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Photovoltaic Manufacturing Outlook in India

Ambitious Targets and Incentives Brighten the Future for the Solar Industry

Executive Summary

India has made substantial progress in domestic solar module manufacturing capacity in recent years. However, stronger impetus is needed in this regard to achieve 300 gigawatts (GW) of solar power generation capacity by 2030.

As of November 2021, India had a cell manufacturing capacity of 4.3GW and a module manufacturing capacity of ~18GW.[1] These are, however, just nameplate capacities. Actual production output at any given time is significantly lower as most of Indian solar manufacturing facilities operate at a capacity utilisation factor (CUF) of less than 50%. Moreover, multi-Si module technology, which accounts for the majority (60-70%) of existing domestic module production capacity, is on the verge of becoming obsolete. Local demand for these modules continues to dwindle and is expected to last for another 1-2 years. On the brighter side, new major manufacturers planning to expand or enter the market are seeking to install machinery that can handle cell sizes of up to M12 (210mm x 210mm), in both mono facial and bi-facial configuration.

There is no existing manufacturing capacity in India for the initial stages of the photovoltaic (PV) value chain, namely from polysilicon to wafer. For these raw materials, Indian solar manufacturers are still dependent on imports, mainly from China. Prolonged dependence on the imports raises the severity of the associated risks. Shortage of raw materials, a power price hike in China and a surge in international freight charges have inflated module prices in 2021 by more than 25%[2]. This highlights the need for a sustainable,

India needs a sustainable, vertically integrated domestic solar manufacturing ecosystem.

[1] JMK Research.
[2] JMK Research.

vertically integrated domestic solar manufacturing ecosystem.

Without large-scale domestic manufacturing of upstream PV value chain products, the overarching risks of logistics and commodity price fluctuations for imports will persist. The Indian PV industry also faces mid- to long-term challenges of high manufacturing expenses, inadequate Research and Development (R&D) and a shortage of skilled manpower.

To encourage vertically integrated facilities, the Indian Government introduced the Production-Linked Incentive (PLI) scheme for 10GW capacity of integrated manufacturing of "High Efficiency Solar PV Modules" with a financial outlay of Rs4,500crore (US$616 million). The PLI tender received a tremendous response (54.8GW of bids, a fourfold over-subscription) from the industry, pushing the government to increase the PLI amount by an additional Rs19,500 crore (US$2.5 billion) for solar module manufacturing.

Dozens of companies are vying to make a mark in the Indian solar sector.

The Indian government's ambitious targets and support for the solar sector have made indigenous PV manufacturing's prospects even more vibrant. As a result, dozens of companies are vying to make a mark in the Indian solar sector. In coming years, given the high growth potential of the domestic solar market and rising favourability of India as an alternative manufacturing hub (for geopolitical reasons), diverse stakeholders such as solar project developers, government-run organisations, PV ancillary players, etc will strive to build their stake in the solar manufacturing market.

In addition to the PV manufacturing landscape, this report delves into key aspects such as major government initiatives, ongoing challenges and an overview of the way forward for India.

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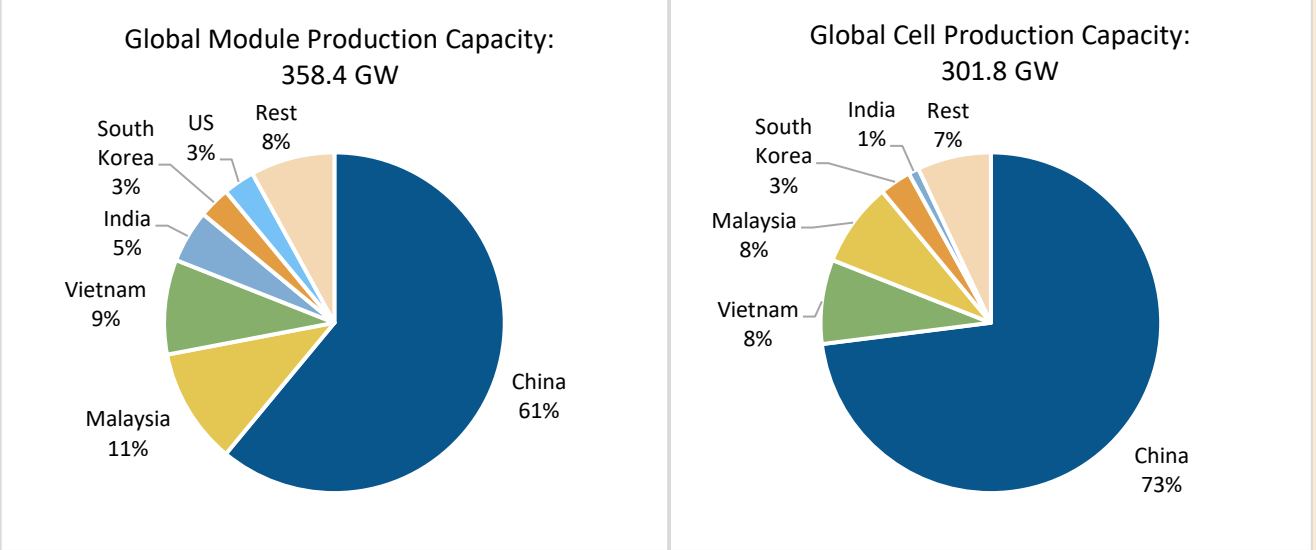
Global PV Manufacturing Landscape: A Snapshot

Of the total global solar module manufacturing capacity of 358GW, China accounts for about 61%.[3] The dominance of China is visible throughout the entire supply chain of solar manufacturing. It holds the leading market share in manufacturing capacities of materials such as solar cells, wafers, polysilicon etc, which are critical to manufacturing of solar modules. In terms of worldwide production capacity (GW), China accounted for 75.2% of polysilicon, 97.9% of wafers, and 73% of solar cells in 2020.[4]

India's manufacturing capacity share of 5% may make it one of the top five module manufacturers in the world but most of this capacity (about 10GW[5]) is either outdated in terms of cell sizes that can be handled (less than 158mm x 158mm) or not used efficiently. Also, the production output of Indian manufacturers is significantly lower than their nameplate capacities. Lower capacity utilisation in Indian production facilities adversely affects the pricing of their modules, presenting a challenge for domestic players to compete with global competitors in quality and pricing terms alike.

Figure 1: Global Annual Module and Cell Production Capacity (as of November 2021)



Source: Paula Mints: "Solar's History and Future in Pictures", SPV Market Research, November 2021.

Note the positions of Malaysia and Vietnam in the global industry (refer figure 1). These countries have become offshore manufacturing hubs for various Chinese

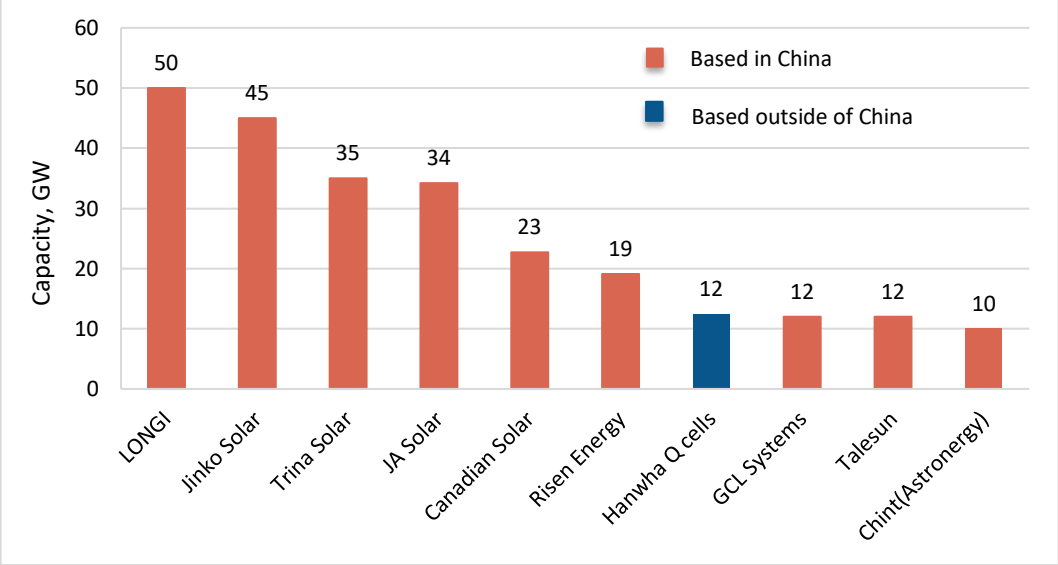
[3]Paula Mints SPV Market Research, Solar's History and future in Pictures, November 2021.
[4]IEA, PVPS National Survey Report of PV Power Applications in China 2020, September 2021.
[5] Industry Interviews.

players and are showing continuous growth in the relevant sector over the recent years.

From early 2010s, Chinese suppliers began flooding the market with cheap solar panels and in the process weakened local solar manufacturing industry in most of the relevant countries including India. In response, several countries then introduced policies to limit Chinese dominance and provided protection measures for the local manufacturers. Some of these measures/barriers against the cheap solar imports are anti-dumping duty (ADD) in the U.S. and safeguard duty (SGD) in India. As a result, several of the leading Chinese suppliers set up new manufacturing capacities in countries such as Malaysia and Vietnam to mitigate the international trade risks and also facilitated creation of these new solar PV export hubs in Southeast Asia. Leading Chinese suppliers such as Trina, Jinko etc have PV fabrication facilities (fabs) in China and Malaysia/Vietnam.

Favourable business environments, in terms of local government support and availability of skilled workforce, are among the key factors that led to the selection of Malaysia and Vietnam as preferred PV manufacturing destinations outside of China. Another factor is the countries' strategic location in the middle of Asia, enabling manufacturers to have their supply networks closer to the source of demand. Following suit, non-Chinese players such as First Solar, Hanwha Q cells etc have also set up manufacturing facilities in Southeast Asia.

