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India's Photovoltaic Manufacturing Capacity Set to Surge

Conducive policies and growing private sector interest pushing the country towards self-sustenance for solar PV modules

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Key Findings

Around 110 gigawatts (GW) of photovoltaic (PV) module manufacturing capacity is set to come online in India by the financial year (FY) 2026, which will make the country self-sufficient.

India's cumulative module manufacturing nameplate capacity more than doubled from 18GW in March 2022 to 38GW in March 2023.

The two tranches of the production-linked incentive scheme will help add 51.6GW of module capacity and at least 27.4GW of integrated ‘polysilicon-to-module’ capacity in India in the next three to four years.

Compared to FY2022, Indian PV exports (by value) have already risen by more than 5x in FY2023.

Executive Summary

India's nameplate manufacturing capacity for solar photovoltaic (PV) modules will likely reach 110 gigawatts (GW) by 2026. Upon reaching that mark, the country would attain self-sufficiency for its solar PV module demand. India should then focus on expanding its reach in other global markets and offer its PV products as a viable alternative to China in terms of quality and price. Favourable policies, particularly the production-linked incentive (PLI) scheme have helped PV manufacturing grow rapidly in the last two to three years, with the nameplate capacity for both cells and modules more than doubling. Yet, overreliance on imports for upstream components, muted interest among domestic consumers for locally made PV products and lack of skilled manpower to install and operate the high-tech machinery is holding back the full potential of the industry. Policy stability must continue to sustain investor confidence in the PV manufacturing sector.

Since the early 2010s, the world has largely depended on China for its photovoltaic (PV) equipment requirements. The huge concentration of the entire PV value chain in one country poses a potential risk to other countries. It leaves them susceptible to localised supply chain shocks and other challenges.

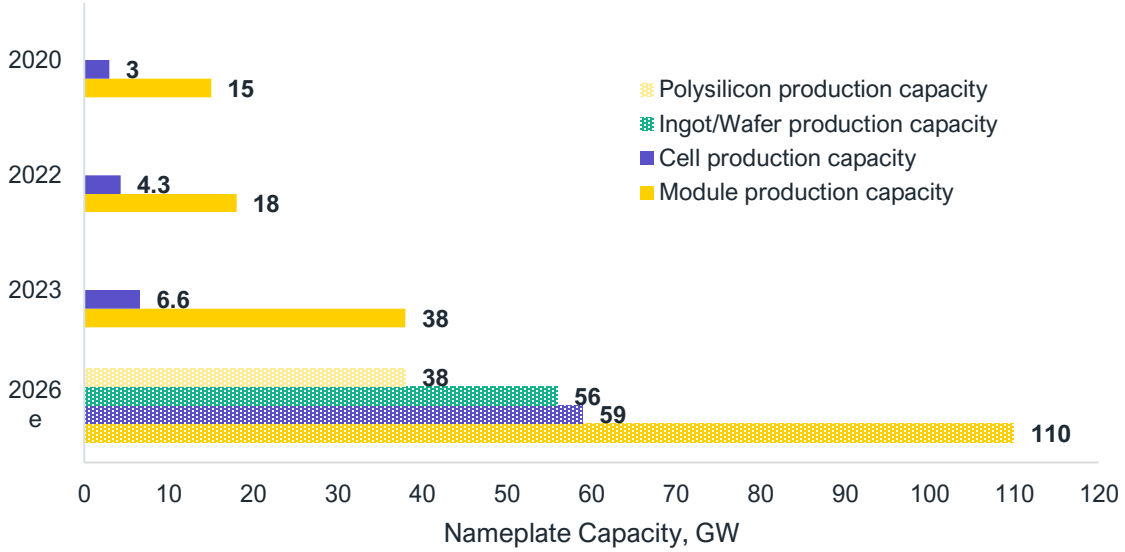
In recent years, PV importers, such as India, the United States of America (the U.S.) and Europe, have enacted several measures to limit the dependence on China and support local PV manufacturing.

India introduced a safeguard duty (SGD) in 2018, while the U.S. instated anti-dumping duty (ADD) on Chinese PV imports. More recently, the U.S. issued its Inflation Reduction Act (IRA), which provides an extensive production-linked incentive plan to support PV manufacturing.

In India, the government has put in place several tariff (basic customs duty (BCD)) and non-tariff (Approved List of Models and Manufacturers (ALMM)) barriers to PV imports. In addition, the government included solar PV manufacturing in its production-linked incentive scheme (PLI) scheme, with a total outlay of approximately US$3.2 billion spread over two tranches.

Echoing the favourable policy environment created by the Indian government, PV manufacturing has grown rapidly in the last two to three years. Between 2020 and 2023, the nameplate capacity for both cells and modules more than doubled in India. We estimate that the operational capacity for both cells and modules is between 50-60% for most manufacturers.

Figure 1: Growth of Domestic PV Manufacturing Capacity



Source: JMK Research

By 2026, India will likely reach the 110 gigawatts (GW) mark in solar module manufacturing nameplate capacity. India will also have a notable presence in all upstream components of PV manufacturing, such as cells, ingots/wafers and polysilicon.

The PLI scheme is one of the primary catalysts spurring the growth of the entire PV manufacturing ecosystem in India. Besides the augmentation of infrastructure in all stages of PV manufacturing, from polysilicon to modules, it will also lead to the simultaneous development of an ancillary market. Based on the result of both tranches of PLI, the scheme will lead to the direct augmentation of 51.6GW of module capacity and at least 27.4GW of integrated polysilicon-to-module capacity in India.

PV technology is continuously evolving. Poly-crystalline, which was the mainstay just a few years back, is already obsolete. Currently, designs for all existing and proposed manufacturing lines are for mono-passivation emitter rear contact cells (PERC). This continuous technology shift highlights the need for manufacturers to plan carefully while designing their PV lines to accommodate all future scenarios. Hence, all current mono-PERC line designs can easily upgrade to other upcoming technologies, such as Heterojunction technology (HJT) or Tunnel Oxide Passivated Contact (TOPCon).

Furthermore, all major PV importers also aim for a "China+1" strategy for their PV sourcing requirements. In addition to already having the second largest module manufacturing capacity, India has significant expansion plans in the next two to three years. Hence, Indian tier-1 manufacturers have a huge interest and demand from abroad for their products. Compared to the financial year (FY) 2022, Indian PV exports (by value) have already risen by more than 5x in FY2023.

However, despite the growth and demand from other exports market, the Indian PV manufacturing sector is still facing headwinds. These include sustained reliance on imports, especially for upstream components (polysilicon and ingots/wafers), ancillaries and PV machinery. Although the quality of all tier-1 Indian manufacturers is comparable to global standards, the manufacturers have complained that the domestic consumer base is largely hesitant towards Indian PV products. In addition, the lack of skilled manpower to install and operate the high-tech machinery, especially for cells and other upstream components, is also an ongoing challenge.

The future of the Indian PV manufacturing sector is bright. Upon attaining self-sufficiency in the next two to three years, India must focus on expanding its reach in other global markets and offer its PV products as a viable alternative to China in terms of quality and price. In the meantime, policy stability is a must for sustaining investor confidence in the market.

Glossary of Terms

Abbreviation	Definition
ADD	Anti-Dumping Duty
ALMM	Approved List of Modules and Manufacturers
BCD	Basic Customs Duty
CAPEX	Capital expenditure
DCR	Domestic content requirement
EVA	Ethylene Vinyl Acetate
EU	European Union
EC	European Commission
FY	Financial year
GW	Gigawatt
GDP	Gross Domestic Product
HJT	Heterojunction Technology
IRA	Inflation Reduction Act
IEA	International Energy Agency
IREDA	Indian Renewable Energy Development Agency
mm	Millimetre
Mono PERC	Monocrystalline Passivated Emitter and Rear Cell
MNRE	Ministry of New and Renewable Energy
MW	Megawatt
PLI	Production Linked Incentive
PERC	Mono Passivation Emitter Rear Contact Cell
PV	Photovoltaic
PM-KUSUM	Pradhan Mantri Kisan Urja Suraksha Evam Utthaan Mahabhiyan
R&D	Research & development
ROW	Rest of world
SGD	Safeguard Duty
SEIA	Solar Energy Industries Association
TOPCon	Tunnel Oxide Passivated Contact
US	United States
USA	United States of America
USD	United States Dollar
UAE	United Arab Emirates
Wp	Watt-peak
XUAR	Xinjiang Uyghur Autonomous Region

1. Indian Solar Photovoltaic Manufacturing Landscape

The Indian solar photovoltaic (PV) manufacturing industry is in a pivotal growth phase. It has witnessed an accelerated transformation post-COVID-19, primarily aided by a favourable policy environment. As a result, the industry is gearing up to support the surging demand for solar power in domestic and international markets.

Over the years, India and other net PV importing countries, such as the United States of America (the U.S.), have enacted several measures to limit dependence on China for PV products. These include implementing tariff barriers, such as a safeguard duty (SGD) in India and an anti-dumping duty in the U.S.

With the implementation of the Atmanirbhar Bharat Abhiyan campaign in 2020,[1] domestic manufacturing has become one of the key pillars of India's long-term development strategy. In line with this vision, the central government introduced a production-linked incentive (PLI) scheme for 14 key sectors with a total outlay of Rs1.97 trillion (US$23.8 billion). The government chose labour-intensive and heavy import-dependent sectors for the scheme to reduce the import bills and drive employment growth simultaneously. The integrated manufacture of high-efficiency solar PV modules was one of those sectors, highlighting how important PV manufacturing is to the government.

The government is currently removing all potential roadblocks to domestic PV manufacturing to reduce enterprises' import dependence and mitigate their risk of exposure to uncertainty in global supply chains.

To enable and maintain the sustainable development of the solar PV manufacturing industry, the Indian government is aiding simultaneous growth in the demand and supply of domestically manufactured PV products. Schemes with a domestic content requirement (DCR) aid demand through the mandatory use of domestically manufactured modules. These include Pradhan Mantri Kisan Urja Suraksha Evam Utthaan Mahabhiyan (PM-KUSUM) Scheme and the Central Public Sector Undertaking (CPSU) Scheme. On the other hand, schemes such as PLI aid supply by providing financial support to the manufacturers.

Since the start of 2022, the PV value chain's downstream stages (cells and modules) manufacturing capacity has grown significantly. Though the upstream stages (polysilicon and ingot/wafers) remain virtually non-existent in the Indian context, there are some notable preliminary developments.

[1] Ministry of Finance. Finance Minister announces Government Reforms and Enablers across Seven Sectors under Aatma Nirbhar Bharat Abhiyaan. May 2020.

Figure 2: Stages of Solar PV Manufacturing

Source: JMK Research

In India, PV manufacturing capabilities drastically reduce as we move up the value chain, from solar modules and cells to ingots/wafers and polysilicon. This is due to the increasing complexity and manufacturing capital expenditure (capex) requirements as we move upstream in the PV value chain. Historically, polysilicon and ingots/wafers have had negligible to zero relevance in India's overall PV commodities/products trade. The domestic industry has relied entirely on imported products from international markets for these components.

