Market Intelligence
& Analytics

CRISIL
An S&P Global Company

Industry research report on solar equipment and renewable energy

GK Energy Limited

Review and outlook | December 2024

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Module 1: Global macroeconomic view

Monetary stance begins to ease as inflation moderates; growth holds steady

Global economic growth remains steady, but moderate, with emerging economies growing faster than developed ones. The United States of America (US) seems to be outperforming other advanced economies in calendar year (CY) 2024, while India remains one of the fastest growing among emerging economies.

The International Monetary Fund (IMF) estimates that global GDP will grow 3.2% each year in 2024 and 2025. Growth is expected to be divergent, with advanced economies experiencing slightly modest growth and emerging economies logging steady growth through the two years.

India is expected to emerge relatively stronger amid the global uncertainties, logging 8.2% GDP growth in Fiscal 2024 and 6.8% in Fiscal 2025. References to “Fiscal” or “FY” herein are to the year ended/ending on March 31 of the identified year.

Table 1: Real GDP growth

YoY (%)	CY18	CY19	CY20	CY21	CY22	CY23	CY24P	CY25P
World	3.6	2.9	-3.1	6.0	3.5	3.3	3.2	3.3
Advanced economies	2.3	1.7	-4.5	5.2	2.6	1.7	1.8	1.8
- Euro area	1.8	1.6	-6.1	5.2	3.4	0.5	0.8	1.2
- US	2.9	2.3	-3.4	5.7	1.9	2.5	2.8	2.2
- UK	1.7	1.7	-9.3	7.4	4.3	0.1	1.1	1.5
- Germany	1.1	1.05	-4.6	2.6	1.8	-0.2	0.0	0.8
- Japan	0.6	-0.2	-4.5	1.7	1.0	1.9	0.3	1.1
Emerging and developing economies	4.6	3.7	-2.0	6.6	4.1	4.4	4.2	4.2
- China	6.7	6.0	2.2	8.1	3.0	5.2	4.8	4.5
- India*^	6.5	3.9	-5.8	9.7	7.0	8.2	6.8	6 to 7 %

**India numbers are on a Fiscal-year basis, where CY18 would correspond to Fiscal 2019*

^CRISIL MI&A Research projections for CY24; IMF projections for CY25

E – estimated; P – projected; NA – not available

Source: IMF World Economic Outlook, October 2024

Easing monetary cycles expected in the medium term

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

Table 2: Inflation movement across key economies

YoY (%)	CY18	CY19	CY20	CY21	CY22	CY23	CY24P^	CY25P^
Advanced economies								
- Euro area	1.8	1.2	0.3	2.6	8.4	5.4	2.4	2.2
- US	2.4	1.8	1.2	4.7	8.0	4.1	3.0	2.0
- UK	2.5	1.8	0.9	2.6	9.1	7.3	2.8	2.4
- Germany	1.9	1.4	0.4	3.2	8.7	6.0	2.7	2.3
- Japan	1.0	0.5	0.0	-0.2	2.5	3.3	2.4	2.2
Emerging and developing economies								
- China	2.1	2.9	2.5	0.9	2.0	0.2	0.5	1.5
- India	3.4	4.8	6.2	5.5	6.7	5.4	4.5	4.6

Notes:

E – estimated; P – projected

^Projections for CY24 and CY25 are based on S&P Global forecasts

Source: IMF World Outlook, July and October 2024; S&P Global June 2024 regional releases

Inflation has started easing due to the steps as food inflation is expected to be lower in Fiscal 2025 compared with the last, owing to healthy kharif sowing. Non-food inflation is expected to remain benign. Overall, the consumer price inflation (CPI) to expected to soften to 4.6% in Fiscal 2025, from 5.4% last Fiscal.

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. Bank of Canada and the European Central Bank lowered rates by 25 basis points (bps) in June 2024. The US Federal Reserve also cut rates by 50 bps in its September 2024 meeting, indicating an easing of monetary policy. This relationship between demand, inflation and rate cuts is now expected to be the dominant narrative in the medium term.

Module 2: Indian macroeconomic view

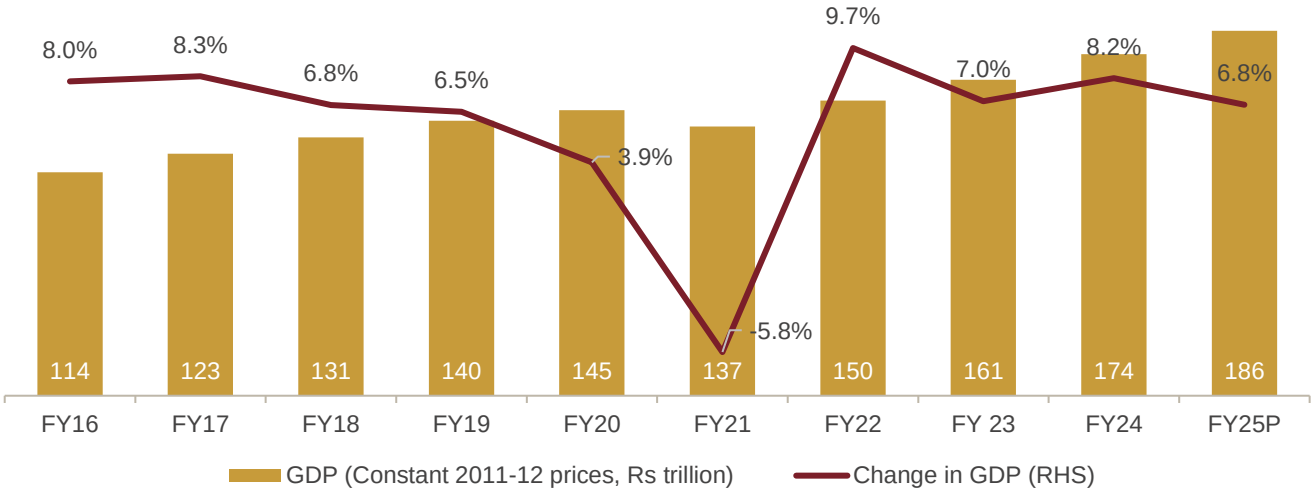
GDP review and outlook

India is the 5th largest economy in the world. It logged a strong 7.8% on-year growth in the fourth quarter of Fiscal 2024, compared with 5.9% pencilled-in by the National Statistical Office (NSO) in its second advance estimates in February 2024. With this, real GDP growth printed at 8.2% on-year for Fiscal 2024, higher than the 7.0% in the previous Fiscal, driven by fixed investments on the demand side and industry on the supply side.

In Fiscal 2025, GDP grew 6.7% on-year in the first quarter, aided by a significant pickup in private consumption in contrast to Fiscal 2024, but limited by slower government spending and slower manufacturing. The momentum slowed in second quarter of Fiscal 2025 with 5.4% growth on-year owing to sluggish urban demand.

Following a strong GDP print over Fiscals 2022 to 2024E, GDP growth is expected to moderate to 6.8% in Fiscal 2025 as Fiscal consolidation will reduce the Fiscal impulse to growth, credit conditions can tighten this year moderating urban demand, and slower global growth can restrict the upside to goods exports due to the normalisation of supply chains and an expected pickup in trade volume in calendar year 2024. Nevertheless, this would still mean India will log the fastest growth among major economies and fare better than the 6.7% growth seen in the decade preceding the pandemic.

Figure 1: Historical GDP growth and outlook



P – projected

Source: Ministry of Statistics and Programme Implementation ("MoSPI"), CRISIL MI&A Research

In the medium term, the Indian economy is projected to grow 6-7% on-year, boosted by healthy public capital expenditure (capex), domestic-consumption-led growth, the ongoing supply-chain de-risking strategy of global companies that should boost manufacturing in India and the thrust provided by the PLI scheme. However, the slowdown in global economies could negatively impact Indian exports, limiting GDP growth to some extent.

Table 3: India's GDP and macroeconomic outlook

Macro variable	FY22	FY23	FY24	FY25P	Rationale for outlook
Real GDP (%, y-o-y)	9.1	7.2	8.2	6.8	High interest rates and lower Fiscal impulse (from reduction in the Fiscal deficit) are expected to weigh on growth. But growth will become more balanced as the last year's laggards — agriculture and private consumption — are poised to rise. High rural demand and easing food inflation are expected to lift consumption.
Consumer price Index (CPI) inflation (%, y-o-y)	5.5	6.7	5.4	4.6	In our base case, we expect food inflation to be lower this Fiscal compared with the last, as kharif sowing has been healthy. Non-food inflation is expected to remain benign. Overall, we expect the consumer price inflation (CPI) to soften to 4.6% in Fiscal 2025, from 5.4% last Fiscal.
Current account balance/GDP (%)	1.2	-2.0	-0.7	-1.0	Higher imports given the uptick in consumption demand this Fiscal is expected to widen the trade deficit and put some pressure on the current account deficit. That said, healthy services trade surplus and remittances should keep a tab on the current account deficit.
₹/US$ (March end)	76.2	82.3	83.0	84.0	Although the current account deficit is expected to remain manageable, it may face some risks amid the uneven global growth scenario and geopolitical uncertainties. That said, India's healthy domestic macros should cushion the Indian Rupee.

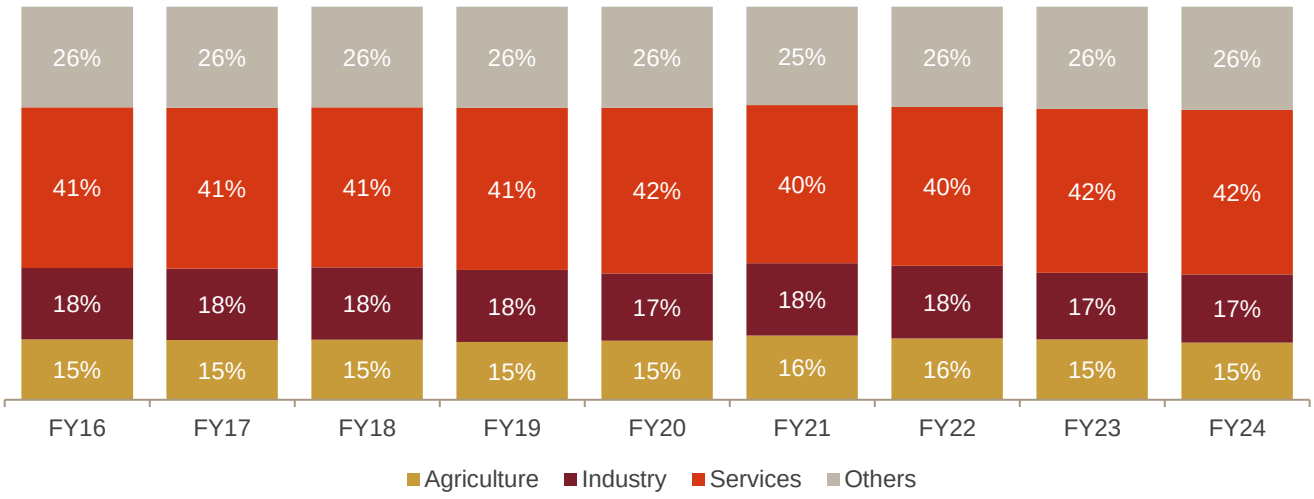
P: Projected

Source: RBI, NSO, CRISIL MI&A Research

Contribution of key sectors to gross value added

India's gross value added (GVA) has consistently grown over the years, except in Fiscal 2021 due to the pandemic. The services sector remains a significant contributor to GVA, with services exports growing faster than the economy. The manufacturing sector has grown at a 3% CAGR between Fiscals 2017 and 2022, driven by central government (Government) initiatives like Atmanirbhar Bharat, Make in India, and the PLI scheme. Although the industry's share in GVA remains constant, pending PLI investments are expected to boost growth. Agriculture GVA has grown at a 3% CAGR, driven by government support to farmers, including subsidies, infrastructure development, and schemes like PM Kisan and PM Fasal Bima Yojana. The Government has increased its budget allocation for agriculture and farmers' welfare from ₹276.6 billion in Fiscal 2014 to ₹1,250.3 billion in Fiscal 2024. Normal monsoons, government schemes, and favourable agricultural prices have aided growth, but erratic monsoon patterns remain a concern, driving demand for reliable irrigation solutions like solar pumps.

Figure 2: Contribution of key sectors (industry, agriculture and services) to GVA



Source: MoSPI, CRISIL MI&A Research

Multi-pronged policy focus helps prop up rural segment

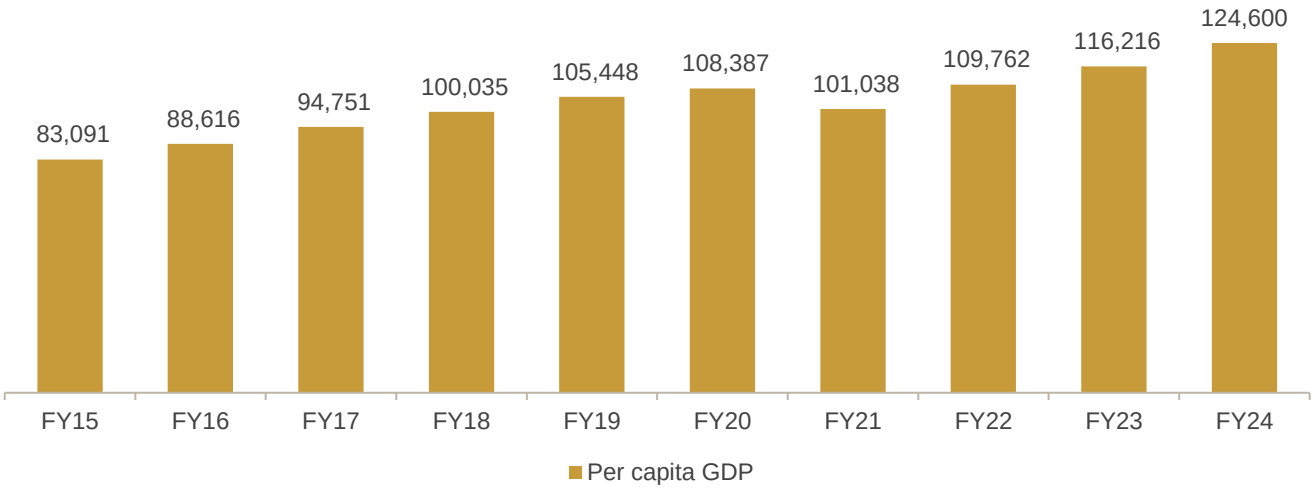
The rural economy has benefitted from two consecutive years of good monsoon and increased spending under the Mahatma Gandhi National Rural Employment Guarantee Act, irrigation programmes and schemes such as Direct Benefit Transfer, PM Kisan, PM KUSUM, PM Ujjwala Yojana for cooking gas, PM Awas Yojana for housing and Ayushman Bharat Yojana for healthcare. To supplement this, there has been a continuous improvement in electricity and road infrastructure in rural areas. In addition, the Reserve Bank of India mandates priority sector lending to specific sectors, such as agriculture and allied activities, education, housing and food for the poorer population. Out of the overall target of 75% of total outstanding towards priority sector lending by regional rural banks, the agriculture sector is allotted 18%. The lending is categorised as (i) farm credit (short-term crop loans and medium/long-term credit to farmers) (ii) agriculture infrastructure and (iii) ancillary activities. Such initiatives have led to reduced leakages and higher incomes for the rural populace, thereby enhancing their ability and willingness to spend on discretionary products and services. To boost agriculture growth and developing the product dynamics in the country, the government also established Agriculture infrastructure fund of ₹ 1 trillion at farm-gate and aggregation points aimed at making the sector affordable and financially viable. The rural economy accounts for almost half of India's gross domestic product and has recorded a better performance in last decade, compared with its urban counterpart in the aftermath of the pandemic.

There are three reasons for this. First, agricultural activity has continued largely unhindered, with normal monsoon and lower spread of the pandemic in rural areas, given lower population density. Second, the government offered support, making available an additional Indian Rupees (₹ or Rs.) 500 billion of funding towards MGNREGA as well as disbursing over ₹2.6 trillion towards the PM Kisan scheme till July 2023. Third, the structure of the non-agricultural rural economy has helped it bear the COVID-induced shock better. The rural economy accounts for 51% of India's manufacturing GDP, but the rural share in services GDP (excluding public administration, defence, and utilities) is much lower, at ~26%.

GDP per capita trends

India's GDP per capita in real terms logged CAGR of 5.46% between Fiscals 2015 and 2020, rising from ~₹ 83,000 to ~₹108,000.

Figure 3: India's GDP per capita (₹)



Note: Data is based on constant prices, 2011-12 base; Fiscal 2024 data is provisional

Source: National Accounts Statistics, CRISIL MI&A Research

Crop cycles, pricing and production are major factors towards influencing farmer incomes and hence largely rural growth. For instance, farmer income would be largely impacted by the monsoon quality, the crop chosen for sewing and the market pricing policy for the crop.

Consequently, to mitigate the volatility related to agricultural income, the government through various schemes has tried to improve income levels for this segment of the economy. Some of them are:

- Direct financial assistance to 118 million farmers under the PM Kisan scheme, crop insurance to 40 million farmers under the PM Fasal Bima Yojana scheme.
- PM-KUSUM (Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan) Scheme is aimed at ensuring energy security for farmers in India, along with increasing the renewable energy share in India.
- Introduced PM Surya Ghar Muft Bijli Yojana. Under this scheme, the government aims to make 10 million households self-sufficient in generating up to 300 units of electricity per month.
- The PM Kisan Sampada Yojana scheme has benefitted 3.8 million farmers and generated 1 million employment. The PM Formalisation of Micro Food Processing Enterprises Yojana scheme has assisted 0.24 million self-help groups and 0.06 million individuals with credit linkages.

Global focus increases on energy transition and power decarbonisation

The shift towards renewable energy is crucial for decarbonization and mitigating climate change. International initiatives like the Kyoto Protocol, Paris Agreement, and COP26 have promoted the growth of renewable energy. The Paris Agreement requires countries to submit nationally determined contributions (NDCs) to reduce emissions and limit global temperature rise to below 2°C and ideally 1.5°C. Solar power has driven the clean energy transition, with global installed capacity tripling since 2018 to 1,418 gigawatts (GW) in 2023, accounting for 37% of total renewable energy capacity. Governments have supported the solar industry through policies like feed-in tariffs, tax incentives, and subsidies, accelerating global growth. The 2021 COP26 conference aimed to update NDCs and accelerate climate action. India also updated its NDCs, which would be crucial in the global effort to

combat climate change. The transition to renewable energy is critical to meeting global climate goals and ensuring a sustainable future. India's goals are:

- To reduce emissions intensity of its GDP by 45% by 2030, from 2005 level
- To achieve about 50% cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030
- To promote a sustainable way of living through the 'LIFE' (Lifestyle for Environment) movement
- By the year 2070, India will achieve the target of Net Zero

The Government has initiated efforts to combat climate change through multiple programmes and schemes, such as the National Action Plan on Climate Change (NAPCC), The National Solar Mission under NAPCC is one of the key initiatives 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. Some of the measures undertaken by the Centre to promote renewable power in India are as follows:

Table 4: Policy drivers

Policy initiatives launched by the Indian government	
1. Allowing foreign direct investment upto 100% under automatic route	2. Extension of waiver of inter-state transmission system charges for inter-state sale of solar and wind power for projects to be commissioned by June 30, 2025
3. Declaration of trajectory for RPOs until 2030	4. Setting up of Ultra Mega Renewable Energy Parks to provide land and transmission to renewable energy developers for installation of related projects on a large scale
5. Introduction of schemes such as PM-KUSUM, Solar Rooftop Phase II, 12,000 MW Central Public Sector Undertaking Phase II, among others	6. Laying of new transmission lines and creating new sub-station capacity under the Green Energy Corridor Scheme for evacuation of renewable power
7. Notification of standards for deployment of solar PV system/devices	8. Setting up a project development cell for attracting and facilitating investments
9. Standard bidding guidelines for tariff-based competitive bidding process for procurement of power from grid-connected solar PV systems, wind and hybrid projects	10. Notification of promoting renewable energy through Green Energy Open Access Rules, 2022
11. Notification of The Electricity (Late Payment Surcharge and related matters) Rules, 2002	12. Mandates that power shall be dispatched against Letter of Credit or advance payment to ensure timely payment by distribution licensees to renewable energy generators
13. The Electricity Act, 2003, requires distribution licensees to purchase a percentage of their electricity from renewable sources, which can be met through own generation, procurement, or certificates.	14. PM-KUSUM Yojana, implemented in 2019, aims to set up 10,000 MW of decentralised renewable energy, and solarize 1.4 million standalone solar-powered pump systems and 3.5 grid connected agricultural solar-powered pump systems including feeder level solarisation
15. The PLI scheme, announced in the 2022 Union budget, aims to boost India's renewable energy sector by incentivising GW-scale solar PV manufacturing facilities and reducing import dependence.	16. The PM Surya Ghar Muft Bijli Yojna launched in February 2024, with a proposed outlay of ₹750 billion, aims to provide up to 300 units of free electricity to 10 million households with rooftop solar systems.

Source: CRISIL MI&A Research, MoP, MNRE, GoI

These are more ambitious and are beyond the NDCs agreed under the Paris Agreement.

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

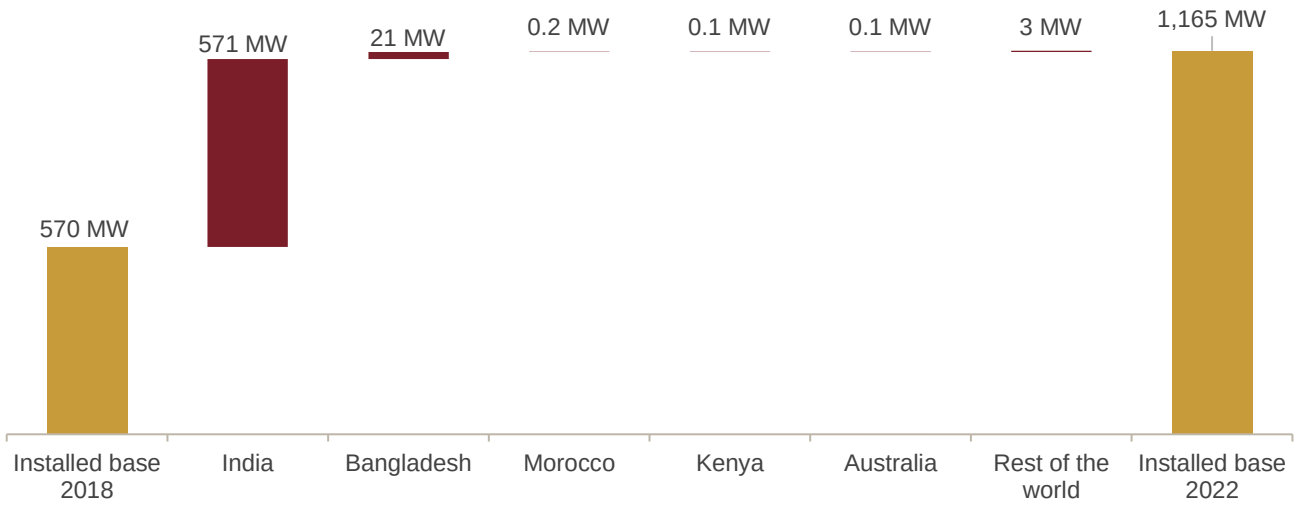
Module 3: Domestic solar-powered pump systems market

Growth drivers for global solar-powered pump systems market

The solar-powered pump systems market has witnessed significant growth globally over the past five years from the beginning of CY2018 to CY2022. These pumps are increasingly seen as a sustainable and economically viable alternative to traditional diesel-powered irrigation systems, especially in rural areas with limited access to electricity. To respond to growing concerns over climate change, energy access, and rising fuel prices, governments and international organizations are providing incentives to encourage the adoption of solar-powered pump systems.

As per IRENA off grid statistics, the agriculture solar-powered pump systems installed capacity has grown nearly 2 times between 2018 and 2022. The total additions from the beginning of CY2019 till the end of CY2022 touched 596 MW with India accounting for 96% of the additions.

