

भारत सरकार
विद्युत मंत्रालय
केन्द्रीय विद्युत प्राधिकरण
वित्तीय एवं वाणिज्यिक मूल्यांकन प्रभाग

Sewa Bhawan, New Delhi-66

दिनांक: 04.10.2024

विषय: नवीकरणीय ऊर्जा (आरई) बिजली उपकरण की उचित कीमत और आरई बिजली की उचित दरों का आकलन करने के लिए गठित ऑडिट टीम की रिपोर्ट - के बारे में/ Report of Audit Team constituted to assess the fair price of Renewable Energy (RE) power equipment and fair tariffs of RE power -- Reg.

The undersigned is directed to say that the erstwhile Hon'ble Minister of Power and New & Renewable Energy during the meeting with Renewable Energy Implementing Agencies (NTPC, NHPDC, SECI and SJVN) on 27th and 28th March 2024 had directed that CEA shall constitute an Audit Team to assess the fair price of major RE power equipment like Solar PV modules, wind turbines, other major ancillary inputs/equipment etc. and based on the same, also assess the fair tariff for RE power and submit a report.

2. In this regard, CEA had constituted a Team with representatives from MNRE, SECI, NISE and NTPC Green Energy Ltd. The report of the Team is enclosed for information and appropriate action.

3. This issues with the approval of Chairperson, CEA.

Encl: as above



(Goutam Ghosh)

Chief Engineer (F&CA)

Secretary, Ministry of New and Renewable Energy, Atal Akshaya Urja Bhawan, CGO Complex, Lodhi Road,, New Delhi-1

Copy to:

All Audit Team members

**Report of the Audit Team
formed by CEA to assess the
fair price of major RE
equipment**

Chapter I: Introduction

1. Background

The erstwhile Hon'ble Minister of Power and New & Renewable Energy during the meeting with Renewable Energy Implementing Agencies (NTPC, NHPDC, SECI and SJVN) on 27th and 28th March 2024 had directed that CEA shall constitute an Audit Team to continuously assess the fair price of major RE power equipment like Solar PV modules, wind turbines, other major ancillary inputs/equipment etc. and based on the same, also assess the fair tariff for RE power and submit a report.

2. Constitution of Audit Team

CEA had constituted an audit team vide order dated 08.05.2024 under Chief Engineer (F&CA), CEA with following Team Members:

- i. Dr Chandan Banerjee, Deputy Director General, National Institute of Solar Energy
- ii. Shri Sanjay G Karnadhar, Scientist E, MNRE
- iii. Shri Prabir Kumar Dash, Scientist E, MNRE
- iv. Shri Balaji Malepati, Deputy General Manager-Strategy, NTPC GEL
- v. Shri Abhinav Kumar, Deputy General Manager, SECI
- vi. Shri Deepak Choudhary, Deputy Director, CEA

3. Meetings of Audit Team

The Audit Team had its first meeting with Chairperson, CEA and Member (E&C), CEA on 28.05.2024. It was informed that the international Solar Cell prices have reduced by half since 2021. But solar tariff quoted by the bidders have not fallen commensurately. In view of above, the Audit Team could examine what is the fair price of cell/module and accordingly, estimate the fair solar tariff. This exercise will help in taking informed decision while examining discovered tariff in the bids

conducted by REIAs. It was also noted that the exercise may be taken up first for RE solar project and subsequently for wind project.

The Audit Team had subsequent internal meetings on 06.06.2024 and 09.07.2024. The Audit Team also had discussion with module/cell manufacturers on 01.08.2024.

4. Orientation of the Report

This report of the Audit team is laid out in four sections. **Chapter II** discusses the Anatomy of the Solar PV Plant. **Chapter III** gives the overview of solar module manufacturing capacities in the World and India. It also discusses the Government of India schemes for enhancing manufacturing capacity in renewable sector. **Chapter-IV** deals with the costing of solar modules. **Chapter V** gives the key findings/observations of the audit team.

Chapter-II: Anatomy of a Solar Power Plant

1. Overview of a Solar Power Plant

Figure 1 gives an overview of a megawatt scale grid connected solar PV Power Plant.