Table 1: Domestic PV Supply Chain: Current Status and Outlook (December 2022)

Parameter	Module	Cell	Ingot/Wafer	Polysilicon
Nameplate Capacity	38GW	6.6GW	Negligible	Nil
Operational Capacity	19-20GW	3-4GW	Negligible	Nil
Number of Active Players	70+	8+	1 (Adani Solar)	Nil
Current Status	Numerous mid- to large-scale capacity additions are in progress	Pace of development strongest of all stages	Substantial progress underway in terms of capacity addition; Adani Solar aims to expand to 2GW capacity by the end of 2023	No presence currently. PLI scheme to act as a critical catalyst.
Outlook	Very strong mid- to long-term prospects with total nameplate capacity to reach about 110 GW in three years	Total nameplate capacity to exceed 50GW in three years on account of high demand	Moderate to highly favourable near-term prospects will advance the progress of the manufacturing plans of big and established manufacturers	Low favourability for capacity addition in the near term owing to the highly complex manufacturing process and capex

Source: JMK Research

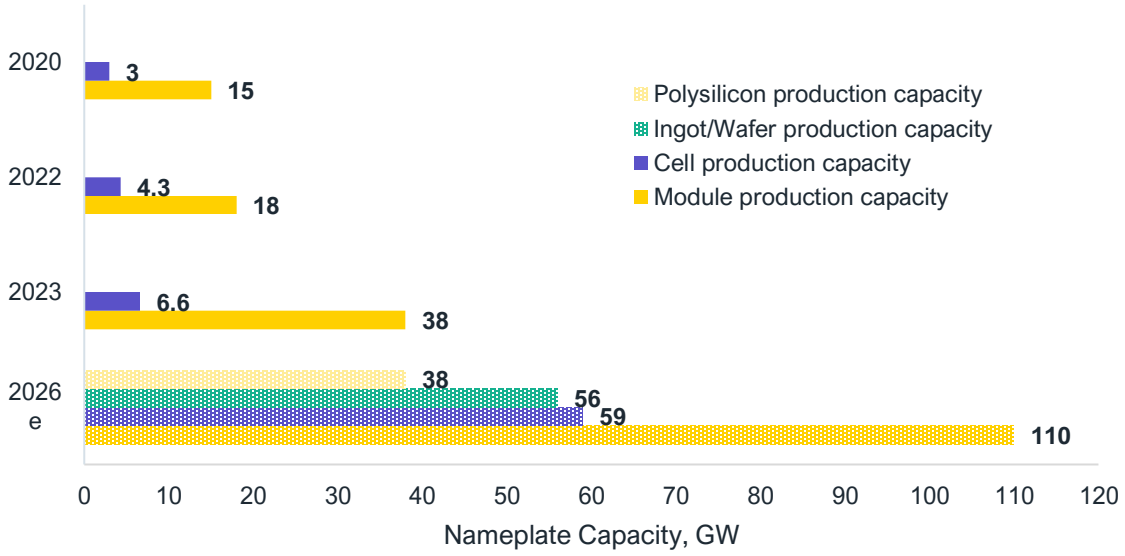
Over the next two to three years, India aims to build its presence across all stages of PV manufacturing. It has a long-term target to build enough capacity to meet the needs of both the domestic and export markets.

Domestic Manufacturing Capacity

While the current manufacturing capacity in India across the PV value chain is sub-optimal, it is likely to grow by leaps and bounds this decade.

Indian enterprises currently can manufacture only modules and cells. By 2026, they will likely have a significant manufacturing presence in polysilicon (38GW) and ingots/wafers (56GW).[2] By the same time, module production capacity will reach 110GW, approximately 3x the current capacity and around 7x the capacity in 2020 (see Figure 3).

Figure 3: Growth of Domestic PV Manufacturing Capacity



Source: JMK Research

Modules

India currently has one of the largest solar module manufacturing capacities outside China. Moreover, with several manufacturers announcing their expansion plans, the near to mid-term prospects of the sector are also very strong.

Existing Capacity

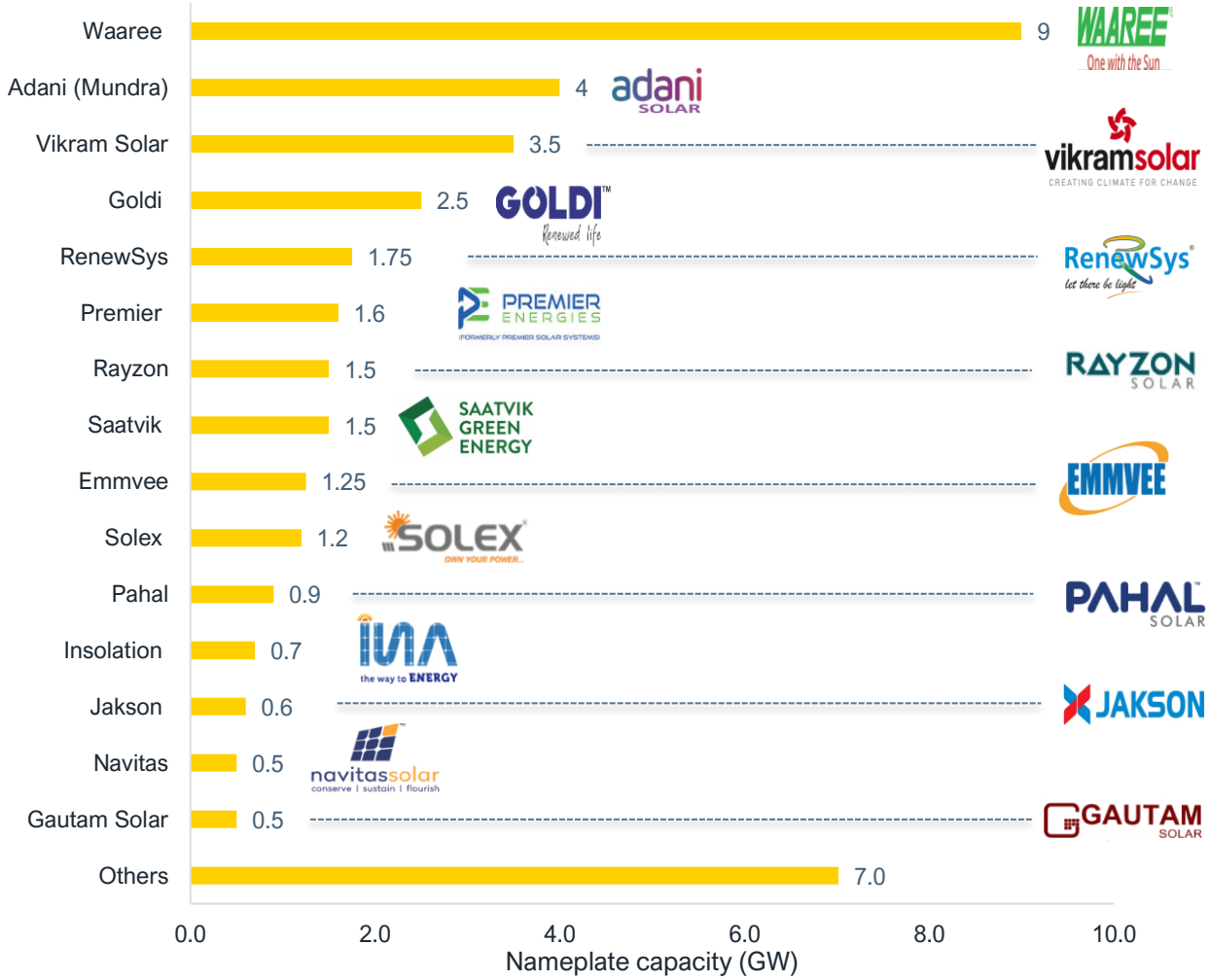
According to JMK Research, India's cumulative module manufacturing nameplate capacity as of March 2022 was 18GW. By March 2023, the cumulative capacity had leapfrogged to around 38GW, a remarkable addition of more than 100%.

[2] Business Standard. Solar manufacturing PLI to create 90 GW additional capacity: RK Singh. October 2022.

JMK Research estimates that leading manufacturers' operational module manufacturing capacity is about 50-60% of their nameplate capacities.

The top ten domestic manufacturers contribute 72.3% of this cumulative capacity (see Figure 4). As of March 2023, Waaree, with a capacity of 9GW, is the largest module manufacturer in India.

Figure 4: Current Solar Module Manufacturing Capacity of Leading Indian Companies

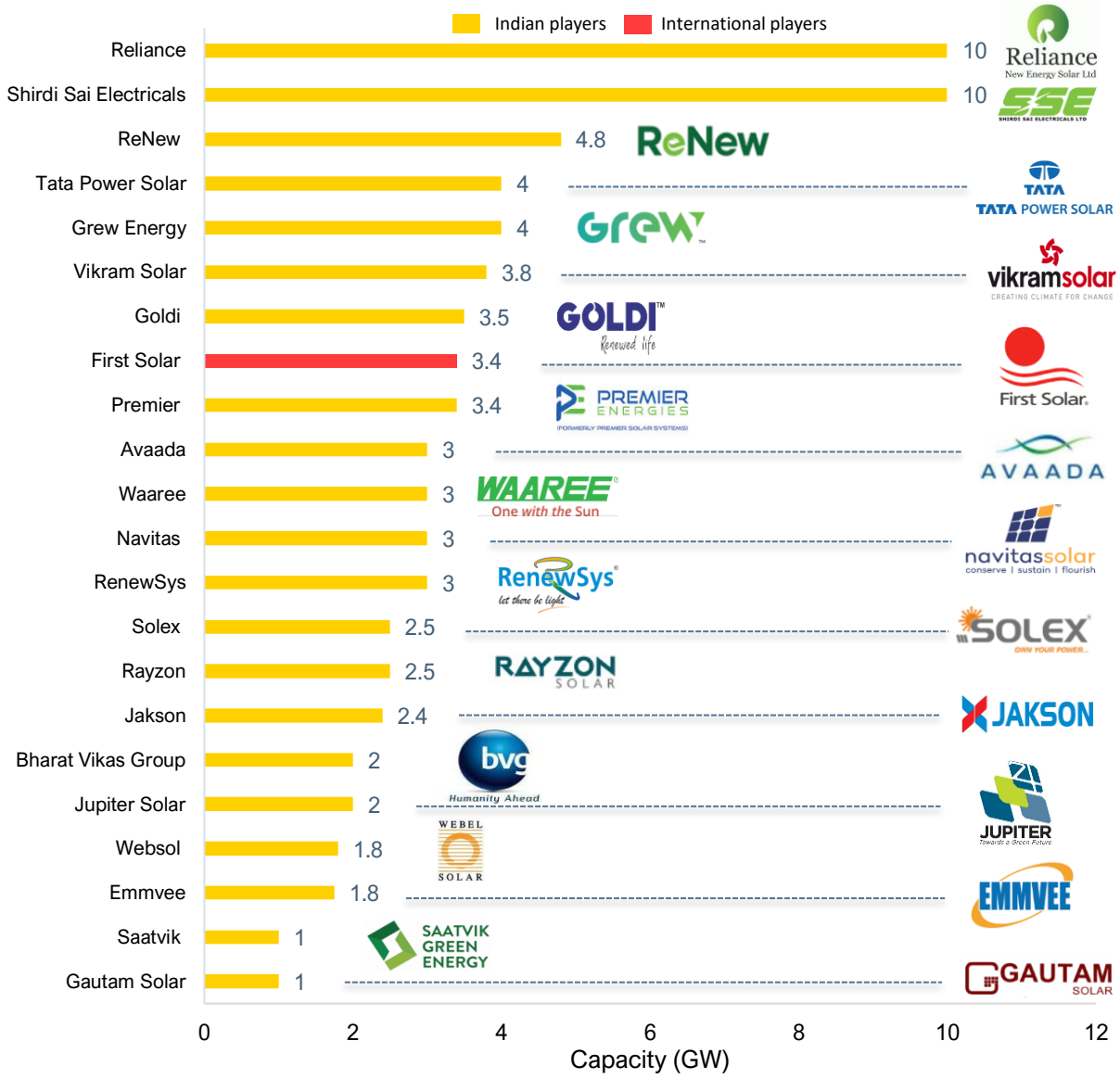


Source: News articles, JMK Research

Upcoming Capacity by 2026

Currently, at least 23 companies have proposed setting up GW-scale new module manufacturing capacities in the country. Based on the proposed capacity addition size, Reliance New Energy Solar (Reliance), Shirdi Sai Electricals, ReNew, Tata Power Solar (Tata) and Grew Energy (a subsidiary of Chiripal group, a Gujarat-based textile manufacturer) are the top five manufacturers. According to JMK Research, the top five manufacturers will add ~33GW of new module capacity in India by 2026.