Figure 2: Leading Module Manufacturers in the World (Basis Production Capacity)

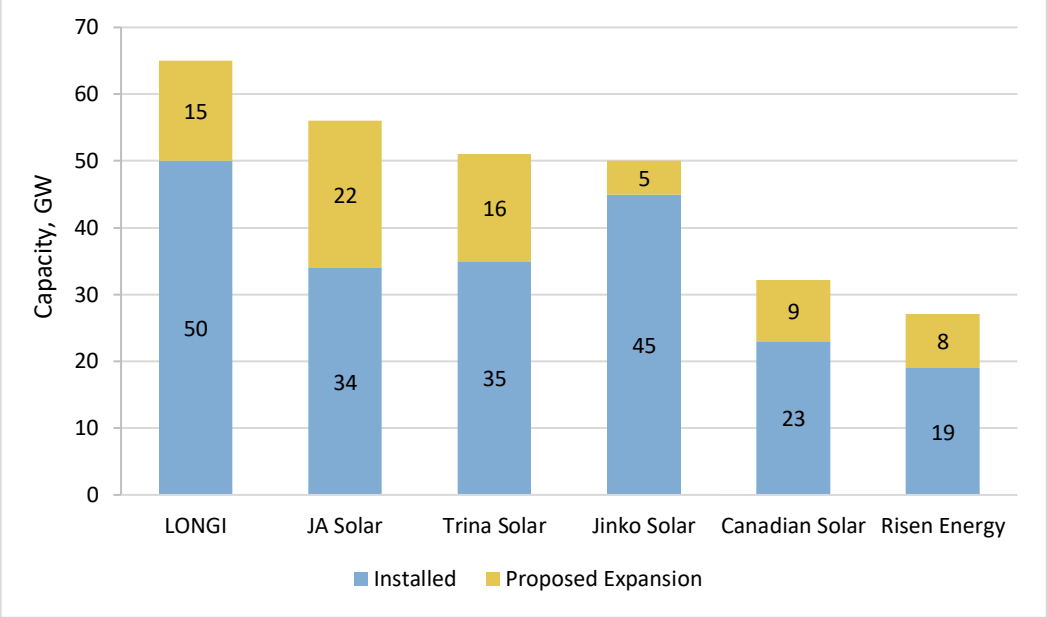


Source: IEA PVPS National Survey Report of PV Power Applications in China 2020; BloombergNEF, 4Q 2021 Global PV Market Outlook, Nov 2021, Industry Interviews.

Of the 10 leading solar module suppliers, nine are Chinese. Most of the leading Chinese manufacturers maintain a capacity utilisation factor (CUF) of more than

50%.[6] Huge production scale coupled with their high CUF allow them to produce high-quality modules and simultaneously maintain competitive pricing. Anticipating an increase in demand globally in the post-pandemic era, many Chinese manufacturers plan to expand capacity at each level of their solar PV value chain, from polysilicon to modules.

Figure 3: Proposed Module Capacity Expansions of Top Chinese PV Manufacturers, November 2021



Source: PV Magazine, IEA PVPS National Survey Report of PV Power Applications in China 2020, JMK Research. [7]

In CY2020, JA solar announced module capacity expansion of 33GW, while Trina, Jinko and Longi have announced phased expansions of 29GW, 19GW and 15GW respectively[8] up to CY2024. By the end of CY2021, JA Solar managed to reach 11GW of its 33GW target, while Trina and Jinko achieved 13GW and 14GW of their expansion targets. However, some analysts say achieving these targets in a timely manner would be difficult in a post-pandemic economy, owing to short-term constraints such as supply chain disruption and shortage of raw materials such as polysilicon.

The Chinese solar PV industry is also driving technology advancement. First, in early 2010s, Chinese players acted as the dominant force to bring back crystalline silicon (c-Si), specifically polycrystalline silicon (poly-Si) technology in the global market as it was losing ground to other technologies. In just a few years since the resurgence

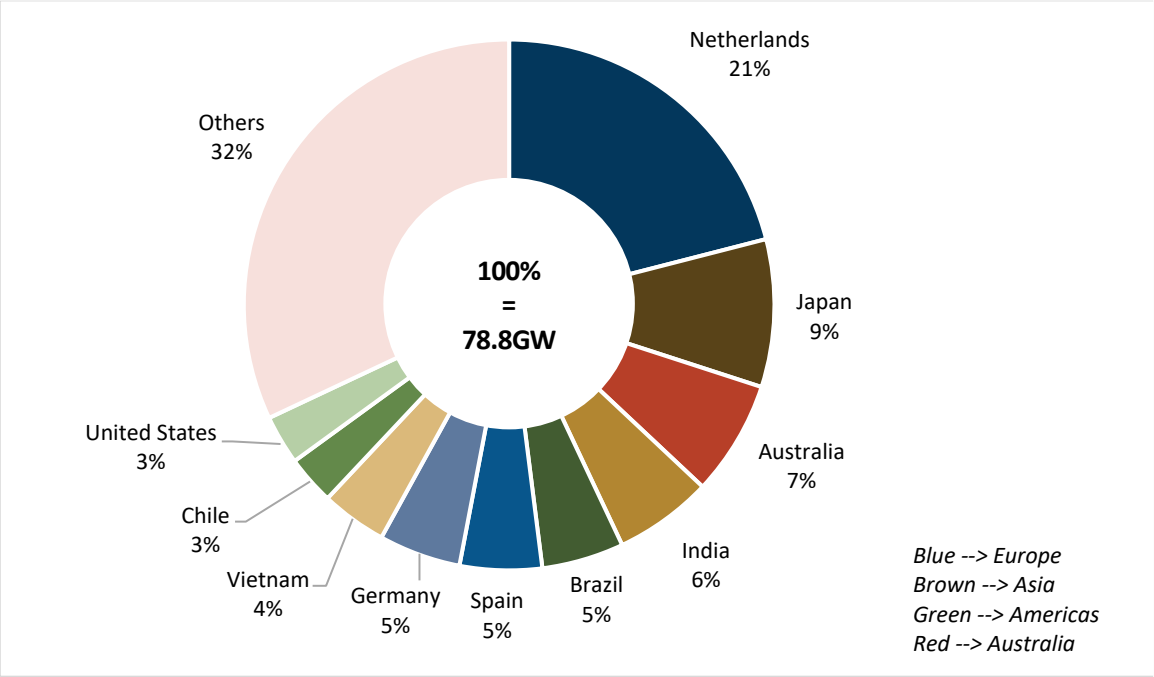
[6]IEA, PVPS National Survey Report of PV Power Applications in China 2020, September 2021.
[7] PV magazine, Canadian Solar prepares to rein in production capacity expansion plans, November 2021
[8] PV magazine, Unprecedented plans and investments in Chinese PV production capacity, November 2021.

of c-Si, global PV technology demand began to shift from poly-Si to monocrystalline silicon (mono-Si) modules, chiefly driven again by the Chinese industry. Under mono-Si type, passivated emitter and rear contact (PERC) technology has become the workhorse globally. Coming technologies such as Hetero-Junction (HJT) and Tunnel Oxide Passivated Contacts (TOPCon) are already on the horizon. The unrelenting strides in technological innovation and massive scale of PV adoption across the globe have been largely promoted by Chinese players capitalising on extensive R&D, economies of scale and large government incentives.

Import-Export Trends

Undoubtedly, China has become one of the main drivers for solar PV development globally. The industry relies heavily on exports. In CY2020, from total PV production of 124.6GW in China, exports constituted 78.8GW.[9] The leading Chinese solar export markets are depicted below.

Figure 4: Leading Chinese Export Markets, 2020



Source: PV InfoLink.[10]

Europe is the biggest export market for Chinese modules, with Netherlands, Spain and Germany among top 10. India, with a share of 6%, is in the top five.

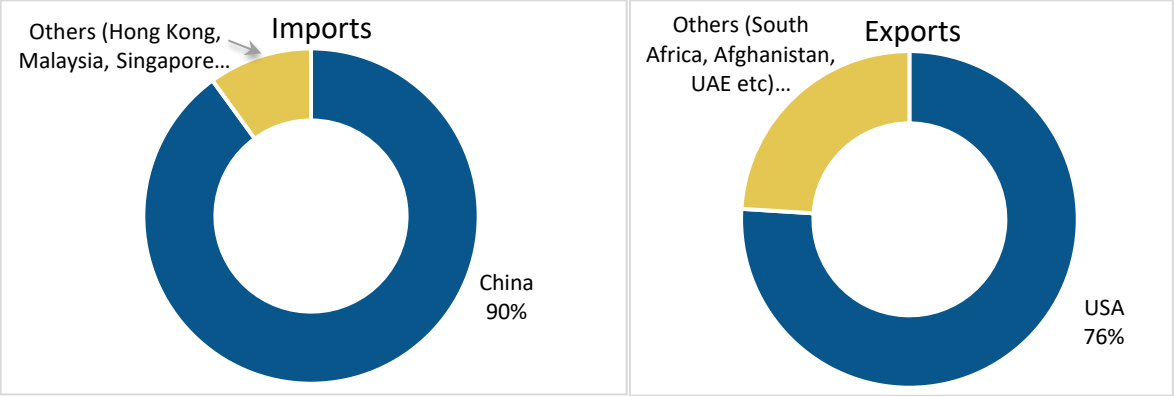
Considering solar PV international trade data vis-à-vis India (April to November 2021), Chinese suppliers account for 90% of India's solar imports.[11] The share of Chinese suppliers in net import of solar cells and finished panels is 91.1% and

[9] IEA, PVPS National Survey Report of PV Power Applications in China 2020, September 2021.
[10] PV InfoLink, 2H20 module trends from a perspective of China exports, October 2020.
[11] Ministry of Commerce and Industry, Government of India.

89.9% respectively. The remainder comes from countries including Hong Kong, Malaysia and Singapore.

The bulk of India's PV exports (76%) is shipped to the U.S. This market accounts for 71% and 77% of solar cell and finished panel exports respectively. Other countries in India's export manifest are South Africa, Afghanistan, UAE, Turkey, Canada etc.

Figure 5: India Solar PV Import-Export Scenario - H1 FY2022 (April-November 2021)

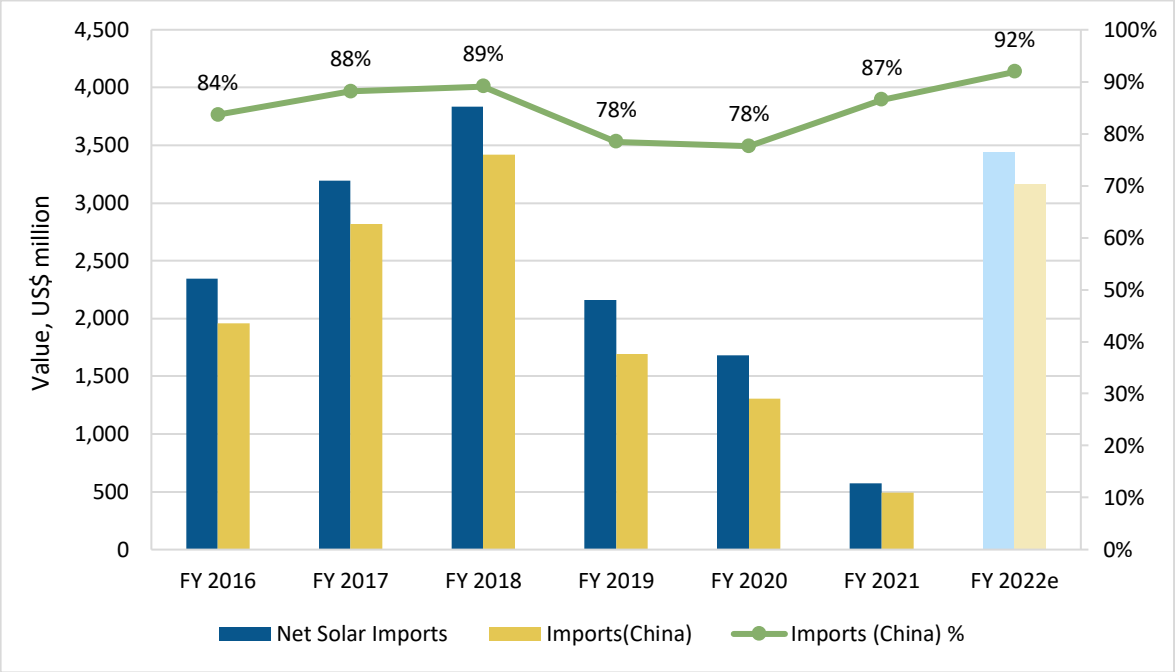


Source: Ministry of Commerce and Industry.

