rayzon Solar Ltd				Waaree Energies Ltd				Premier Energies Limited			
	9MFY25	FY24	FY23	FY22	9MFY25	FY24	FY23	FY22	9MFY25	FY24	FY23	FY22
Revenue from operations (Rs million)	19,570	12,739	6,981	2,621	1,04,406	1,14,013	67,548	28,575	48,979	31,586	14,425	7,483
Revenue growth (%)	NA	82%	166%	98%	23%	69%	136%	46%	143%	119%	93%	6%
Total income (Rs million)	19,640	12,740	6,982	2,622	1,07,051	1,15,832	68,124	29,251	49,726	31,711	14,568	7,581
EBITDA (Rs million)	3,478	1,013	449	134	17,991	16,266	8,861	1,349	12,524	4,926	924	350
EBITDA margin in %	18%	8%	6%	5%	17%	14%	13%	5%	26%	16%	6%	5%
PAT (Rs million)	2,390	609	255	39	12,837	12,744	5,003	808	6,593	2,314	-133	-144
PAT margin in %	12%	5%	4%	1%	12%	11%	7%	3%	13%	7%	-1%	-2%
Raw material cost (Rs million)	14,037	11,010	6,180	2,540	75,805	83,565	58,973	17,989	27,035	22,280	11,105	3,987
Gross debt (Rs million)	NA	1,029	549	459	NA	3,173	2,735	3,131	NA	13,927	7,643	4,541
Net debt (Rs million)	NA	779	532	444	NA	-34,619	-14,629	-533	NA	11,357	6,998	3,740
Debt/Equity (times)	NA	1.2	2.1	3.2	NA	0.1	0.1	0.7	NA	2.1	1.8	1.1
Net debt to EBITDA (times)	NA	0.8	1.2	3.3	NA	-2.1	-1.7	-0.4	NA	2.0	3.2	2.0
ROCE (%)	NA	66%	57%	21%	NA	57%	52%	23%	NA	25%	6%	4%
ROE (%)	NA	107%	125%	38%	NA	43%	44%	20%	NA	43%	-3%	-4%
Net WC (Rs. million)	NA	339	14	-34	NA	25,183	5,158	-2,312	NA	2,021	-34	466
Net WC days	NA	10	1	-5	NA	81	28	-30	NA	23	-1	23
FA turnover ratio (times)	NA	16.84	19.60	13.63	NA	5.2	5.9	6.0	NA	2.8	1.8	1.5
Inventory turnover ratio (times)	NA	18.8	11.7	7.5	NA	3.3	3.2	5.2	NA	2.9	2.8	3.6
Receivable turnover ratio (times)	NA	35.9	92.7	53.0	NA	17.8	33.0	25.9	NA	8.9	10.9	4.2

Particulars	Rayzon Solar Ltd				Waaree Energies Ltd				Premier Energies Limited			
	9MFY25	FY24	FY23	FY22	9MFY25	FY24	FY23	FY22	9MFY25	FY24	FY23	FY22
Trade payable turnover ratio (times)	NA	17.5	18.7	10.9	NA	4.3	3.9	4.6	NA	3.4	3.5	2.3

Notes:

1. *Financial line-items are reclassified and standardized, while arriving at above ratios as per CRISIL's internal methodologies. Therefore, they may not match the company reported numbers.*
2. *NA: Not Applicable*
3. *Rayzon Solar Limited's financial for 9M FY25 are on consolidated basis. Financials for FY22 to FY24 are on standalone basis*
4. *Waaree Energies Limited and Premier Energies Limited's financial are on consolidated basis.*
5. *EBITDA is calculated as revenue from operations minus raw material cost minus power & fuel cost minus employee cost minus other manufacturing expenses minus other expenses (excluding interest and finance charges and depreciation and amortisation charges)*
6. *EBITDA Margin is calculated as EBITDA divided by revenue from operations*
7. *PAT is calculated as EBITDA minus interest and finance charges minus depreciation & amortisation minus tax*
8. *PAT Margin is calculated as PAT divided by operating income*
9. *Net debt is calculated as total external debt minus cash & cash equivalents*
10. *Debt/Equity ratio is calculated as total debt divided by tangible net worth*
11. *Net debt to EBITDA ratio is calculated as net debt divided by EBITDA*
12. *ROCE is calculated as EBIT for current fiscal year divided by average of (sum of equity and debt of current fiscal year) and (sum of debt and equity of previous fiscal year)*
13. *ROE is calculated as PAT for current fiscal year divided by average of equity of current fiscal year and equity of previous fiscal year*
14. *Net working capital is calculated as current assets minus current liabilities*
15. *Net working capital days is calculated as Net working capital divided by revenue from operations*
16. *FA turnover ratio is calculated as sales of current fiscal year divided by average of fixed asset of current fiscal year and fixed asset of previous fiscal year*
17. *Inventory turnover ratio is calculated as cost of goods sold of current fiscal year divided by average of inventory of current fiscal year and inventory of previous fiscal year*
18. *Receivable turnover ratio is calculated as revenue of the current fiscal year divided by average of receivables of current fiscal year and receivables of previous fiscal year*
19. *Trade payable turnover ratio is calculated as cost of goods sold of the current year divided by average of payables of current fiscal year and payables of previous fiscal year*

Source: Crisil Intelligence

Here are some pointers that provide a perspective on Rayzon's position in the competition landscape of the photovoltaic industry:

- Rayzon commenced its operations in 2017 as a partnership firm called M/s Rayzon Green Energies
- Rayzon is among the top 10 manufacturers of solar photovoltaic (PV) modules in India with ALMM enlisted capacity of 3.00 GW as of April 21, 2025
- According the ALMM list, Rayzon Solar had a share of 3.8% in the total ALMM enlisted capacity as on April 21, 2025.
- Rayzon operates two manufacturing facilities in Karanj and Sava, Gujarat, spread across 21.14 acres and 22.99 acres, respectively.