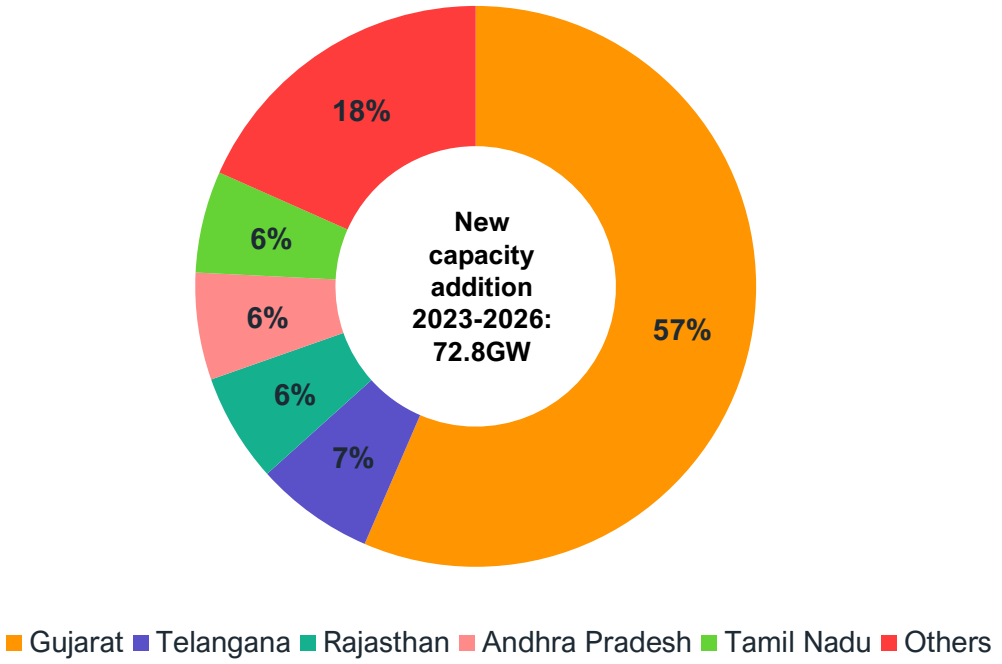
Figure 5: Proposed Addition to Module Production Capacity in India: Manufacturer-wise Distribution by 2026



Source: News articles, JMK Research

The coastal state of Gujarat alone accounts for nearly 57% of all the forthcoming PV manufacturing capacity. Some major reasons manufacturers chose Gujarat for setting up their PV fabrication facilities (fabs) include cheaper industrial electricity prices and easy access to ports for imports and exports. Further, the base of some of the largest Indian PV manufacturers, such as Adani and Waaree, is already in Gujarat.

Figure 6: State-wise Share of Upcoming PV Module Manufacturing Capacity in India, 2023-2026



Source: JMK Research

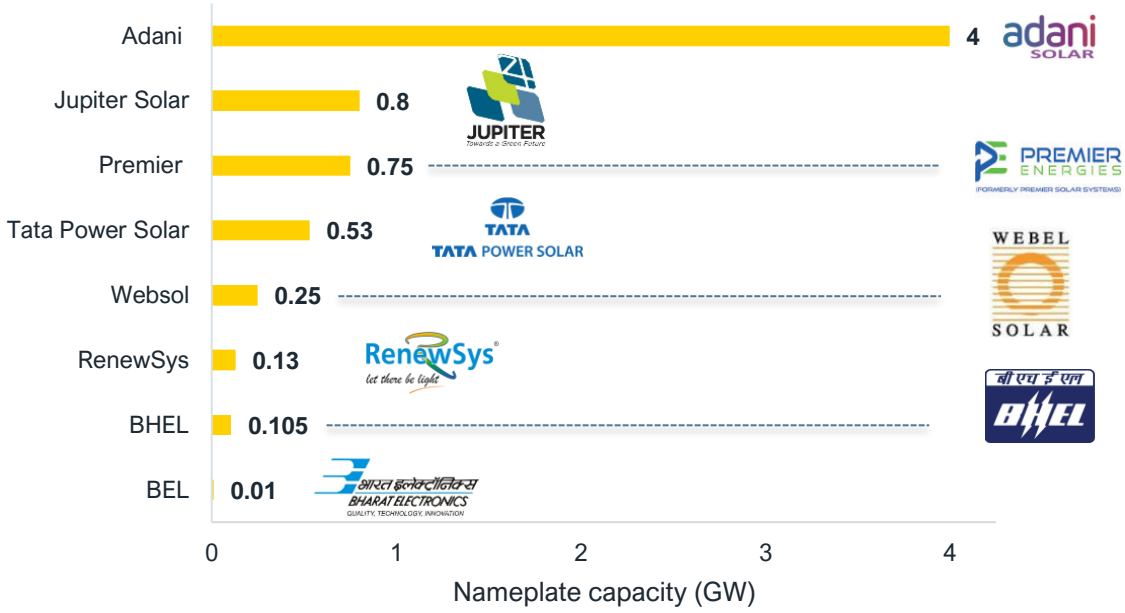
Cells

In the past few years, solar cell manufacturing capacity in India has risen. Still, it lags significantly behind the module manufacturing capacity. However, based on the announced expansion plans of several local manufacturers, domestic cell manufacturing is likely to grow rapidly in the next two to three years.

Existing Capacity

In March 2022, the cumulative capacity of cell manufacturing was about 4.3GW, which increased to about 6.6GW by March 2023, an addition of 53.4%. According to industry estimates, the operational capacity could be 50% (or even less) of the nameplate capacity.

Figure 7: Current Solar Cell Manufacturing Capacity in India: Manufacturer-wise Distribution



Note: BHEL stands for Bharat Heavy Electricals Limited

Source: News articles, JMK Research

Upcoming Capacity by 2026

JMK Research expects nearly 52GW of additional cell manufacturing capacity to be online in India by 2026. We expect five big Indian manufacturers — Reliance, Waaree, Goldi Solar, Shirdi Sai Electricals and Tata Power Solar — alone to contribute ~58% of this new capacity addition.

In 2021, Reliance announced that it would start building a 10GW solar cell and module factory in Jamnagar, Gujarat, by 2024, with plans to scale up the annual capacity to 20GW in a phased manner by 2026.

- In April 2022, Reliance signed an agreement with Chinese solar cell equipment supplier Suzhou Maxwell Technology to purchase heterojunction technology (HJT) cell manufacturing lines to manufacture 4.8GW of HJT cells.
- Reliance will use the high-efficiency HJT of Renewable Energy Corporation (REC) Solar Holdings, a Norway-based PV manufacturer it acquired in October 2021, for its Jamnagar factory.[3]

Other companies are also planning expansions. For example, Grew Energy plans to enter the big league of solar PV manufacturers, aiming to build a 2GW cell manufacturing facility by 2026. In a more recent development, Centrotherm, a Germany-based technology and equipment provider to

[3] PV Tech. Reliance Industries' REC Group lands PV equipment supply deal with Maxwell Technologies for HJT modules. October 2022.

the PV industry, disclosed that it had received orders for delivering solar cell manufacturing lines of more than 10GW capacity from six customers in India.[4]

Some other prominent players looking to set up new cell manufacturing lines include Vikram Solar, ReNew, Emmvee, Premier Energies and Solex. Existing players, such as Jupiter and Websol, are also expanding their operational cell capacities.

Ingots/Wafers

China has 97% of the global solar wafer manufacturing capacity, according to the International Energy Agency (IEA).[5] It also holds 80–85% of the manufacturing capacity of polysilicon, the raw material for wafer manufacturing. The polysilicon capacity outside of China (15–20%), translating to 60-80GW, is in the U.S., Germany etc. Therefore, as an alternative to China, India must source a significant portion of its polysilicon requirement from these countries for domestic wafer manufacturing.

The capex of ingot/wafer manufacturing is roughly the same as cell manufacturing. However, the current technology associated with wafer manufacturing is less complex than that of cells. We expect these fundamental aspects, inter alia, to drive domestic opportunities in India for wafer manufacturing.

Existing Capacity

So far, in India, Adani Solar is the only company that has demonstrated a product in the ingots/wafers stage. In December 2022, Adani Solar introduced a large-sized monocrystalline silicon ingot in its Mundra (Gujarat) facility. This development led the company to become India's first manufacturer of monocrystalline silicon ingots, capable of producing M10 (182mm) and M12 (210mm) size wafers. Adani Solar will exclusively use these ingots to produce its modules, whose efficiencies will range from 21% to 24%.[6]

Upcoming Capacity

While Adani Solar has initiated wafer production, it also plans to add 2GW of ingots/wafers capacity by December 2023, which it intends to scale up to 10GW by 2025.

In addition, in October 2021, Reliance New Energy Solar, a subsidiary of Reliance Industries Limited, invested US$29 million in German wafer manufacturer, NexWafe. The two companies also entered an agreement through which Reliance will access NexWafe's proprietary technology, which the Indian company will use to build large-scale wafer manufacturing facilities in India.

Finally, in July 2022, Emmvee Photovoltaic announced its plan to set up 1.5GW of wafer-to-module capacity in India by the end of 2023.[7]

[4] PV Magazine. Centrotherm's order book exceeds 10 GW in India. January 2023.
[5] IEA. Special Report on Solar PV Global Supply Chains. July 2022.
[6] Mint. Adani Solar introduces India's first large sized monocrystalline silicon ingot. December 2022.
[7] Company Website.

Polysilicon

Polysilicon, the first stage in the PV manufacturing chain, involves the most complex manufacturing process. Its capex requirement is very high. For example, setting up a polysilicon manufacturing facility to produce 1GW of solar modules can cost approximately US$100–150 million.

Manufacturers with access to large capital reserves, such as Reliance and Adani, will likely be at the forefront of domestic polysilicon manufacturing. The polysilicon they produce will likely be for self-consumption as raw material for their own wafer manufacturing facilities. Building fully integrated PV manufacturing capacities is prudent for these companies which have laid down huge commitments in the larger renewable energy ecosystem, including building large-scale green hydrogen production facilities.

Through integrated factories that PLI beneficiaries are setting up, we expect India to host the first of the future polysilicon manufacturing capacities within the next couple of years.

2. Trends in Domestic PV Manufacturing

New Entrants

Among those looking to set up GW-scale PV manufacturing facilities, Reliance, ReNew, the Chiripal Group (through its subsidiary Grew Energy) and the Bharat Vikas Group, one of India's largest integrated services companies, are some new entrants.

One of the largest coal producers in the world, Coal India, and power developers, such as Avaada, ReNew, and Amp Energy, have announced their plans to enter the domestic PV manufacturing landscape in the past two years.

As modules are the most expensive component of a solar project, developers are entering the manufacturing space for better cost controls and to ensure an all-year-round module supply. ReNew’s 6GW module and 2GW cell plants are likely to commence operation by the end of 2023.

PLI provides conglomerates and companies operating in other business domains a chance to invest in solar manufacturing. Hence, Reliance and Shirdi Sai Electricals, both beneficiaries of the first tranche of PLI, have ventured into large-scale PV manufacturing.

Even some global manufacturers are vying to set up their manufacturing facilities in India. The most prominent name in this is First Solar (a U.S.-based solar PV manufacturer), which is also one of the winners under PLI Tranche 2.

Shift in Technology

Over the last two to three years, the domestic PV manufacturing industry has dramatically moved to adopt advanced manufacturing technologies. We expect this trend to become stronger in the mid-term. Companies have set up the latest manufacturing facilities, which host semi- or fully automated machinery, either as an upgrade to obsolete manufacturing lines (usually on the part of big, established manufacturers) or as greenfield assets by new entrants.

Mono PERC technology, the workhorse of the global PV industry, predominantly forms the basis of new PV manufacturing lines. Though the domestic industry now possesses the technological capabilities to produce high-efficiency mono PERC cells and modules, it lacks production capacities at scale.

Many Indian manufacturers are transitioning to producing cells and modules with large wafer formats/dimensions. These modules have improved power output (wattage) between 435–650 watt-peak (Wp) or even higher. In addition, the adoption of bifacial module technology has also gained substantial momentum in the last one to two years.

The following section covers the recent trends in domestic PV manufacturing in India in detail in terms of aspects like cell technology and wafer format.

Manufacturing Line Technology

About 90% of the Indian solar market has transitioned to using mono PERC technology, according to industry estimates. Mono PERC will likely remain the mainstream technology for another two to three years in the global PV landscape. Thus, the Indian industry, in all likelihood, will follow this trend.

Typically, the capex of a mono PERC module manufacturing line is about Rs1 billion (~US$13 million) per GW. Meanwhile, a mono PERC cell manufacturing line costs 5x more, i.e., Rs5 billion (~US$65 million) per GW. Many Indian manufacturers have set up, or are in the process of setting up, new cell manufacturing lines with greater flexibility in terms of upgradability.

Companies such as Adani, Premier Energies, Jupiter Solar and Tata Power Solar have mono PERC cell and module manufacturing lines that are upgradable to Tunnel Oxide Passivated Contact (TOPCon) technology. On the other hand, Reliance will be using HJT for its upcoming Jamnagar PV manufacturing line.

Both TOPCon and HJT are the newest high-efficiency technologies in PV manufacturing that are swiftly gaining prominence.

TOPCon is gaining popularity in China. From 2023, we expect TOPCon's use to gradually increase and grab the market share of mono PERC in India. Many Indian businesses, including Adani and Emmvee, have already announced plans to set up either greenfield TOPCon capacities or modify existing mono PERC ones.