Observing the solar import statistics for India in the past six fiscal years, imports were the least in FY2021 owing to covid-induced disruptions, though imports (refer figure 7 below) were declining since FY2019. Safeguard Duty (SGD), applicable on imported solar modules from countries such as China, Malaysia and Taiwan from July 2018, is the key factor behind the downward curve between FY2019 and FY2021.

Several policy uncertainties (regarding Open Access, Net Metering regulations etc) in various states also can be attributed to the reduced demand.

Figure 6: India Solar PV Import Trend



Source: Ministry of Commerce and Industry.

FY2022 is expected to be a significant year for solar PV imports, owing to the resumption of construction activity of solar projects delayed in FY2021 due to the pandemic. The expiry of SGD in July 2021 also will enable a major uptake in imports. However, 40% Basic Customs Duty (BCD) applicable on solar module and 25% on cells from April 2022 is again likely to lead to lesser imports post-FY2022.

Domestic PV Manufacturing Landscape

Currently, India has a cell manufacturing capacity of 4.3GW and a module manufacturing capacity of ~18GW.[12] These are however, just nameplate capacities. Actual production output at any given time is significantly lower as most of India's solar manufacturing facilities operate at CUF 40-50% or less., as discussed in detail in the Key Challenges section of the report.

India has made substantial progress in expanding domestic module manufacturing capacity in recent years but greater impetus is needed to achieve the renewables target of 500GW[13] (300GW of solar) by 2030. Prolonged dependence on imports increases the potential for severe associated risks. Shortages of raw materials, power price hikes in China and surges in international freight charges pushed up module prices by more than 25% in 2021. This highlights the need to have sustainable, vertically integrated domestic solar manufacturing.

[12] JMK Research.
[13] Ministry Of Power, Mission 500 GW by 2030, November 2021.

India has been a big laggard in manufacturing, not just upstream PV components such as wafers and cells but also of modules.

In May 2020, the Atmanirbhar Bharat Abhiyan (Self-reliant India) campaign was launched to benefit all sectors of the national economy. In line with this objective, the government approved the Ministry of New and Renewable Energy (MNRE)-proposed Production-Linked Incentive (PLI) scheme in April 2021 to encourage domestic manufacturing of globally competitive solar PV modules.

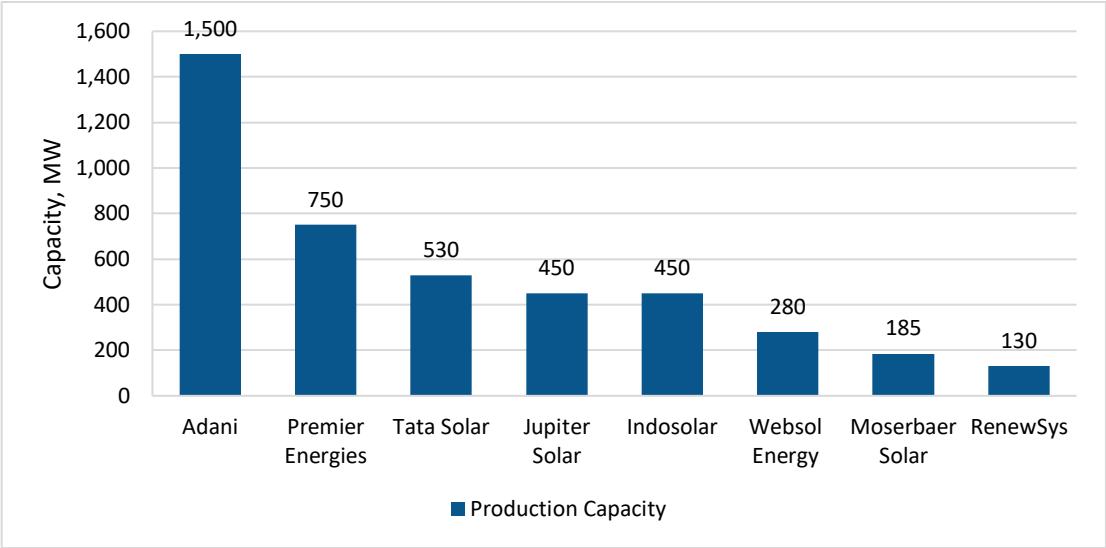
Despite major plans announced by several domestic manufacturers, to date there is no upstream manufacturing of materials such as wafers or ingots. So strong was the industry response to the PLI scheme for integrated manufacturing of "High Efficiency Solar PV Modules" – from domestic and international companies – that the government increased the PLI funding for the segment from Rs4500 crore to Rs24,000 crore. This scheme alone, if judiciously implemented, can increase the integrated solar module, cell and wafer domestic manufacturing capacity several times over in the next three to four years.

Figure 7: Stages of Solar PV Manufacturing

A. Cell Manufacturing Capacity

As of November 2021, the total domestic cell production (nameplate) capacity in India was 4.3GW, or nearly a quarter of domestic module production capacity. Lack of vertical integration of domestic solar fabs is one reason for the gap between cell and module manufacturing capacities. Also, the demand for India-made solar cells is generally low because module suppliers demand cells of higher grade (in terms of wattage, efficiency etc). Further, the narrow production scale of solar cell fabs means domestic cells are more expensive, so the general preference in cell demand is for the cheaper yet superior import counterparts.

Figure 8: Leading Domestic Solar Cell Manufacturers in India (December 2021)

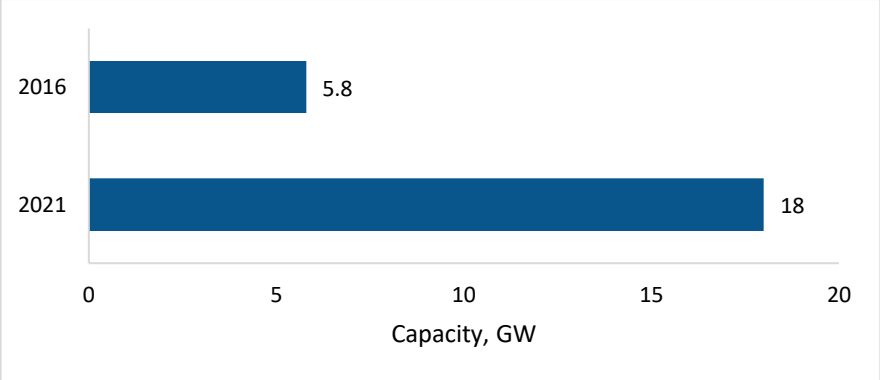


Source: JMK Research.

B. Module Manufacturing Capacity

Over the past five years (see figure 5), India has made substantial progress in solar manufacturing. Solar module manufacturing capacity has trebled from 5.8GW in 2016 to about 18GW in December 2021. However, as much as these numbers paint a positive outlook, there is still a long way to go in achieving self-sustenance.

Figure 9: Domestic Solar Module Manufacturing Nameplate Capacity (2016 vs 2021)

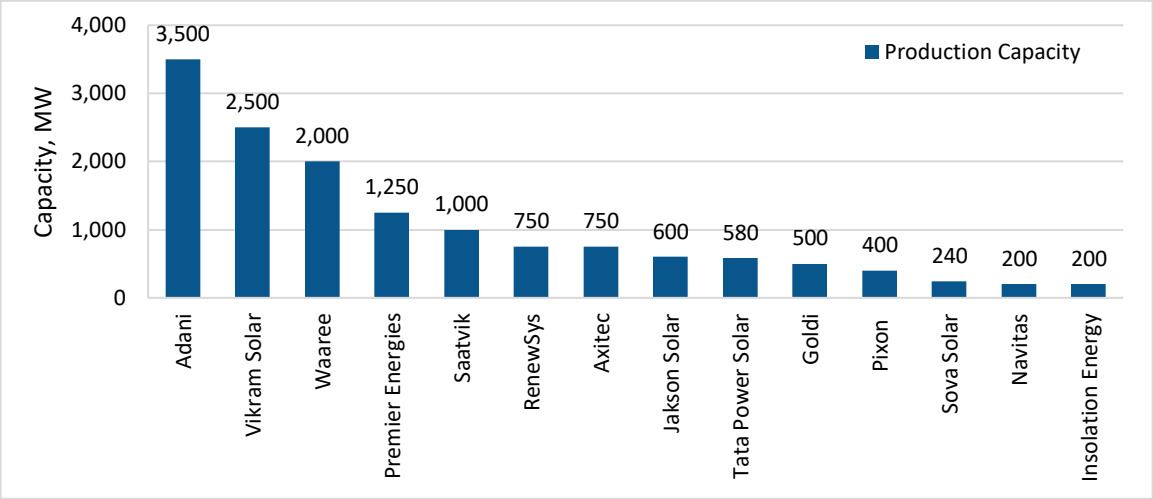


Source: JMK Research.

Vikram Solar, with the opening of a new factory in Tamil Nadu, became India's largest solar module manufacturer at 2.5GW capacity in mid-2021. Adani expanded its solar fab by 2GW in December 2021, regaining its position as the largest domestic module manufacturer. As several leading companies have announced major expansion plans in solar manufacturing, it is highly likely that the domestic

player rankings for cell and module manufacturing will change often in coming years.

Figure 10: Leading Domestic Solar Module Manufacturers in India (December 2021)



Source: JMK Research.

It's also interesting to note that most of the solar module manufacturing is concentrated in a few states. Easy access to ports (for international trade), cheap land and available power near special economic zones (SEZ) are among the reasons for the concentration of solar module manufacturing in these states. Gujarat will continue to host the majority of manufacturing capacity.

Figure 11: Domestic Solar Module Manufacturing Capacity by State

Source: JMK Research.