Figure 4: India added 571 MW of agricultural solar-powered pump systems from CY2019 till CY2022

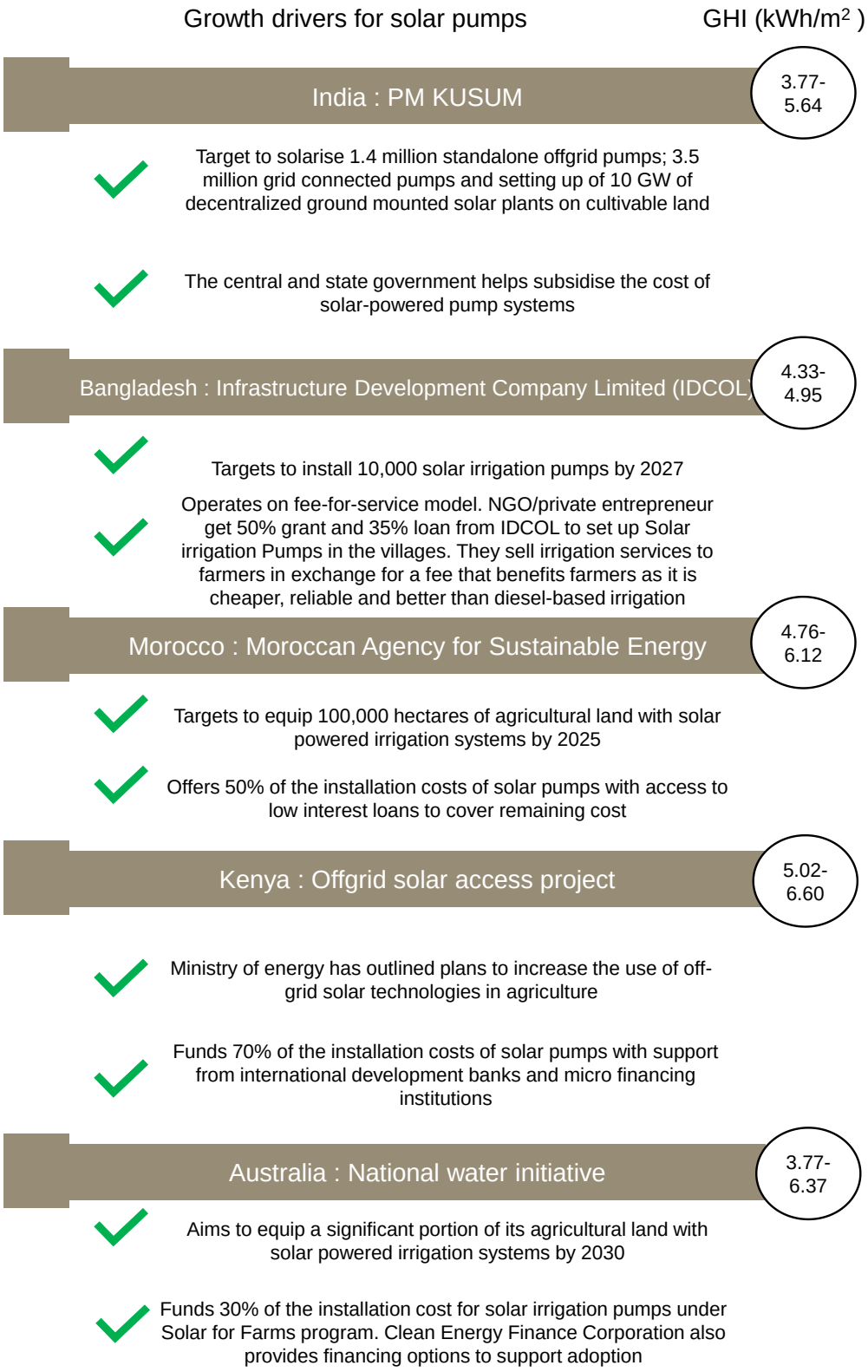


Source: IRENA, CRISIL MI&A Research

Estimates suggest that 1 MW of power output would translate to 250-450 solar-powered pump systems in India, basis the average power output of solar-powered pump systems installed in the country.

India's agriculture land as share of land area was 60% while that of Bangladesh was 77%. These economies also benefit from a good global horizontal irradiance and have policies/incentives in place to promote installations of solar-powered pump systems.

Figure 5: Policy measures in place to boost solar adoption



Note: GHI stands for global horizontal irradiance.

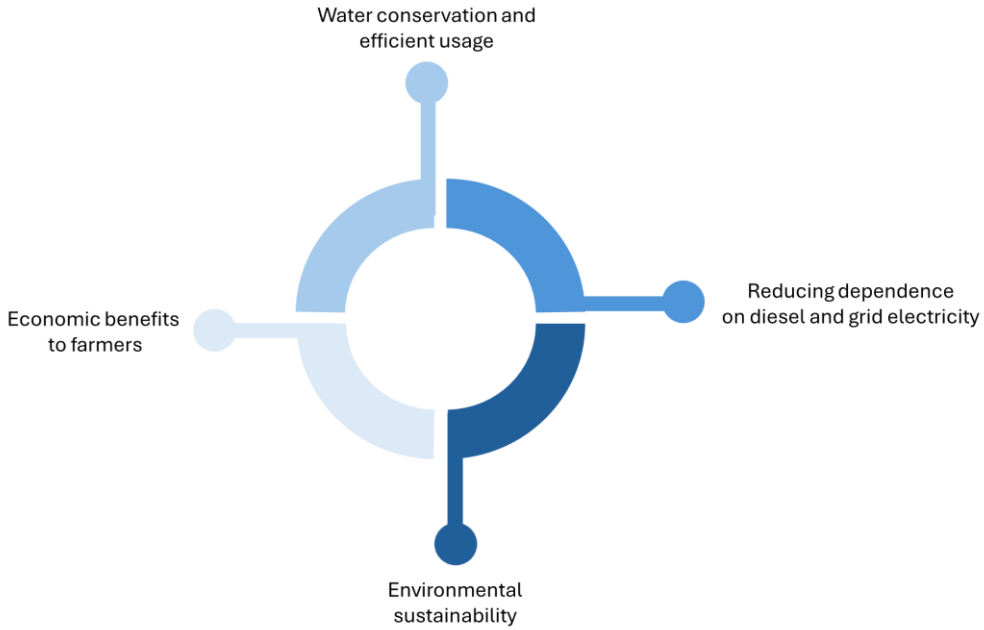
Source: Global Solar Atlas, Asian Development Bank, Government websites, CRISIL MI&A Research

Need for solar-powered pump systems in India

India as a country has a large agricultural base with more than 42.3% of its population depending on agriculture for their livelihood, as of 31 March 2024. In fact, as per the PM-KISAN, the number of farmer beneficiaries reached nearly 118 million. Indian farmers are heavily dependent on erratic monsoons and groundwater extraction for irrigation, both of which face significant challenges. As per government report on PM-KUSUM, as of 2022, 8 million pumps out of approximately 30 million agriculture pumps installed in India were diesel based. Furthermore, the total diesel consumption of these pumps in a year was 5.52 billion litre per annum along with equivalent CO_2 emissions of 15.4 million tonnes. The balance 22 million pumps largely relied on grid electricity where challenges such as limited supply of electricity (many regions provided electricity primarily at night forcing farmers to irrigate under unsafe conditions, risking accidents from wildlife and adverse weather) and frequent power cuts (extending up to 12 hours in some regions) impede the irrigation process thereby impacting agricultural productivity. Hence, the reliance on diesel pumps poses economic and environmental challenges, reliance on electricity grids poses operational issues to tackle.

In this context, the solar-powered pump systems industry looks at the robust prospect going ahead as it presents a transformative solution, offering an environmentally sustainable cost effective and reliable alternative to traditional irrigation methods. Some of the incentives a solar-powered pump systems offers are it reduces dependency on diesel and grid electricity, saves costs and increases revenue with multiple crops over the years for farmers and also conserves water. The standalone solar-powered pump systems offer a viable solution for irrigation in remote locations, hilly terrains etc. where grid connectivity is a challenge.

Figure 6: Reduction in grid dependence and improvement in farmers' income key objectives of PM KUSUM



Source: CRISIL MI&A Research

1. Reducing dependence on diesel and grid electricity

Diesel powered pumps are widely used in Indian agriculture due to limited access to grid electricity, especially in remote and rural areas. However, they come with high operational costs, particularly due to the volatile prices of diesel. Furthermore, access to grid electricity is inconsistent, especially in remote agricultural areas. Even in

regions where electricity is available, the supply is often unreliable, with frequent power cuts. As per government released data disclosures, rural power supply over the past five years witnessed power cuts of an average of ~3.5 hours at least per day. Farmers in many parts of India receive electricity for limited hours a day, which often forces them to irrigate during odd hours, impacting farm productivity. Solar-powered pump systems provide an irrigation solution without reliance on either diesel or grid electricity.

Table 5: A shift from diesel/grid to solar powered pump systems enables farmers to save ₹0.8-1.4 million

3 and 5 HP	Units	Diesel	Grid	PM-KUSUM	
				Non-special category states	Special category states
Cost of ownership to farmer	₹ million	1 - 2	0.19 - 0.2	0.07 - 0.11	0.04 - 0.06
Cost of ownership to government		0	0.23 - 0.24	0.1 - 0.15	0.14 - 0.22
Cost of ownership to farmers and government		1 - 2	0.41 - 0.42	0.17 - 0.26	0.18 - 0.28
Savings to farmer from shifting to solar pump		0.8 - 1.4	0.09 - 0.12		
Savings to farmers and government from shifting to solar pump		0.7 - 1.3	0.16 - 0.24		

Note: Operational expenses considered have been for a 10-year period. Excludes replacement cost of pumps.

Source: CRISIL MI&A Research

2. Environmental sustainability

Reduction in carbon emissions: India has set ambitious targets to reduce carbon emissions and transition toward renewable energy. Diesel pumps contribute significantly to carbon emissions in the agriculture sector. On an average, a 3 horsepower (HP), 5 HP, 7.5 HP and 10 HP diesel pump emit 2-3, 3-4, 4-6 and 5-7 tonnes respectively of CO_2 annually assuming 5 to 6 operational hours per day with 200 days of operations. Solar-powered pump systems, on the other hand, are a zero-emission technology once deployed. The widespread adoption of solar-powered pump systems could replace India's agricultural carbon footprint by millions of tons annually, supporting the country's commitment to the Paris agreement and its goal of achieving net zero emissions by 2070.

3. Economic benefits to farmers

a. Reduction in operational cost: Solar-powered pump systems, while having a higher initial installation cost, results in substantial long-term savings for farmers. Under the PM-KUSUM scheme, launched in 2019, the central and state governments provide subsidy making solar power pump systems more affordable for small and marginal farmers. Under this scheme, depending on state subsidy contribution and actual discovered price of the pump systems, farmers are required to pay anywhere between 5-69% of the total cost upfront, with options for financing via loans.

b. Additional income through solar power sale: An additional economic benefit of solar-powered pump systems is the ability to sell surplus electricity back to the grid. Under Component C of the PM-KUSUM scheme, farmers with solar-powered pump systems can generate more electricity than they need for irrigation and sell the excess to the grid. This provides an additional income stream.

4. Water conservation and efficient usage: As per The Energy and Resource Institute (TERI), India is one of the world's largest consumers of groundwater, with more than 60% of irrigated agriculture and 85% of drinking water supplies dependent on it. This has led to over-extraction of groundwater in many states such as Punjab, Haryana, and Uttar Pradesh, where the water table is depleting at an alarming rate. Solar-powered pump systems when combined with technologies like drip irrigation and micro irrigation can help farmers use water more efficiently. Since solar-powered pump systems operate during the day, farmers are encouraged to adopt

water efficient practices. They can run their pumps in shorter, more controlled bursts rather than keeping them running continuously, which is common with diesel pumps.

Market size of agriculture solar-powered pump systems in India

The Indian solar-powered pump systems market has experienced remarkable growth, especially driven by the PM-KUSUM initiative launched by the central government in 2019. Fresh installations of solar-powered pump systems under PM KUSUM from the beginning of Fiscal 2019 to September 2024 scaled up to approximately 0.5 million.

Within PM-KUSUM, the installed base by Fiscal 2024 was largely driven under component B to the extent of 96%. States like Maharashtra, Haryana, Rajasthan have shown high policy focus on enhancing deployment. They collectively accounted for 73% of the sanctions under component B by September 2024.

Table 6: Top three states comprise 73% of sanctions under component B of PM KUSUM

States	Sanctioned as of September 30, 2024	Share in total (%)
Maharashtra	505,000	38%
Rajasthan	262,914	20%
Haryana	197,655	15%
Uttar Pradesh	110,948	8%
Madhya Pradesh	59,400	4%
Others	206,410	15%

Note: The above data is as per dashboard accessed on 29th November 2024 on PM KUSUM portal

Source: MNRE

Table 7: PM-KUSUM state wise installations under component B

States	Installed base till September 30, 2024	Share (%)
Maharashtra	163,906	33%
Haryana	136,036	27%
Rajasthan	82,253	16%
Uttar Pradesh	53,150	11%
Jharkhand	19,254	4%
Others	44,720	9%

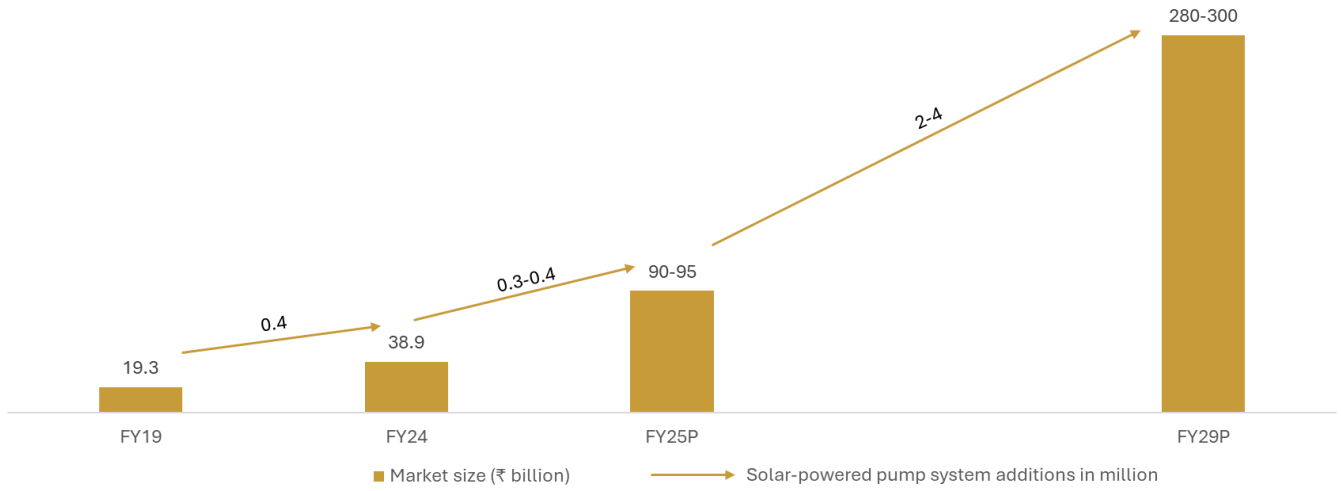
Note: The above data is as per dashboard accessed on 29th November 2024 on PM KUSUM portal

Source: MNRE

The top three states of Maharashtra (33%), Haryana (27%) and Rajasthan (16%) were cumulatively responsible for 76% of all installations in PM-KUSUM component B from the beginning of Fiscal 2019 to September 30, 2024.

The market size of domestic solar-powered pump systems logged a 15% CAGR from ₹19.3 billion in Fiscal 2019 to ~₹39 billion in Fiscal 2024. A key driver for the market has been the inclusion of other categories of players, especially EPC participants, post November 2020. This has led to a rapid rise in installation rate since the beginning of Fiscal 2022.

Figure 7: Indian solar-powered pump systems market to grow ~7 times between Fiscals 2024 and 2029



Note: The above market estimation is based on solar power pump system additions within and outside of PM KUSUM purview coupled with view on solar-powered pump system prices.

Source: CRISIL MI&A Research

Going ahead, installations are expected to be driven by policy, increased consumer awareness and player proliferation. The segment is expected to witness a multi-fold growth under the PM KUSUM initiative.

CRISIL MI&A Research expects the installed base under PM-KUSUM to increase from 0.3 million (as per "List of beneficiaries" details from PM KUSUM portal as accessed on 3rd December 2024) at the end of Fiscal 2024 to ~3.6 million by the end of Fiscal 2029. With this, nearly 65-70% of the sanctioned base under PM-KUSUM components B and C would have been installed by Fiscal 2029. This will be further supported by state-driven initiatives such as Maharashtra's Magel Tyala Saur Krushi Pump Yojana, with a similar completion rate expected against a sanction of 0.85 million by Fiscal 2029. Furthermore, the price of domestically manufactured modules (module cost accounts for 40% of the total bill of materials) is expected to fall by Fiscal 2029 owing to expansion in upstream manufacturing capacity.

Thus, CRISIL MI&A Research expects the market size to reach ₹280-300 billion by Fiscal 2029, witnessing a significant CAGR of ~49% between Fiscals 2024 and 2029. Close to 90% of the additions will be under the PM-KUSUM components B and C. The balance additions are expected to be driven by state government schemes.

Overall, the sector presents a market potential of at least ₹1.5 trillion since the beginning of Fiscal 2019 until over the course of the scheme implementation, which is expected to extend beyond Fiscal 2029. While prior to government efforts to popularise and subsidise solar-powered pump systems, farmers were hesitant to move away from AC-based power systems and diesel-powered pumps because of the high initial costs and unfamiliarity with the technology, the market's growth now can be attributed to several factors, including supportive policies, escalating diesel costs and improved affordability. The key driver are the distinct advantages solar-powered pump systems enjoy over diesel/grid pumps. These advantages include reduced dependency of the user on electricity supply and protection against motor damage caused by voltage fluctuations. These and the continuous rise in diesel prices are compelling farmers to shift to more viable solar-powered pump systems alternatives to irrigate their fields. Further, solar-powered pump systems are easily available now as there are multiple vendors in the market and their information is available on a central portal. Going forward, technological innovations, such as Internet of Things ("IoT") and Artificial Intelligence ("AI") applications, will further drive growth. IoT enables real-time

monitoring and remote control, while AI-driven predictive maintenance and smart irrigation optimise efficiency and reduce costs

Apart from this, MNRE has also proposed an update to standards and specifications for solar-powered pump systems with micro pumps. Module capacity in the range of 200 watt-peak (Wp) to 500 Wp with a motor pump capacity of 0.2 HP to 0.5 HP are expected to be deployed. The micro solar-powered pump systems are beneficial to micro, small and marginal farmers as they enable benefits of a large solar-powered pump systems at low cost suitable for their small land holdings. With over 100 million small farmers in India, the potential for micro solar-powered pump systems is also high.

Policy support at multiple levels to help improve access to solar powered pump systems for farmers

PM – KUSUM

In March 2019, the Government of India launched the Pradhan Mantri Kisan Urja Suraksha evan Utthaan Mahabhivan Scheme (PM-Kusum Scheme), with an outlay of ₹344 billion as central financial support. The objective is to install 10 GW of solar capacity under component A, 1.4 million standalone solar-powered pump systems under component B and 3.5 million grid connected solar-powered pump systems including feeder level solarisation under component C in off-grid areas to provide energy and water security for farmers, reduce the consumption of diesel, promote the use of renewable energy in the agricultural sector and reduce environmental pollution. The PM-KUSUM Scheme also focuses on the solarisation of pumps in India for agriculture. The scheme consists of three components.

Figure 8: PM KUSUM consists of three components

Component A	Component B	Component C
Set up 10 GW of decentralized ground or still mounted grid connected solar/renewable power plant on barren or cultivable land Solar power generated will be purchased by DISCOMs at a feed-in-tariff determined by SERC	Target to install 1.4 million standalone off-grid solar water pumps in off-grid areas to replace diesel pumps Individual farmers will be supported to install standalone solar agriculture pumps of capacity up to 7.5 HP in off-grid areas	Solarise 3.5 million existing grid connected agriculture pumps, reducing dependence on grid power and providing reliable, sustainable energy for irrigation

Source: PM-KUSUM, CRISIL MI&A Research

For the pump cost, under component B, the central government offers financial assistance to special and non-special states.

1. Special states: North-eastern states, Sikkim, Jammu & Kashmir, Himachal Pradesh and Uttarakhand, Lakshadweep and A&N Islands benefit from central financial assistance (CFA) of 50% of the benchmark cost.
2. Nonspecial states: Remaining states benefit from a CFA of 30% of the benchmark cost

The farmers' contribution for solar-powered pump systems is determined by two factors: the state subsidy contribution and the actual pump rates discovered during the empanelment process. Some states may offer subsidies over and above the standard 30% (non-special category states) as per the central PM KUSUM policy, and the discovered pump rates may exceed the benchmark costs set by the central nodal agency.

As a result, farmers' contribution for solar-powered pump systems can vary widely, ranging from 5% to 69%.

Table 8: Farmer's contribution ranges from 5-69% across states

State	Central share	State share	Farmer's share	State	Central share	State share	Farmer's share
Maharashtra	22-24%	68-73%	5-10%	Karnataka	29-31%	48-51%	18-24%
Haryana	23%	35%	42%	Manipur	23-26%	23-26%	49-53%
Rajasthan	19-25%	19-25%	49-61%	Nagaland	25-27%	25-27%	47-50%
Uttar Pradesh	22-24%	22-24%	53-57%	Odisha	18-20%	18-20%	61-64%
Gujarat	23-26%	23-26%	48-55%	Jammu and Kashmir	38-45%	23-27%	28-39%
Tamil Nadu	23-25%	23-25%	50-53%	Jharkhand	21-24%	47-53%	22-32%
Punjab	19-26%	19-26%	48-62%	Uttarakhand	47-52%	28-31%	16-25%
Himachal Pradesh	19-52%	12-31%	16-69%	Arunachal Pradesh	16-20%	16-20%	61-69%

Source: PM-KUSUM, SERC, CRISIL MI&A Research

Higher state subsidy contribution than the recommended 30% (non-special category states) under PM KUSUM help greatly reduce the final burden on the farmer. To provide a perspective, the agricultural power consumption from two of the leading solar pump states, Haryana and Maharashtra, accounted for nearly 20% of the India's agricultural power consumption in Fiscal 2023. This led to the promotion of solar-powered pumps systems being a significant policy area for the two states. Consequently, Maharashtra announced to provide solar-powered pumps to 0.85 million farmers under Magel Tyala Saur Krushi Pump Yojana and Haryana also increased its state subsidy contribution to 45%.

As a result, these two states have accounted for 60% of total installations by September 2024 under PM-KUSUM Component B. This high penetration is also supported by the CFA under PM KUSUM, where Haryana and Maharashtra accounted for 48% of the total CFA released between Fiscal 2021 to June 2023 (₹7,262 million). Rajasthan is emerging as another active state with a rising rate of solar-powered pump system installations under PM-KUSUM and has witnessed CFA of ₹4,532 million over the same period.

The major beneficiaries of the PM-KUSUM scheme are individual farmers (with priority given to micro, small and marginal farmers), farmer cooperatives, panchayats, and Farmer Producer Organizations (FPOs). The scheme provides financial support for the installation of solar-powered pump systems and promotes sustainable agricultural practices. State and central governments also benefit from the PM-KUSUM scheme through decentralized solar power and subsidy reduction. The scheme supports broader socio-economic and environmental goals, contributing to sustainable development in rural areas.

Benefits of solar-powered pump systems:

1. Reduction in electricity costs: By installing solar-powered pumps, farmers can harness free solar energy, leading to substantial savings on electricity and fuel costs for both farmers and the government.
2. Enhanced irrigation efficiency: Solar-powered pump systems ensure a consistent water supply during the day, which is beneficial in regions with uncertain electricity supply during daytime. This reliability allows farmers to irrigate their crops more efficiently, leading to better crop yields and more consistent agricultural output.
3. Energy independence: Solar installations provide farmers with greater control over their energy resources, reducing their dependency on grid power or expensive diesel generators.