Table 2: PV Technologies Preferred by Various Indian Manufacturers

TOPCon		HJT
WAAREE One with the Sun	adani	WAAREE One with the Sun
EMMVEE	SSE Shirdi Sai Electricals Ltd	Reliance New Energy Solar Ltd
SAATVIK	WEBEL SOLAR	GOLDI SOLAR

Source: JMK Research

Wafer Format

Existing and prospective domestic cell manufacturers are either adopting or looking to adopt mono PERC technology with wafer sizes up to M12 (210mm) through M6 (166mm) and M10 (182mm). M10 wafers will likely be the preferred domestic market choice in the foreseeable future, based on lower logistics costs during transportation vis-à-vis M12-based modules.

It must, however, be noted that any greenfield investment for new manufacturing lines or any modifications to existing manufacturing lines dealing with wafer sizes up to M6 requires a moderate capex as opposed to wafers sized M10 and beyond. The latter needs many manufacturing line modifications, and the associated equipment requires huge capex investments.

With the larger wafers (M10 and M12) linked to superior performance (significantly greater power output), the overall cost of production vis-à-vis smaller wafers would be only modestly higher.

Table 3: Solar Wafer Sizes and Their Module Wattage

Wafer Size	Nominal Power Output (Wp)
M3	370–390
M6	435–460
M10	535–560
M12	590–650

Source: JMK Research

Progress of the PLI Scheme for Solar PV

In November 2020, the Indian government introduced a PLI scheme for manufacturing high-efficiency solar PV modules, among other things. The government approved the implementation of PLI for solar manufacturing in April 2021 with a financial outlay of Rs45 billion (US$605 million). It later enhanced the outlay by Rs195 billion (US$2.6 billion) under the Union Budget for 2022–23 in February 2022.

The government is implementing the PLI scheme in two tranches. It concluded the selection of PLI beneficiaries (final list) under the first tranche in February 2022. SECI announced the winners of the second tranche in March 2023.

Solar PLI Scheme Tranche 1

In May 2021, the Indian Renewable Energy Development Agency (IREDA) issued a tender inviting bids to set up 10GW of high-efficiency solar module manufacturing capacities. This tender received an overwhelming response, with 18 eligible bids aggregating 54.8GW. IREDA announced the successful bidders/beneficiaries – Shirdi Sai Electricals, Jindal India Solar Energy and Reliance New Energy Solar – in November 2021.

However, in February 2022, the IREDA updated the winners' list, adding Adani Infrastructure and excluding Jindal India Solar Energy. The total PLI to be granted across the three final awardees is Rs44.55 billion (US$542 million), which would lead to the setting up of 8,737 megawatts (MW) of PLI-linked capacity (see Table 5).

Table 4: List of Beneficiaries Under Solar PLI Tranche 1

Winner Name	Bidder's Manufacturing Capacity (MW)	Eligible Capacity for PLI (MW)	Total PLI for Five Years (Rs billion)
Reliance New Solar Energy	4,000	4,000	19.17
Shirdi Sai Electricals	4,000	4,000	18.75
Adani Infrastructure	4,000	737	6.63
Total		**8,737**	**44.55**

Source: IREDA, News Articles, JMK Research

Integrated wafer-to-module manufacturing lines under the first tranche will likely be online in the short-to-medium term. The main challenge lies in the setting up of polysilicon manufacturing lines. Setting up polysilicon manufacturing lines of 4GW (PLI-linked) capacity is financially unviable owing to its high capex requirements.

Thus, PLI Tranche 1 winners, Reliance and Shirdi Sai Electricals, both bid in the second tranche, where they were allotted additional capacities of 6GW each (Total PLI (PLI 1 + PLI 2) Cap – 10GW).

Table 5: Current Status of PV Manufacturing Facilities of PLI Beneficiaries

Company	Plant Capacity	Solar Technology	Land Procurement	Location	Equipment Procurement	Date of Commissioning	Proposed Expansion To…
Shirdi Sai Electricals	4GW	Mono PERC + TOPCon	Completed (5,147 acres)	Nellore, Andhra Pradesh	Under progress	April 2024	10GW
Reliance New Solar Energy	10GW	HJT	Completed (~5,000 acres)	Jamnagar, Gujarat	Done	2024	20GW, later than 2026
Adani Infrastructure	10GW (4GW already operational)	Mono PERC + TOPCon	Completed	Mundra, Gujarat	Under progress	2024	-

Source: News Articles, JMK Research

PLI beneficiaries are already planning and setting up factories. Reliance and Adani are in various stages of setting up fabs of 10GW each. Shirdi Sai Electricals, which is currently setting up only 4GW capacity, will expand to 10GW of PV manufacturing capacity in the future, owing to its win in the second tranche of PLI.

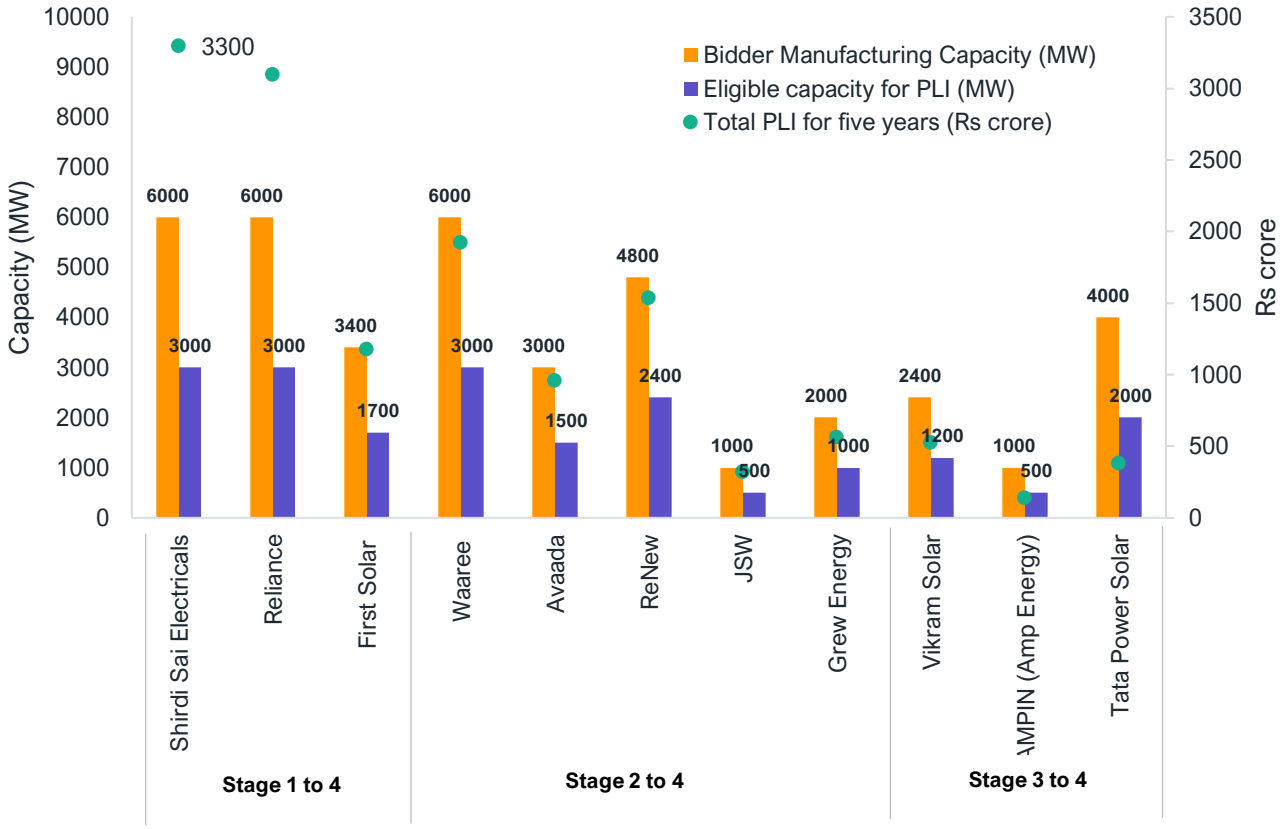
Solar PLI Scheme Tranche 2

The Indian government approved the second tranche (PLI outlay of Rs195 billion (US$2.6 billion)) in September 2022. The government expects this to substitute PV imports worth Rs1.40 trillion (US$16.94 billion) annually and create 975,000 direct and indirect jobs.[8]

Of the total Tranche 2 outlay, the government has reserved Rs120 billion (US$1.45 billion) for companies setting up integrated manufacturing of polysilicon, wafers, cells and modules. The funds allocated are Rs45 billion (US$605 million) for wafers, cells and modules and Rs30 billion (US$362.97 million) for cells and modules.

The Ministry of New and Renewable Energy (MNRE) anticipates the second tranche to significantly augment the country's PV manufacturing infrastructure (directly and indirectly) and boost the module manufacturing capacity multifold.[9]

Figure 8: PLI Tranche 2 Result and Winner Details



Note: Stage 1 (Polysilicon), Stage 2 (Ingot/Wafer), Stage 3 (Cell), Stage 4 (Module)

Source: SECI

[8] The Economic Times. Solar PLI of Rs 19500 crore under tranche II puts focus on product efficiency levels. October 2022.
[9] Business Standard. Solar manufacturing PLI to create 90 Gw addl capacity in India: R K Singh. October 2022.

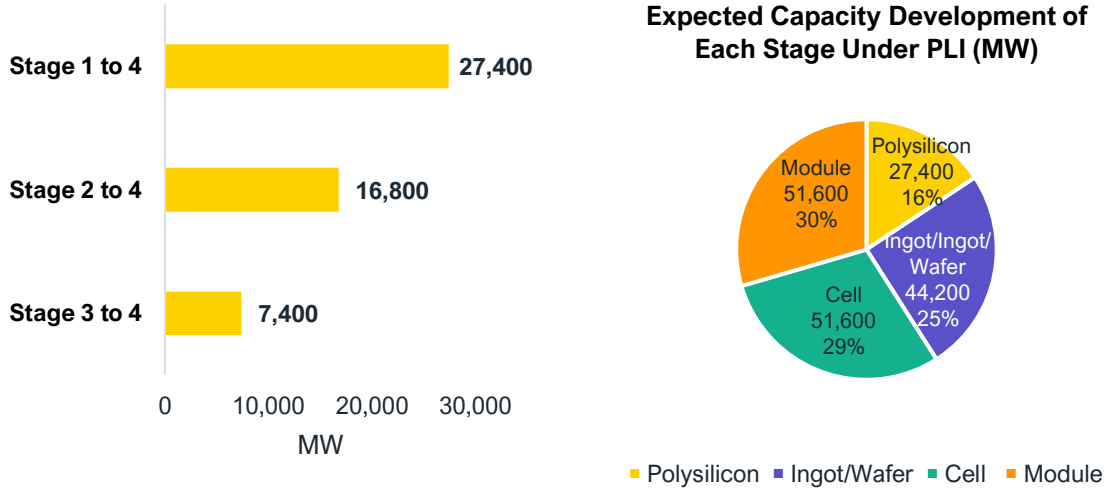
SECI conducted the bidding process for this second tranche of PLI, which concluded on 28 February 2023. As per the results announced on 28 March 2023, Shirdi Sai Electricals, through its subsidiary Indosol Solar Private Limited, secured the highest PLI amount of Rs33 billion (US$401 million) for an integrated polysilicon-to-module manufacturing capacity of 6,000MW.

Other prominent winners include Reliance (6,000MW), Waaree (6,000MW), ReNew (4,800MW), Vikram Solar (2,400MW), and Tata Power Solar (4,000MW). Adani, one of the largest domestic solar PV manufacturers, did not participate in PLI Tranche 2 bidding process.

Notably, U.S.-based solar manufacturer, First Solar, became the first and only non-Indian entity to secure a PLI. It received an incentive of Rs11.78 billion (US$143 million) for setting up a 3,400MW integrated polysilicon-to-module factory.

PLI Tranche 2 marks the entry of some prominent Indian solar developers into the manufacturing space. These include Avaada, ReNew and Amp energy. However, a significant portion of the manufacturing capacity by these developers will be for self-consumption in their own solar projects.