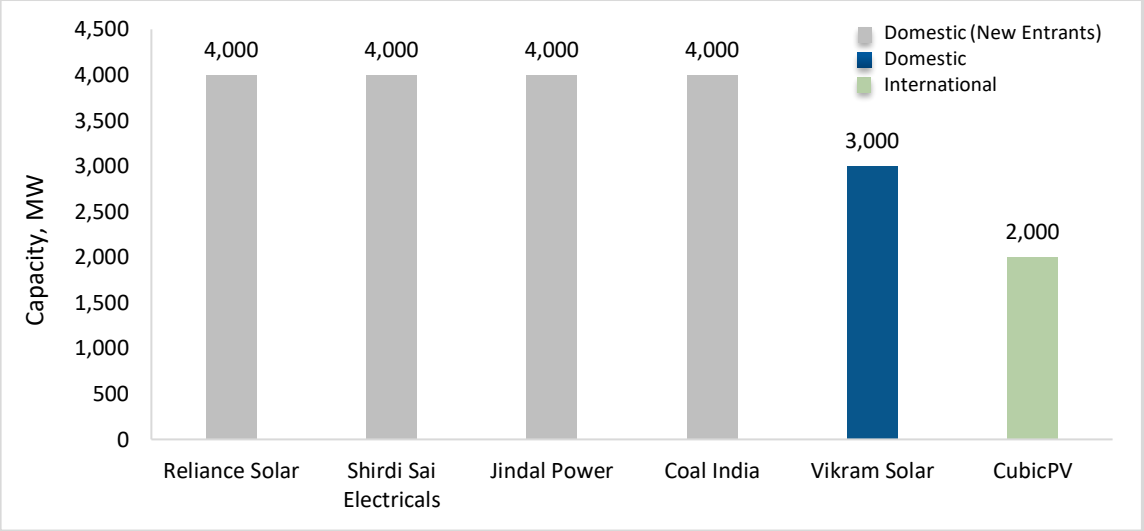
C. Wafer Manufacturing Plans

India has no existing manufacturing capacity for the initial stages of the PV value chain, namely from polysilicon to wafer. For raw materials, Indian solar manufacturers still depend on imports, mainly from China. China is the leading producer of silicon wafer with a 97.4% share of the global market, and polysilicon with 67% share.[14]

India cannot achieve self-sustenance in solar technology without a holistic and integrated manufacturing approach. Without large-scale domestic manufacturing of upstream PV value chain products, there remain overarching risks of logistics and commodity price fluctuations posed by huge solar imports.

Several manufacturers now entering the field of solar manufacturing are looking to build an integrated facility that includes all PV value chain components from polysilicon to solar module. Among those looking at wafer manufacturing are big private Indian conglomerates such as Reliance and Jindal, as well as one of the world's biggest coal companies, Coal India. Reliance invested $29 million in German wafer manufacturer NexWafe GmbH. Reliance will use NexWafe proprietary technology for manufacturing solar wafers in its coming PV factory in Jamnagar. There has been interest from U.S.-based CubicPV, a merger of 1366 Technologies and Hunt Perovskite Technologies (HPT), two disruptive technologies in the solar manufacturing domain -- 1366 via its direct wafer process and HPT using perovskite crystal technology. Credit must be given to the PLI scheme for the immense impact it has had on how businesses, domestic and international alike, view solar manufacturing in India.

Figure 12: Wafer Manufacturing Plans (For Next 3-4 Years)



Source: JMK Research.

[14] IEA. IEA PVPS Annual Report 2019, China. May 2020.

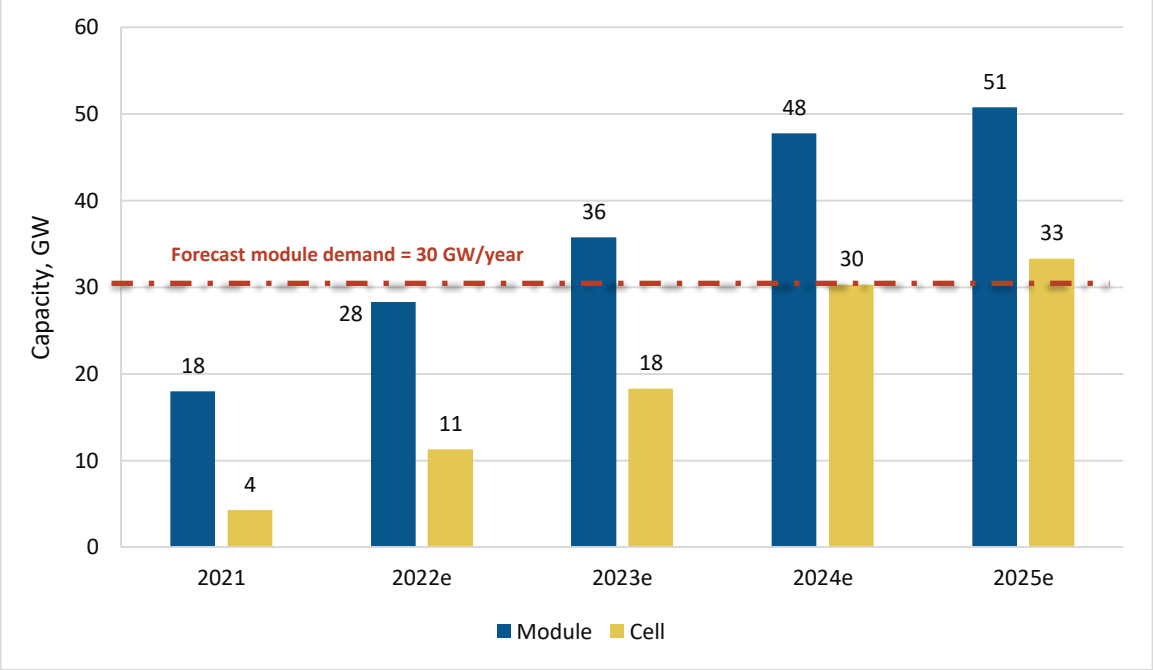
Addition of these capacities in the Indian solar industry in the medium term will be a welcome move to boost upstream solar manufacturing.

Domestic Manufacturers' Expansion Plans

Announcements in the past year by industry leaders or new entrants exploring the market indicate solar manufacturing will be a key area of growth domestically. Cumulatively, about 33GW of module and 29GW of cell production capacity are in the pipeline to add to existing domestic capacity by 2025.[15] For domestic solar module manufacturing, this represents an impressive CAGR of ~30%. Despite the industry's short-term challenges, manufacturers are very optimistic about the long-term sustainability of the solar sector.

To reach the 500GW target of non-fossil fuel-based installed capacity by 2030, India needs about 30GW of solar installations each year. Current domestic output cannot meet such demand. Based on expansion plans announced by several manufacturers, it is estimated domestic capacity is likely to exponentially increase to fulfil that 30GW/year requirement by the end of 2023.

Figure 13: Proposed Cumulative Manufacturing Capacity (to 2025)



Source: JMK Research.

In this projected increase of solar manufacturing capacity in coming years, much will depend on the timely and efficient implementation of government policies.

[15] JMK Research.

New Entrants Looking to Explore the Market

Favourable scenarios for solar manufacturing have generated huge interest from several companies and these conducive conditions can make India a solar manufacturing hub in years to come.

- **Favourable government policy environment** – With the introduction of schemes such as PLI, Approved List of Models and Manufacturers (ALMM) and BCD, the government is betting big on making India self-sustainable in solar equipment. These schemes are either in the pipeline or have been implemented and the positive impact of the policies can already be felt. PLI tender for Solar PV manufacturing received bids worth 54.8GW against a total sanctioned bid of 10GW.

- **Augmentation of required demand** – India has promised to reach 500GW renewable energy capacity in 2030, including about 300GW from solar. To add about 30GW of solar capacity a year, existing and imminent players see the sense of keeping supply as close as possible to the demand.

- **Availability of raw materials** – Access to raw materials such as polysilicon, wafers etc, critical to manufacturing of solar cells and modules, has been a major hurdle for Indian major manufacturers scaling up and competing with Chinese counterparts in price and quality. Impending entries include big Indian conglomerates such as Reliance Group and powerful state public sector undertakings (PSUs) such as BHEL and Coal India (which declared plans for wafer and polysilicon manufacturing within the country). It seems highly likely that Indian manufacturers soon will not have to depend entirely on exports and contend with the risks associated with critical raw materials.

- **Easier financing options** – It is widely accepted that the quality of funding influences the selling price of the product. According to leading players, the outlook of investors, banks and non-banking financial companies (NBFCs) towards investing and lending funds/loans for solar manufacturing installations has changed. Loans are easily available at a stable 7-8%. Various firms are looking at going public, following the recent Initial Public Offering (IPO) of ReNew Power. Waaree Energies filed for IPO in September 2021, with approval awarded in January 2022. The issue size of the IPO will be Rs1500 crore (US$201m), the proceeds to be used for new solar cell and module fabs.

- **Predicted technological changes** – Over the years, cells and wafers have become bigger and more efficient and the underlining technology has evolved, e.g., from the once-dominant poly-Si to mono-Si at present. It is estimated that “mono PERC bifacial” will be the dominant technology in five years. Original equipment manufacturers (OEMs) around the world have prepared for this and the solar module and cell lines under construction are such that they can handle various cell and wafer size. Market entrants have an opportunity, if planned properly, to Invest in a low-risk, high-profit business.

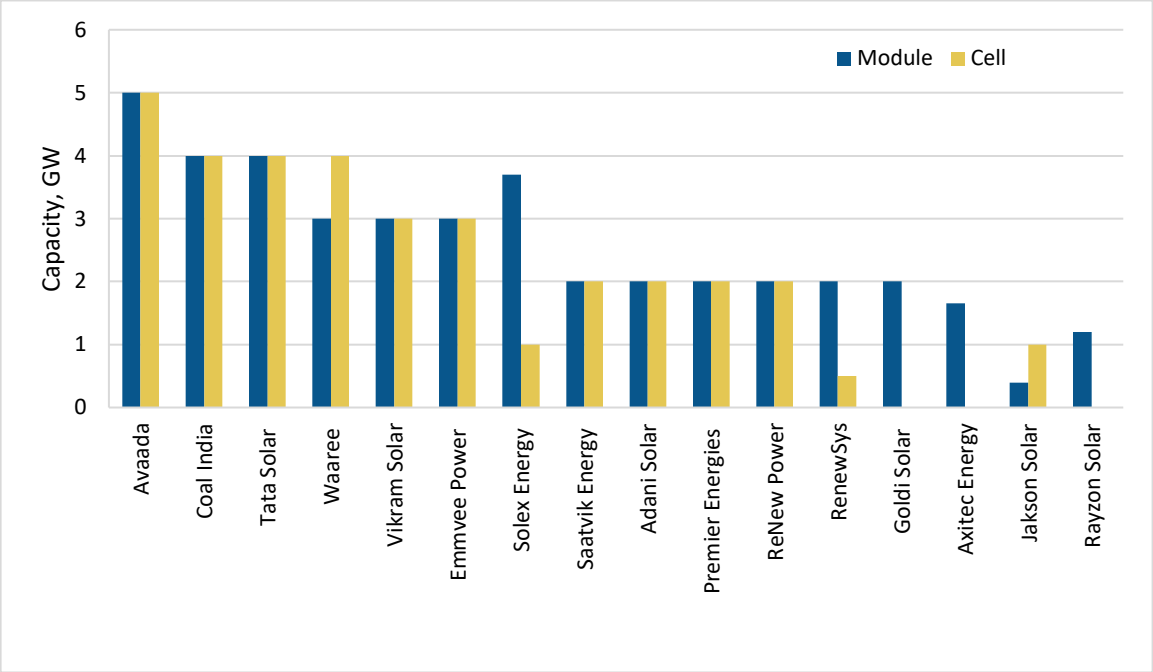
Those entering solar manufacturing in India are targeting big installation capacities as well as upstream integration in line with what the Government of India (GoI) is trying to achieve with its PLI scheme for solar modules. India is currently not a hub of solar manufacturing but there is great potential, and confidence, in its solar growth story.