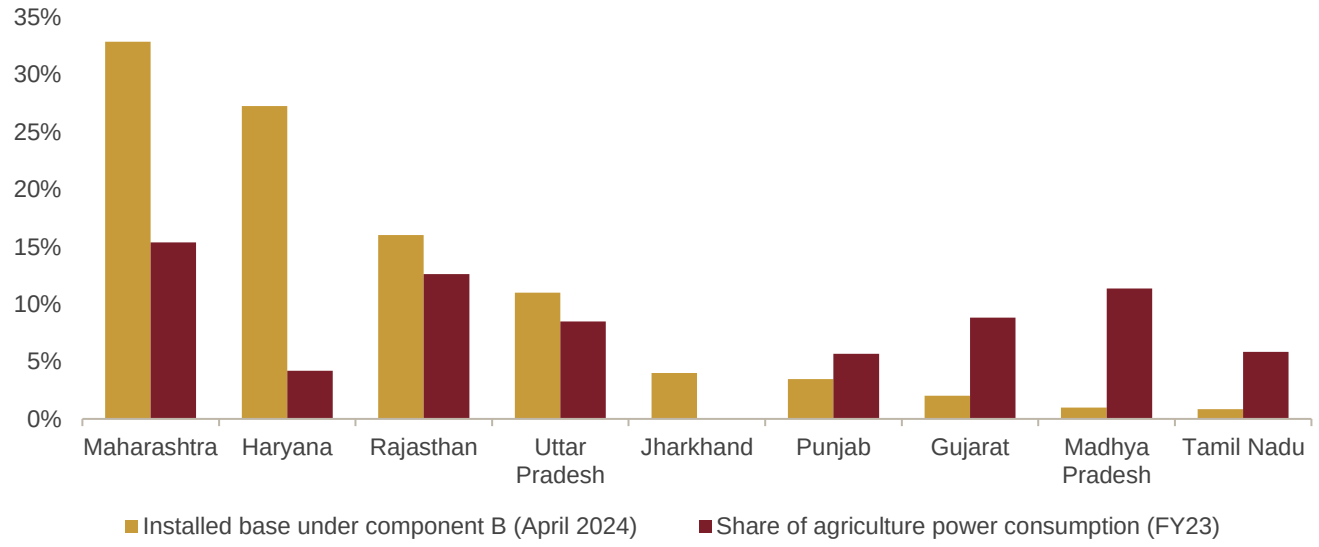
4. Long-term financial benefits: Solar-powered pump systems and installations have low operational and maintenance costs compared to traditional diesel pumps. While the initial capital cost of solar-powered pump systems is higher, the operating expenses are low at ₹2,000-3,000 per annum. On the other hand, the operational expenses for a diesel pump are ₹0.06-0.16 million per annum for a 3 and 5 HP pump. The long lifespan of solar equipment translates to lower long-term costs, further enhancing the economic viability for farmers.
5. Less capex and subsidy outflow requirement from DISCOM: It also reduces capital expenditure needs of the government to set up distribution infrastructure in rural / remote areas. Discoms lose large amounts of cash while supplying subsidised power to agricultural consumers. Agricultural connections are prone to power theft and/or unthoughtful use of power (using cheap inefficient equipment) resulting in huge losses to discoms. Solar-powered pump systems will help reduce the subsidy burden for the government as well as relieving farmers from erratic and staggered supply of power.

As per PM-KUSUM guidelines released on 22nd July 2019, only manufacturers of solar-powered pump systems, controllers or solar panels were allowed to participate in the bidding process to ensure quality and post installation servicing. However, this was later amended on 13th November 2020 with the scope of participation extending to those who formed joint ventures with such manufacturers.

Out of the total 4,99,319 solar-powered pump systems installed by the end of September 2024 (as per data accessed from PM KUSUM dashboard), the states of Maharashtra, Haryana and Rajasthan accounted for a lion's share of 76% in the installations owing to high irrigation requirements. To provide a perspective, the power consumption in the agriculture segment for these three states accounted for 37% of pan India agricultural power consumption in Fiscal 2022-23. The remaining solar-powered pump systems were contributed by the states of Uttar Pradesh (11%), Jharkhand (4%), Punjab (3%), Gujarat (2%), Madhya Pradesh (1%), Odisha (1%), Tamil Nadu (1%), Tripura (0.6%), Jammu and Kashmir (0.3%), Karnataka (0.3%).

Nearly 97% of the additions were under component B of PM-KUSUM from the beginning of CY2022 to the end of H1 Fiscal 2025.

Figure 9: States that dominate agricultural power consumption take the lion's share under component B



*Note: * PM-KUSUM data as accessed from PM-KUSUM dashboard provided till 30th September 2024*

Source: PM-KUSUM, CRISIL MI&A Research

Table 9: Player wise share in installations

Players	Type of player	Installations under PM KUSUM		
		CY 2022	CY 2023	CY 2024*
Shakti Pumps Limited	Pump manufacturer	28,376	11,227	24,797
GK Energy Limited	Pure play EPC	6,975	10,392	6,860
Avi Appliance Private Limited	Pure play EPC	1,375	6,630	6,138
Oswal Pumps Limited	Pump and module manufacturer, EPC services	14	3,424	5,642
Rotomag Motors and Controls Private Limited	Pump manufacturer	8,905	6,374	4,228
Icon Solar En Power Technologies Private Limited	PV module manufacturer	4,844	6,585	2,854
Sahaj Solar Private Limited	PV module manufacturer	2,555	3,799	2,689
Akshaya Solar Power Private Limited	Pump and module manufacturer	2,701	3,000	588
Gautam Solar Private Limited	PV module manufacturer	4,392	4,967	212
Tata Power Solar Systems Limited	Module manufacturer	29,005	23,980	16

Note:

** PM-KUSUM data accessed from PM-KUSUM "List of beneficiaries" as on 3rd December 2024*

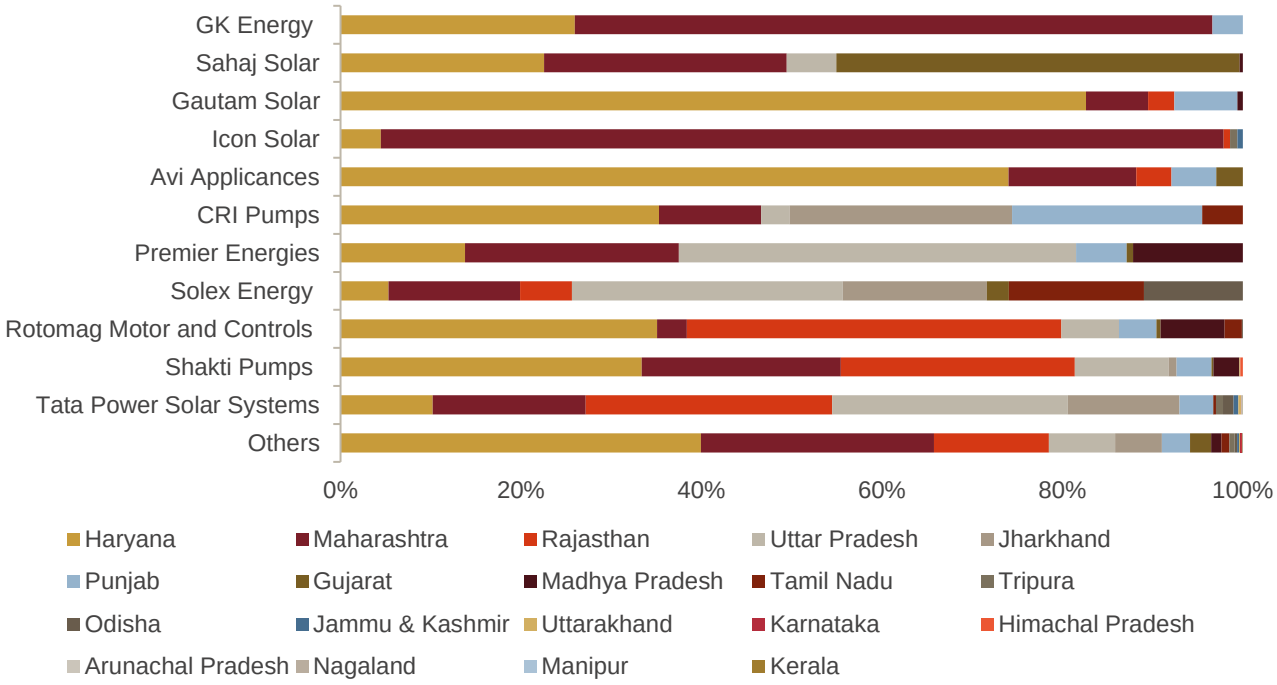
Order of the players sorted in order of installations as on CY 2024.

Source: PM-KUSUM, CRISIL MI&A Research

The industry is characterised by a diverse range of players, across photovoltaic (PV) module and pump manufacturers and engineering, procurement, and commissioning (EPC) companies. Shakti Pumps emerged as the leading pump manufacturer on an average across past three years, while GK Energy was the largest pureplay EPC player in terms of installations. To provide a perspective on concentration, from 1st of January 2022 till 3rd of December 2024, top 10 players in the solar-powered pump systems market accounted for an average of 73% of share.

Further upon examining state-wise dynamics, player share varied significantly. Out of the 3,83,982 solar-powered pump systems installed (as per data accessed from PM KUSUM "List of beneficiaries" as on December 3, 2024), markets across most states were dominated by 5 to 10 players.

Figure 10: Player presence across states (PM-KUSUM)

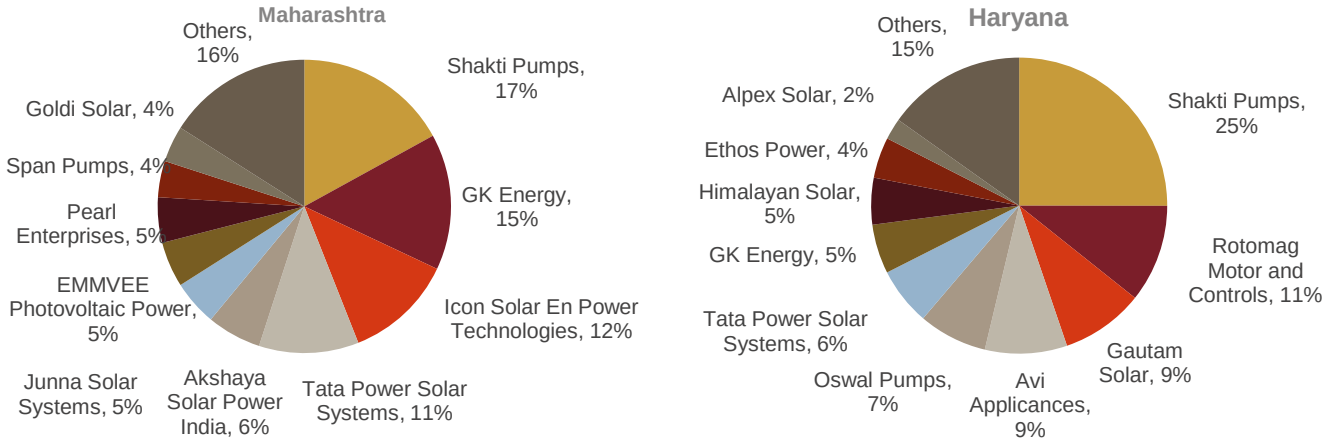


*Note: *PM-KUSUM data accessed from PM-KUSUM "List of beneficiaries" as on 3rd December 2024*

The graph denotes the share of a particular state in a player's portfolio. Order of the players in ascending order of their presence in count of states.

Source: PM-KUSUM, CRISIL MI&A Research

Figure 11: Ten players account for 85% of the installations under PM KUSUM in Maharashtra and Haryana

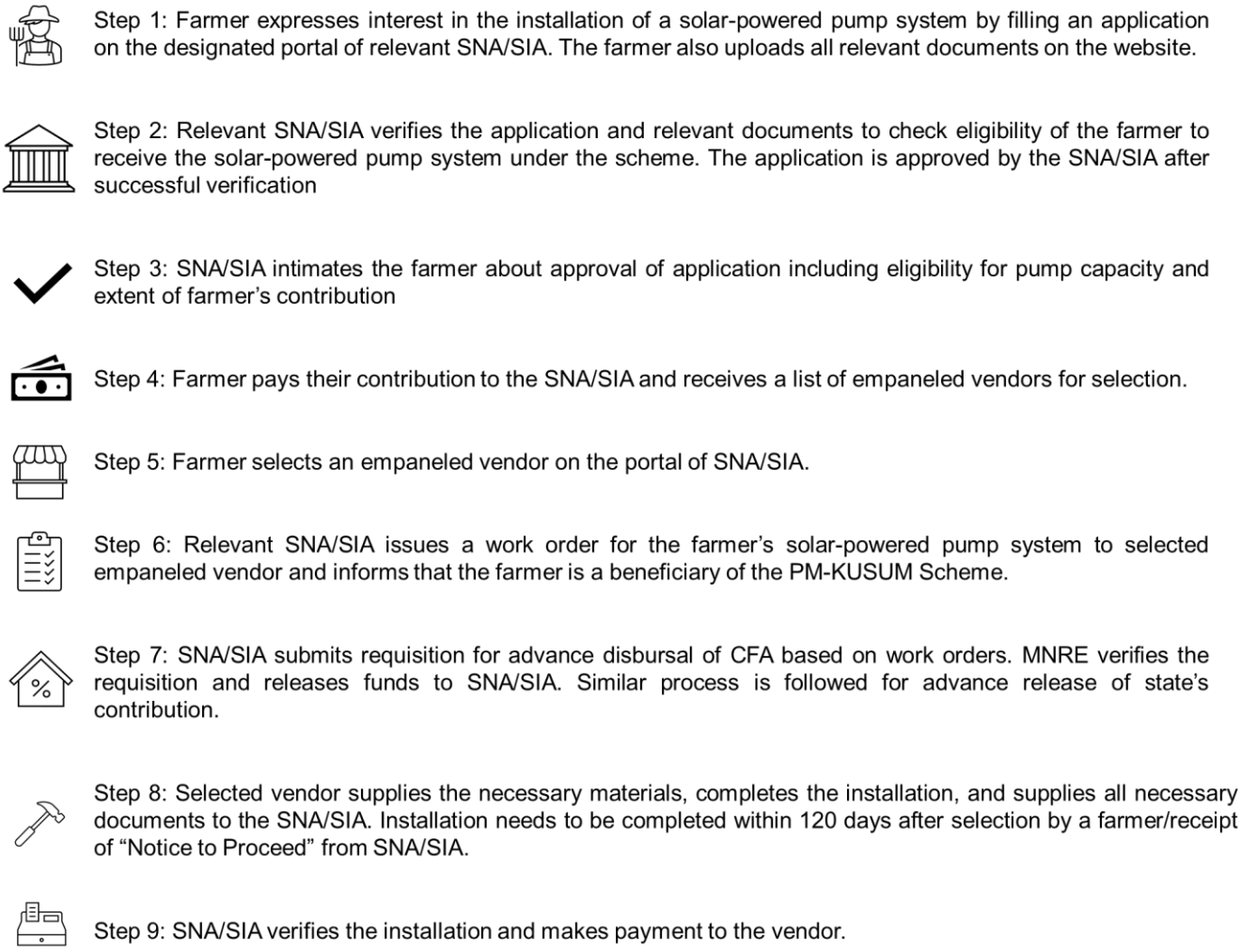


Note: Share calculated as per data accessed from PM-KUSUM "List of beneficiaries" as on 3rd December 2024.

Source: PM-KUSUM, CRISIL MI&A Research

The execution process under PM-KUSUM follows the major steps as outlined below:

Figure 12: Process under PM KUSUM



Note: SNA/SIA – State nodal agency / state implementation agency

Source: CRISIL MI&A Research

Mukhyamantri Saur Krushi Pump Yojana

The Maharashtra government launched a scheme in 2019 to provide farmers with solar-powered pump systems, reducing their dependence on conventional electric or diesel pumps and addressing irregular power supply in rural areas. The scheme aimed to reduce electricity bills, ensure uninterrupted irrigation, and achieve the state's target of reducing greenhouse gas emissions and improving agricultural productivity. The beneficiary's contribution was limited to 5-10% of the total price for the pump system. The scheme was applicable for three years and has successfully deployed nearly 100,000 solar-powered pump systems, benefiting thousands of farmers.

Magel Tyala Saur Krushi Pump Yojana

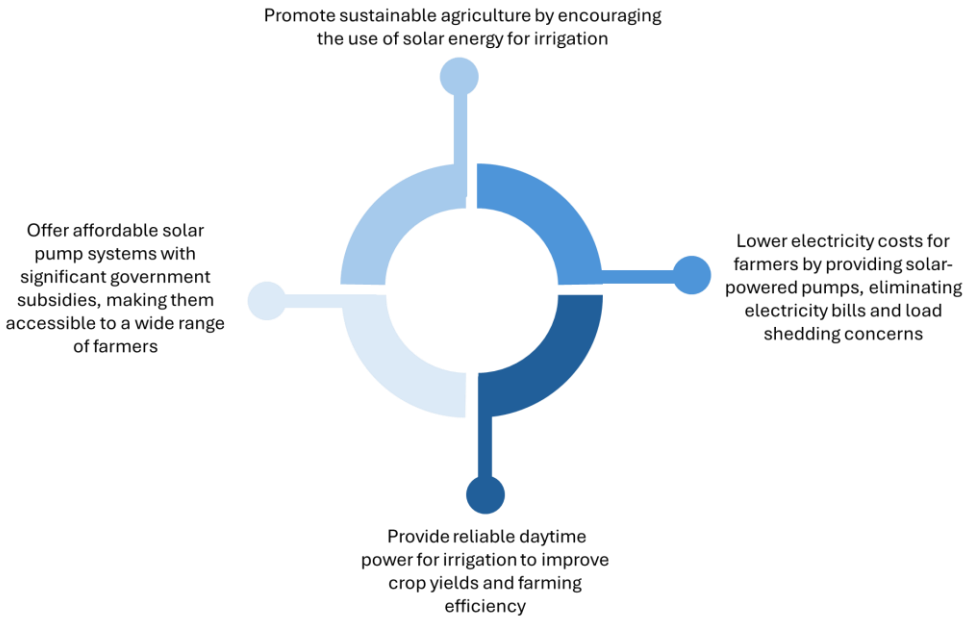
The Government of Maharashtra, having seen the success of Mukhyamantri Saur Krushi Pump Yojana, and PM-KUSUM, and considering the significant benefits to farmers and the state, as well as the significant demand for solar-powered pump systems, launched another initiative in the form of the Magel Tyala Saur Urja Yojana. This initiative was aimed at providing sustainable solar-powered irrigation solutions to farmers. Currently, tenders of 0.1 million solar-powered pump systems have been initiated under the scheme. Under this, farmers can install solar

panels and agricultural pumps with minimal upfront costs. The state subsidy ensures farmers must only bear 10% of the total cost (upto 7.5 HP pumps) for general category farmers and 5% for Scheduled Caste and Scheduled Tribe farmers. Additionally, the scheme includes a five-year repair guarantee and insurance. By eliminating electricity bills, it ensures reliable daytime power for irrigation, benefiting farmers with access to water sources like wells and borewells.

The scheme includes eligible applicants with individual or community water sources. Furthermore, farmers who have not previously benefited from any of the earlier schemes are eligible to receive benefits under the Magel Tyala Saur Krushi Pump Yojana.

The objectives and benefits of the scheme include:

Figure 13: Objectives of PM KUSUM



Source: MahaVitaran, CRISIL MI&A Research

The application process under the scheme is as follows

Figure 14: Process under Magel Tyala Saur Krushi Pump Yojana

Step 1: Farmer expresses interest in the installation of a solar-powered pump system by filling an application on the designated portal of relevant SNA/SIA. The farmer also uploads all relevant documents on the website

Step 2: Relevant SNA/SIA verifies the application and relevant documents to check eligibility of the farmer to receive solar-powered pump systems under the scheme. The application is approved by the SNA/SIA after successful verification

Step 3: SNA/SIA intimates the farmer about approval of application including eligibility for pump capacity and extent of farmer's contribution

Step 4: Farmer pays their contribution to the SNA/SIA and receives a list of empaneled vendors for selection

Step 5: Farmer selects an empaneled vendor on the portal of SNA/SIA.

Step 6: Relevant SNA/SIA issues a work order for the farmer's solar-powered pump system to selected empaneled vendor and informs that the farmer is a beneficiary of the Magel Tyala Saur Krushi Pump Yojana.

Step 7: SNA/SIA submits a requisition to the state for advance disbursal of CFA based on work orders. State verifies the requisition and releases funds to SNA/SIA.

Step 8: Selected vendor supplies the necessary materials, completes the installation, and supplies all necessary documents to the SNA/SIA. Installation needs to be completed within 120 days after selection by a farmer/receipt of "Notice to Proceed" from SNA/SIA.

Step 9: SNA/SIA verifies the installation and makes payment to the vendor.

Note: SNA/SIA – State nodal agency / state implementation agency

Source: MahaVitaran, CRISIL MI&A Research

A farmer receives updates via SMS at every step of the process. The state presents a robust opportunity to the solar-powered pump systems industry as ~4.4 million farmers of the total 9.1 million individual farmer beneficiaries in the state rely on grid electric pumps while the balance await connections.

Chattisgarh's Saur Sujala Yojana

The Saur Sujala Yojana aims to provide solar-powered pump systems to farmers at subsidised rates to increase agricultural production and conserve groundwater. Launched in 2016, the scheme offers 3 HP and 5 HP surface and submersible solar-powered pump systems with a 5-year on-site warranty and maintenance. The Chhattisgarh State Renewable Energy Development Agency (CREDA) implements the scheme, and beneficiaries are selected by the agricultural department. Farmers contribute a portion of the installation cost, with varying amounts based on category. The scheme aims to empower farmers, strengthen the rural economy, and promote sustainable agriculture practices. The beneficiary's contribution in the scheme ranges from ₹7,000 to ₹20,000 depending on various pump capacities and caste.

In addition to the beneficiary contribution, a processing fee of ₹1 per watt (₹3,000 for 3 HP / 3,000 watt and ₹4,800 for 5 HP / 4,800 watt) has to be paid.

As of March 2024, more than 0.1 million solar-powered pump systems have been installed under the scheme.

Initiatives to improve scale and propagate benefits needed for solar powered pump systems

Despite state and central government subsidy to promote usage of solar power pumps, the adoption has been slow in the past. However, recent trends show that the installations have picked up pace with better product awareness and visible benefits to farmers already using solar-powered pump systems. Additions in the 6 months of April to September 2024 were already 47% of the cumulative pumps installed over April 2018 to March 2024.

The two areas of concern for the sector initially have been high initial costs with savings accruing later and gradual spread of awareness on benefits.

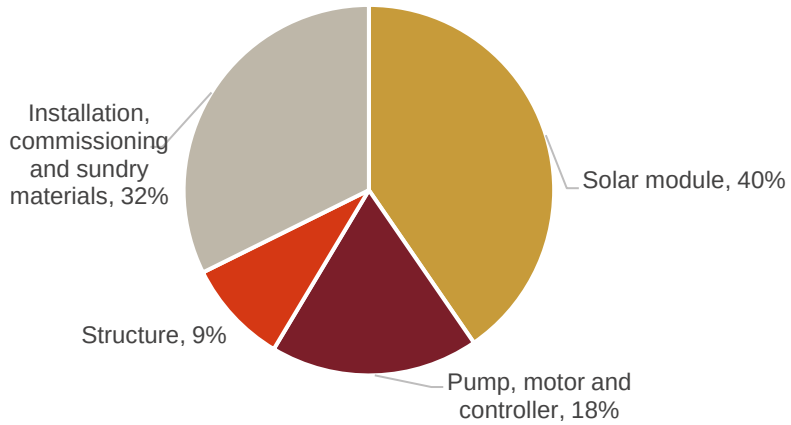
Figure 15: Solar-powered pump systems cost and awareness outreach remain opportunity areas

Source: CRISIL MI&A Research

Pricing trend of key raw materials

The cost breakdown of a solar powered pump typically involves three main components: Steel (for the pump and support structures), copper (for electrical wiring and components) and the solar module. Collectively these account for more than 40% of the cost of solar-powered pump systems.