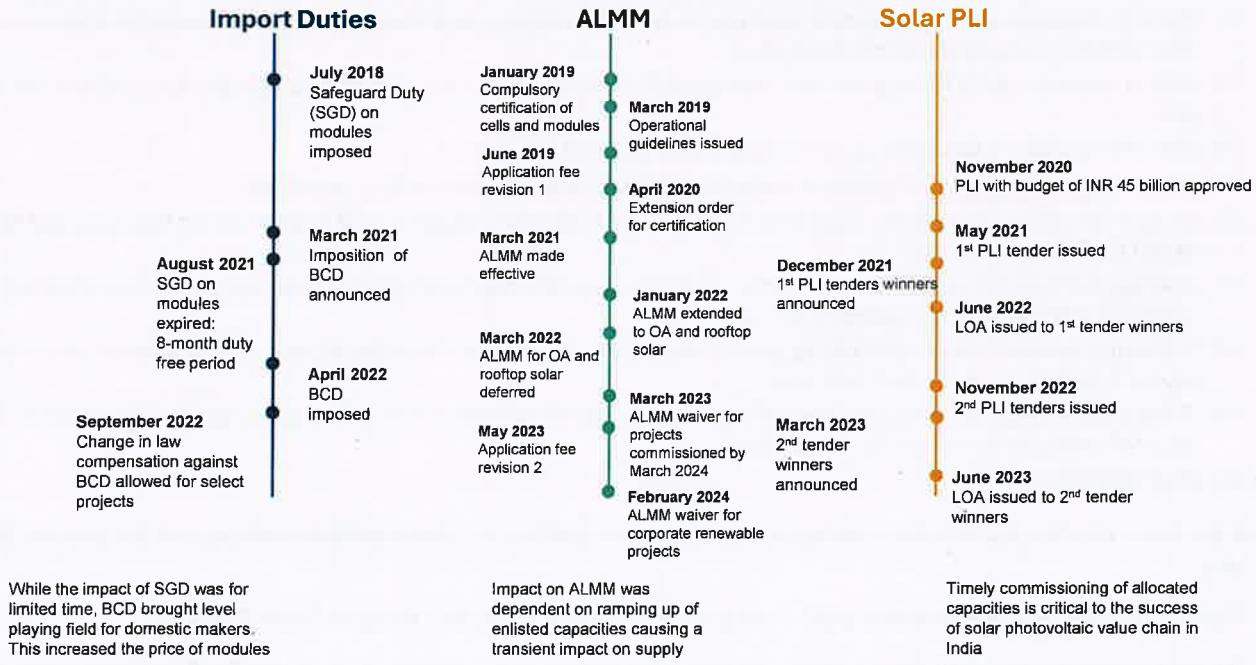
- The company has added 3 GW of manufacturing capacity in March 2025, resulting in an installed capacity of 6.00 GW as of March 31, 2025
- Rayzon has expanded its manufacturing capacity for solar PV modules from 40 MW as on March 31, 2018, to 2.10 GW as on March 31, 2024, and 3.00 GW as on December 31, 2024, to 6 GW as on March 31, 2025.
- Rayzon's revenue from operations has grown at a CAGR of 120.46% from Fiscal 2022 to fiscal 2024
- Rayzon had an FA turnover ratio of 16.84 times and net working capital ratio of 37.53 as of fiscal 2024
- The company had a debt/equity ratio of 1.18 in Fiscal 2024 and its revenue grew 82.48% on-year in fiscal 2024

Threats and challenges

1. Policy challenges

The solar energy industry is heavily reliant on government policies, which significantly influence the solar module manufacturing landscape in India. Crucial policy measures, such as the ALMM, safeguard duty, Basic Customs Duty (BCD), and the Production-Linked Incentive (PLI) scheme for solar module manufacturing, have a profound impact on the sector. However, despite the government's supportive stance, the policy framework often undergoes changes which the industry needs to adapt to.

Figure 55: Policy uncertainty and reversals have impacted the industry in the past



Source: Crisil Intelligence

2. Industry challenges

The Indian solar PV manufacturing industry has witnessed an allocation of 24 GW of polysilicon, 40 GW of wafers and 48.3 GW of cells and modules in two PLI tranches. Over and above this, the industry has seen multiple announcements in the cells to module segment. The domestic cell to module capacity is expected to increase over

fiscal 2029 resulting in low import dependency. However, the dependence on the import of wafers and polysilicon will continue owing to the limited capacity expansion plan over the next five years.

3. **Export market concentration**

The solar module capacity has expanded to 82 GW in fiscal 2025 from 22 GW in fiscal 2022, opening the doors for export opportunities. The industry received a further boost from the Uyghur Forced Labour Prevention Act. This has resulted in over 90% exports being driven to the US market during fiscals 2023, 2024 and 2025. However, India does not share an export agreement with the US. Therefore, any change in the US policies can impact Indian exporters. Given that Indian manufacturers largely focus on the US market, their presence in the import basket of other top importing nations such as Netherlands, Germany, Spain and Brazil remains low.

4. **Technology advancements**

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 knowhow and even manufacturing lines and installation personnel for new PV cell and module lines being set up currently are mostly being sourced from Chinese suppliers. Therefore, maintaining high quality standards and keeping up with rapid technological advancements can be challenging for this industry.

5. **Environment and sustainability**

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

Source: Crisil Intelligence

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