Figure 9: Cumulative Manufacturing Capacities Under Both Tranches of PLI, by PV Manufacturing Stages



Note: Stage 1 (Polysilicon), Stage 2 (Ingot/Wafer), Stage 3 (Cell), Stage 4 (Module)

Source: IREDA, SECI

Over the next few years, the PLI scheme (both tranches combined) will directly lead to the setting up of 27.4GW of integrated polysilicon-to-module manufacturing capacity in India. Additionally, the PLI scheme will add at least 51.6GW of module production capacity to reach 110GW by FY2026.

3. Impact of the Approved List of Module Manufacturers in Driving the Indigenisation of PV Manufacturing

The MNRE introduced the Approved List of Module Manufacturers (ALMM) in 2019 to ensure quality standardisation and lower the industry's dependency on imported solar modules. It updated the ALMM on 27 February 2023. The latest list includes 70+ MNRE-approved manufacturers and an enlisted capacity of 22,389MW.[10] All of these manufacturers are domestic companies.

Only those solar module models listed in the ALMM would be eligible for use in open access and net metering projects along with government projects, government-assisted projects, and projects under various government schemes and programmes.

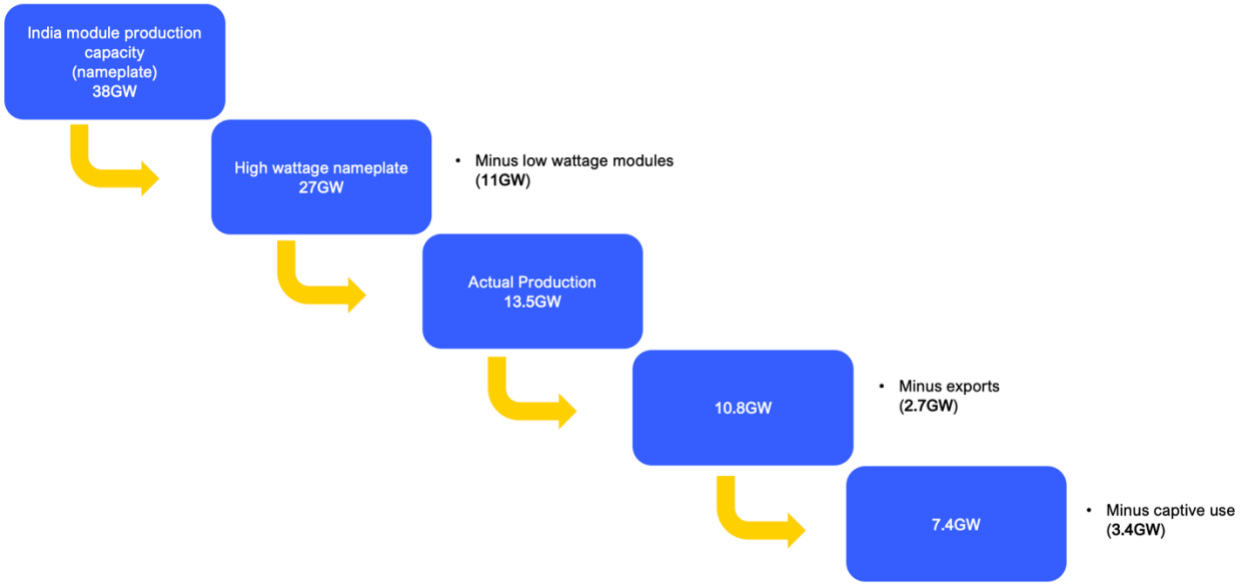
Even after applying the basic customs duty (BCD) on imported modules, the current cost differential between a domestic and imported module is negligible. In such a scenario, the ALMM acts as an absolute trade barrier protecting the interests of domestic manufacturers. Thus, over the past year, ALMM has been the most important driver for the development of domestic PV manufacturing.

Paucity of Domestic High-Wattage Module Availability Impeding ALMM Effectiveness

Most domestic module manufacturers lack higher wattage modules (>500Wp) in their portfolio. Thus, project developers in India face a paucity of module procurement options. Against the Indian nameplate PV module manufacturing capacity of around 38GW, the actual net availability of high-wattage, high-quality modules within the open domestic market is quite limited (around 7.4GW).

[10] MNRE. Updation of list 1 of ALMM. February 2023.

Figure 10: Net Availability of Domestic High-Quality High-Wattage Modules in the Open Market



Source: JMK Research

The limited availability of high-wattage modules consequently results in a substantial delay in the commissioning timeline of multiple solar projects, especially in the utility-scale segment. To address this shortage, in March 2023, the Indian government announced that it would defer ALMM implementation by a year until March 2024, until domestic PV manufacturing could sustain local demand.[11]

While the ALMM deferment is a big relief to the developers, it is a temporary setback to domestic manufacturers' rapid expansion plans. At this juncture, it is critical for regulatory stakeholders to carefully balance the needs of developers and manufacturers in the best interests of the overall growth of the solar sector in India.

[11] MNRE. Approved models and manufacturers of solar photovoltaic modules order amendment. March 2023.

4. Risks and Challenges

Despite all the current growth drivers, several major challenges are still hampering the growth of the Indian PV manufacturing sector. While some key challenges, including supply chain disruptions, reductions in polysilicon price, and regulatory clarity regarding BCD, have found a resolution, other pertinent ones remain.

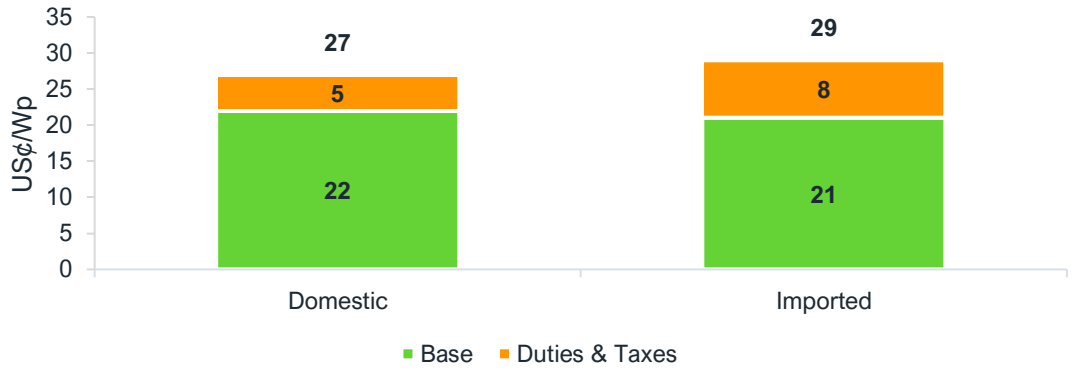
Duties on Cell and Ancillary Components

A BCD of 40% is applicable on solar modules imported after March 2022. Also, a BCD of 25% is applicable on the import of solar cells. While all manufacturers unanimously supported the BCD on solar modules, they were not in favour of the BCD on solar cells.

Indian solar cell manufacturing (around 6.6GW nameplate capacity) lags significantly and is unable to meet the demands of domestic module manufacturing (around 38GW nameplate capacity). Thus, without ample domestic cell manufacturing, Indian module manufacturers must import solar cells and pay a BCD of 25%.

In addition, manufacturers also have to pay anti-dumping duties for importing ancillary components of a solar module, such as the backsheet, frame, glass, ethylene vinyl acetate (EVA), etc.

Figure 11: Module Price Comparison: Imported vs Domestic (December 2022)



Note: 1. The module type considered in the price trend in this figure is 440–450Wp Mono PERC (Monofacial).
2. These prices do not include freight charges and other associated costs.

Source: JMK Research

This further adds to higher input costs for manufacturers and, hence, higher selling prices of modules compared to Chinese counterparts. All these duties add up and form a significant portion of the landed price of a domestically manufactured module. Hence, a domestically manufactured module's final landed price is almost equal (only a US$0.01-0.02/Wp difference) to its imported counterpart, even with a 40% BCD.

Lack of Domestic Solar Equipment Manufacturing

Although India has made significant strides towards achieving self-sufficiency in solar PV manufacturing through capacity addition, the machinery for this comes almost entirely through imports, mainly from China. Thus, in the event of breakdowns or process fine-tuning, etc., there is an understated overreliance on spare parts/assistance from the PV machinery supplier (viz., located outside India).

Table 6: Major Solar Equipment Manufacturing Deals (2022 onwards)

Supplier	Importer	Order Date	Country of Origin	Capacity (GW)	Type
SC-Solar	Reliance New Energy	January 2023	China	5.2GW	Module (HJT)
Centrotherm	6 different Indian manufacturers	December 2022	Germany	10GW	Cell (Mono PERC)
Maxwell	Reliance New Energy	April 2022	China	4.8GW	Cell (HJT)
Jinchen Machinery	All major tier-1 Indian manufacturers	H1 2022	China	18GW	Module

Source: News Articles, JMK Research

The Polysilicon Hurdle

As highlighted earlier in this report, polysilicon production is the solar PV manufacturing supply chain's most capital-intensive and time-consuming process. Setting up a polysilicon factory takes at least two to four years. The considerable infrastructure investment makes any polysilicon facility of less than 3-4GW financially unviable.

Table 7: Polysilicon Production Parameters (India vs China)

Parameter	India	China
Cost to develop (per GW)	US$130 million	US$60 million
Polysilicon nameplate capacity (2022)	-	340GW
Proposed polysilicon capacity (by 2026)	38GW	637GW
Industrial electricity prices	US$100/megawatt-hour (MWh)	US$60–80/MWh

Source: IEA, JMK Research

Due to the higher initial capex and industrial electricity prices, it is more expensive to build and operate a polysilicon factory in India vis-à-vis China. With China scaling up its polysilicon production

significantly over the next few years, it will be difficult for Indian manufacturers to maintain cost competitiveness with their Chinese counterparts.

For the same reasons, Indian manufacturers are apprehensive about entering polysilicon production. Even those that have announced plans to enter the segment (such as Adani) may use a large proportion of their polysilicon production mostly for their own plants. Hence, even with the rest of the solar supply chain secured domestically, polysilicon may be India's last persistent hurdle to achieving self-sufficiency in solar PV manufacturing.

Lack of Skilled Manpower in Solar Manufacturing

There is a dearth of skilled professionals with experienced know-how in installing, commissioning and operating a solar manufacturing facility, especially for upstream components, such as cells, wafers, polysilicon, etc.

Recently, Indian solar PV manufacturers have cited instances of a shortage of skilled engineers while commissioning or configuring their modules or cell lines. This shortage led to improper site configuration, leading to installation delays and inefficient operations, affecting the factory production output.

A significant reason for this lack of skilled professionals is the massive concentration of the solar manufacturing industry in China — it stands to reason that most skilled PV engineers are Chinese. In addition, since 2020, multiple waves of COVID-19 have impacted travel between China and India. Thus, the resulting scarcity of manpower in India trained to handle the installation of cell lines has limited the expansion plans of several solar cell manufacturers.

With the anticipated scaling up in Indian PV manufacturing capabilities over the next few years, India must develop academic capabilities to enable a skilled workforce to drive this growth. It is imperative for Indian manufacturers to bridge the gap between academia and industry through tie-ups with leading educational institutes. Leading institutes must establish courses and departments catering to PV manufacturing. A close interaction between academia and industry may also spur India's starkly deficient research and development (R&D) capabilities.

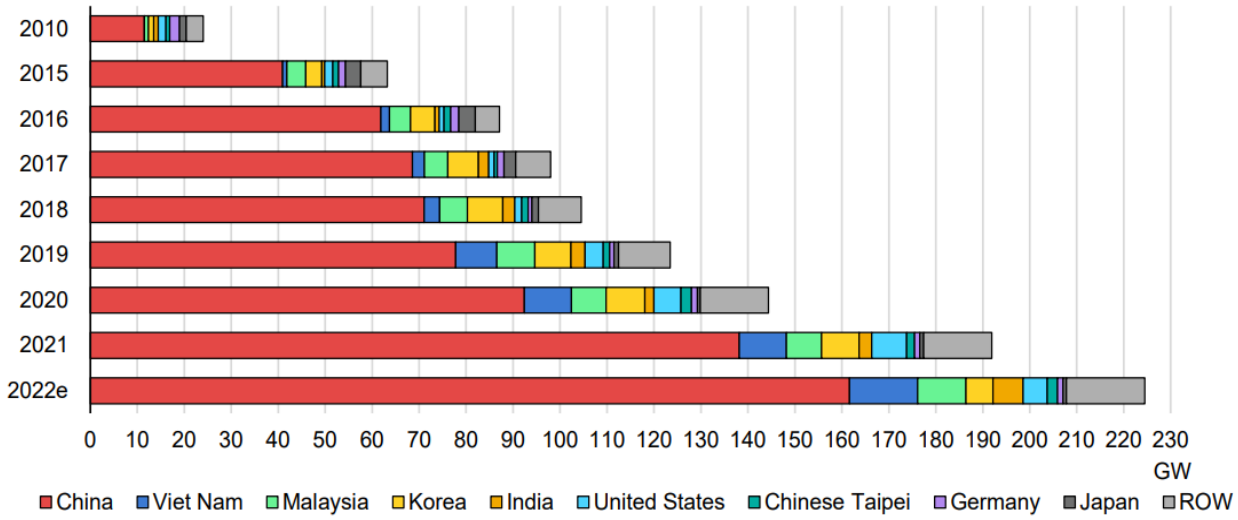
5. Analysis of Emerging Global PV Hubs Outside of China

Besides India, many other global counterparts are proactively introducing initiatives to build their domestic manufacturing capabilities post-COVID-19. In this section, we will discuss in detail some of those initiatives.