Major project developers such as ReNew Power and Avaada are entering the solar manufacturing space to exploit the advantages of vertical integration. As solar modules make up 50-60% of the total cost of solar projects, using in-house modules reduces the considerable risks and so overall project cost. Most of the coming plants are in coastal states with easy access to ports. ReNew Power's under-construction integrated solar cell and module fab has a capacity of 2GW. Avaada Group intends to set up a 5GW integrated solar cell and module manufacturing unit. The trend of project developers venturing into solar manufacturing to have better control of their input costs is expected to grow in the coming years.

India is currently not a hub of solar manufacturing but there is great potential, and confidence, in its solar growth story.

Coal India, one of the biggest coal suppliers in the world, will install 4GW of integrated wafer, cell and module manufacturing fab in India. India's largest power generation equipment manufacturer, BHEL, has begun solar module manufacturing. Clearly, Indian PSUs that have long been associated with conventional sources of energy have realised the significance of RE. Many PSUs are expected to invest in solar manufacturing at various scales. With central government oversight, PSUs could become one of the leading players in domestic solar manufacturing.

Figure 14: Proposed Additional Manufacturing Capacity (Until 2025)



Source: JMK Research.

With encouraging government policies and in anticipation of huge demand in India in the coming decade, several international players see huge potential in solar manufacturing in India. This is demonstrated by the move of U.S. manufacturers First Solar and CubicPV to set up facilities in India in coming years. Both bid for the PLI scheme. First Solar, interestingly, is betting on its thin-film modules to make a comeback in India by setting up a 3.3GW facility.

Numerous Indian conglomerates are also expected to enter the solar manufacturing business. Reliance, Jindal Power and Shirdi Sai Electricals were declared the winners in the first tranche of the PLI scheme and combined are looking to set up about 12GW of integrated manufacturing. Tata is already manufacturing solar modules and cells, if at a smaller scale. With capital backing and manufacturing at scale, the conglomerates can be a major game-changer in the nation's global standing. However, if the entry of conglomerates diminished the visibility of small and medium players, it would create concerns of business shutdown.

Going big in renewables and backed by huge capital, Reliance plans to target every RE segment, not just solar manufacturing. The newly formed entity Reliance New Energy Solar Limited aims to invest US$10bn in clean energy, adding significant capacity at every vertical in renewables and acquiring talent, experience and technology expertise. Recent acquisitions of companies such as NexWafe (a wafer manufacturer), REC Solar holdings (solar module manufacturer) and taking a 40% stake in Sterling and Wilson Solar Limited illustrate the intent to be a market leader in renewables in the long term.

Backed by huge capital, Reliance plans to target every renewable energy segment.

It is also expected that PLI winners might use substantial sanctioned plant capacity for captive consumption in their coming solar projects. This will help reduce procurement expenses and increase overall profits significantly. The entry of conglomerates such as Reliance and Jindal into solar manufacturing gives further traction towards renewables in India.

Table 1: New Entrants Looking to Explore the Indian Domestic Solar Manufacturing Market

New Entrant	Country of Origin	Type	Planned Capacity
First Solar	U.S.	Private	• 3.3GW of total module manufacturing capacity. • Technology: Thin Film • Investment of US$684m
Reliance Industries Limited	India	Private Conglomerate	• 4GW capacity of integrated manufacturing from metallic silicon to modules. • Technology: Heterojunction technology (HJT) mono-Si • Investment of US$10.1billion in clean energy. • PLI beneficiary. • Acquisition/Strategic Investments in REC Solar and NexWafe.
JINDAL POWER	India	Private Conglomerate	• 4GW capacity of integrated manufacturing from M.G. Silica to modules. • PLI beneficiary.
SSE SHIRDI SAI ELECTRICALS LTD	India	Private	• 4GW capacity of integrated manufacturing from M.G. Silica to modules. • PLI beneficiary.
कोल इण्डिया लिमिटेड Coal India Limited भारत सरकार का उपक्रम A Government of India Undertaking एक महारत्न कंपनी A Maharatna Company	India	PSU	• 4GW capacity of integrated manufacturing from Ingot to modules.
CUBIC PV	U.S.	Private Merger	• 2GW capacity of wafers and cells. • Expand to 10GW over five years. • Total planned investment: US$1.1bn.

Source: JMK Research, Industry news articles.

Policy Support and Government Initiatives

This section discusses the updates over the past year on key government initiatives to support a domestic PV manufacturing industry.

A. Domestic Content Requirement (DCR)

The DCR mandates the use of solar cells and modules manufactured domestically as per specifications and testing requirements fixed by MNRE. Under this program, government subsidies are provided for the following schemes.

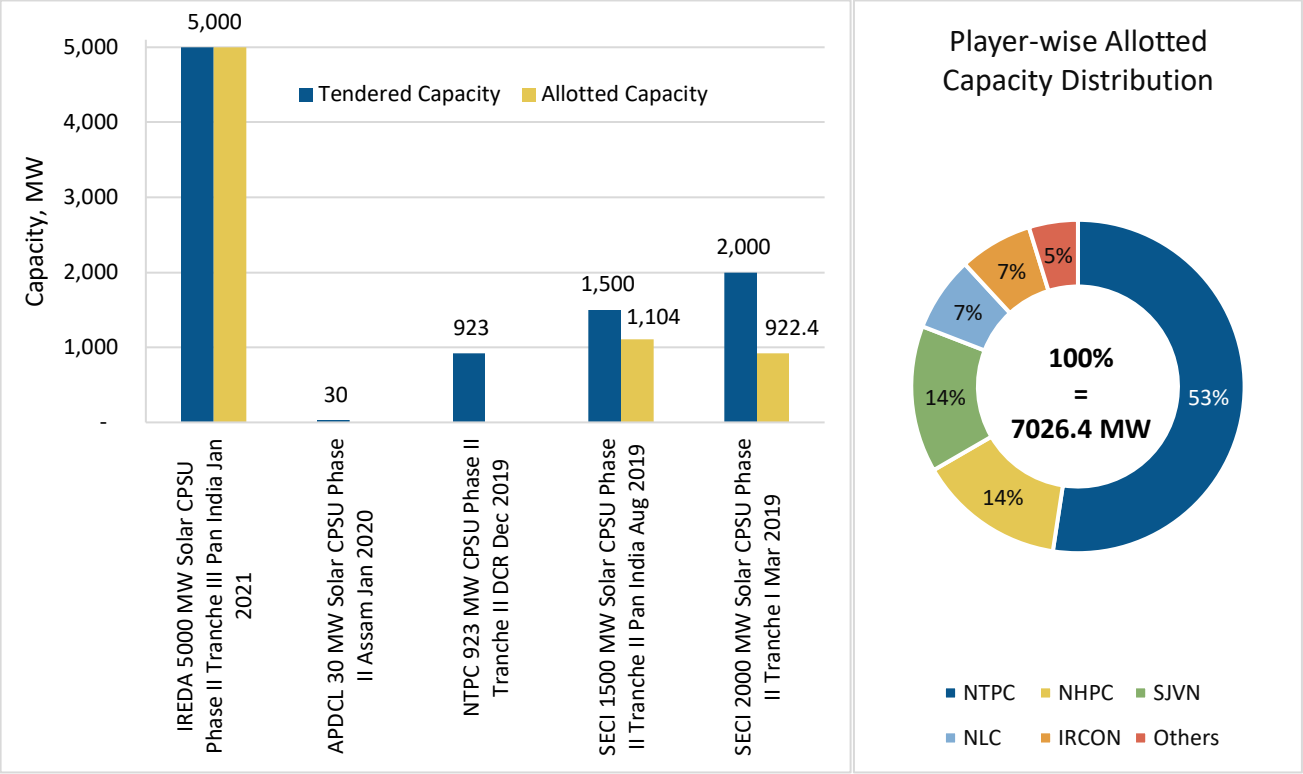
Central Public Sector Undertaking (CPSU) Scheme

The CPSU scheme was introduced in 2015 to implement 1GW of grid-connected solar PV power projects using domestic cells and modules, to be set up by CPSUs/Government of India organisations with viability gap funding (VGF) to cover the cost difference between imported and domestic solar cells and modules. The government producer receives the funding through a bidding process using the VGF amount as a parameter to select the project developer. In phase 2 of the scheme, approved in 2019, the target was revised to 12GW by FY2022/23. The Indian government sanctioned VGF support of Rs85,800m for phase 2, capping funding at Rs7m/MW.

Under MNRE guidelines for implementation of phase 2, the power generated by the government producers can be used on payment of mutually agreed usage charges of not more than Rs2.45/kWh for self-use or use by the Government or its entities, directly or through discoms. The maximum permissible VGF was later reduced to Rs5.5m/MW, via an amendment from MNRE.

Of the targeted 12GW capacity, 9.5GW of aggregate capacity has been tendered by multiple authorities (SECI, NTPC, IREDA and APDCL). So far, 7GW of the tendered capacity have been allotted, of which ~53% has been allotted to NTPC.

Figure 15: Capacity Allotment Status Under CPSU Scheme



Source: Relevant Tendering Authorities, JMK Research.

PM-KUSUM

The Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM) scheme was launched in 2019 and in FY2020/21 was expanded to add a total solar capacity of 30.8GW by 2022, up from the initial target of 25.7GW. The total central financial support allocated under the scheme is Rs34,035 crore (~US$4.6b). With proper execution of the government scheme under the domestic content requirement (DCR) purview, domestic manufacturers can boost their visibility, potentially exposing themselves to greater demand opportunities in the Indian market.

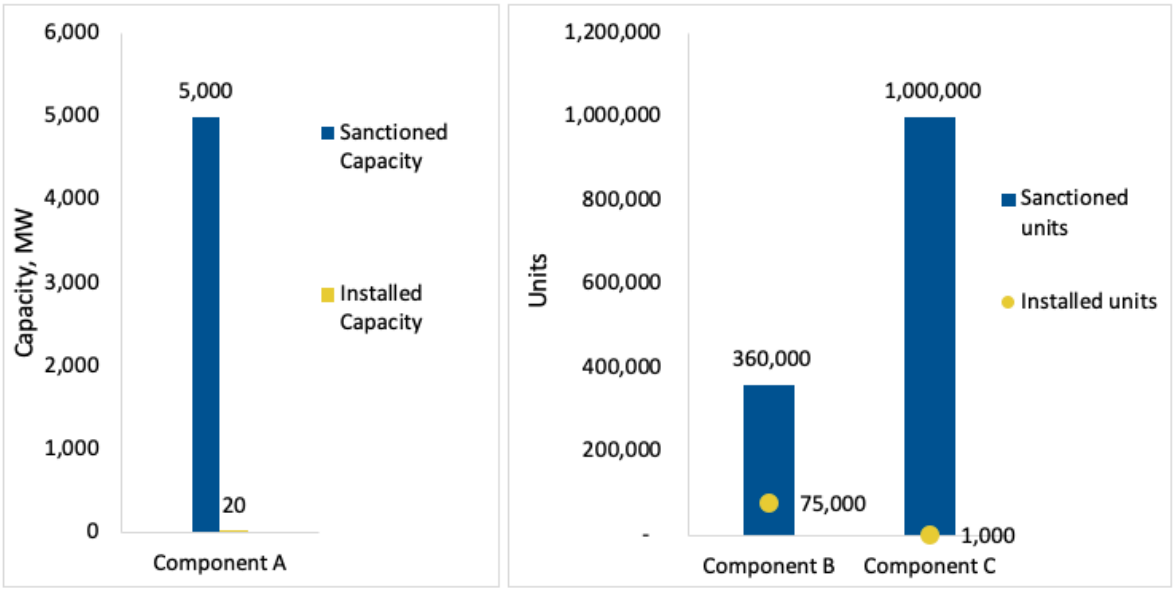
The scheme is divided into three components.