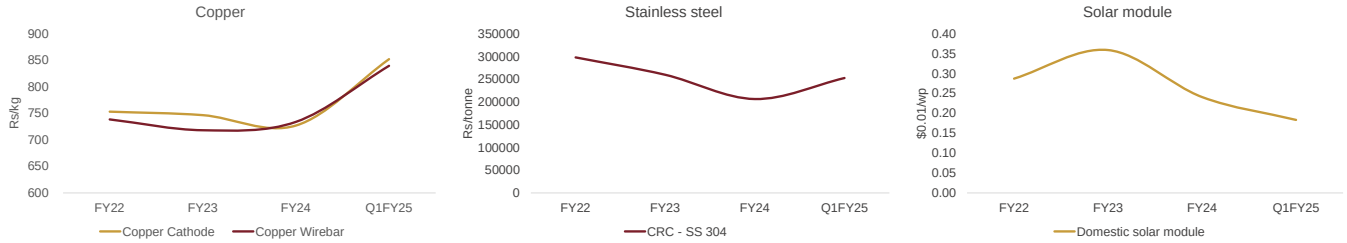
Figure 16: Solar modules, pumps, motors and controllers account for 58% of the bill of materials



Source: Industry, CRISIL MI&A Research

The ability to pass through copper, steel and solar module costs or otherwise mitigate impacts the profitability of the industry. Within the cost structure for solar powered pump systems, the share of EPC related services is the second largest component at 32% after solar modules and is thus a critical area of the solar powered pump system value chain.

Figure 17: The price of key inputs has remained volatile over the past three Fiscals



Note: Copper prices are provided for cathode and wirebar while steel prices considered for CRC – SS 304. Module prices are considered for domestic modules made using imported cells.

Source: CRISIL MI&A Research

Between Fiscal 2022 and Q1 of Fiscal 2025, copper and stainless-steel prices fluctuated due to global dynamics. Copper prices dropped from Fiscal 2022 to 2024, then surged in Q1 of Fiscal 2025, driven by increased demand in renewable energy and electric vehicles, as well as supply chain constraints and the Russia-Ukraine conflict. Stainless-steel prices followed a similar trend, dropping sharply between 2022 and 2024 due to reduced construction and manufacturing activities, then recovering in Q1 of Fiscal 2025 driven by increased demand in infrastructure projects and industrial applications, as well as rising raw material and energy costs influenced by geopolitical tensions. On the other hand, solar modules have witnessed a sharp fall over the years, except a blip in Fiscal 2023, owing to the oversupply supply of upstream components such as polysilicon, wafers and cells with the supply capacity being at least two times that of demand in 2023. On the domestic front, the sharp fall of 78% in Q1 Fiscal 2025 over Fiscal 2022 and 53% over Fiscal 2024 in imported wafer prices has helped reduce prices of Indian cells, resulting in moderation in prices of Indian-made solar modules. With the global oversupply situation likely to continue in Fiscal 2025, the prices of modules made using domestic cells are expected to be muted despite low cell manufacturing capacity in India.

Competition landscape in the solar powered pump segment

Diverse set of players function in the solar powered pump systems market. Business activity ranges from manufacturing a variety of pumps, providing EPC services across multiple verticals and specialising in only a specific component of the value chain.

Table 10: Operational profile comparison of key players from the industry

Players	Installation in 2022	Installation in 2023	Installation in 2024	Latest order book (₹ billion)	Product profile/business presence
GK Energy Limited	7,633	10,600	24,545	7.6	Solar agriculture pump, solar photovoltaic module, Solar water pump controller, solar rooftop
Shakti Pumps Limited	28,376	11,227	24,797	18	Submersible pumps, centrifugal pumps, firefighting pumps, sewage and waste-water pumps, solar-powered pump systems, motors, controllers, inverter, tracker, cable
Oswal Pumps Limited	14	3,424	5,642	8.21	Solar, domestic, industrial, agriculture and pump controller

Notes:

Installations:

GK Energy installations are as per company disclosures as of 30th November 2024.

Shakti Pumps' and Oswal Pumps' installations are on a calendar year basis as per data accessed from PM KUSUM "List of beneficiaries" as on 3rd December 2024

Order book: GK Energy's order book is as of 1st October 2024;

Shakti Pump's order book is as of 30 September 2024; Oswal Pumps' order book is as of 31 July 2024

Source: Rating rationales, Company filings, PM-KUSUM, CRISIL MI&A Research

Table 11: Financial profile comparison of key players from the industry

		GK Energy Limited					Shakti Pumps Limited					Oswal Pumps Limited		
Financial parameters	Units	6MFY25	6MFY24	FY24	FY23	FY22	6MFY25	6MFY24	FY24	FY23	FY22	FY24	FY23	FY22
Revenue from operations	₹ billion	4.22	1.76	4.11	2.85	0.70	12.02	2.66	13.71	9.68	11.79	7.59	3.85	3.60
Revenue from operations growth	%	139.76%	NA	44.23%	304.63%	NA	352.21%	NA	41.65%	(17.89%)	NA	97.01%	6.84%	NA
Operating EBITDA(1)	₹ billion	0.78	0.11	0.54	0.17	0.05	2.85	0.23	2.25	0.67	1.10	1.50	0.58	0.39
Operating EBITDA margin(2)	%	18.56%	6.04%	13.09%	6.03%	7.12%	23.67%	8.70%	16.40%	6.88%	9.37%	19.79%	15.02%	10.69%
Profit after Tax(3)	₹ billion	0.51	0.06	0.36	0.10	0.02	1.94	0.07	1.42	0.24	0.65	0.98	0.34	0.17

		GK Energy Limited					Shakti Pumps Limited					Oswal Pumps Limited		
Financial parameters	**Units**	**6MFY25**	**6MFY24**	**FY24**	**FY23**	**FY22**	**6MFY25**	**6MFY24**	**FY24**	**FY23**	**FY22**	**FY24**	**FY23**	**FY22**
Profit after Tax Margin[4]	%	12.06%	3.46%	8.75%	3.53%	2.20%	16.03%	2.56%	10.31%	2.49%	5.47%	12.83%	8.83%	4.69%
Return on Equity[5]	%	47.72%	23.49%	64.49%	50.73%	17.08%	20.60%	1.62%	18.75%	5.77%	16.49%	54.48%	43.25%	38.76%
Return on Capital Employed[6]	%	29.67%	17.20%	50.10%	29.36%	15.73%	30.67%	2.81%	32.85%	10.85%	21.61%	57.42%	40.22%	27.67%
Net Debt to Equity Ratio[7]	Times	1.50	1.42	0.94	1.93	2.30	(0.02)	0.27	(0.16)	0.13	0.15	0.40	0.65	1.67
Total Borrowings[8]	₹ billion	2.03	0.39	0.62	0.43	0.24	1.61	1.36	0.83	0.73	1.05	0.75	0.59	0.88
Net Debt to Operating EBITDA[9]	Times	2.05	3.47	0.98	2.24	4.18	(0.06)	4.86	(0.53)	0.84	0.55	0.48	0.89	1.90
Net Working Capital days[10]	Days	118	42	80	51	113	94	276	124	132	91	157	80	68
Receivable days[11]	Days	135	78	135	144	224	154	176	178	92	119	115	69	38

Notes:

6M Fiscal 2025 data unavailable for Oswal Pumps Limited. Audited consolidated financials are considered for Shakti Pumps Limited, Oswal Pumps Limited and GK Energy Limited.

(1) Operating EBITDA is calculated as profit for the year/period minus other income plus finance cost plus depreciation and amortization plus tax expense for the year/period.

(2) Operating EBITDA Margin is calculated by dividing Operating EBITDA by revenue from operations.

(3) Profit after Tax is profit for the period/year is calculated as profit after tax is profit / (loss) for the year/period.

(4) Profit after Tax Margin is calculated by dividing profit/(loss) for the year/period by the total income.

(5) Return on Equity is calculated as profit attributable to the owners of the Company for the period/year divided by Shareholders Equity as at the end of the year/period. Shareholders Equity is the sum of share capital and other equity as at the last day of the year/period. For 6M Fiscal 2025 and 6M Fiscal 2024, the ratio is calculated based on 6 monthly financial parameters.

(6) Return on Capital Employed is calculated as EBIT divided by the Capital Employed. EBIT is calculated as profit for the year/period plus finance cost plus tax expense for the year/period. Capital employed is calculated as the sum of Shareholders Equity and Net Debt as at the last day of the year/period. Net debt is calculated as total borrowings reduced by current cash and bank balances as at the last day of the year/period. For 6M Fiscal 2025 and 6M Fiscal 2024, the ratio is calculated based on 6 monthly financial parameters.

(7) Net Debt to Equity Ratio is calculated as Net Debt divided by Shareholders Equity as at the last day of the year/period. Net Debt is calculated as Total Borrowings reduced by current cash and bank balances as at the last day of the year/period.

(8) Total Borrowings is calculated as current borrowings plus non-current borrowings as at the last day of the year/period.

(9) Net Debt to Operating EBITDA Ratio is calculated as Net Debt as at the last day of the year/period divided by Operating EBITDA for the year/period.

(10) Net working capital days are calculated as Receivables Days plus Inventory Outstanding Days reduced by Accounts Payables Days. Inventory Outstanding Days is calculated as closing inventory as at the last day of the year/period, divided by the cost of goods sold for the year/period, multiplied by 365. Accounts Payables Days is calculated as closing accounts payables as at the last day of the year/period, divided by the cost of goods sold for the year/period, multiplied by 365. 6M Fiscal 2025 and 6M Fiscal 2024 are calculated on the basis of 6 monthly financial parameters.

(11) Receivable Days is calculated as closing receivables as at the last day of the year/period, divided by revenue from operations for the year/period, multiplied by 365. 6M Fiscal 2025 and 6M Fiscal 2024 are calculated on the basis of 6 monthly financial parameters.

Source: Company filings, CRISIL MI&A Research

Revenue for key players increased ~1.6x in Fiscal 2024, owing to deeper penetration of solar-powered pump systems in India. Under PM-KUSUM, the solar-powered pump system capacity addition expanded 1.4x on-year last Fiscal and 1.3x already in the first half of Fiscal 2025 over Fiscal 2024. Similarly, operating profit and profit after tax expanded ~824 bps and 658 bps, respectively. Further, for some players, the share of solar-powered pump systems in their total revenue mix increased in Fiscal 2024, boosting revenue.

The Net Working Capital days were 126 days, with an average of 152 days of the receivable period against a payable period of 119 days. Receivable days remain high as the companies are exposed to government entities as a counterparty.

Module 4: Solar rooftop

Solar rooftop segmentation

The rooftop solar segment can be categorised as per consumer types into residential, commercial and industrial (C&I), government and social (institutions, colleges, hospitals, etc.). Residential rooftop solar systems are primarily aimed at individual households, with an average plant size of 1-10 kW. Consumer awareness and affordability play a key role in boosting installations in this category. C&I rooftop solar average sizes vary ranging from 30-1000 kW. This segment is driven by rising electricity costs and the need for energy independence. Lastly, government and the social categories' average plant size can vary from 10 kW to over 1,000 kW. These installations are driven not only to save energy costs but to also promote environmental awareness. All the categories may or may not be connected to the grid.

Review of global solar rooftop installations (CY 2018-2022)

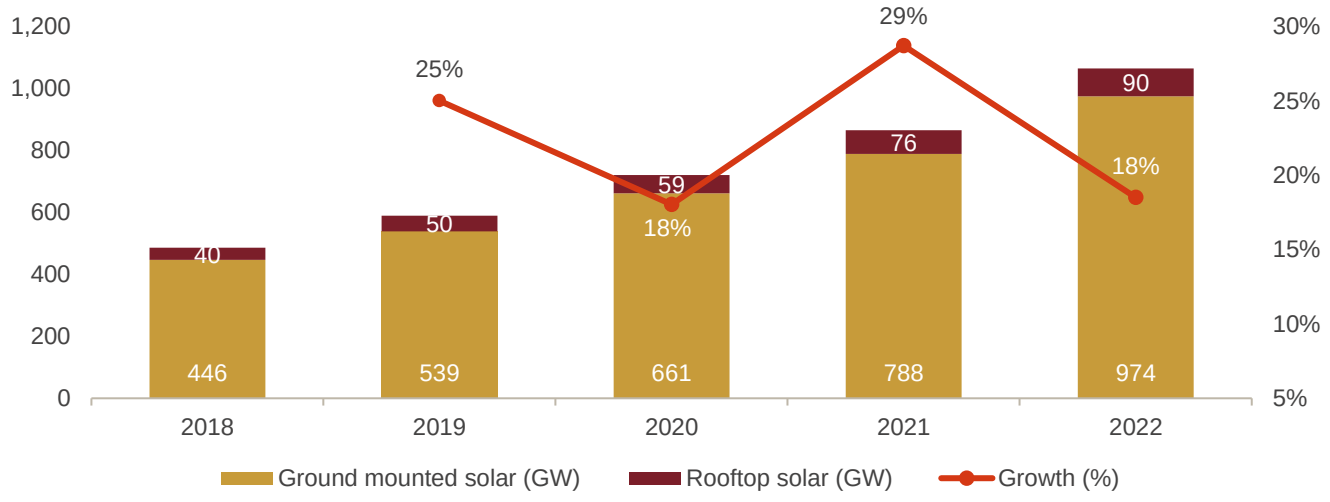
Rooftop installations on buildings are playing a major role in the global adoption of PV systems, accounting for approximately 40% of total solar installation. In various competitive environments, these rooftop systems are alleviating pressure on distribution grids, enabling both businesses and households to cut their electricity costs and helping reduce carbon emissions.

Rooftop solar close to surpassing utility-level installations to achieve biggest share in solar market additions globally

Out of the 200 GW solar PV installations globally in 2022, solar rooftop contributed ~45%. This was an 18% growth on-year from 2021. In 2021 as well, the solar rooftop segment experienced significant growth with capacity additions increasing 29% from 59 GW added in 2020.

The increase in rooftop installations was driven by the residential and commercial sectors demonstrating a strong interest in generating electricity for self-consumption. This is driven by the benefits of reducing reliance on the grid and mitigating the impact of power price fluctuations, mainly caused by fossil fuels.

Figure 18: The total global rooftop installed base grew at a CAGR of ~24% from 2018 to 2022



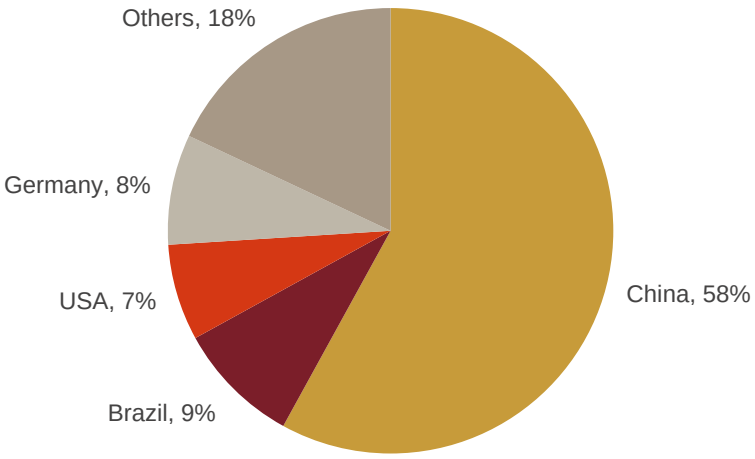
Source: IEA, IRENA

Four key countries drive growth especially through the residential segment

The distributed solar PV sector, encompassing small-scale power generation projects under 1 MW such as residential, commercial, industrial, and off-grid systems, is gaining traction due to favourable economic factors and policies. Key markets emerging in this sector include China, the US, Brazil and Germany.

The significant increase in global solar rooftop capacity has been driven by three major countries, China, the US, Brazil and Germany, contributing more than 80% to the global rooftop additions in 2022 as per data reported by National Renewable Energy Laboratory (NREL).

Figure 19: Solar rooftop additions in CY2022



Source: NREL, IEA, CRISIL MI&A Research

Favourable policies coupled with low PV system costs spur the global rooftop segment

While the policies that have resulted in solar rooftop growth are specific to each country, there are a few common drivers leading to high growth in the segment. These are high retail electricity costs, low PV system costs, and spare roof space.

Reduced PV system costs

Between 2010 and 2022, the average installed cost of PV worldwide declined consistently, largely due to the increased availability of materials, which led to reduced production expenses. Over the past decade, the cost of equipment and installation has decreased by more than 80%. China's focus on continuous innovation and development of a complete industrial chain has played a significant role in driving down production costs and making new energy products more affordable globally.

High retail electricity costs

Globally, solar rooftops offer a way for consumers to reduce dependence on traditional energy sources and mitigate the impact of fluctuating energy prices. In countries with high retail electricity prices, such as Brazil, Australia and the USA, consumers are motivated to seek energy independence. Rooftop solar systems enable individuals to generate their own power, thereby reducing reliance on centralised grids.

New business models

The adoption of rooftop solar PV systems is accelerating due to innovative business models and policy frameworks. Net billing and rental/lease options make solar energy more accessible, while new policies enable the sale of excess energy to third parties or neighbours. These developments maximize economic benefits, facilitate community-based solutions, and enhance the feasibility and attractiveness of solar PV systems for individuals and communities, driving sector growth.

Government incentives and regulatory support

Many countries offer subsidies, tax credits, and other incentives, which are crucial for the adoption of rooftop solar systems. Supportive policies and regulations, such as net metering and renewable energy mandates, have significantly contributed to the growth of solar rooftop installations.

China: China's Whole-County Rooftop Solar policy has been successful in promoting solar energy adoption at the county level. The policy involves partnering counties with large PV developers to cover a substantial percentage of rooftops within a specified timeframe. In 2021, 676 pilot projects were introduced across 31 provinces, driving significant progress in solar PV deployment.

Brazil: Brazil has established a new regulatory framework for distributed generation, covering renewable energy power generators up to 5 MW which are operating under a net metering regime. The framework ensures eligibility for net metering tariffs until 2045 and guarantees that projects installed by 2022 will not be subject to grid fees introduced in 2023. This aims to maintain economic attractiveness for Brazilian prosumers using rooftop PV and small solar parks.

USA: Federal policy has significantly supported the adoption of residential solar rooftop installations. The residential energy efficient property credit, which provided a 30% tax credit for solar panels, was available until the end of 2019. This credit decreased to 26% by the end of 2020 and 22% by the end of 2021.

Australia: The federal government's renewable energy target is a key support mechanism for rooftop PV systems under 100 kW. Additionally, several jurisdictions offer no-interest loans for solar PV systems and batteries, further facilitating the adoption of renewable energy solutions.

Germany: Germany has a rooftop solar technical potential of 409 GW as per market estimates, nearly twice the total solar PV 2030 target set by the federal government. The consistent increase in Germany’s rooftop solar deployment, particularly in the 0–30 kW category, has been driven by government programmes and legislation such as the 1,000 roofs and 100,000 roofs programme, the Renewable Energy Sources (EEG) Act, and solar package I.

Domestic solar market

Solar energy segment is categorized into two segments: utility and distributed

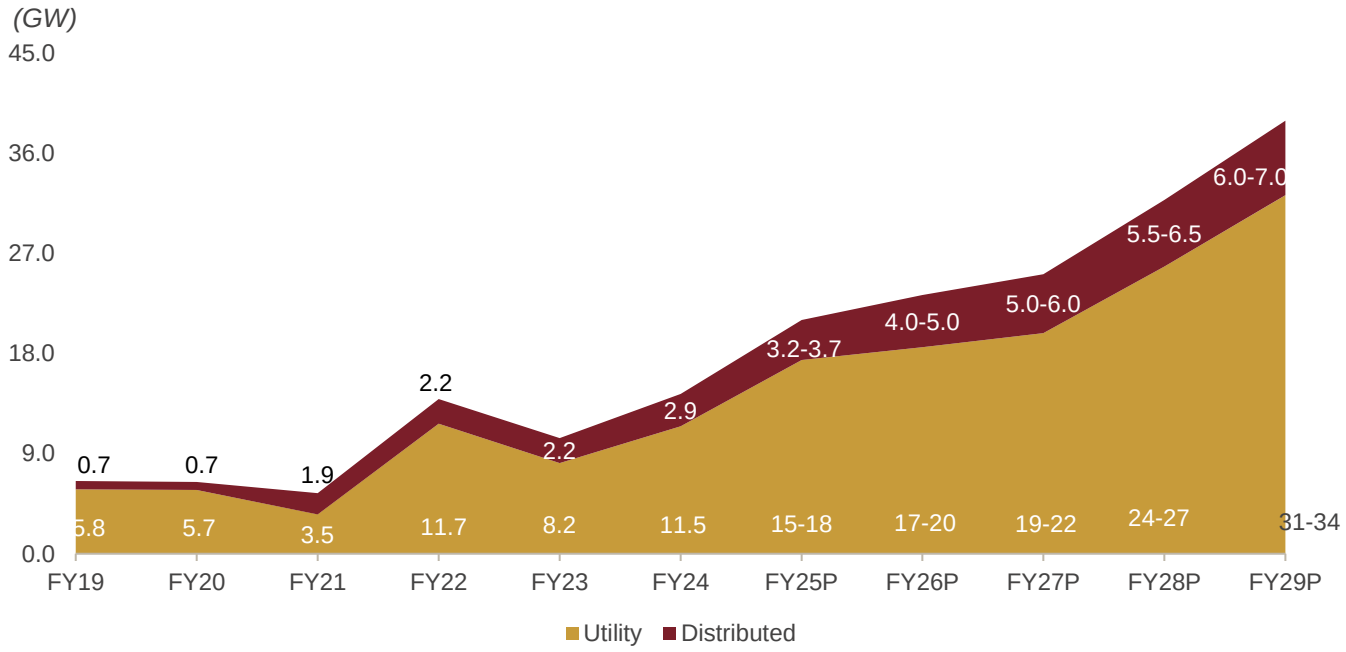
Utility-scale solar projects: These are large-scale power plants that generate electricity from solar energy, typically with a capacity of over 5 MW. These projects are ground-mounted and connected to the transmission or distribution grid. They sell electricity to wholesale utility buyers or markets under long-term power purchase agreements and operate as independent power producers.

Distributed solar photovoltaic (PV) systems: These are small-scale installations, rooftop-mounted, ground mounted or integrated into buildings, with a capacity of less than 5 MW. These systems generate electricity for on-site use and export excess power back to the grid. They are connected to the distribution network and typically operate under net metering arrangements or feed-in tariffs with utilities.

Simply put, utility solar plants are larger-scale facilities that generate electricity in bulk to be used by multiple customers, while distributed solar systems are useful for individual homes and businesses.

The total installed capacity in India of the utility segment (competitively bid solar power plants and open access solar) was 72.6 gigawatt (GW) as of September 2024, while that of the distributed segment (solar rooftop and off grid) was 18 GW. The government has set a target of achieving 40 GW of rooftop solar by March 2026. In the next five Fiscals over Fiscals 2025 to 2029, we expect an addition of 112-118 GW capacity under the utility segment and 25-27 GW in distributed.

Figure 20: Solar additions of 137-145 GW expected over Fiscals 2025-2029



Note: Utility includes competitive bidding and open access projects

Source: MNRE, CRISIL MI&A Research

Domestic solar rooftop market

Solar rooftop segments in India operate primarily through two business models

In the context of a solar power plant, a business model involves generating revenue through the sale of produced energy or savings by consuming the generated electricity. For consumers and investors, selecting the appropriate business model is crucial to reduce risks and maximise returns.

The two most prevalent models of operation in rooftop solar PV plants are the capex and Renewable Energy Service Company (RESCO) models. In the capex model, the project developer installs the rooftop power plant on its own roof, while in the RESCO (also known as operating expenditure (opex) model), the developer utilises the rooftop, and receives proceeds from the sale of power to the rooftop owner and discom, on a mutually agreed power purchase agreement price.