Regarding global PV module production, shipments and installations, 2022 was a year of vast growth. Overall global PV shipments were well above 300GW. Of the 245GW shipped by the top 10 global module suppliers, over 55% was by China and Europe.[12]

Of the 10 leading solar module suppliers in the world, eight are Chinese. These companies shipped more than 40GW each of their branded modules in 2022.

Figure 12: Global Solar PV Module Production, 2010-2022



Note: ROW = Rest of World

Source: IEA. Special report on solar PV global supply chains. July 2022

The dominance of China in solar PV manufacturing is visible in the output module production volumes of each country in the past 12 years. The share of China in global solar module production has increased from around 50% in 2010 to around 70% in 2021 and 2022.

[12] PV TECH. Top 10 PV module suppliers in 2022 shipped 245 GW. February 2023.

The United States of America

The U.S. is one of the leading consumers of the solar PV industry. Lately, the American solar industry has been vying to make a mark in the manufacturing space, mainly to reduce dependence on PV imports from China and Southeast Asia.

Currently, the U.S. solar PV industry faces supply chain disruptions due to the anti-circumvention probe and the Uyghur Forced Labor Prevention Act. In FY2022, the US imported more than 80% of its solar modules from Southeast Asian countries.[13] The Department of Commerce's preliminary anti-circumvention probe found that some cells and modules exported from Cambodia, Thailand, Malaysia and Vietnam circumvent tariffs on goods made in China. They were evading the anti-dumping and countervailing duties in place for Chinese imports.

Upon investigation, the U.S. Department of Commerce decided that solar cells made by any of these four countries, using only wafers from China, exported to a different country, and further assembled into modules, would not be eligible for imports.

In June 2022, the U.S. Customs and Border Protection implemented the Uyghur Forced Labour Act. The Act, first passed in December 2021, probits the import of solar modules produced through forced labour practices in the Xinjiang Uyghur Autonomous Region (XUAR). The resulting market uncertainty led to delays in approvals for hundreds of stranded solar equipment manufacturers whose shipments were in the U.S. ports, leading to a dip in solar installations across the country.[14]

Policies and Incentives

The solar manufacturing industry in the U.S. is developing at a rapid pace. Over time, the government has introduced several policy incentives and actions beneficial to solar PV manufacturers. These measures also aim to enable the competitiveness of domestic manufacturing via subsidies and tax rebates.

- In 2014, the U.S. Department of Commerce imposed anti-dumping duties on solar PV cells and crystalline silicon imports from China and Taiwan.[15]
- In 2018, the US imposed a safeguard duty on solar cells and modules. Initially, it was 30% and later reduced to 18% in 2022.
- In 2022, the U.S. Senate approved the Inflation Reduction Act, which commits an investment of US$30 billion towards manufacturing renewable energy components and electric vehicle batteries. This kind of policy intervention significantly boosts local manufacturers' trust in the demand for local products, resulting in more progressive expansion plans. Further, the Act provides manufacturing credit for all stages of PV manufacturing, from polysilicon to modules.

[13] Reuters. U.S to consider tariffs on solar panels made in southeast Asia. March 2022.
[14] Baird Holm LLP. Uyghur forced labor prevention act will affect imported solar modules. July 2022.
[15] PV Magazine. Solar trade war: US imposes preliminary anti-dumping tariffs of 26-165% on solar PV from China, Taiwan. July 2014.

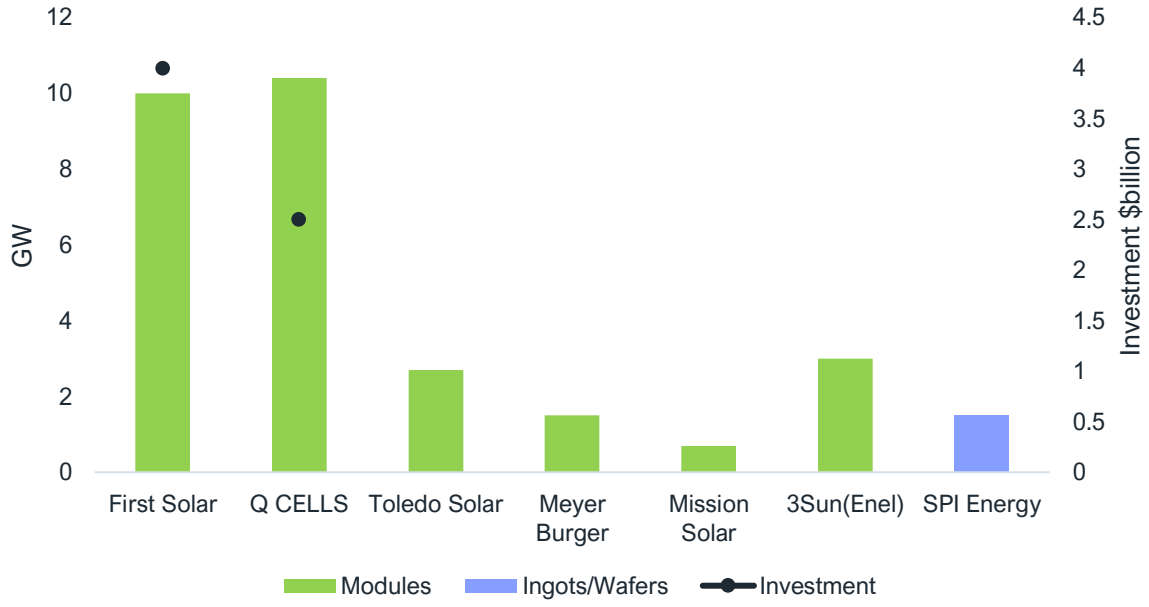
Table 8: Manufacturing Credit Accorded to PV Manufacturers Under the Inflation Reduction Act

S. No	Components	Credit Amount for Manufacturers
1	Solar grade polysilicon	US$3 per kilogram
2	PV wafer	US$12 per square metre
3	PV cell	US$0.04 per Wdc
4	Polymeric back sheet	US$0.4 per square metre
5	PV module	US$0.07 per Wdc

Source: U.S. Department of Energy

The passing of the Inflation Reduction Act and the implementation of favourable solar PV manufacturing policies in the U.S. spurred multiple new project announcements in 2022 (see Figure 13).

Figure 13: Proposed Expansion Plans of Solar PV Module Manufacturers in the U.S.



Source: IEA

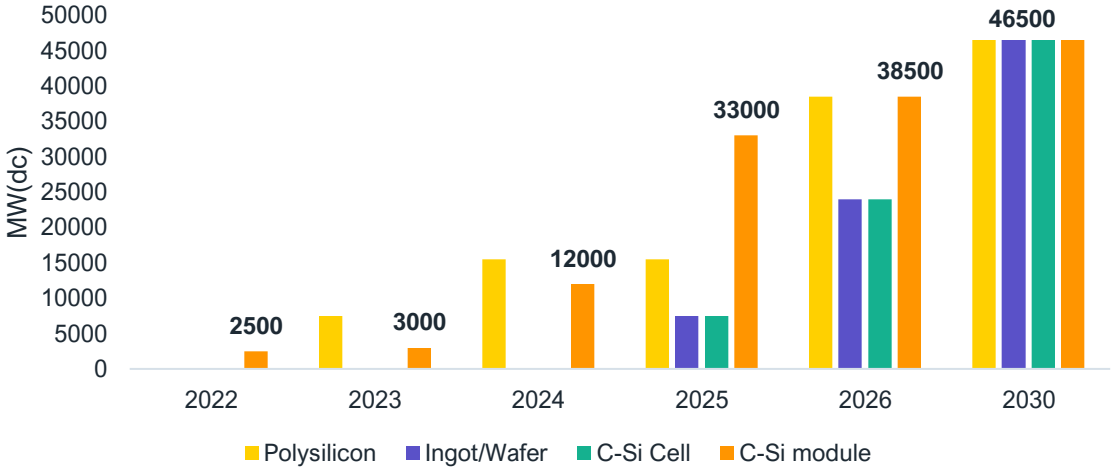
First Solar, a leading solar PV manufacturer in the U.S., announced its plans to invest up to US$4 billion in increasing the production of American-made solar modules. This investment is forecasted to expand the solar module production capacity in the U.S. to more than 10GW by 2025.[16]

In addition, Hanwha Q CELLS, a South Korea-based solar PV manufacturer, has announced that it will invest more than US$2.5 billion to build a complete solar supply chain in the U.S. This is one of the largest investments in the U.S. solar industry. The project will establish a fully integrated silicon-based solar supply chain in the U.S. with an anticipated total production capacity of 9GW.[17]

Target to Reach 50GW of Solar Manufacturing Capacity by 2030

The U.S. Department of Energy has realised that the U.S. will not be able to meet its climate goals until it expands domestic manufacturing in clean energy, specifically in solar energy. As a result, the Solar Energy Industries Association (SEIA) released a roadmap to establish a complete domestic PV supply chain in the country. It prepared the roadmap to achieve 50GW integrated annual solar manufacturing capacity by 2030.

Figure 14: Projected Solar PV Module Manufacturing Capacity in the U.S. 2022–2030



Source: SEIA

Currently, the U.S. has limited capacity to manufacture PV components like polysilicon, steel, aluminium, resins and mountings. However, there is still a significant gap in the supply chain. In addition, there is no domestic manufacturing capacity for solar ingots/wafers and cells, and only a restricted capacity to produce solar modules. Thus, these segments require enhanced focus and support to achieve 50GW of manufacturing capacity.[18]

[16] PV Magazine. First Solar to invest up to $1.2 billion to expand US solar output by 4.4 GW. August 2022.
[17] Utility Dive. First Solar brings US manufacturing investment to $ 4B after selling out of panels through 2025. February 2023.
[18] PV Magazine. Solar industry eyes 50GW of manufacturing capacity by end of this decade. August 2022.

European Union

The European Union (EU) plans to scale up its solar PV-based electricity to meet its climate goals, decarbonising its electricity grid and being less dependent on countries outside the EU, like China, for solar PV components.

Policies and Incentives

As part of the EU's solar strategy, it aims to reach 30GW of solar module production capacity by 2025. Accordingly, the EU has introduced policies and incentives to reach this target.