- **Component A**: Setting up of 10,000MW of decentralised ground-mounted grid-connected solar or other renewable energy-based power plants
- **Component B**: Installation of 2 million standalone solar agriculture pumps
- **Component C:** Solarisation of 1.5 million existing grid-connected agriculture pumps

Using DCR cells and modules is mandatory for components B and C. As of November 2021, under Component A, only 20MW had been installed out of the sanctioned

capacity. Out of the sanctioned units under Component B, 75,000 standalone solar pumps had been installed in various states. Under Component C, solarisation of more than 1 million grid connected pumps had been allocated under two variants, individual pump and feeder level. Of the allocated units, only 1,000 had been installed.

Figure 16: Sanctioned Capacity Under PM-KUSUM Scheme, as of November 2021



Source: JMK Research.

Note: Installed units under Component C indicate solarised pumps under individual pump solarisation variant of Component C. Implementation of feeder level solarisation variant under Component C (introduced in December 2020) has not been considered in the figure above.

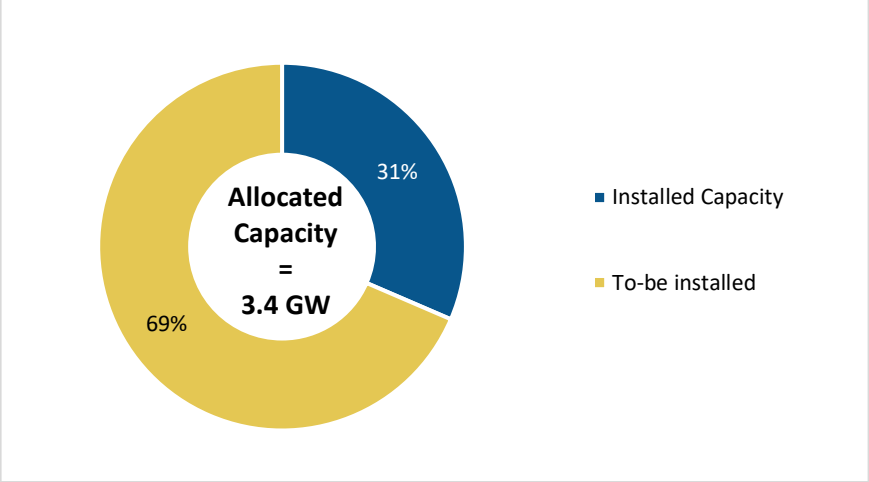
Grid-connected Rooftop Solar Program

In December 2015, phase 1 of the program was launched with the intent of providing incentives for residential, institutional and social segments. For the government segment, achievement-linked incentives were provided. Phase 2 was approved in February 2019 with a target of 40GW of cumulative capacity from rooftop solar (RTS) projects by 2022. Within the ambit of phase 2, incentives in the form of Central Financial Assistance (CFA) were designed on the basis of RTS capacity.

- For RTS systems up to 3kW capacity – CFA of 40%
- For RTS systems beyond 3kW and up to 10kW capacity – CFA of 20%
- In addition, CFA of up to 20% for RTS, limited to 500kW capacity, for supply of power to common facilities of Group Housing Societies (GHS) and Residents Welfare Associations (RWA).

Discoms of various states and union territories (UTs) are implementing the RTS program. The DCR mandate applies for the program's residential sector, with the aim of spurring development of domestic PV manufacturing. Of the phase 2 target of 4GW set for the residential sector, 3.4GW has been allocated to various states and UTs and of this allocation, 1.07GW had been installed as of November 2021.

Figure 17: Status of Grid-connected Rooftop Solar Program – Residential Sector, as of November 2021



Source: JMK Research.

A parliamentary panel noted that the target set for solar rooftops cannot be achieved without proper implementation of net/gross metering and there is a need to maintain uniformity in terms of regulations/model operating procedures/online unified portals etc.

B. Production-Linked Incentive (PLI) Scheme

The Government of India's production-linked incentive (PLI) scheme, National Program on High Efficiency Solar PV (Photovoltaic) Modules, was officially approved in April 2021. The scheme, with a financial outlay of Rs4,500 crore (US$616 million), was intended to support 10GW capacity of integrated solar PV manufacturing plants.

In relation to this, additional direct and indirect benefits were foreseen as:

- Direct investment of about Rs17,200 crore in solar PV manufacturing projects
- Demand of Rs17,500 crore over five years for Balance of Materials
- Direct employment of about 30,000 and indirect employment of about 120,000
- Import substitution of about Rs17,500 crore every year

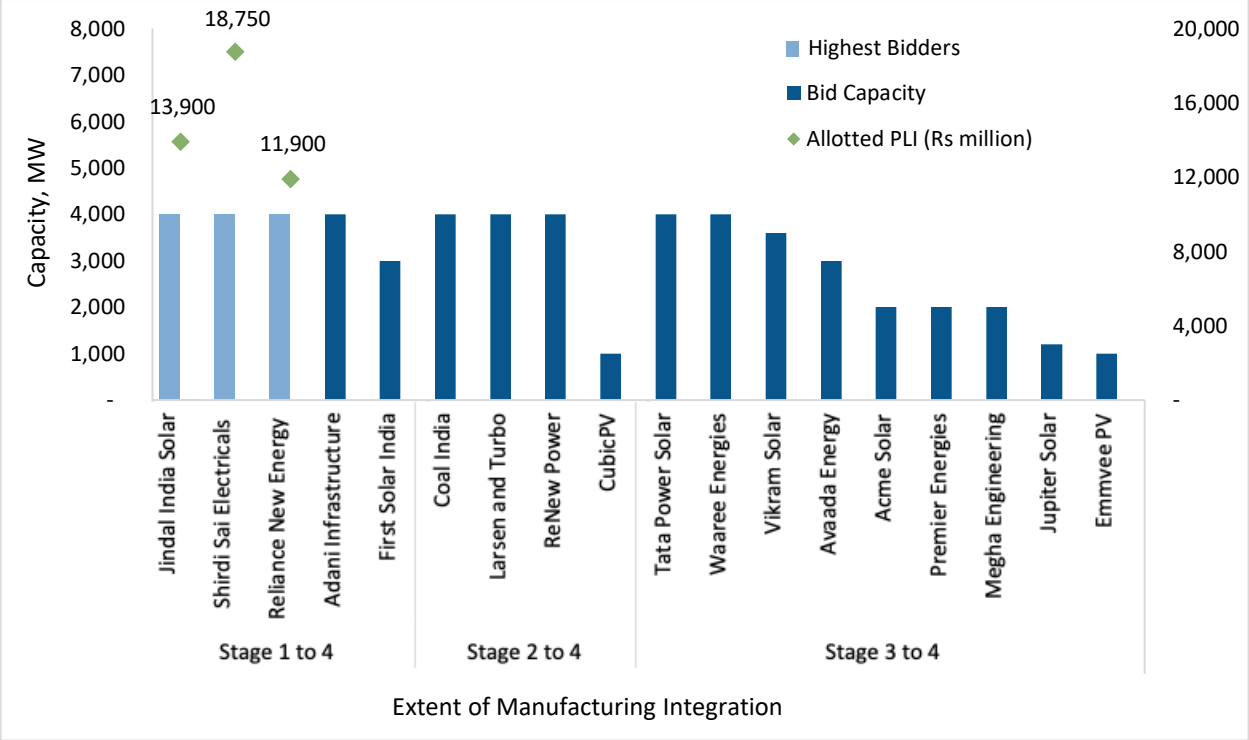
- Impetus to R&D to achieve higher efficiency in solar PV modules

In May 2021, the Indian Renewable Energy Development Agency (IREDA), a PSU under the Ministry of New & Renewable Energy (MNRE), invited bids under the PLI scheme for integrated solar manufacturing units.

The total bids received were 54.8GW, resulting in more than fourfold over-subscription. Bidders were shortlisted based on two parameters, extent of manufacturing integration (or extent of integration of manufacturing stages) and manufacturing capacity.

Shirdi Sai Electricals, Jindal India Solar Energy and Reliance New Energy Solar were selected as the PLI beneficiaries for setting up stages 1-4 (Polysilicon + Ingot-Wafer + Cell + Module) integrated manufacturing. Jindal and Shirdi Sai were awarded 4GW each and Reliance secured 2,483MW.

Figure 18: Capacity Allocation Under Solar Manufacturing PLI Scheme



Source: IREDA, JMK Research.

India's high import dependency for high-efficiency solar PV products makes it critically susceptible to supply chain disruption and market price shocks. The PLI scheme can help mitigate the PV supply chain risks.

However, a cumulative ~10GW of PV manufacturing distributed between three players (the PLI awardees) cannot translate to adequate economies of scale, despite incentives for vertical integration. Additionally, projects under PLI scheme are

expected to have a latency period of at least 18-24 months prior to initiation of the manufacturing process.

With the additional infusion of Rs19,500 crore (US$2.5 billion) into the solar PV PLI budget in February 2022, integrated PV manufacturing of at least 40GW capacity could be incentivised, in addition to the existing PLI-linked 10GW capacity. This will help in creating a huge demand potential for the PV ancillary (solar glass, ethylene vinyl acetate (EVA), backsheet, etc.) market and skilled workforce. The direct investment in the country on account of the PLI budget expansion would potentially rise to about Rs90,000 crore (US$11.5 billion).

C. Basic Customs Duty

On March 9, 2021, the Ministry of Finance approved the imposition of 25% basic customs duty (BCD) on solar cells and 40% on solar modules, with effect from April 1, 2022. The BCD was aimed at improving the price competitiveness of domestic PV products, though the industry regarded it as a counterproductive measure.

Safeguard Duty (SGD) applied for two years, ending in July 2021, on imports from China, Thailand and Vietnam. BCD remains applicable to all imports, regardless of the country of origin, and this has specifically become an additional cause of concern for solar equipment manufacturers in special economic zones (SEZs).