In the capex model, the consumer owns the solar system and bears all upfront costs, including setup, maintenance, and operation, as well as expenses for equipment, labour, upgrades, and materials. Majority of the rooftop solar installations in India fall under this model.

The RESCO model involves the developer owning the solar project and using the consumer's rooftop for installation. The developer sells power to the consumer at a lower rate than the grid tariff, ensuring profitability.

Customers pay only for the electricity used, not the solar system. They sign a long-term agreement for rooftop use and a power purchase agreement (PPA) for up to 25 years at a fixed rate. The power generated can be sold to the utility (gross metering) or partly consumed and sold to the utility (net metering), with a cap on capacity connected to the grid. Net metering is more prevalent due to state rooftop policies.

For improving the pace of solar rooftop installations in the residential segment, the government launched the PM Surya Ghar Yojna in 2024 which provides a subsidy of ₹30,000 per kW for plant sizes up to 2 kW. For plant sizes of 3 kW and above, the maximum subsidy available is ₹78,000. Along with this, housing Societies will also be given a subsidy of ₹18,000 per KW for rooftop solar plants up to 500 KW for common area lighting, EV charging, etc. Furthermore, states like Maharashtra have also approved a target of installing 2 million solar rooftop projects under the PM Surya Ghar Yojna to boost residential rooftop solar additions.

Review of the solar rooftop market (Fiscal 2019-2024)

The Indian solar rooftop market has grown ~6.7 times from the end of Fiscal 2019 to the end of 2024. While the installations have expanded rapidly, the pace has still been lower than required to meet the proposed government target of 40 GW by Fiscal 2026.

Grid-connected rooftop capacity was ~11.9 GW as of March 31, 2024

Around 11.9 GW of rooftop capacity was installed until March 31, 2024, with ~3.0 GW added in Fiscal 2024 itself. Gujarat (31%), Maharashtra (19%), and Rajasthan (10%) accounted for 61% of the additions. The addition is due to several factors, including increased consumer awareness, advancements in technology and proactive subsidy initiatives implemented by central and state governments. Additionally, global solar module prices reached a historic low of United States dollar (US$ or $)0.20 per watt-peak (Wp) in Fiscal 2024 with the pricing of domestically manufactured modules also touching $0.25-0.27, which helped stimulate growth in solar capacity further.

In January 2024, the residential rooftop segment received a boost from the launch of PM Surya Ghar Yojna, which aims to solarise 10 million households. Apart from this, the central government also announced that all government rooftops under the administrative control of central government ministries/departments, including autonomous bodies, subordinate offices etc. shall be saturated with rooftop solar to the extent that is technically feasible by 31st December 2025. Ministries may utilise available rooftop space for such saturation, through the RESCO mode or capex mode, on a priority basis.

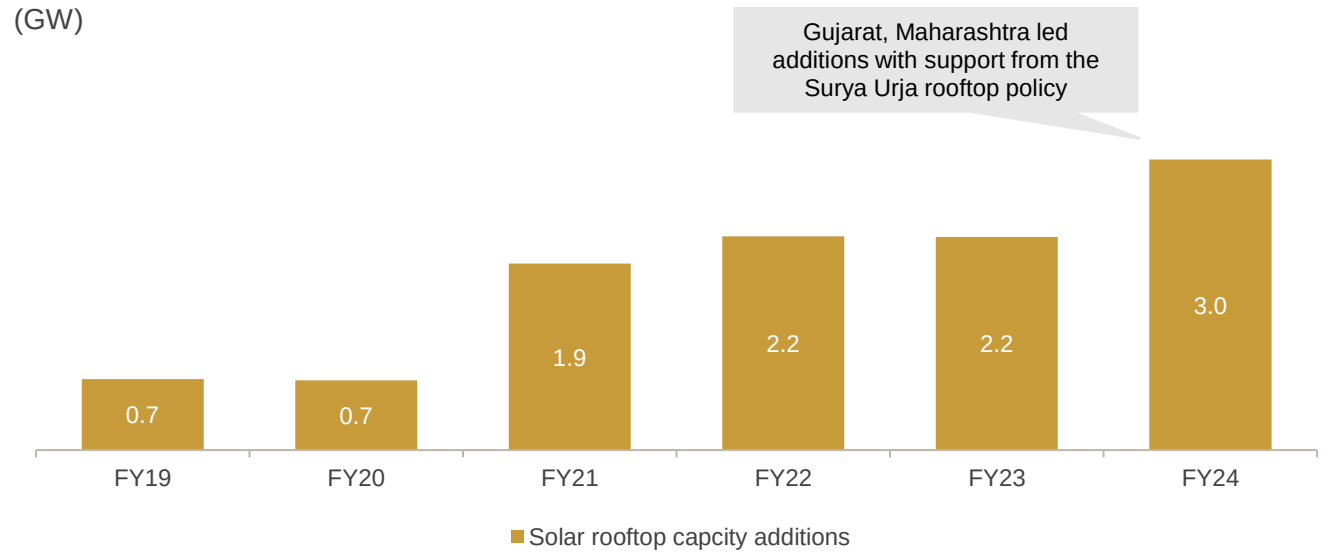
At a state level, the Telangana State Renewable Energy Development Corporation Ltd (TSREDCO) aims to install solar panels on 500 school buildings, promoting decentralised electricity generation, mitigating power shedding issues in the state. Such initiatives are contributing to the growth of the solar rooftop sector across India. Gujarat launched the Surya Urja Rooftop Yojana; the scheme provided 40% and 20% state subsidy for installations up to 3 kW and 3-10 kW, respectively. Furthermore, the state allowed consumers to rent their premises or roofs to third parties for electricity generation under its solar policy, encouraging installations. Additionally, the micro, small and medium enterprise (MSME) policy of 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 could sell excess power to the state government at ₹2.25 per unit for the first 5 years of the project and thereafter at 75% of the latest tariff discovered through competitive bidding process over the preceding 6 months, which shall remain fixed for the remaining project life, leading to increased installations.

Capacity additions in Fiscal 2023 were fuelled by robust additions under the residential rooftop segment, especially in Gujarat (0.68 GW), driven by Surya Urja Rooftop Yojana, and Maharashtra (0.54 GW), driven by a favourable rooftop policy. These states accounted for 58% of the 2.2 GW additions in Fiscal 2023. The 40% subsidy for 3 kW projects announced by the Haryana government also contributed to capacity additions. Majority of the additions

were under the capex model, with states empanelling vendors and commissioning the allocated capacities under the Ministry of New and Renewable Energy's (MNRE) Phase II of the rooftop solar programme.

Capacity additions were also higher in Fiscal 2022 spurred by the deadline of Gujarat's Surya Urja Rooftop Yojana, which targeted rooftop installations for 0.8 million consumers by March 2022.

Figure 21: Fiscal 2024 a bumper year for rooftop additions



Source: CRISIL MI&A Research

From a pan-India perspective, the segment has faced roadblocks, including higher cost of rooftop projects compared to utility-scale projects, limited availability of financing for all types of rooftop consumers, lack of uniform policies across states, weak infrastructure of power discoms and divergence between state policies and implementation.

Nevertheless, rooftop solar projects have attracted interest from players across the entire value chain, ranging from module manufacturers (Tata Power Solar, Waaree Energies and Vikram Solar) to system integrators (Rays Power and Jackson Engineers) and independent power producers (Fourth Partner and Mahindra Solar), owing to declining costs and favourable regulatory policies in key states (net metering, exemption of electricity duty, wheeling and cross-subsidy charges).

Indian rooftop solar capacity concentrated in six states

While pan-India capacity has accelerated over Fiscals 2019 to 2024, the pace of growth across states has not been uniform. The growth is driven by installations in a few key states with favourable government policies and higher acceptance by consumers, supporting the momentum.

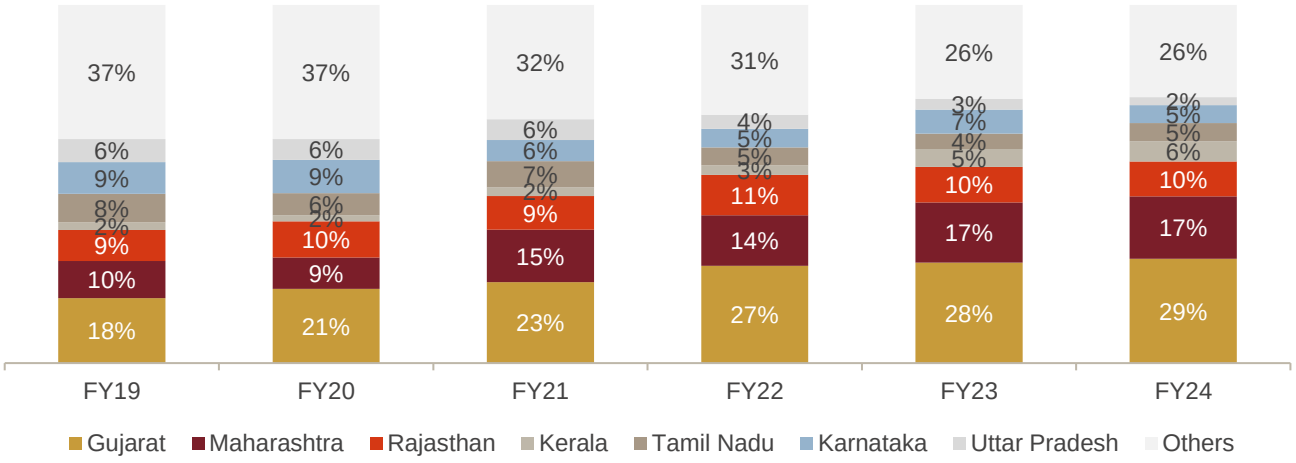
Gujarat, Maharashtra and Rajasthan continue to lead in installations, with their cumulative share increasing to 56% in Fiscal 2024 from 37% in Fiscal 2019. Gujarat, a state with high solar irradiance and favourable policies, led the additions when the state government introduced the solar subsidy scheme, Surya Urja Rooftop Yojana-Gujarat in 2019. Maharashtra, too, with clarity on policies by allowing net metering for all consumers set a positive precedent in the rooftop segment.

While Tamil Nadu, Karnataka and Uttar Pradesh accounted for a cumulative share of 23% of the installed base in Fiscal 2019, progress in these states did not follow the same momentum, and their share declined to 12% in Fiscal 2024. Tamil Nadu's restrictive policy on setting up rooftop solar units that interact with the state grid and the

revocation of net metering facility for C&I consumers in 2017 hindered growth. In Karnataka and Uttar Pradesh, rooftop solar growth was challenged by ineffective implementation on the ground as well as consumer reluctance, seen especially in smaller districts and low-income households.

Other states like Kerala started slow with a 2% share in rooftop installations in Fiscal 2019 but tripled its share to 6% by Fiscal 2024. This was mainly on account of the Soura Program phases I and II launched in 2019 and 2020 where the discom played a crucial role as a demand aggregator and paid for the total cost of installing rooftop projects, attracting more consumers. Price correction in installation costs due to falling global component prices was a factor which helped in greater adoption of solar rooftop systems across.

Figure 22: Gujarat, Maharashtra and Rajasthan accounted for ~56% of total additions in Fiscal 2024



Source: MNRE, CRISIL MI&A Research

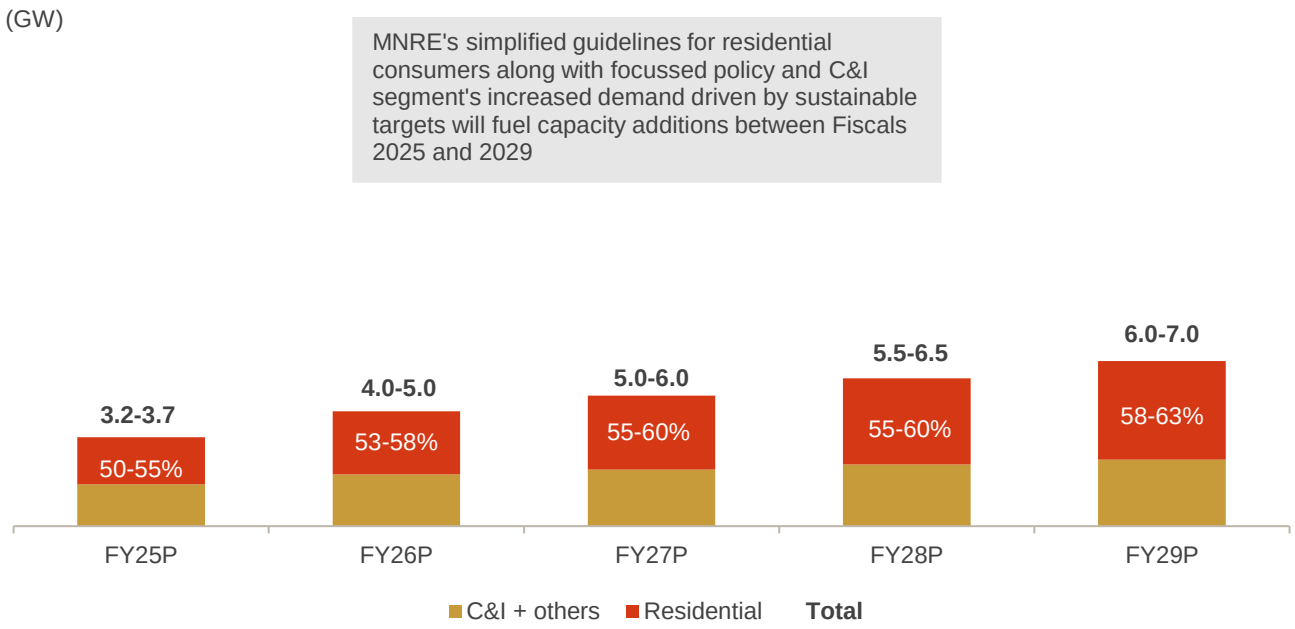
Outlook on solar rooftop capacity (Fiscal 2025-2029)

Over the next five Fiscals, solar rooftop installations in India are expected to accelerate supported by robust policies and focus on the residential segment by the government of India.

Rooftop solar additions of 25-27 GW expected over Fiscal 2025-2029 (~2.6 times higher than Fiscal 2019-2024)

CRISIL MI&A Research expects 25-27 GW of projects to be commissioned in the solar rooftop segment over Fiscal 2025-2029 led by the residential segment (14-15 GW) with the implementation of the PM Surya Ghar Yojna; however, the pace and success of execution remains a key monitorable. The remaining capacity will be added by the C&I segment (11-12 GW), under net/gross metering schemes of various states. 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 ₹1.3 trillion during Fiscals 2025 to 2029.

Figure 23: Residential segment to drive rooftop additions over the medium term



Source: CRISIL MI&A Research

To promote the installation of residential solar rooftops, MNRE provided the following for consumers:

- A national portal for consumers was developed with all relevant information on the segment
- Rooftop solar plants could be installed by consumers through an empanelled vendor of choice
- Any household beneficiary under the PM Surya Ghar Yojana would apply on the national portal in a centralised manner and the subsidy amount would be processed for installation of the RTS plant. As per the government of India, the scheme is expected to result in a saving of approximately ₹15,000 in a year for a household consuming up to 300 units a month, by installing a rooftop solar unit of 3 kW capacity.

Solar power can act as an alternative for states with high load shedding, such as Tamil Nadu, Uttar Pradesh and Punjab, which are also served by diesel generator sets, and for rural areas with poor grid connectivity.

Key policy drivers act as an enabler for driving rooftop additions

The central government's aim to achieve 40% of the 100 GW generation capacity target under the National Solar Mission (NSM) from the rooftop segment by 2022 fell short by ~31 GW. Hence, favourable policy plays a key role in driving additions. The government allocated a budget of ₹100 billion toward its solar programme in the Fiscal 2025 budgeted expenditure in July 2024. This was 110% more than the Fiscal 2024 revised expenditure allocations. The government further allocated ₹62.5 billion in the Fiscal 2025 budgeted expenditure towards PM Surya Ghar Yojna. This is equivalent to a potential 1.9-2.1 GW of residential rooftop additions in Fiscal 2025.

Policy support to drive residential growth, C&I to be spurred by economics

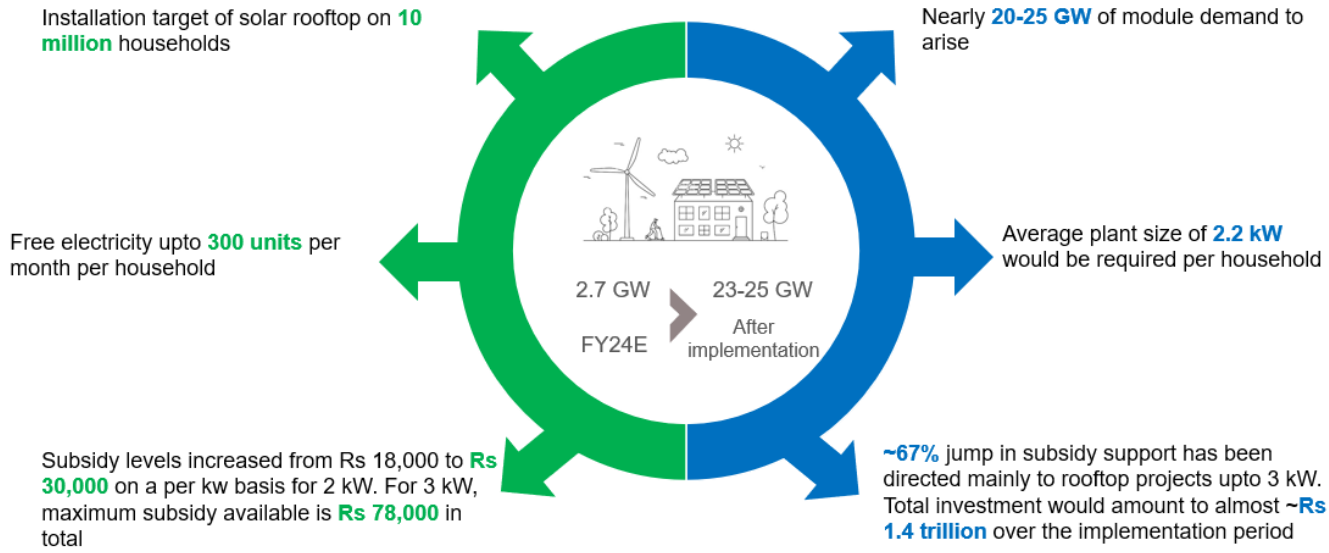
The PM Surya Ghar Yojna, launched in 2024, aims to boost residential solar rooftop adoption by addressing cost hurdles. The scheme provides subsidies for installing rooftop solar, helping households save on electricity bills. Some salient features of the scheme are:

- Subsidy has been increased to ₹30,000/kW for up to 2 kW plants and ₹78,000 for 3 kW plants
- Electricity benefit as per the government is estimated to be up to 300 units/month/household

- The scheme is expected to contribute 13-16 GW of residential rooftop additions over 5 years, where implementation is expected to continue post Fiscal 2029.

As of November 2024, almost 25 banks have registered to provide financing for solar rooftop under the scheme. These banks will provide loans at a floating rate of interest and for a maximum tenure of 5-10 years. While most banks, such as State Bank of India (SBI) and Canara Bank, provide a maximum loan of ₹0.2 million, a few banks such as HDFC and Saraswat Bank will provide a maximum loan of ₹4-5 million.

Figure 24: Residential solar rooftop to contribute 20-25 GW to incremental solar rooftop demand



Source: CRISIL MI&A Research

In addition, the Indian government has also mandated public sector utilities under the power ministry to equip all buildings under central government administration with solar rooftops by 2025, as part of the PM Surya Ghar Yojna. The scheme outlines the roles of various stakeholders in achieving solar rooftop saturation. These stakeholders include Central Public Sector Enterprises (CPSEs) with renewable energy expertise, central ministries, state and union territory (UT) government departments, autonomous bodies, public sector enterprises, and other units under the administrative control of central ministries and state/UT government departments. The government has identified CPSEs, which have experience in the renewable energy sector as Scheme Implementation Partners (SIPs) for government rooftop solar programme. The ministry may identify additional SIPs under the scheme from time to time.

Declining PV system costs and sustainability goals have made rooftop projects increasingly appealing to C&I consumers. Availability of net metering in particular, under which power generated can be consumed captively and the balance/excess can be sold, has also been instrumental in spurring rooftop solar in the C&I segment.

Competition landscape in the solar rooftop segment

The solar rooftop segment, due to its fragmented nature, sees participation from many small to mid-sized companies as well as from large renewable energy generators who are also present in other renewable energy verticals.

Table 12: Peer comparison

Player	Business presence	Rooftop solar geographic presence	Capacity (MW)	Main state for player (% of rooftop capacity)
Roofsol Energy	Ground mounted and rooftop solar	Madhya Pradesh, Maharashtra, West Bengal, Punjab, Uttar Pradesh, Tamil Nadu, Gujarat, Rajasthan, Odisha and Assam	87	Punjab (68%)
Orb energy	Ground mounted and rooftop solar	Karnataka, Maharashtra, Andhra Pradesh, Gujarat, Odisha and Uttar Pradesh	28	Karnataka (85%)
Amplus Solar	Ground mounted and rooftop solar	Karnataka, Maharashtra, West Bengal, Haryana, Uttar Pradesh, Telangana and Tamil Nadu	32	Karnataka and Uttar Pradesh (63%)
Candi solar	Ground mounted and rooftop solar	Telangana, Maharashtra, Uttar Pradesh, Chandigarh, Punjab, Odisha, Haryana, West Bengal, Madhya Pradesh, Rajasthan, Tamil Nadu and Karnataka	19	Maharashtra (55%)

Note: Company websites accessed as on 21st October 2024

Source: Company websites, CRISIL MI&A Research

While the industry is a mix of large and small players, the market dynamics suggest a regional focus. The above sample considered comprises of some of the key players with operational portfolios across India. While players naturally expand their presence across the country, nearly 70-75% of their installations are concentrated in only one or two states. This is also reflected by the PM Surya Ghar Yojna scheme where 35,000 vendors are enlisted owing to presence of regional players and the high fragmentation of the consumer base in the residential solar rooftop segment. States like Gujarat, Uttar Pradesh, Rajasthan, Maharashtra and the union territories of Dadra and Nagar Haveli and Daman and Diu see the most fragmentation in the vendor base, cumulatively accounting for 67% of total vendor options under the empanelled list.

Rooftop solar plants are generally more expensive on a per megawatt basis than ground mounted systems due to several factors.

1. Installation complexity: Rooftop systems require specialised mounting equipment and labour to secure panels on existing structures, leading to higher costs
2. Limited space: They often face constraints in rooftop size, orientation, and obstructions, which can limit efficiency and necessitate additional engineering solutions.
3. Operational requirements: From a developer's perspective, due to the decentralised nature of the solar rooftop segment, the requirement for decentralised infrastructure also rises leading to higher costs.

This usually results in rooftop solar being 1.1-1.2 times more expensive than ground mounted solar projects.

Financing landscape

Due to its classification as a green energy initiative, the solar rooftop sector has emerged as a focus area for multilateral and domestic financial institutions. As a result, these institutions are now prioritizing efforts to facilitate seamless access to financing for this rapidly growing market.

For instance, the Asian Development Bank (ADB) has approved $240.5 million in loans to finance rooftop solar systems in India. The funding will support the installation of rooftop solar systems through loans provided by the State Bank of India (SBI) and National Bank for Agriculture and Rural Development (NABARD). This is in addition

to previous support from the World Bank, which had provided $813 million in financing for rooftop solar projects since 2017. The initiatives aim to accelerate the adoption of rooftop solar, reduce greenhouse gas emissions by 13.9 million tonnes, and provide loans to consumers and developers. The Indian Renewable Energy Development Agency (IREDA) also launched a retail division to provide loans to rooftop solar consumers and other business-to-consumer segments.

Securing focus and support from the lending community will be crucial in overcoming the operational challenges that affect the solar rooftop sector.