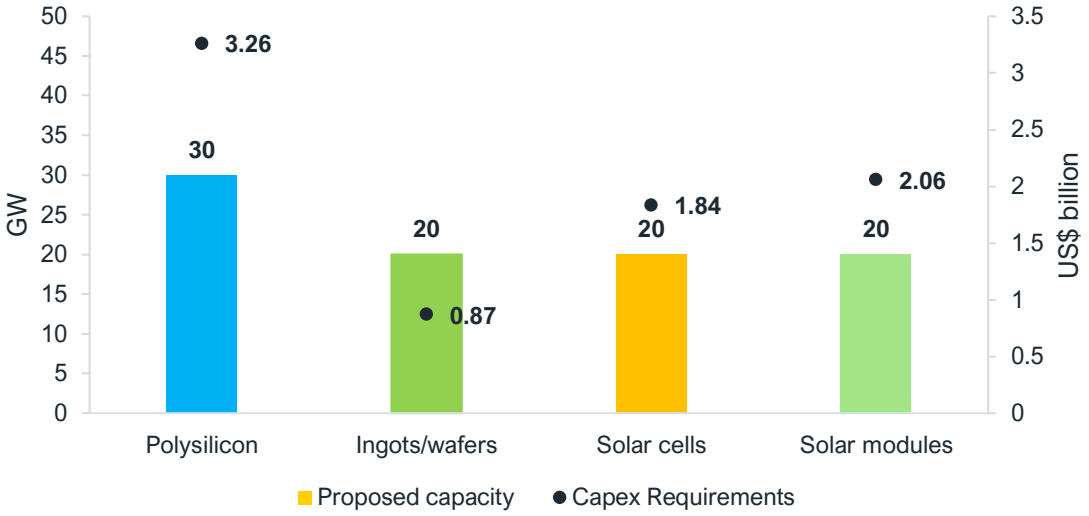
- In June 2013, the European Commission (EC) imposed anti-dumping duties on Chinese solar panel components, including wafers and cells. A product is considered dumped if it is exported to another country at prices lower than its normal value in its own domestic market.
- In May 2022, the EC announced the REPower EU plan, which responded to the energy hardships caused by the Russian-Ukraine conflict. It aims to save energy, produce clean energy and diversify energy supplies. It includes financial and legal measures to ramp up the new clean energy infrastructure in the EU.[19]

EU Aims to Reach 30GW Solar Module Production by 2025

EU aims to increase its solar module manufacturing capacity from around 4.5GW at present to 30GW by 2025. This capacity addition will ultimately result in an annual addition of €60 billion (US$65 billion) to the EU's gross domestic product (GDP).[20] In addition, European solar manufacturing companies have recently announced cumulative expansion plans of around 20-30GW capacity in each solar supply chain component.

[19] European Commission. REPower EU: affordable, secure, and sustainable energy for Europe. May 2022.
[20] EIT InnoEnergy. EU Solar PV Industry Alliance sets target of 30GW of PV Manufacturing Capacity by 2025. December 2022.

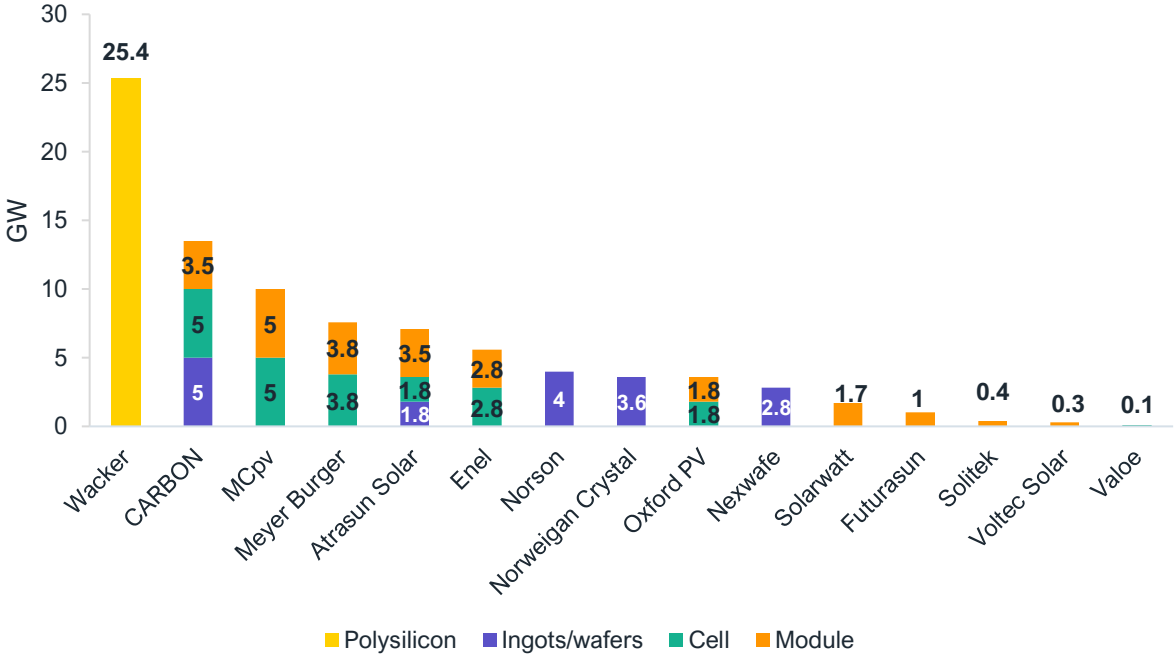
Figure 15: Proposed Expansion (by PV Segment) and Associated Investments in Europe by 2025



Source: Fraunhofer Institute for Solar Energy Systems

Establishing this proposed capacity in the EU requires a cumulative capex investment of ~US$8 billion across PV verticals. The highest share (around 40%) of this investment will go towards setting up 30GW of polysilicon manufacturing.

Figure 16: Expansion Plans of Major European PV Manufacturers by 2025

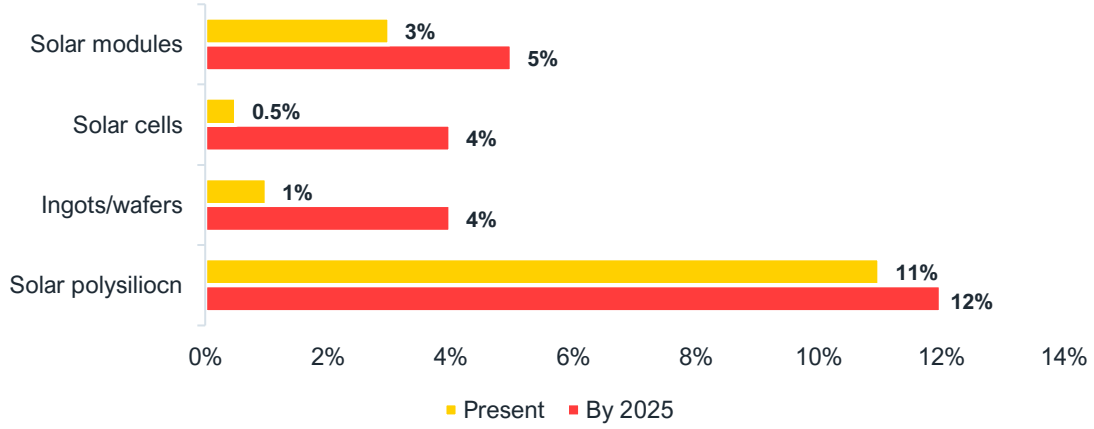


Source: Fraunhofer Institute for Solar Energy Systems

We highlight some of the key PV manufacturing expansion announcements in the EU below.

- German chemical producer Wacker Chemie AG (Wacker) has announced the expansion of its polysilicon production capacity at its plant in Holla, near Trondheim, in Norway. Wacker is among the top five companies in the world in polysilicon production and has approximately 28GW of production capacity in Europe. It plans to roughly double its manufacturing capacity to 53GW by 2025.
- French Industrial start-up CARBON has declared that it will build a 5GW solar panel factory in France by 2025 and then expand its production capacity to 15GW by 2030.[21]
- In Sicily, Enel S.p.A is setting up a 3GW capacity for HJT-based bifacial modules.[22] It has set an ambitious cell efficiency target of 30% for its facility.
- Companies like Norsan and Norwegian Crystal are setting up dedicated ingot/wafer manufacturing units, and both are planning around 4GW of new capacity. Nexwafe also aims to reach 3GW of manufacturing capacity in ingots/wafers by 2024–25.

Figure 17: Expected Global Market Share Growth of the EU by 2025 (% Segment Wise)



Source: Fraunhofer Institute for Solar Energy Systems

Various policies and the planned increase in PV manufacturing capacity in the EU will increase production capabilities outside of China. By 2025, Europe will enhance its global market share in all PV supply chain verticals. The increase is especially notable in the cells and ingots/wafers segments. The market share of the manufacturing of polysilicon and solar modules will also increase by almost 1-2% for each.

[21] Renewables Now. Solar start-up carbon plans 5-GW PV factory in France. March 2022.
[22] Enel Green Power. The 3 Sun Gigafactory Story: Towards the Gigafactory in record time.

6. The Way Forward

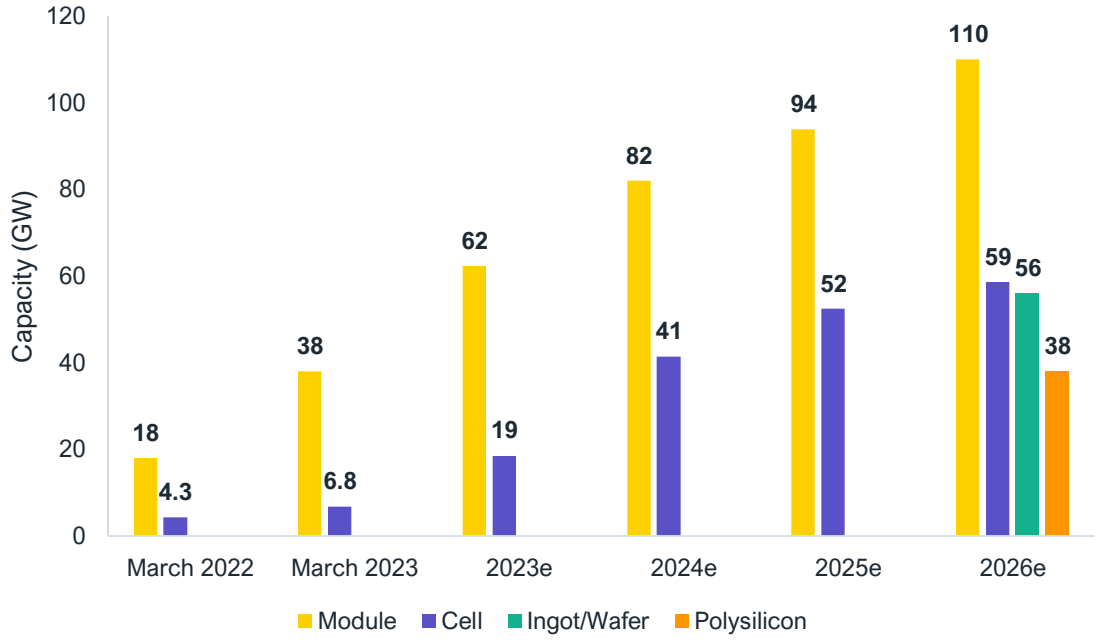
Like the U.S. and Europe, India has been a net importer of PV products and is now vying for self-sufficiency and reduced dependence on China. Thus, the global market trends will likely define the future course of PV manufacturing in India.

The PV manufacturing sector in India is undergoing a radical change, both in terms of scale and quality. Looking ahead, we can see the development of current trends in the sector blossoming into further opportunities.

Augmentation of Domestic PV Manufacturing Capabilities

India's PV module manufacturing capacity has more than doubled from 18GW in 2022 to around 38GW in 2023. This growth in domestic manufacturers' capacities will continue for the next two to three years.

Figure 18: Year-Wise Estimated Additional Manufacturing PV Capacity



Source: JMK Research

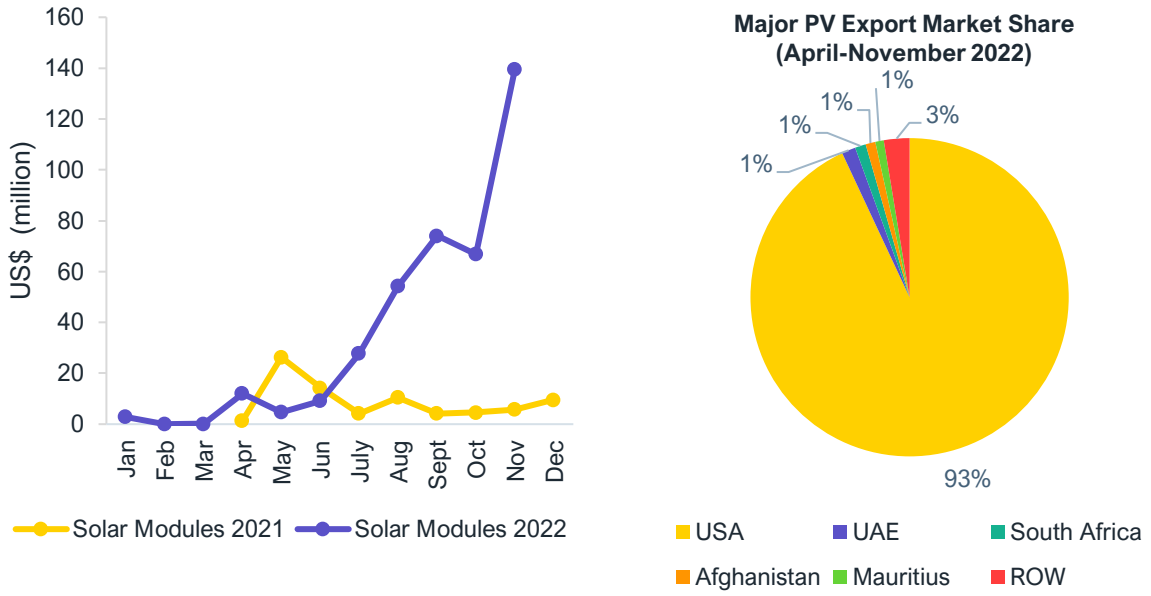
With ~72GW in the pipeline, the Indian module manufacturing capacity will reach around 110GW by 2026. Additionally, there is likely to be a similar growth rate in cell manufacturing capacity with ~52GW in the pipeline.