Goods and services from SEZs, when offered to entities in the domestic tariff area, are considered imports and so subject to customs duty. More than half of India's solar cell manufacturing units and about 40% of solar panel manufacturing units are situated in SEZs. SEZ PV products would become even more expensive than during the duty-free period.

D. Purchase Preference to Local Suppliers

In a wider decoupling exercise, as part of India's economic response against China, firms defined as Class 1 local suppliers are the only ones eligible to bid for public procurement contracts if there is sufficient domestic capacity for the nominated product. Class 1 takes in local suppliers or service providers whose goods, services or works offered for procurement have local content of at least 50%.

Solar PV modules are among the products identified as having sufficient local capacity and competition.

E. Approved List of Models and Manufacturers (ALMM)

The MNRE has made it mandatory for solar cell and module manufacturers to register under the ALMM. The list consists of eligible models and manufacturers of solar cells and modules complying with the Bureau of Indian Standards (BIS) Standards. The objective of ALMM is to enhance domestic manufacturing and to have a quality benchmark for cells and modules. The ministry released the first list of photovoltaic module manufacturers at the beginning of March 2021.

The latest list issued in December 2021 includes 41 module manufacturers and a total capacity of 10.9GW. Standard bidding guidelines from April 10, 2021 require procurement of modules from the approved list.

Validity of models will be for two years from the date of being listed. ALMM consists of a mix of multi-Si and mono-Si (including mono PERC) technology-based modules. Vikram Solar is the sole listed manufacturer with bifacial-type models.

In January 2022, the MNRE amended the list to broaden the ambit of project type for which ALMM models would be eligible. It added open access and net metering projects (in addition to government projects, government-assisted projects, projects under government schemes and programs, the latter including projects set up under Component A of PM-KUSUM).

The amendment will cover renewable energy projects that apply for open access or net metering facility from April 2022.

F. First Ever Project Development Tender With Manufacturing

In SECI's 12GW Solar PV (manufacturing linked) tender, Adani Green Energy won a bid for solar panel manufacturing capacity of 2GW of solar and the associated generation capacity of 8GW, out of which a power purchase agreement (PPA) was signed for 5.5GW. For the same tender, Azure Power won a bid for 1GW solar panel manufacturing and 4GW generation capacity, with PPA of 600MW.

Adani will develop its 2GW via its manufacturing subsidiary. Azure Power is set to fulfil its manufacturing component through its tie-up with Waaree.

Key Challenges for Indian Manufacturers

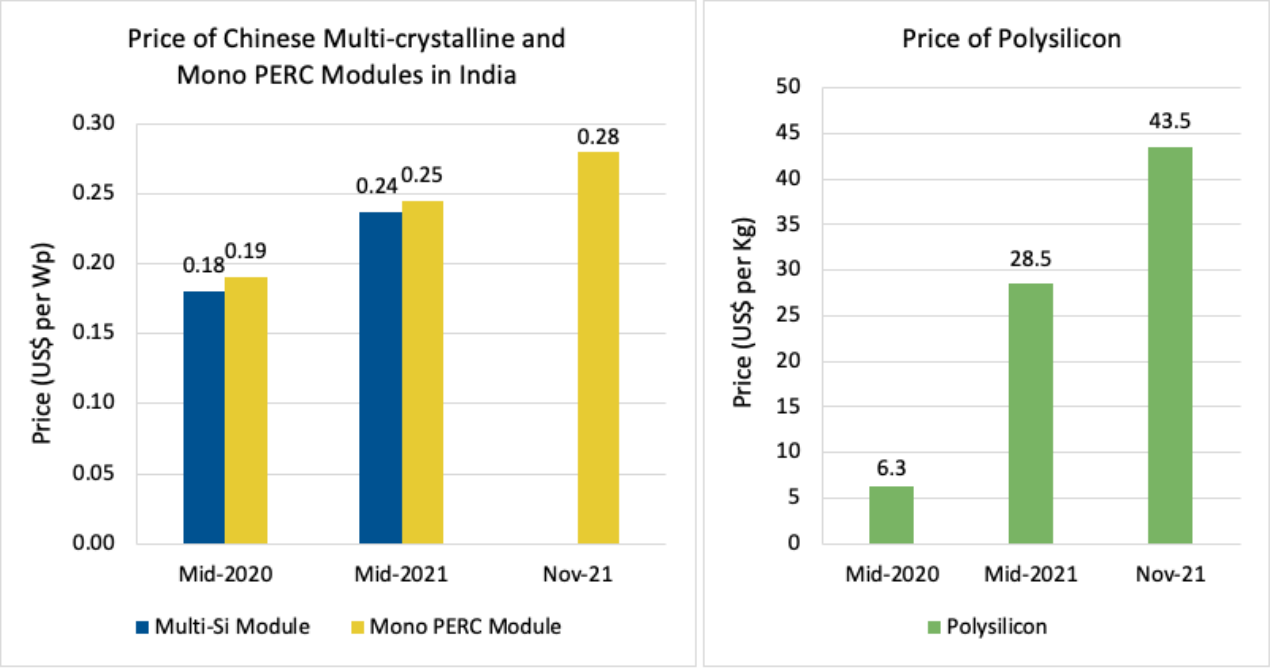
The solar market in India is currently facing more headwinds than usual, especially due to challenges owing to COVID-19. The demand-supply imbalance in terms of solar PV products, although still severe, is gradually alleviating. For domestic PV manufacturers, on the brighter side, the ongoing phase of supply slack presents an opportunity to upgrade manufacturing capabilities. Other stakeholders such as the policymakers, investors, allied manufacturers in the PV value chain etc need to provide a synergistic thrust for development of sustainable PV power in India.

A. Supply Chain Fluctuations

In mid-2020, the landed price for a Chinese multi-Si module was (excluding GST and SGD) ~US$0.18 per watt peak (Wp) and about 1 cent higher for a Chinese mono PERC module. A year later, the prices of these modules rose by ~30% and in November 2021, the landed price of Chinese mono PERC module climbed to approximately US$0.28/Wp, registering a ~50% spike from the record-low (mid-2020) price.

The steep rise in module prices over the past 1.5 years has been due to a severe shortage in polysilicon, translating to a massive surge (more than 500%) in its price. Another key driver for the sharp price increase is the resurgence of solar market demand post COVID-induced lockdowns.

Figure 19: Recent Price Trends of Solar PV Products



Source: BloombergNEF, PV InfoLink, JMK Research.
Note: Module Prices are FOB prices.

However, after trading at a 10-year high, the polysilicon price has declined by ~17% since November 2021, as key global polysilicon suppliers expanded production, adding 160,000 tons/year to the existing global capacity of ~620,000 tons/year. Elevated polysilicon prices are expected to last through the first half of 2022.[16]

Other disrupting factors in the PV supply chain include price hikes for commodities such as glass and metals, the recent power crisis in China, shortage of containers etc. As polysilicon is the single most critical part of the supply chain, such disruption underscores the need for its integration in PV manufacturing in India.

[16] BloombergQuint, China's Solar Giants Have a Fix for Their Broken Supply Chain, January 2022.

B. High Capital Cost

India has been a laggard with PV technology. To remedy this, it is important that new domestic module factories are as vertically integrated as possible. The complex and capital-intensive nature of solar module production is a major challenge -- setting up a solar cell production line is even more capital-intensive and complicated. A new 1GW (mono-PERC) cell production line in India would cost about Rs5,000m, and take three to six months for facility setup, machinery installation and process fine-tuning.[17] Furthermore, debt financing for fab set-up is costlier (8-9% interest rate) in India than in developed nations (2-4%). The impact of the more expensive debt option is even more pronounced considering fabs are 70-75% funded by debt.

The complex and capital-intensive nature of solar module production is a major challenge.

C. High Operating Cost

Operating expenses (opex) are significant in PV manufacturing and are not addressed under the PLI. Opex components including 24/7 electricity, transportation cost, water requirement etc need to be optimised to improve viability of managing solar fab.

PV manufacturing is a power-intensive process. And the power intensity increases upstream along the PV value chain, so affordable power supply is also critical. States that have greater concentration of solar fabs such as Gujarat, Telangana etc need to provide these facilities with power at subsidised rates or ensure unfettered open access (OA) power (either via third party sale or captive/group captive plant).

D. Policy Uncertainty & Inadequacy

Lack of cohesive renewable energy (RE) policies among centre and state governments and frequent fluctuations of the same have stalled the growth of RE installations mainly in open access (OA) and rooftop solar market in India. The solar sector leads the renewables charge but constantly faces policy impediments. Step-by-step intervention guided by relevant stakeholder discussions must be undertaken to remove the limits on OA market across states.

Ambiguity around Goods and Services Tax (GST) rates, curbing of favourable provisions such as net metering and banking of RE are among the main issues affecting the solar industry. Attempting to apply ALMM against the backdrop of will

[17] JMK Research Interview insights.

put undue pressure upon the domestic solar industry in the near future as the market seeks to strike a demand-supply balance, potentially exacerbating domestic module price volatility.

Furthermore, India's dependence of PV imports is not expected to undergo a drastic change post BCD imposition in the medium-term. This is because new solar fab with stage 1 to 4 integrated manufacturing would take at least three to four years from setup to producing globally competitive PV products. Until then government could plan to defer the BCD imposition on solar cells.

JMK Research estimates that manufacturing capacity additions, coupled with tariff and non-tariff barriers, can reduce the import dependence of India's solar module market from 80% to 60-65% only in the next two to three years.

E. Export Limitation

Only a handful of domestic players are exporters. In the absence of a domestic certifying agency permitting export of PV products, Indian manufacturers must rely on international authorities to obtain certification, a highly expensive and time-consuming process that is more prohibitive than attractive. Moreover, there is no single globally recognised certification – different countries have differing standard certifications. The Indian government needs to aid the development of world-class certifying labs for solar PV.

F. Lack of Skilled Manpower

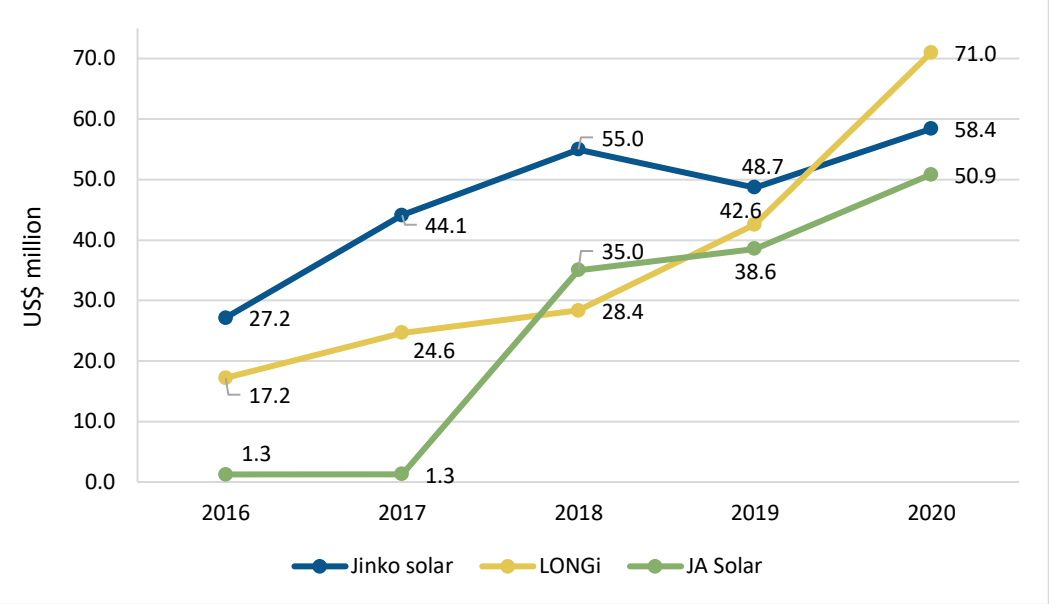
During and after the pandemic, the scarcity of skilled manpower in India trained to handle installation of cell lines limited the expansion plans of several solar cell manufacturers. With the scaling-up of domestic cell capacities, as proposed by various local manufacturers, the skills shortage will most likely be resolved in the next few years.