Risks and monitorable

The segment is poised for rapid growth owing to states with supportive policies and high solar irradiance.

Nevertheless, the growth of India's solar rooftop sector may face continued challenges such as ineffective state policies, poor consumer creditworthiness, and enforcement issues.

Distribution companies (DISCOMs) encounter difficulties in integrating rooftop energy into their grids due to aging infrastructure and net metering complexities. Furthermore, their revenue dependence on industrial customers and the availability of cheaper electricity from ground-mounted projects diminishes their motivation to promote rooftop solar connections. This often translates into poor frameworks for and implementation of rooftop solar.

The weak credit profiles of potential customers are another challenge for developers. Innovative solutions such as guarantees and access rights, combined with credit availability from multilateral agencies, can help stimulate adoption.

Enforcement of lease agreements and PPAs between producers and buyers is another critical challenge. Measures such as third-party access rights, dispute redressal, payment security, and insurance schemes could improve investor confidence. Under the RESCO model, the absence of long-term rooftop agreements and collateral limitations for service companies further impede growth. Further, grid variability due to rising rooftop solar penetration may strain infrastructure.

Addressing these challenges by ensuring legal safeguards for rooftop availability, strengthening transformer maintenance, employing battery-based storage solutions, would be vital to meeting the 40 GW target.

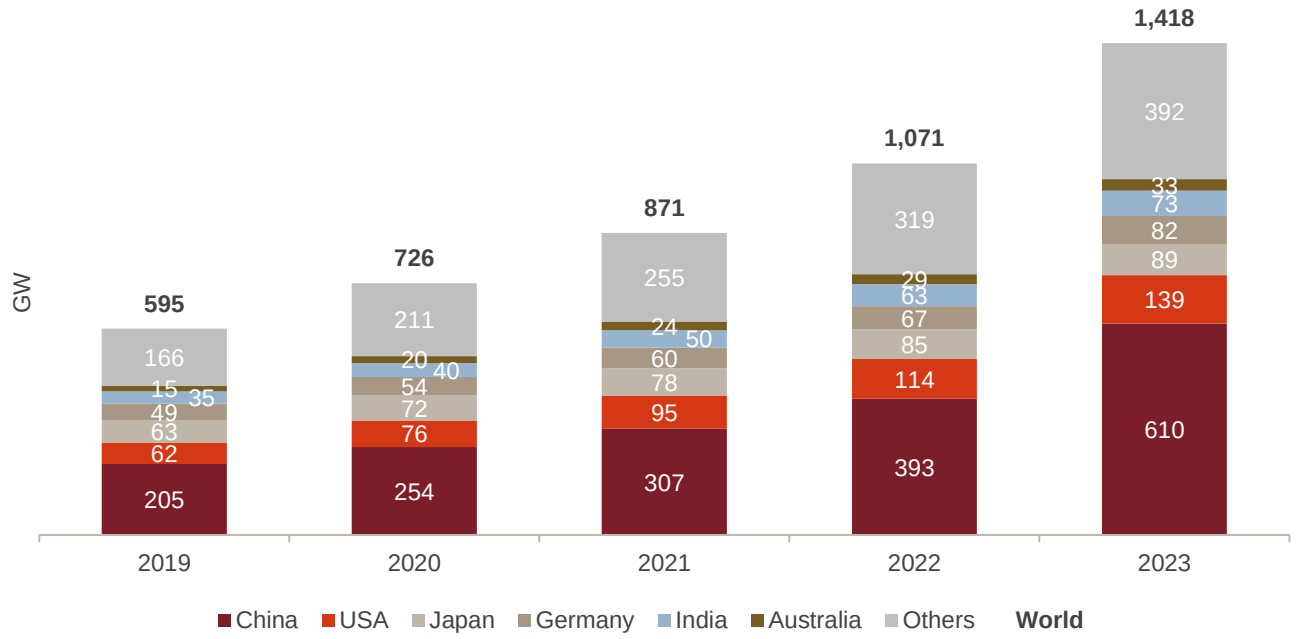
Notwithstanding the challenges in the segment, residential rooftop solar offers a promising avenue for the government to meet its renewable energy targets along with sustainability focus from corporates. Moreover, the combination of government subsidies and accessible financing options from multiple banks makes rooftop solar an attractive and affordable option for even small households

Module 5 – Solar PV manufacturing

Global solar energy installation trend

According to the International Renewable Energy Agency (IRENA), the global solar energy installed capacity has nearly tripled since 2018, reaching 1,418 GW by the end of 2023, which was a record year for solar installations. While increase in solar capacity in India, Germany and US hit all-time highs, China's acceleration was extraordinary. In 2023, China alone commissioned as much solar energy as the entire world did in 2022.

Figure 25: Installed solar generation capacity almost triples in 5 years

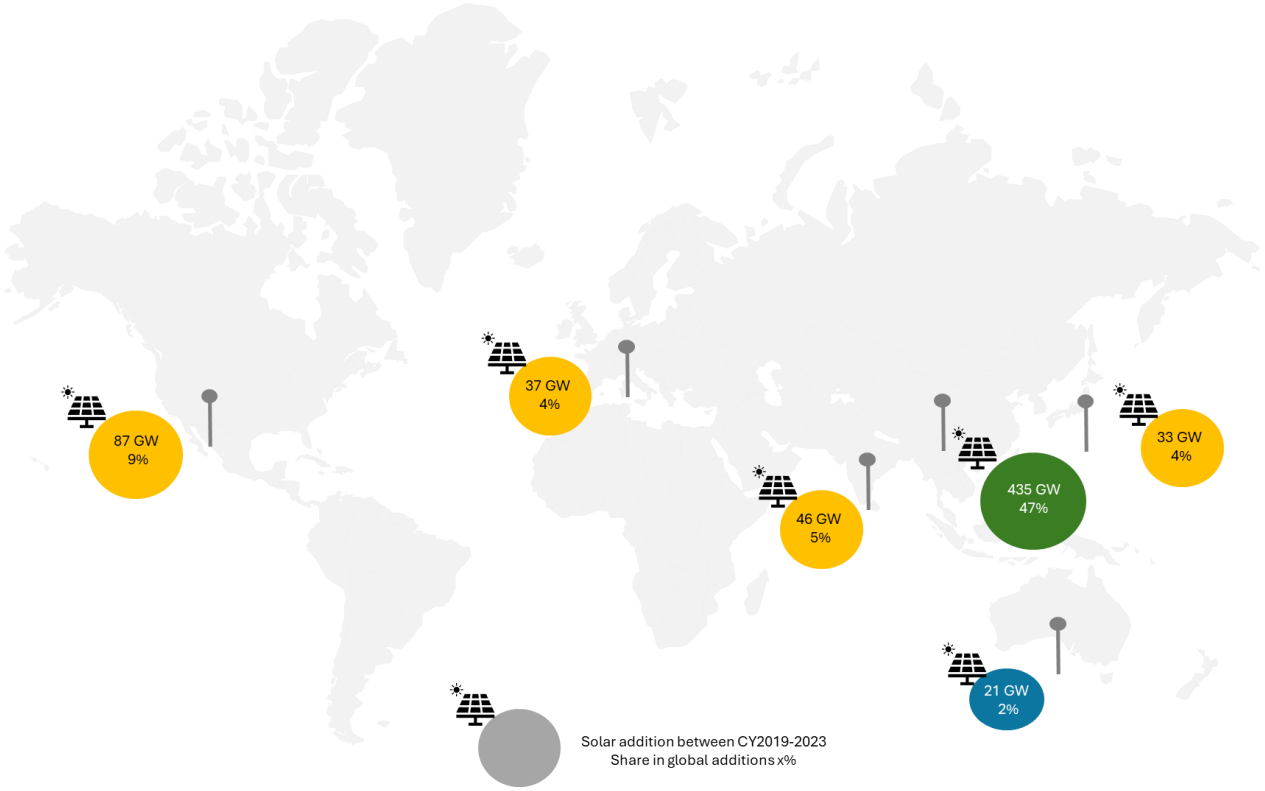


Source: IRENA

Review of global solar module demand

Global solar module demand is estimated to be at least 926 GW cumulatively over 2019 to 2023, with at least 347 GW in 2023. Going by installation rates, 47% of the demand was driven by China, followed by US (9%), India (5%), Germany and Japan (4% each) and Australia (2%). Factors such as cost reduction resulting from the fall in prices and technological advancements globally is a major factor that drove additions in 2023.

Figure 26: China accounts for a lion's share in global solar installations



Note:

The demand does not factor DC overloading

The above-mentioned nations account for 71% of solar capacity additions between CY2019-2023.

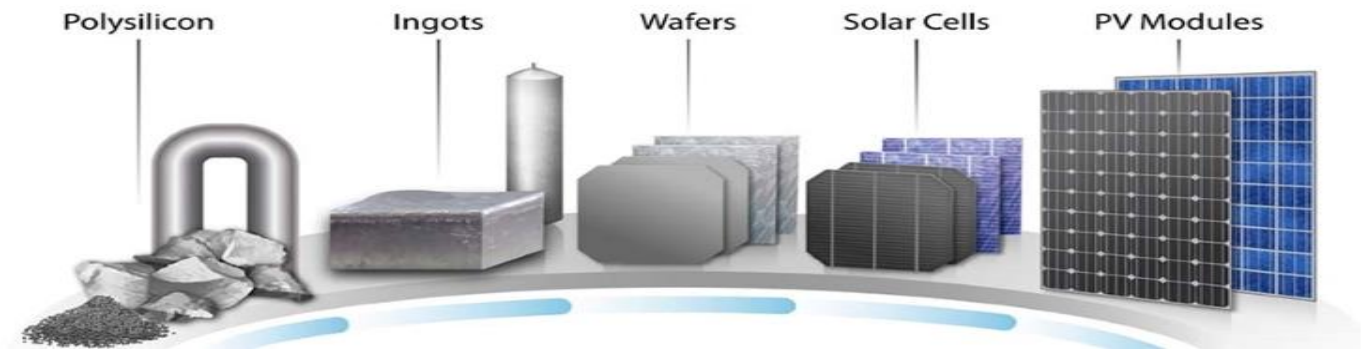
Legend - Green colour indicates over 10% share in global addition, amber indicates 5-10% share in global addition and blue colour indicates less than 5% share in global addition.

Source: IRENA, CRISIL MI&A Research

Review of global solar module manufacturing

The solar photovoltaic (PV) manufacturing process can be broken down into four distinct stages, forming a comprehensive value chain.

Figure 27: PV manufacturing value chain



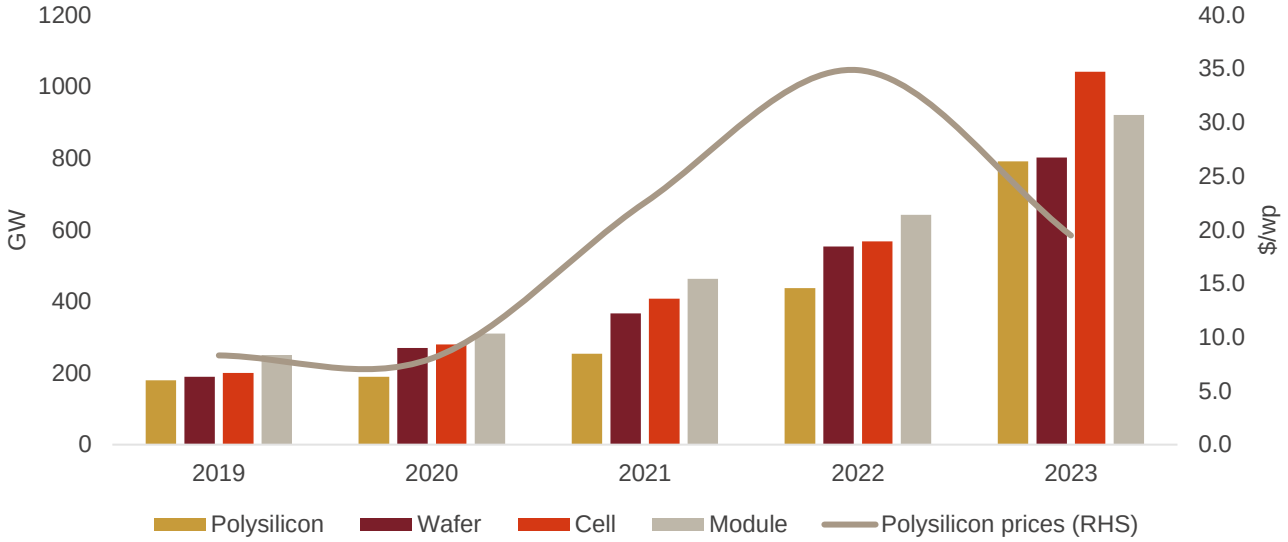
Silica (SiO_2) is refined to metallurgical grade silicon (MG-Si) using a carbothermic process in an electric arc furnace. MG-Si is then purified through a chemical vapor deposition process converting it to trichlorosilane gas which is decomposed to produce ultra-pure solar-grade polysilicon.	Solar polysilicon 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 for the widely used cell technology (monocrystalline) in the world as of 2023.

Source: CRISIL MI&A Research

According to the International Energy Agency, global solar module manufacturing capacity has experienced a fourfold increase, reaching 921 GW from 2019 to at the end of 2023. This growth has outpaced demand, with 2023's solar module demand being nearly one-third of the total manufacturing capacity. In tandem, the production of upstream components has also seen significant expansion over the past five years, with a notable surge in growth since 2023, particularly in the polysilicon segment.

Figure 28: PV manufacturing capacity crosses 800 GW across value chain in 2023; 3x of demand



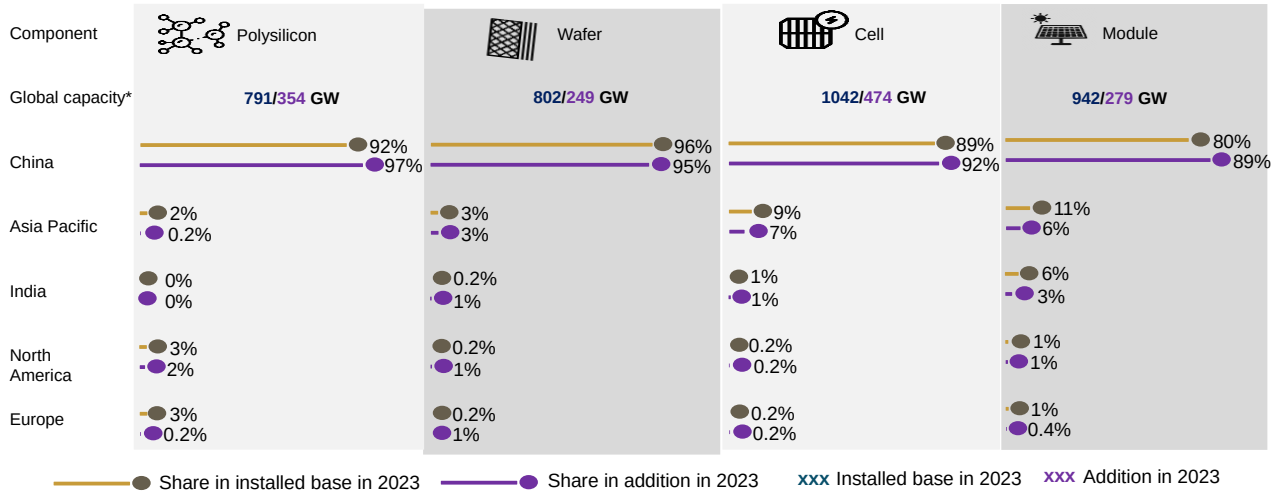
Source: IEA, CRISIL MI&A Research

From 2017 onwards, the limited availability of PV-grade polysilicon manufacturing capacity emerged as a significant constraint in the photovoltaic (PV) supply chain. This bottleneck became particularly 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 2023, China had significantly expanded its polysilicon production capacity, increasing it threefold compared to 2021 levels. As a result, global polysilicon capacity caught up with other PV manufacturing segments, such as wafers, cells, and modules. China's dominance in the PV value chain continued to grow, with the country accounting for over 80% of the installed base on an average across the value chain stages by 2023

Geographical concentration across the value chain

China has a significant presence in the global solar photovoltaic (PV) industry, with a large proportion of manufacturing capacity for PV components concentrated within its borders. Although it is possible to source these components from other countries, the global solar PV supply chain is heavily reliant on China for the production of modules and upstream components, including polysilicon, ingots, wafers, and cells. This manufacturing dominance has created a high degree of dependence on China for the supply of these critical components.

Figure 29: China accounted for over 80% of the global supply in 2023



*Note: Balance share is spread across the rest of the world. *Global capacity is as of 2023. India's capacity is as of March 2024.*

Source: IEA, CRISIL MI&A Research

China accounted for the largest share of polysilicon to module manufacturing capacity and reinforced its dominant position as a manufacturer by increasing its share of global polysilicon production capacity nearly three times by 2023.

China's dominance in the global PV supply chain is evident, with more than 80% of cell and module manufacturing lines located within the country. This concentration of manufacturing capacity has created a high degree of dependence on China. Although China has a monopoly on wafer manufacturing, Southeast Asia has emerged as a significant player in cell and module manufacturing, driven by major Chinese solar cell manufacturers establishing production bases in countries like Vietnam, Malaysia, and Thailand to circumvent USA trade restrictions. The combined production capacity of these countries reached over 40 GW in 2023.

Germany is a leading supplier of polysilicon for the c-Si PV module industry, while the US and Japan also have significant polysilicon manufacturing capacity. However, their production is primarily focused on semiconductor-grade products rather than catering to the PV industry.

While module assembly is geographically diversified, it's crucial to recognize that most of the required inputs, including wafers, cells, and other components, are manufactured in China. Despite the diversified assembly locations, China remains the primary source for essential PV components, highlighting its critical role in the global PV supply chain.

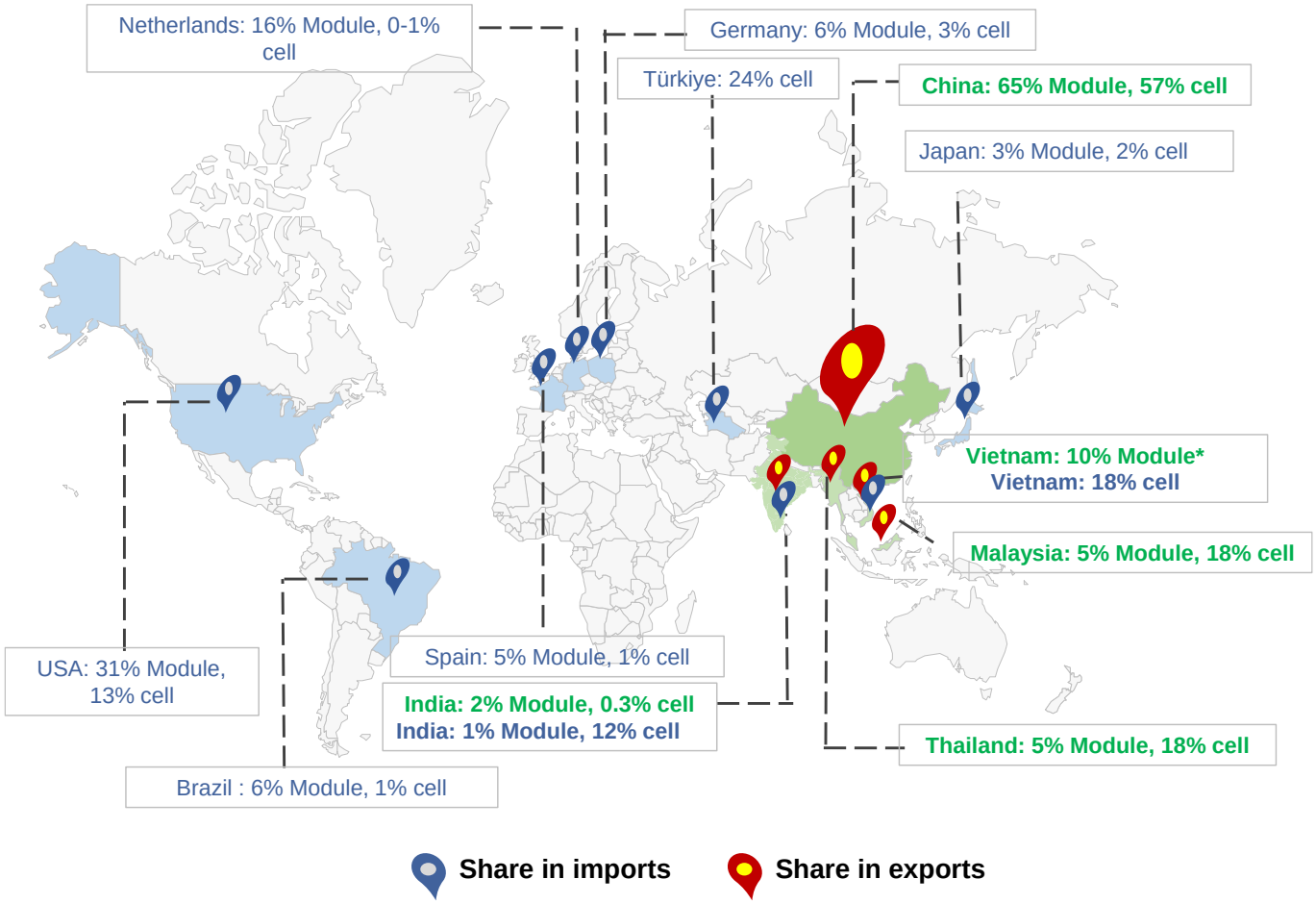
China dominates global trade in PV

The global solar industry experienced a significant upswing in demand for solar modules in 2023, driven by declining prices resulting from a supply surplus. This led to a substantial increase in imports, with an estimated 379 GW of modules and 67 GW of cells being imported worldwide. The United States emerged as the largest importer of solar modules and cells, with around 31% of all module imports and 13% of cell imports destined for the country.

European nations, including Spain, the Netherlands, and Germany, collectively accounted for around 31% of module imports and 5% of cell imports. Asian countries, such as Japan, Vietnam, and India, imported a combined 4% of modules and 33% of cells.

China maintained its position as the leading supplier of solar modules and cells, providing nearly 65% of module imports and 57% of cell imports in 2023. However, the year also saw a notable expansion in manufacturing capacity, particularly in South-East Asian countries such as Vietnam, Malaysia, and Thailand, which increased their share in the global solar supply chain.

Figure 30: China trades over 50% of module and cell exports in 2023; ASEAN countries catching up



*Note: * Vietnam data is for 2022*

Source: ITC Trademap, CRISIL MI&A Research

While share of Chinese imports in the US basket fell to 0.1% in 2023 from 5% in 2019 owing to a ban on imports from the Xinjiang region, its share in European and Asian nations increased rapidly.

Overall, the global photovoltaic (PV) manufacturing capacity has undergone significant expansion and technological advancements over the years, driven by sustained investments in research and development. This has resulted in rapid price decline as well as notable improvements in efficiency.

Evolution of PV cell technology

The rapid growth of the sector, accompanied by intense competition in the supply chain, has driven a 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 is now shifting towards 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 remains the dominant technology globally as of 2023, TopCon and HJT have started to gain traction. On average, TopCon cells are expected to offer an incremental efficiency gain of 2-3% over mono-PERC cells, while HJT cells are estimated to provide an additional 2-3% efficiency gain over TopCon cells. This has enabled the possibility of higher electricity generation.

However, the capital cost intensity required to establish manufacturing facilities also increases with the initial capital expenditure (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 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
Efficiency	Upto 22%	22-24%	24-26%
Losses & Damages	P-type Mono PERC cells are prone to LID & PID losses. Losses highest in group.	PID & LID losses in TopCon are lower compared to Mono PERC, bit higher compared to HJT	Not prone to PID & LID losses, since general cell construction is n-type

Note: PID stands for potential induced degradation and LID stands for light induced degradation

Source: CRISIL MI&A Research

The solar PV industry is constantly at risk of technological disruption. According to Fraunhofer, emerging technologies like Perovskite, III-V on Si (2-terminal), and III-V-Multi Junction Concentrator solar cells have achieved efficiencies of ~34%, ~36%, and ~48%, respectively, in laboratory settings as of H1 2024.