With such a large expansion of PV manufacturing capabilities, there will be no dearth of domestic modules in the market a few years down the line. As noted earlier in this report, Indian manufacturers will then have the potential to meet domestic demand and cater to the export market.

Strengthening Export Opportunities for Domestic Manufacturers

India recorded a huge jump in solar module exports during the current financial year as well, primarily due to the restrictions imposed by other countries on Chinese goods. Data from the Ministry of Commerce and Industry shows that Indian enterprises exported modules worth US$388 million from April to November 2022 compared to over US$71 million in the same period in 2021. The U.S. was the largest consumer of Indian PV modules, accounting for 93% of the exports.

Figure 19: Solar Modules Export from India: Trends and Major Export Markets



Source: Ministry of Commerce and Industry

All major PV importers around the globe are actively pursuing a "China+1" strategy to insulate their PV procurements against future supply chain shocks that become unavoidable in certain cases due to the concentration of manufacturing in just one country. Additionally, for some countries, such as the U.S., geopolitical issues also impact decision-making regarding solar imports.

Naturally, with India having the second-largest module manufacturing capacity globally and significant expansion plans, many countries are looking at India as a viable alternative to China for their PV requirements.

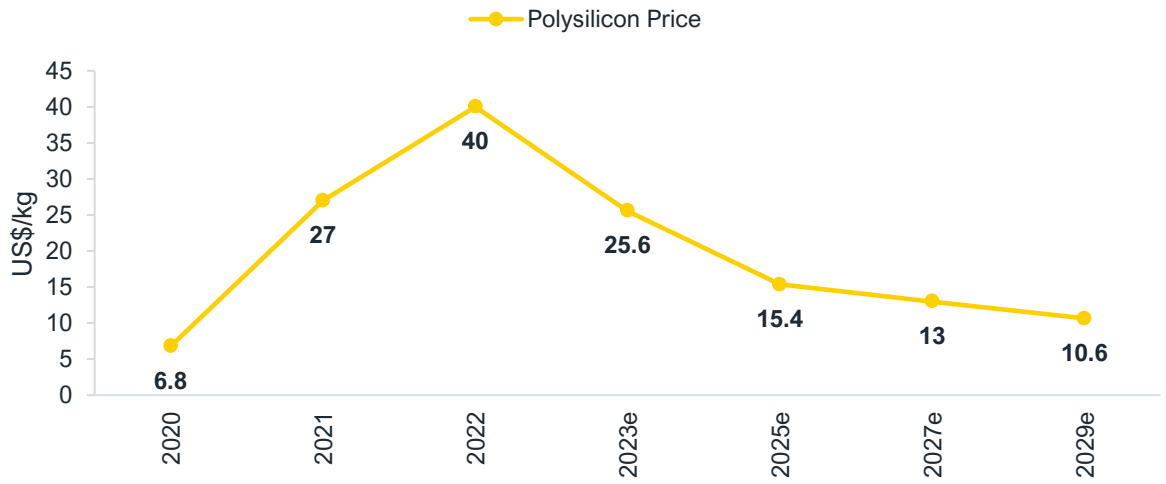
All leading GW-scale manufacturers in India are reporting considerable interest and demand from abroad for their high-quality and high-wattage lines of modules. Thus, they are already earmarking around 20–25% of their manufacturing capacity only for the export market. However, this may inadvertently lead to shortages in the local market for high-quality modules in the short term.

Domestic manufacturers must also factor in the risk of lower overseas demand in the future as major export destinations, such as the U.S. and Europe, are scaling up their PV manufacturing capabilities and becoming self-sufficient.

Reduction in Polysilicon Costs

The last few years (2020-2023) have been turbulent, to say the least, for PV component prices. Since 2020, polysilicon shortages have led to a surge in its prices, which have increased by almost 6x between 2020 and 2022. This unprecedented hike in polysilicon costs has increased the prices of all PV downstream components, such as wafers, cells and, ultimately, modules.

Figure 20: Polysilicon Price Forecast Trend



Source: PwC analysis,[23] PV Infolink

With the polysilicon capacity set to almost double over the next few years, the recent glut in polysilicon availability is nearing its end. Going forward, the polysilicon prices are expected to fall back to their pre-pandemic levels, leading to a simultaneous easing in all PV component prices in India as well.

[23] PwC. PV Price Predictions: Assessment of solar power's cost economics. December 2022.

Ancillary Market Development

Developing the manufacturing capacity of PV ancillary components (glass, EVA, backsheets, etc.) in tandem is crucial to enable a truly integrated production ecosystem. With ongoing efforts by the Indian government to incentivise solar manufacturing, the growth of the ancillary market is imminent. For example, Borosil recently doubled its solar glass manufacturing capacity in India.[24] Other major domestic manufacturers, such as Adani and Reliance, aiming for integrated manufacturing, also plan to start manufacturing ancillaries.

To aid the growth of the ancillary market, the government may also consider including ancillary components in future potential iterations of the PLI scheme. Additionally, the government may provide indirect manufacturing incentives to ancillary components through tax credits, similar to the recently implemented Inflation Reduction Act in the U.S.

Policy Expectations and Recommendations

Recently, the Indian government has created several policies and initiatives to support and spur domestic PV manufacturing. This includes aiding supply (the PLI scheme) and demand (the ALMM, BCD and manufacturing linked tenders) of domestic modules. However, the government can also implement the following policy initiatives to aid PV manufacturing capabilities in India further.

Extension of the PLI Scheme

The current version of the Solar PLI Scheme provides direct incentives for manufacturing polysilicon, wafers, cell and modules, with the extent of integration being an important parameter for monetary disbursement.

However, to develop a complete PV manufacturing ecosystem, the government may consider supporting other important but often overlooked components of solar manufacturing through the PLI Scheme. These include manufacturing PV equipment machinery and ancillary components like glass and EVA.

The Inflation Reduction Act passed in the U.S. provides a suitable blueprint to include the extensive PV manufacturing ecosystem under the production-linked benefits. In addition to the manufacturing stage of polysilicon into modules, the Act also provides incentives for producing inverters, trackers, backsheets, batteries, etc.

Upfront Subsidy Disbursal Scheme

Establishing a PV manufacturing facility is a capital-intensive enterprise. In India, setting up a 1GW cell and module factor requires an investment of approximately Rs10 billion (~US$120 million).[25]

[24] PV Magazine. Borosil expands solar glass capacity in India. January 2023.
[25] IEA. Special Report on Solar PV Global Supply Chains. July 2022.

Additionally, with PV technology constantly evolving, a significant capital influx is also necessary at regular intervals for machinery upgradation and other maintenance-related tasks.

A manufacturing incentive disbursed right at the beginning (pre-construction) can potentially alleviate any likely capital crunch initially, especially for small manufacturers.

Subsidising Electricity Costs

PV manufacturing, especially polysilicon, is an energy-intensive process. The subsidised rates for electricity provided to Chinese PV manufacturers were an important reason they could easily scale up manufacturing capabilities.

On similar lines, the Indian government can also consider incentivising the electricity consumption of PV manufacturers. The government can do this by putting them in a separate tariff category or providing rebates on electricity consumption.

Forthcoming Export Ban by China Can Potentially Slow Manufacturing Growth

Recently, the Chinese government has been mulling a curb on PV exports, especially high-tech PV technologies and machinery.[26] The move aims to sustain China's position as the global leader in PV manufacturing, even as other countries like the U.S. and India continue strengthening their capabilities.

The current version of the proposed ban aims to restrict the technology outflow for the "polysilicon to wafer" stage of the PV manufacturing process. China almost has a monopoly of this stage, considering that 97% of the "polysilicon to wafer" manufacturing capacity is in the country. In addition, no other country can currently manufacture large-sized wafers measuring 182mm and 210mm.

China is still considering the move, and its ministries of commerce and science and technology have yet to finalise the ban. If China implements the ban, it can be a huge setback to other countries' plans to establish integrated PV manufacturing domestically. It might lead to a potential halt or a slower-than-expected push towards integrated solar manufacturing in India and other western markets, such as the U.S. and Europe.

[26] Bloomberg. China Mulls Protecting Solar Tech Dominance With Export Ban. January 2023.

Impact of Manufacturing Push on India's Renewable Energy Capacity Targets

After the application of the BCD and ALMM in the current financial year, solar installations in India have plummeted. Between the first and last quarter of 2023, solar installations fell around 46.4% from 4,650MW in Q12023 to 2,489MW in Q42023.[27] With only a handful of tier 1 domestic manufacturers, developers have complained about the lack of availability of high-quality high-wattage modules.

Meeting India's renewable energy target by 2030 requires an annual addition of 25–30GW of solar PV installed capacity. Until there has been an adequate augmentation of domestic PV manufacturing capabilities, any barrier to developers' procurement options will ultimately result in slower solar installation growth.

Foreseeing the risk to India's renewable energy targets, the government recently deferred the ALMM implementation by a year until March 2024. However, over the next decade, the government must look at balancing the requirements of developers and providing support to PV manufacturers.

[27] CEA. Monthly reports archive. January to December 2022.

7. Conclusion

The Indian PV manufacturing industry is growing by leaps and bounds. Every day, there are announcements of expansion or new investments in the sector. Such a push towards the manufacturing sector is partly due to the favourable policy scenario created by the Indian government. Through both iterations of its PLI scheme, the government aims to catalyse the Indian PV manufacturing landscape, especially for upstream components such as polysilicon and ingots/wafers.

In addition to the PLI scheme, the Indian government has restricted the inflow of PV modules by implementing various tariff and non-tariff barriers. These include a BCD on solar modules and cells and mandatory listings for manufacturers in the ALMM.

However, even with aggressive market drivers and government support, many minor hiccups still impede the development of the domestic PV manufacturing sector.

The biggest challenge is sustained reliance on China for its raw material. Almost all (around 95%) of the upstream PV manufacturing capabilities, i.e. polysilicon and ingots/wafers, are still in China. With the Chinese government mulling restrictions on the outflow of the critical technology used in the manufacture of these upstream components, it is imperative for countries targeting integrated PV manufacturing at scale to identify alternate sources of supply for these raw materials.

Despite the ALMM being one of the most important drivers for the domestic PV manufacturing sector, the government deferred its implementation until March 2024 to address the concerns of developers regarding the shortage of high-quality, high-wattage ALMM-listed domestic modules. This led to a decline in solar installations in the last few months. While this announcement was a major relief for developers, it will derail the future expansion plans of domestic PV manufacturers.

Moreover, as part of the long-term expansion plan, India must aim to build enough PV capacity to satisfy local demand and maintain a healthy global presence to become a viable competitor to Chinese PV products. However, India's current major PV export markets – the U.S. and Europe – are ramping up their own PV manufacturing capabilities. In future, these countries may also potentially become self-sufficient in PV manufacturing. As a result, there is a greater impetus to explore other export markets for Indian tier-1 manufacturers.

To further augment the expansion of domestic PV manufacturing, the government can look at some policy initiatives:

- The PLI scheme, which currently covers the polysilicon to module stages of the manufacturing process, should also include other components in future iterations/tranches for the holistic development of the PV manufacturing ecosystem. These include PV equipment machinery and ancillary components.
- The Inflation Reduction Act implemented in the U.S. can be a possible inspiration for including these components under the ambit of the PLI scheme.

- To help relatively smaller manufacturers having limited capital availability, the government can look at a scheme providing upfront subsidies for setting up manufacturing units.

To conclude, the future of the Indian PV manufacturing sector is bright. With around 110GW of module capacity set to come online in the next three years, India will quickly become the second-biggest PV manufacturing country. After attaining self-sufficiency, India's next course of action will be to challenge and compete for dominance in both quality and scale on the global stage.

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