G. Lack of R&D

Research and development in photovoltaics is starkly deficient. The contribution from India's PV manufacturers, academia, government and investors is insignificant. To cut dependence on imports, PV manufacturers need adequate support from the government to unlock the tremendous potential for innovation and development of indigenous PV cell technology and cutting-edge manufacturing techniques.

R&D in Chinese companies is funded by 1-5% of company revenues, consistently providing the thrust for innovations. To catalyse solar PV R&D in India, the government could support PV manufacturers via special incentives (e.g., tax deductions on R&D spending).

Figure 20: R&D Expenses of Leading Chinese Solar Manufacturing Companies



Source: JMK Research

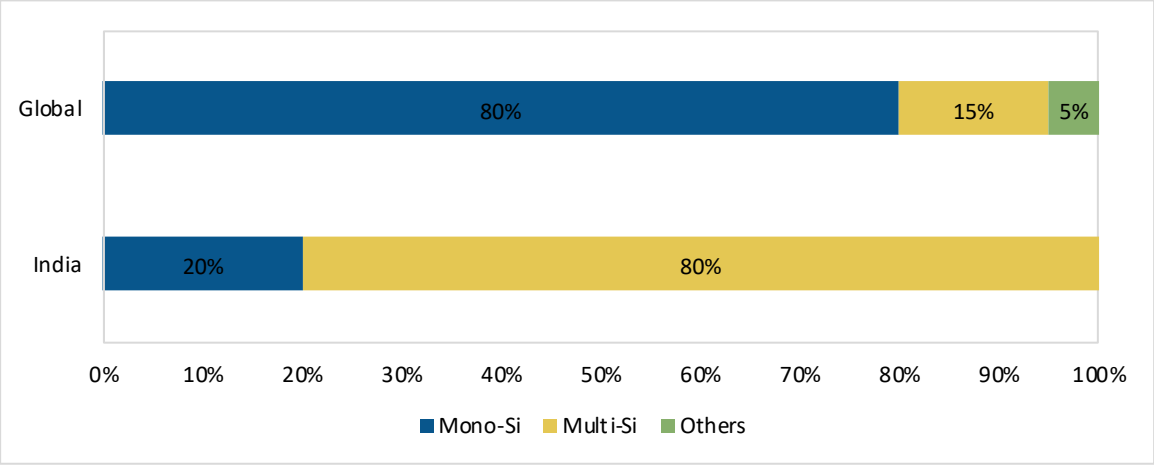
H. Technology Adoption Lag

India has been a laggard in solar PV technology adoption. In the world's major solar markets, mono-Si is ubiquitous yet the Indian solar manufacturing industry has still not caught up, primarily due to the domestic market's price-sensitive nature.

Multi-Si module technology, accounting for the majority (60-70%) of domestic module production capacity in India, is on the verge of becoming obsolete. Local demand for these modules continues to dwindle but is expected to last for another one or two years. In its concluding phase, use of multi-Si technology would be limited to KUSUM agri-pumps, residential rooftop and subsidised off-grid government projects.

In 2020, the share of multi-crystalline silicon (multi-Si) in India's total solar module production indicated its clear dominance over monocrystalline silicon (mono-Si) which is in stark contrast to the global case as illustrated in figure below.

Figure 21: Share of PV Technology: Global vs India (GW) – 2020



Source: Fraunhofer ISE, JMK Research.

Every player looking to expand in or enter the solar manufacturing market must be aware of the risk of technology obsolescence and the imperative of keeping up to date in R&D and manoeuvrability. Existing or intending, major manufacturers aim to install machinery that can handle cell sizes of up to M12 (210mm x 210mm), in both configurations, mono and bi-facial. The quality of the modules manufactured by these new facilities will be comparable with Tier 1 Chinese suppliers.

I. Lack of Production Scale

Even before the recent major supply chain constriction, the average capacity utilisation of Indian PV manufacturing plants was underwhelming due to lack of demand from private solar IPPs. In the recent past, the supply chain conundrum caused capacity utilisation to drop even further, affecting price competitiveness of Indian PV products.

India's aggregate module manufacturing capacity of ~18GW is comparable to the annual capacity addition of the top individual Chinese PV manufacturers, showing the vast scope for Indian companies to match their economies of scale.

J. Summary of Challenges and Opportunities Based on Current Outlook

Key Aspect	Challenge(s)	Opportunity(-ies)
Supply Chain	• Shortage of polysilicon and other commodities leading to sharp price hikes • High uncertainty owing to COVID-related restriction	• Opportune phase for existing/ potential PV manufacturers to upgrade their capabilities/invest in advanced fabs
Production-Linked Incentive (PLI) Scheme	• Requisite PV ancillary manufacturing capacity is virtually absent • Shortage of highly skilled workforce	• Vast potential for development of PV ecosystem • Huge employment opportunity
Policy Implementation	• Inconsistency and fluctuation in policies constraining market demand and therefore, supply activity • Lack of clarity around BCD and ALMM implementation	• Implementing clear and consistent policy for at least five years, uniformity needed from centre and states
Export Market	• Highly resource-consuming certification process • Lack of certifying agencies in India	• Export demand potential on the rise owing to anti-China sentiments • Opportunity to create certifying lab accredited by reputable international organisations
R&D	• Huge void in this domain in terms of infrastructure, quality testing facility, skilled human resource	• Adequate potential for R&D growth, with government capex support and with strategic partnerships: manufacturers, leading technology consultants and academia

Way Forward

Recent market developments mean a boom in domestic solar manufacturing is imminent. Below is a brief outlook for solar manufacturing in India.

A. Diverse Entrants to Go Big

In addition to the vast domestic market potential, the Government of India's ambitious targets and support for solar sector have turned indigenous PV manufacturing's prospects even more vibrant. Dozens of companies are vying to make a mark in Indian PV manufacturing. These players include existing project developers, PSUs, big conglomerates and international players. All the new entrants are planning to setup integrated PV manufacturing at scale.

B. Ancillary Market Development

Several critical ancillary components and services associated with solar module manufacturing are often not highlighted. Components such as solar glass, ethylene vinyl acetate (EVA), backsheet etc are mostly imported, even by the leading Indian solar manufacturers, as there is no significant domestic production. All these factors contribute towards the price difference between a domestic produced module and an imported Chinese example. Module and cell production cannot expand significantly without the development of these ancillary industries. Ongoing PLI activity is expected to be a shot in the arm for the ancillary market, which subsequently would grow in tandem with PV overall.

Module and cell production cannot expand significantly without development of ancillary industries.

C. Domestic Manufacturers' Technological Advancement

The bulk of the existing module manufacturing capacity in India is yet to upgrade from multi-Si to mono-Si. The share of more efficient mono-Si technology was significantly high in total module demand in India in 2020, showing the strength of imports.

It is important that not only do Indian manufacturers need to keep up with the PV trends but also be able to invent them. Reliance will focus on making HJT modules in its new factory. With mono PERC being the major technology in demand, HJT at present is a fringe tech. The announcement that a big Indian conglomerate will focus on an emerging technology lays the framework for other domestic players. In coming years, going by the expansion plans, India will be able to establish itself as a

global leader in solar manufacturing, with the expectation the country might also rival other global players in technological advances.

D. Export Market Development

Prevailing anti-China sentiments in different countries give the Indian PV industry a tremendous opportunity to forge strong trade relations internationally. New export opportunities have emerged with growing demand potential in South Asia (Bangladesh, Sri Lanka) and Middle East and Africa (MEA) for India-made PV products, given the lower logistics expenses in shipping from India as against China. With companies such as First Solar and CubicPV setting up facilities in India, the U.S. will continue as an export destination. Additionally, leading domestic players are reporting huge interest and demand, mainly from U.S. and Europe. This has been accelerated partly due to cancellation of supply contracts in 2021 by Chinese manufacturers to U.S. developers, citing force majeure clauses. The developers are trying to de-risk future projects and so are looking at Indian manufacturers for supply.

Large players who are expanding capacities are now well aware of the importance of exports. It is also important for manufacturers to diversify the risks by being active in several national markets, though lack of certification labs in India at present is a short-term export challenge. It is expected the volume of solar exports in coming years will significantly increase.

Conclusion

India is at a critical point in terms of solar energy adoption and advancement. If the focus of nurturing the sector is purely upon project development, domestic manufacturers become laggards. Also, if the entire focus shifts to manufacturing indigenously, the developers most likely bear the major costs in terms of importing materials. All stakeholders must now decide on a balanced and sustainable PV development road map for the country. It will require a fine balance between the manufacture and consumption of solar PV equipment domestically.

India's sustainable PV road map must cover raw materials and production, subsidies and R&D.

When China came to dominance in solar manufacturing in the early 2010s, it laid emphasis on the whole PV landscape and not just solar cells and modules. The Indian government policy support was mainly focused on the final PV products but the PLI scheme has brought a shift in its approach to solar manufacturing. Now, production of raw materials such as polysilicon and wafers will also gain significance.

Developing significant manufacturing capacities in raw materials, especially polysilicon, will be highly capital intensive and technologically complex but it is of paramount necessity. Significant domestic manufacturing capacities in polysilicon and wafers will not only protect domestic module manufacturers to some extent from international supply chain fluctuations but it will also enable reduction in raw material prices of these components in the domestic market. In coming years, domestic manufacturers are expected to be more cost competitive, further aiding solar project developers to lower their project costs.

At present, the government is trying to attract investments into solar manufacturing by subsidising capex. There should however also be strong emphasis on opex support. Apart from the financial incentives, any new player looking to enter the market must be assured that solar fab can operate smoothly, for example, with dedicated, constant electricity feed and water.

It is also crucial to incentivise the Indian solar manufacturing industry to maintain investment in solar R&D to keep pace with rapid technology improvements. Domestic manufacturing companies need to have a proactive technology partnership with innovators or research institutes. Rather than focusing solely on the production output, it's imperative for the domestic solar manufacturing industry to create a strong foundation for sustainable development overall.

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