Meanwhile, several countries are promoting in-house PV manufacturing to enhance self-reliance and mitigate supply chain risks from international markets.

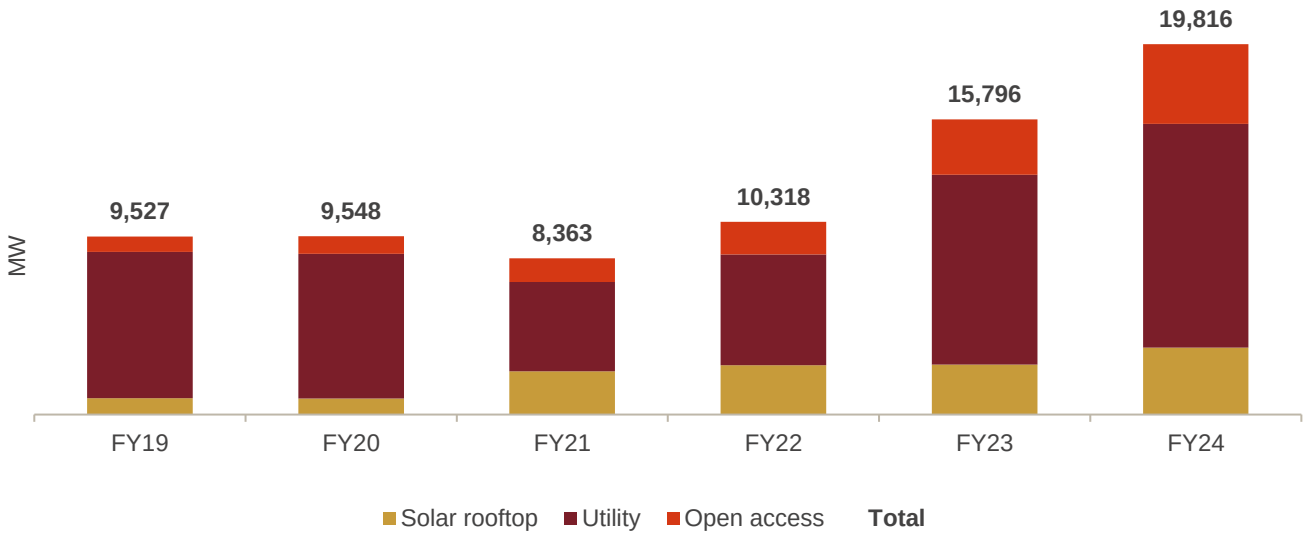
The domestic solar PV segment

The domestic PV segment has been driven by domestic demand for solar modules through various segments such as rooftop, utility scale and open access. From the beginning of Fiscal 2019 to the end of Fiscal 2024, India has witnessed a cumulative solar module demand of ~73 GW.

Review of domestic solar module demand

The domestic demand for solar module has been driven by the competitively bid utility segment at 66%, followed by the rooftop segment at 18% and open access segment at 16% between Fiscals 2019 and 2024.

Figure 31: India experienced an average annual module demand of 12 GW between Fiscals 2019 and 2024



Note: Demand includes DC overloading

Source: CRISIL MI&A Research

The growth of India's solar module demand was driven by a combination of factors, including declining module prices, supportive government policies, and increasing awareness of solar energy's benefits.

The competitively bid segment saw significant growth, with installed capacity more than doubling to 56 GW by the end of Fiscal 2024, driven by initiatives under the National Solar Mission, solar parks, renewable purchase obligations, and the Panchamrit targets pledged under COP26. Central tender allocations, led by SECI, accounted for 28% 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 significant growth, with installed capacity increasing sevenfold by the end of Fiscal 2024, driven by subsidies under the national rooftop mission and state-specific initiatives like Gujarat's Surya Urja Yojana. Favourable policies, including net metering in some states, further incentivized adoption. The top three states - Gujarat, Maharashtra, and Rajasthan - accounted for 56% of the installed base by Fiscal 2024.

Open Access Solar, which allows consumers to purchase solar energy directly from producers, also contributed to the rising 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.

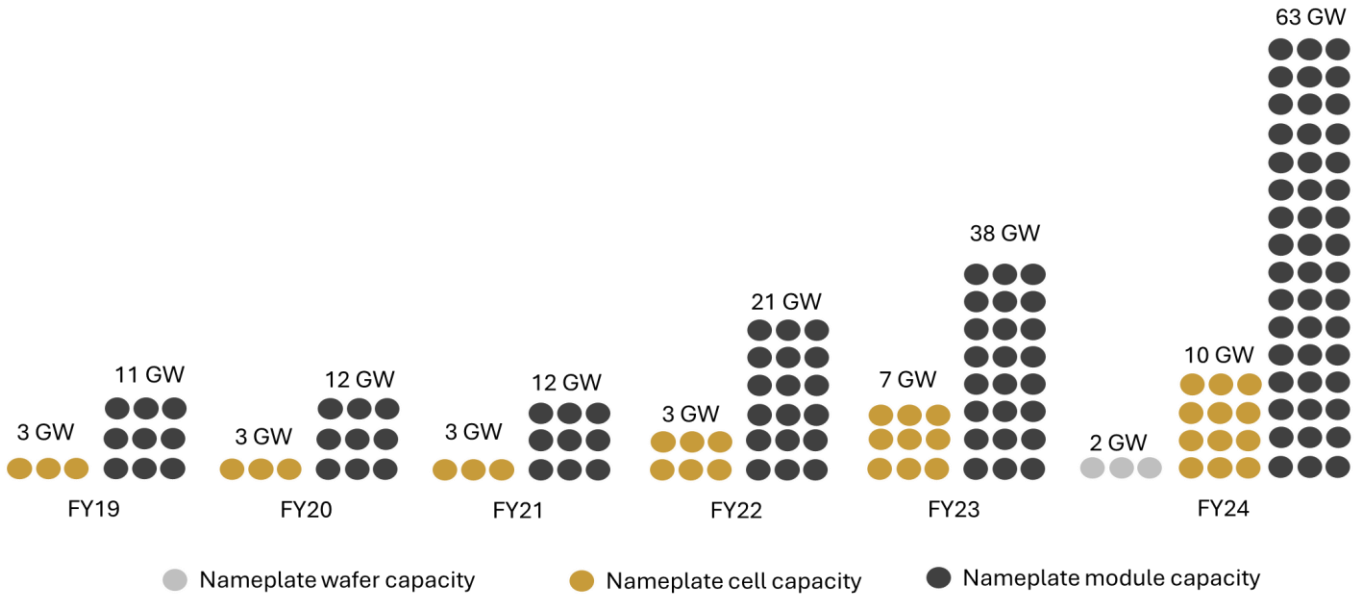
While demand for solar modules remained strong between Fiscals 2019 and 2024, it was largely met by imports. India's presence in PV manufacturing was limited to module assembly, with limited cell manufacturing capacities.

Domestic manufacturing capabilities in India

India's solar PV module and cell manufacturing capacity underwent significant expansion, increasing from 21 GW and 3.2 GW in Fiscal 2022 to 63 GW and 10 GW, respectively, by March 2024. 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 domestic manufacturing ecosystem remained focused on the downstream component stage, primarily due to the capital-intensive nature of upstream components such as wafers and polysilicon. The availability of cheaper alternatives from China further contributed to this concentration.

Figure 32: PLI helps expand capacity in cell to module stage



Source: Company reports, CRISIL MI&A Research

Between Fiscals 2022 and 2024, India's module and cell assembling/manufacturing capacity experienced significant growth, with additions of approximately 42 GW and 6 GW, respectively. This expansion was driven by the government's efforts to reduce dependence on imported solar components, particularly from China.

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 basic customs duty of 40% on modules and 25% on cells was introduced to enhance the competitiveness of Indian-made products. 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 like the approved list of models and manufacturers (ALMM) to ensure quality control and encourage capacity additions in the downstream stages. Furthermore, the Production-Linked Incentive (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.

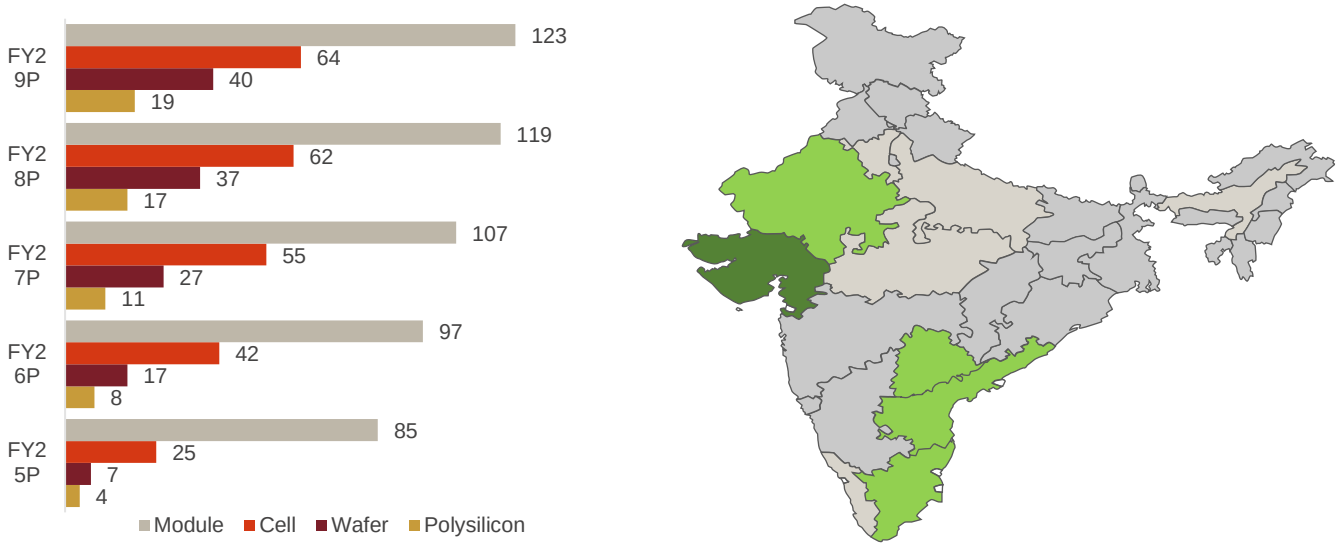
The industry has undergone significant consolidation in recent years, with new large-scale entrants gaining a significant market share. While the industry was highly fragmented in Fiscal 2019, the emergence of major players like Tata Power Solar, Waaree Energies, ReNew Power, and Adani Power has led to consolidation. These players, along with others, are expected to expand their presence across the value chain under the production linked incentive (PLI) scheme.

Domestic PV manufacturing outlook

By the end of Fiscal 2029, 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 approximately 2 times and 7 times, respectively. Additionally, the country is expected to see the establishment of large-scale wafer and polysilicon facilities, with capacities reaching 40 GW and 19 GW, respectively.

This substantial expansion in capacity, particularly in the upstream components, is expected to be driven by the PLI scheme, which aims to encourage investment and growth in the domestic solar manufacturing industry.

Figure 33: Upstream supply chain to be driven by PLI; Gujarat emerges as the favourite destination for PV

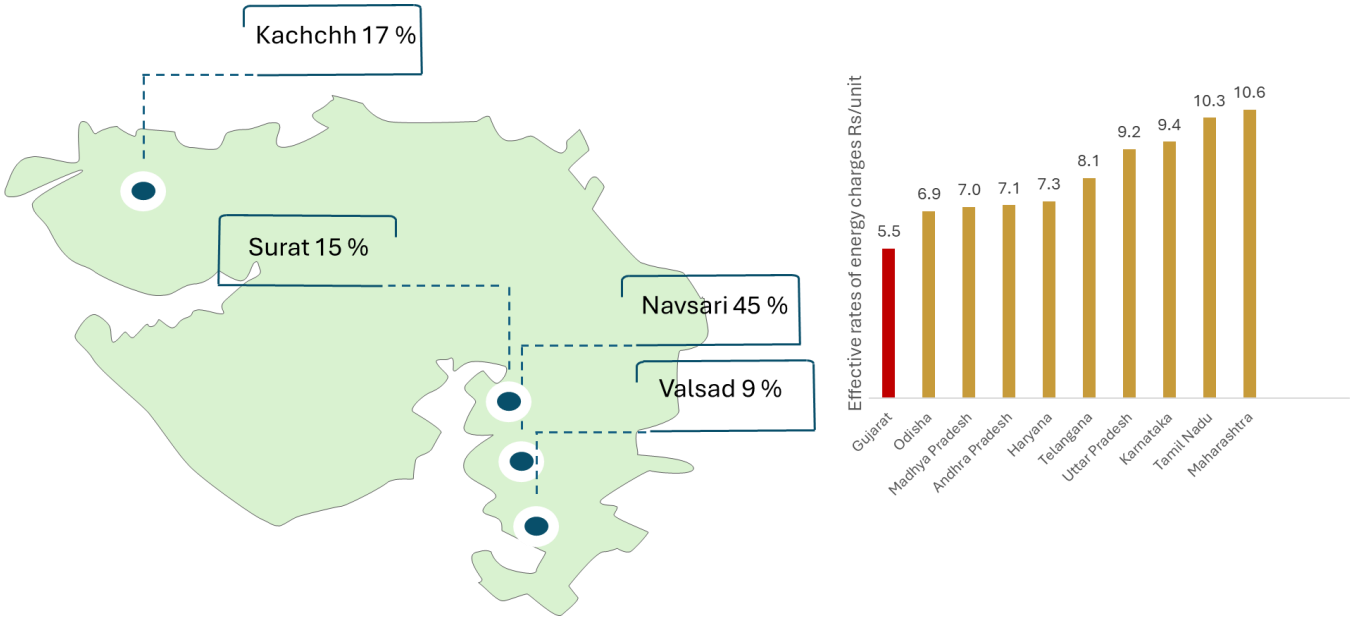


Source: Company reports, CRISIL MI&A Research

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

Nearly 75%, 93% and 100% of the installed base of cells, wafers and polysilicon respectively by Fiscal 2029 will be on account of PLI scheme allocations. Gujarat is expected to be the epicentre of PV manufacturing capacity additions. This is because Gujarat has one of the lowest effective rates for the industrial sector across the major states. In fact, nearly 40% of the enlisted capacity of ~61 GW in the ALMM by August 2024 was situated in Gujarat.

Figure 34: Concentration again high within Gujarat with nearly 87% of capacity located in 4 districts



Source: ALMM, MNRE, REC, CRISIL MI&A Research

Until Fiscal 2024, India's solar industry was in its early stages, heavily reliant on imports for upstream components like cells and wafers. Hence, the availability of ports and trade routes also makes Gujarat an attractive location for manufacturing, and based on the pipeline the state is expected to continue dominating capacity additions in the future.

Over the next five years, the industry's technology setup is expected to undergo an upgrade. While mono PERC technology has been dominant until Fiscal 2024, more than 10 players have announced capacity additions using TopCon technology, and a few have chosen to expand into HJT technology. Although mono PERC is expected to remain dominant, the incremental capital expenditure of 10-15% for TopCon has prompted players to expand into this technology as well. By August 2024, nearly 2.5 GW of TopCon capacity had already been listed in the ALMM.

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

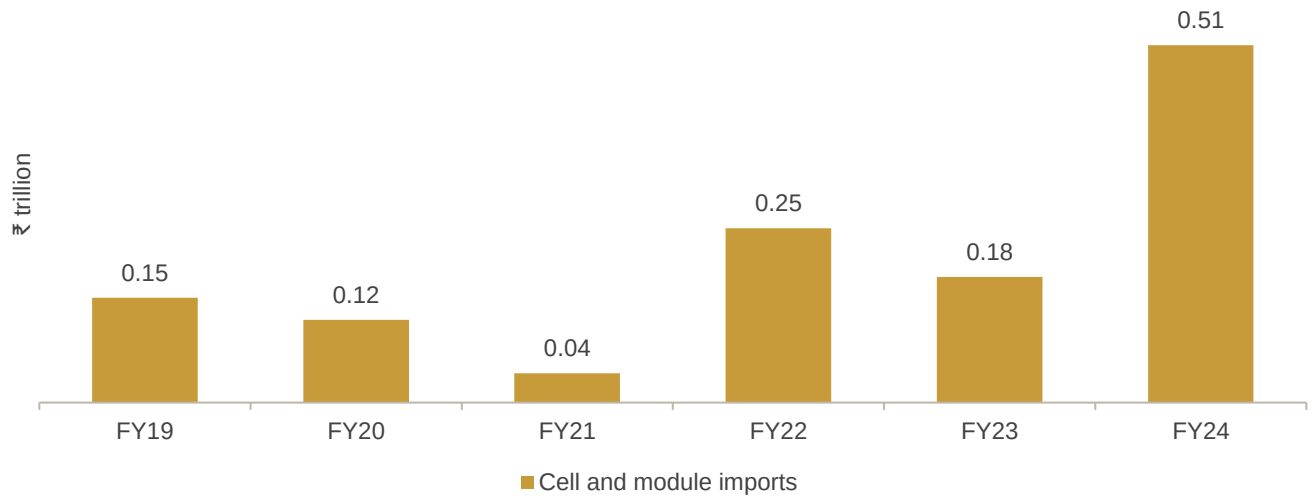
Import reliance to fall while exports to flourish

Share of Chinese imports falls

Between Fiscals 2019 and 2024, 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 and more catered to the domestic content requirement in certain Indian market segments, which were smaller verticals of the overall RE sector. As a result, more than 50% of solar modules installed in India during this period were imported, primarily due to inadequate domestic capacity, competitive pricing, and technology preferences.

As of March 2024, India had ~10 GW installed capacity of solar cells and ~63 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 ₹0.25 trillion (from ₹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. While imports fell in Fiscal 2023 by 28% on-year, it sharply rose 184% on-year in Fiscal 2024 owing to ALMM abeyance to meet rising solar power demand in the country.

Figure 35: ALMM abeyance in Fiscal 2024 results in higher imports

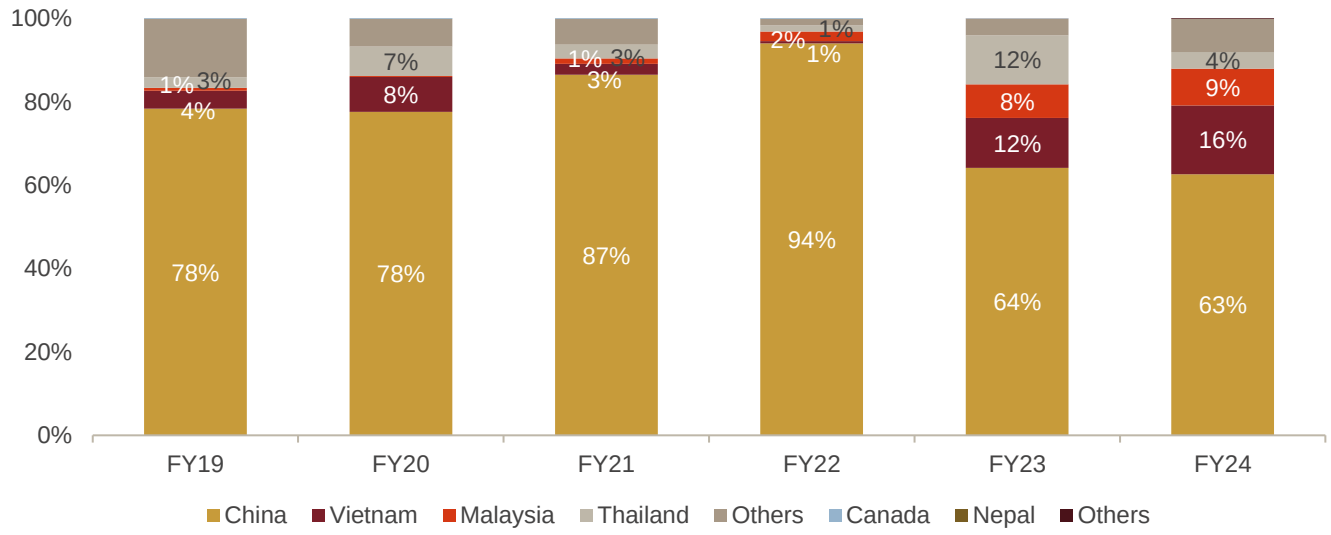


Note: HS Code 85414011 & 12 used till Fiscal 2022 and 85414200 & 300 used from Fiscal 2023.

Source: Ministry of Trade and Commerce, CRISIL MI&A Research

While the share of China has fallen during Fiscals 2019-2024, it continues to be the largest module exporter to India, followed by Malaysia.

Figure 36: Share of China falls in India's import basket



Note: HS Code 85414011 & 12 used till Fiscal 2022 and 85414200 & 300 used from Fiscal 2023.

Source: Ministry of Trade and Commerce, CRISIL MI&A Research

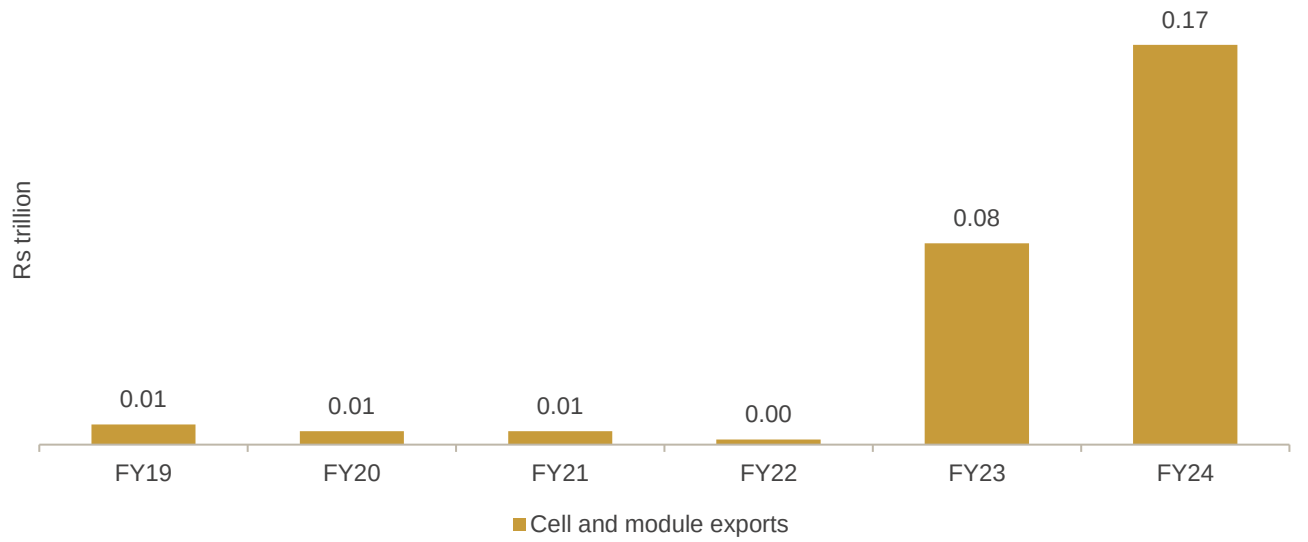
Supply chain diversification has resulted in 16% loss of share for Chinese cells and modules in India's import basket in 2023. Countries such as Vietnam, Malaysia and Thailand have gained 12%, 8%, and 1% market share, respectively in the year. While lack of domestic capacity prompted the need for imports, the pricing of international modules also proved beneficial for domestic developers. On average, the traded price of imported solar modules remained at least ₹ 8-10/Wp lower than that of a domestically manufactured module in Fiscal 2024.

While imports remained above 50% between Fiscals 2019 and 2024, exports have also shown a remarkable growth over the same period.

Exports grow multifold for India, so does geographical concentration

India's solar cell and module exports averaged a modest ₹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 increase in Fiscal 2023 compared to the previous year, followed by a 2-fold increase in Fiscal 2024.

Figure 37: Geopolitical dynamics enables Indian exports

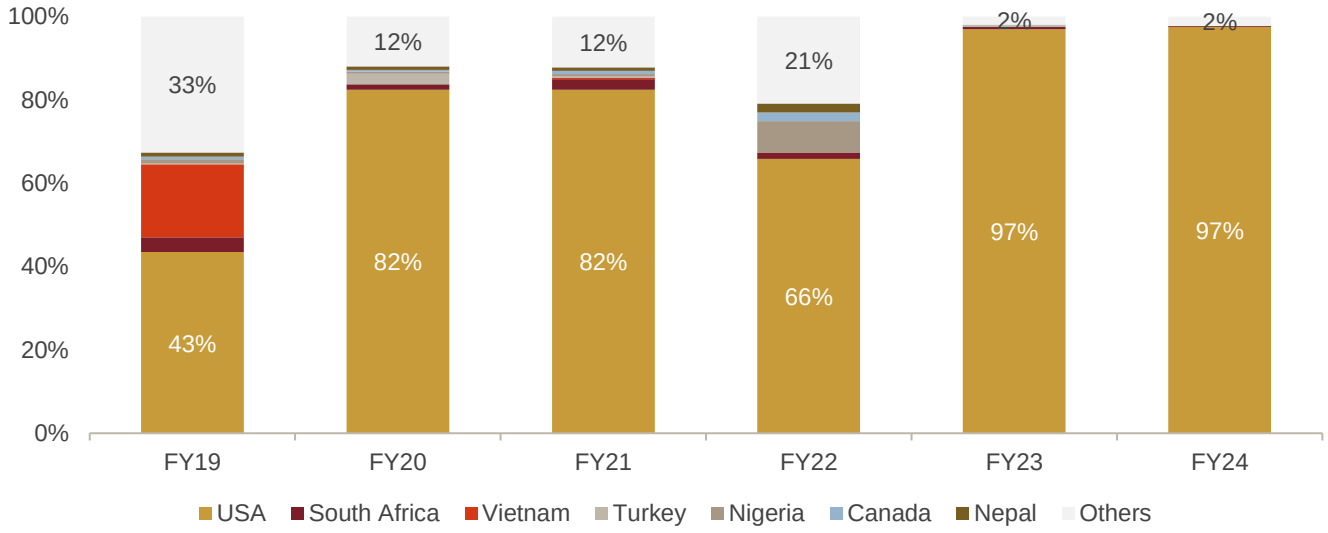


Note: HS Code 85414011 & 12 used till Fiscal 2022 and 85414200 & 300 used from Fiscal 2023.

Source: Ministry of Trade and Commerce, CRISIL MI&A Research

While the share of the US remained at over 60% on an average between Fiscals 2019 and 2022 in India's export basket, the share significantly jumped to 97% during Fiscals 2023 and 2024.

Figure 38: US accounts for 97% of Indian solar exports

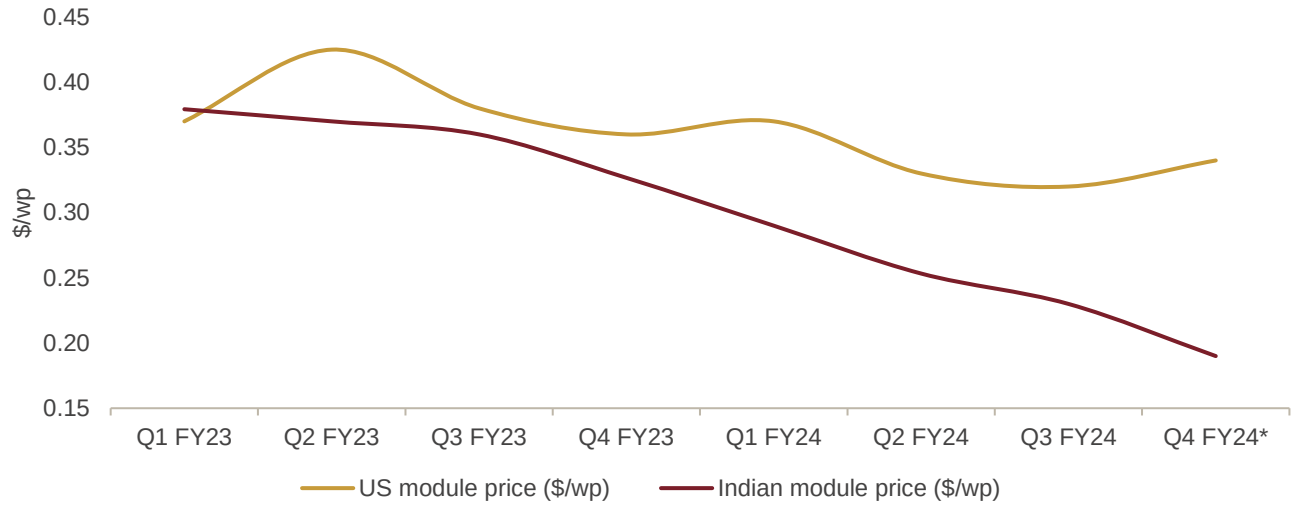


Note: HS Code 85414011 & 12 used till Fiscal 2022 and 85414200 & 300 used from Fiscal 2023.

Source: Ministry of trade and commerce, CRISIL MI&A Research

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 exporting economies such as Vietnam, Malaysia, Thailand and India. While India's prices remained uncompetitive to Chinese suppliers, they still offered a lower price compared to those manufactured in the US.

Figure 39: Gap between average prices of US and India enable premium sales for domestic module makers



*Note: Price for mono modules. *US price of Q4 Fiscal 2024 is two months' average.*

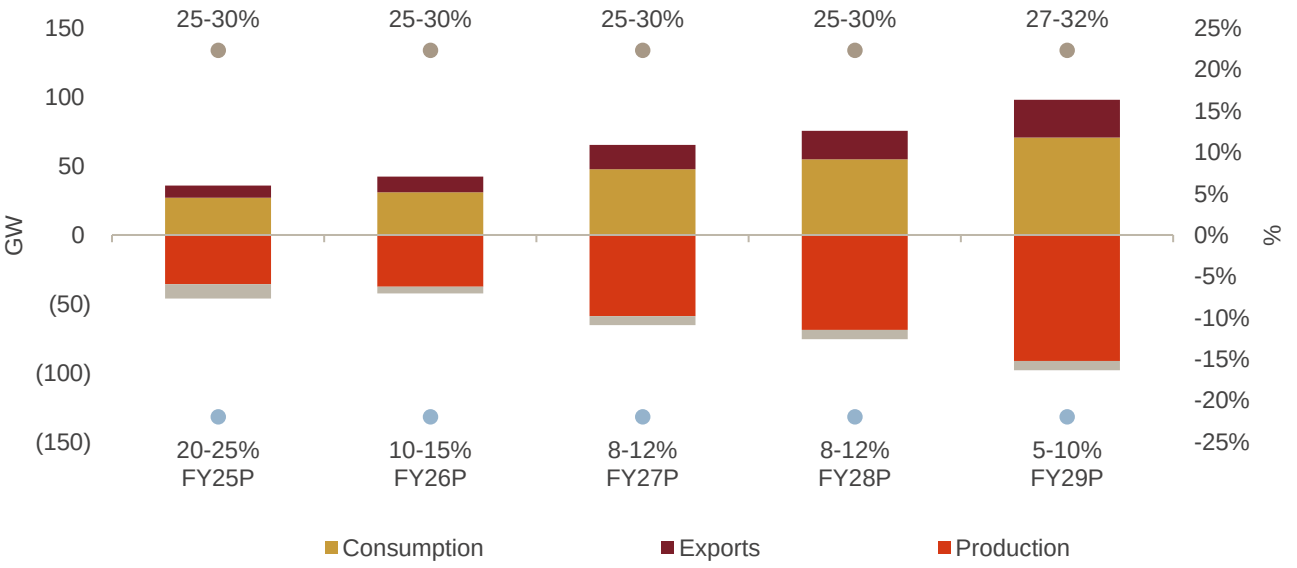
Source: EIA, CRISIL MI&A Research

On average, the difference between the module prices of US and Indian produce has been ~$0.06/Wp between Fiscal 2023 and eleven months of Fiscal 2024.

Export-import balance to improve over the next five Fiscals

While the demand for solar modules remains robust at an average of 50-55 GW between Fiscals 2024 and 2030, the growth in production of modules is expected to result in oversupply from Fiscal 2025 onwards leaving room for exports. India exported ~7 GW of modules in Fiscal 2024, accounting for ~50% of the domestic production. Overcapacity of module manufacturing compared to domestic demand between Fiscals 2024 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.

Figure 40: Import dependence to fall below 10% by Fiscal 2029



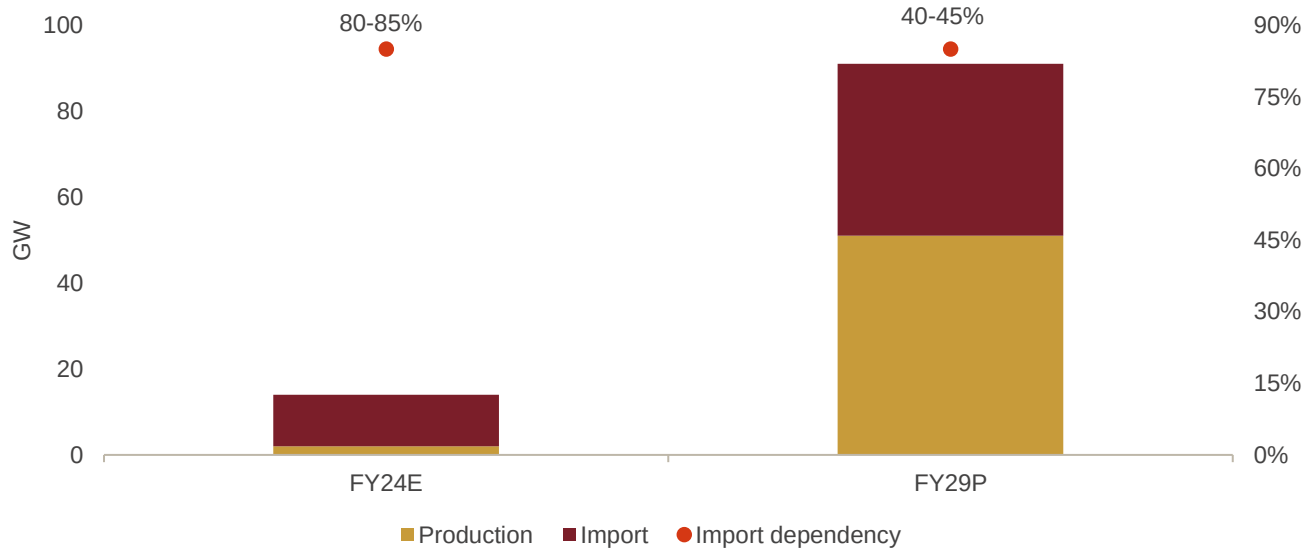
Source: CRISIL MI&A Research

Consequently, with rising nameplate capacity and reimposition of ALMM from Fiscal 2025, import dependency for modules is expected to fall from 59% in Fiscal 2024 to 5-10% by Fiscal 2030. However, a low base of fully integrated capacity would still result in high import reliance for upstream components such as polysilicon, wafers and cells.

The prices of solar components fell significantly over the last three Fiscals supporting imports.

Furthermore, even with significant cell manufacturing capacity additions in the country, reliance of Indian module manufacturers on imported cells would remain high despite reducing significantly over the next five Fiscals. In percentage terms, import dependency is expected to go down from over 80% in Fiscal 2024 to 40-45% by Fiscal 2029.

Figure 41: Expansion of cell capacities to be largely used for in-house production



Note: Import dependency = (Imports / (Production + Imports))

Source: CRISIL MI&A Research

While India does export cells to the US and other Asian nations, the quantum remains low. Thus, the increase in capacity of cells is expected to be largely utilised for production of modules. MNRE had proposed a draft for application of ALMM on solar cells. Imposition of this can result in sharper reduction of cell imports and remains a monitorable as on date.

Sharp fall in prices of components

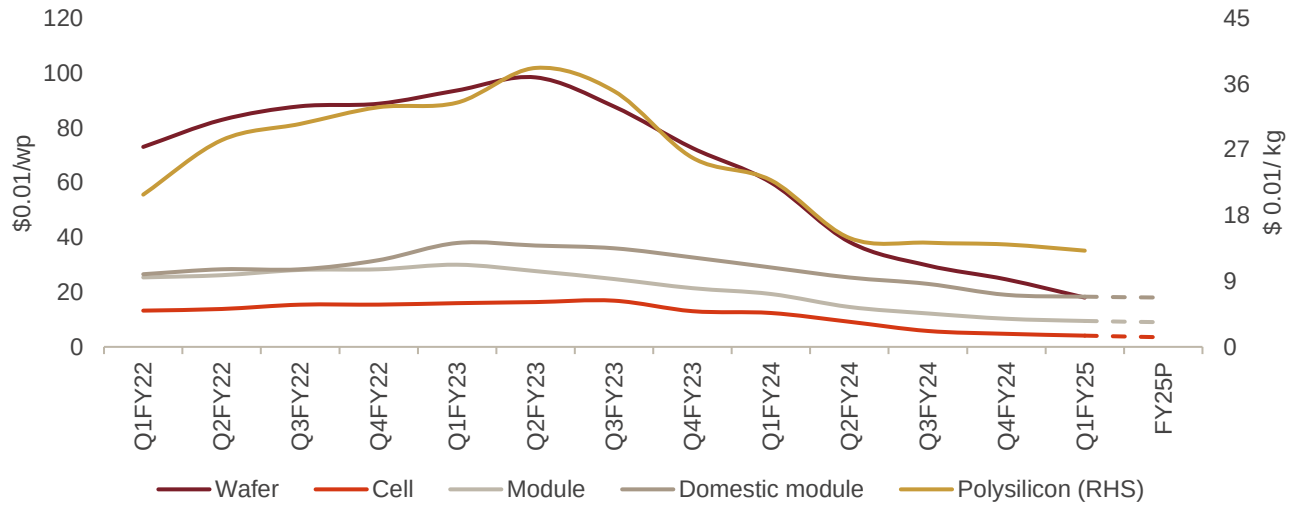
The prices of upstream components such as polysilicon shot up to $0.38 per kg in the second quarter of Fiscal 2023 owing to power rationing in solar provinces in China, followed by the Chinese energy crisis due to low coal stocks and demand surge. However, on a global scale, the polysilicon base expanded by 68% on-year by the end of December 2022, reaching a range of 1,000-1,100 tonne from the previous 600-650 tonne. Despite strong demand from China, the increased installed base by December 2022 resulted in oversupply, causing a dramatic price drop to $0.13 per kg by the first quarter of Fiscal 2025, less than half of the peak of the second quarter of Fiscal 2023.

Consequently, downstream components also witnessed significant price reductions, with wafer prices plummeting 81% to $0.18 per piece in first quarter of 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 prices of its PV wafers twice between April and May 2023, reducing prices by 33% as cell manufacturers sought to fulfil their

order requirements. Cell prices also saw a decrease of 74% in the first quarter of Fiscal 2025 over second quarter of Fiscal 2023, reaching $0.04 per Wp, while module prices fell 68% during the same period.

The combination of weak European demand and an accumulation of Chinese module inventory is expected to keep global module prices subdued in 2024.

Figure 42: Prices plunge as world sees a supply glut



Source: CRISIL MI&A Research

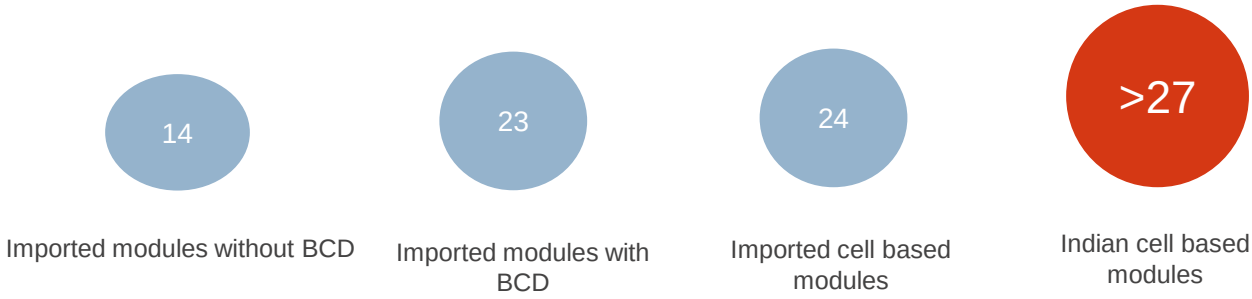
The price of modules assembled using imported cells dropped 52% during the same period. The oversupply is expected to continue this Fiscal, resulting in the prices of imported solar modules ranging $0.08-0.1 per Wp and $0.17-0.19 per Wp for the locally assembled ones. However, prices of modules assembled using Indian cells remained at least 1.2 times higher than those assembled using imported cells.

Pricing of Indian cell-based modules minimum 1.2 times higher than that of imported cell-based

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. While 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 1.2 times more expensive than modules utilising imported cells and ~2 times more expensive than a traded Chinese module.

Figure 43: Indian cell-based module prices nearly double of traded Chinese modules in Fiscal 2024

$ cent / wp



Note: Prices are for Fiscal 2024.

Source: CRISIL MI&A Research

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.

Growth drivers for PV manufacturing

The PV manufacturing industry has received both demand and supply incentives over Fiscals 2019-2024. The fruits of these benefits are expected to materialise over the years.

Figure 44: Demand and supply drivers for PV

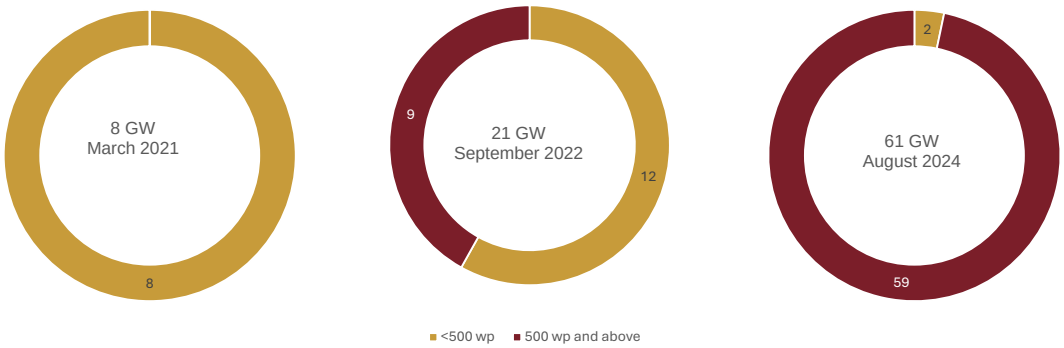
Source: CRISIL MI&A Research

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, that is from Fiscal 2024 till Fiscal 2028. Since RE projects take 18-24

months for commissioning, the bid plan will 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 and manufacturers are used 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 August 2024 with increasing enlistments. The capacity enlisted touched 61 GW in August 2024, 7 times more than that listed in March 2021.

Figure 45: Enlisted capacity grows ~7 times

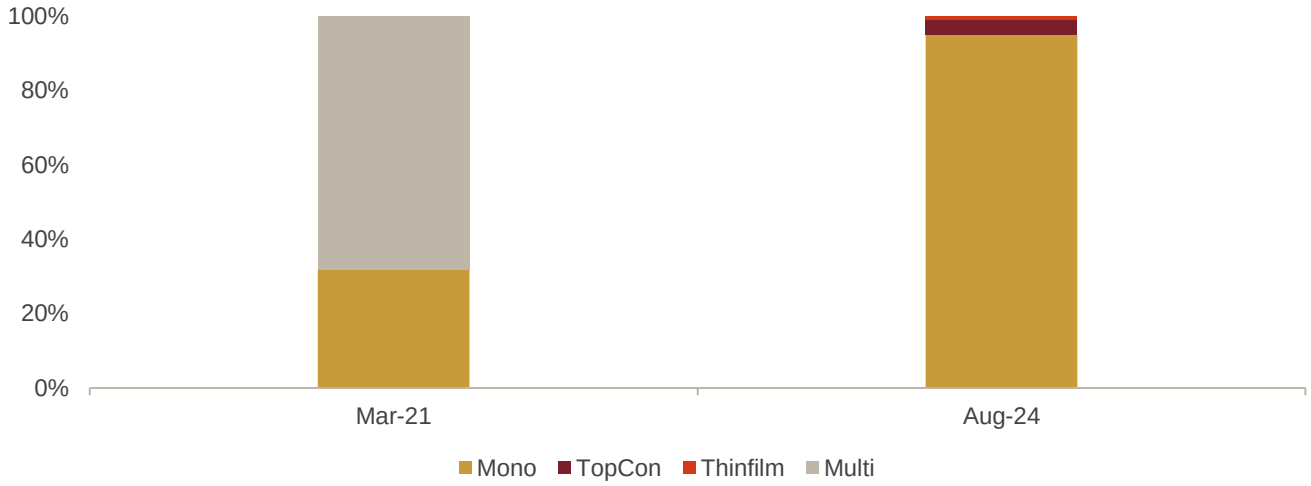


Note: Capacity inside the doughnut is the total enlisted capacity as per ALMM

Source: MNRE, CRISIL MI&A Research

Furthermore, the composition in the list has now also been upgraded with the emergence of TopCon modules in August 2024. Mono C-Si share has increased from 32% in March 2021 to 95% in August 2024, increasing the confidence of domestic developers.

Figure 46: Mono replaces multi as the dominant technology



Note: Share based on enlisted count as per ALMM

Source: MNRE, CRISIL MI&A Research

The initiative does not involve any foreign manufacturer's plant globally as of August 2024, providing price resilience to domestic manufacturers. The ministry is also in discussion to release an ALMM for solar cells.

3. China plus one strategy: The China plus one 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 favourable political and regulatory environment for manufacturing. Rising manufacturing base has enabled domestic manufacturers to tap the export potential with nearly 97% of exports focused on the US alone.

4. PLI scheme: MNRE launched tranche I of the PLI scheme for high efficiency solar modules in April 2021 allocating 8.7 GW to three manufacturers with an outlay of ₹45 billion. However, this was later increased, and a second round of allocation was conducted based on 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 ₹195 billion. The purpose of the scheme was to enable the building of vertically integrated solar manufacturing capacities for better quality control and competitiveness. While the scheme remained technologically agnostic, technologies that yielded better module performances were to be incentivised. The scheme witnessed allocations to 13 unique manufacturers in India across various stages of the value chain.

   The players will only be eligible for half of the capacities allocated. The PLI scheme is expected to be pivotal in setting up a capital-intensive upstream value chain (polysilicon and wafer) as over 80% of all the expected additions in these segments will be driven through the scheme by Fiscal 2030, resulting in a reduction of Indian PV manufacturers' reliance on imports.

5. Basic custom duty (BCD): The government of India from time to time 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 April 1, 2022. While the imposition of BCD of ~40% on modules and 25% on cells led to the capital cost increasing, the price disparity between a domestic assembled module and imported module reduced from $7-8 cents/Wp to $1-2 cents /Wp resulting in demand for domestic manufacturers.

6. SPECs: The scheme for promotion and manufacturing of electronic components and semiconductors in India is a government initiative launched to boost domestic manufacturing of electronic components including those essential for solar PV modules. The scheme is part of the larger effort to create a self-reliant electronics ecosystem in India, reducing dependence on imports, particularly from China. Under the scheme, financial incentives are provided to manufacturers of critical components including solar cells, semiconductors and other electronics, which are vital for solar module production. The incentives include a financial subsidy that covers 25% of capex on new plants or machinery analogy upgrades, and research and development activities, aimed at enhancing India's production capacity and technological capabilities. The solar industry relies heavily on semiconductors, particularly for inverters, storage systems and other components, and the ability to produce these domestically is crucial for building a resilient solar supply chain. The scheme also contributed to India's China plus one strategy by encouraging global companies to invest in India's solar component manufacturing, positioning India as a reliable alternative to China for solar equipment.

While 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, market and competition risk, among others.

Risks and monitorable

The PV industry faces multiple risks across various facets of business.

Figure 47: 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 MI&A Research

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