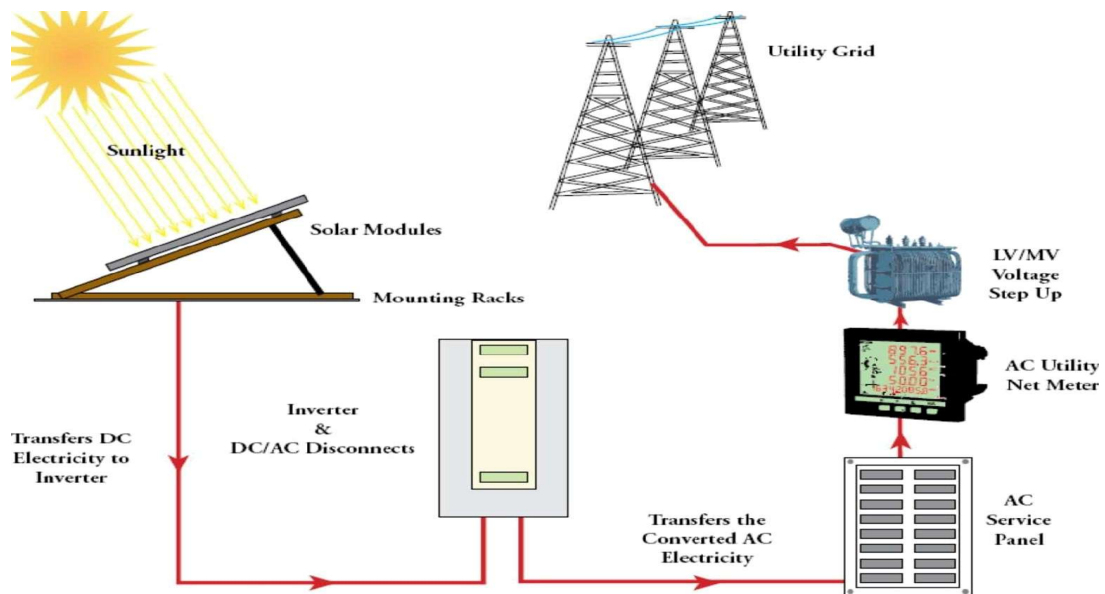


Figure 1: Overview of a megawatt scale grid connected solar PV Power Plant

The main components of Solar PV power plant include:

Solar PV Modules: These convert solar radiation directly into electricity through the photovoltaic effect in a silent and clean process that requires no moving parts. The photovoltaic effect is a semiconductor effect whereby solar radiation falling onto the semiconductor PV cells generates electron movement. The output from a solar PV cell is direct current (DC) electricity. A PV power plant contains many cells connected together in modules and many modules connected together in string to produce the required DC power output.

Module mounting (or tracking) systems: These allow PV modules to be securely attached to the ground at a fixed tilt angle, or on sun tracking frames.

Inverters: These are required to convert the DC electricity to alternating current (AC) for connection to the utility grid. Many modules in series strings and parallel strings are connected to the inverters.

Step up transformers: The output from the inverters generally requires a further step up in voltage to reach the AC grid voltage level. The step up transformer takes the output from the inverters to the required grid voltage (for example 33KV, 132 KV)

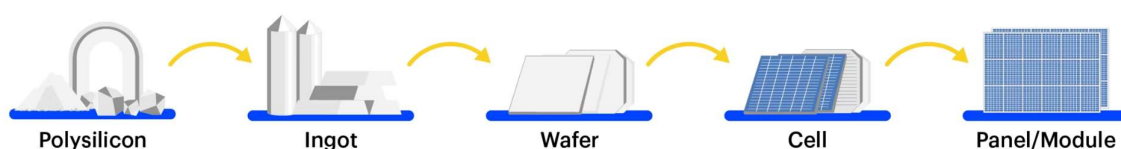
The grid connection interface: This is where the electricity is exported into the grid network. The substation will also have the required grid interface switchgear such as circuit breakers and disconnects for protection and isolation of the PV power plant as well as generation and supply metering equipment. The substation and metering point are often external to the PV power plant boundary and are typically located on the network operator's property.

2. PV cell manufacturing process and evolution:

There are two prominent technologies available in PV modules, namely silicon PV and thin film PV. Each has a unique process of manufacturing to itself and sets of pros and cons to attribute.

2.1 Silicon PV

Silicon PVs are the most commercially adopted in PV module manufacturing. They rely on crystalline silicon as the absorber material. These modules have significantly 5 manufacturing steps that typically occur separately from each other.



- a. **Polysilicon Production:** Polysilicon is a high-purity, fine-grained crystalline silicon product, typically in the shape of rods or beads depending on the method of production. Polysilicon is commonly manufactured using methods that rely on highly reactive gases, synthesized primarily using metallurgical-grade silicon (obtained from quartz sand), hydrogen, and chlorine.
- b. **Ingot Production:** To turn polysilicon into wafers, polysilicon is placed into furnace that is heated until the polysilicon forms a liquid mass. Using Czochralski process, a large cylindrical ingot of monocrystalline silicon is grown by slowly pulling upward the molten liquid silicon through a small crystalline seed in contact with it.
- c. **Wafer Production:** Silicon ingots are sliced into very thin wafers using diamond-coated wire saws. The silicon sawdust that is created is called kerf. Though less common, kerfless wafer production can be accomplished by pulling cooled layers off a molten bath of silicon, or by using gaseous silicon compounds to deposit a thin layer of silicon atoms onto a crystalline template in the shape of a wafer.
- d. **Cell Fabrication:** Silicon wafers are then fabricated into photovoltaic cells. This involves multiple processes depending on the type of cell being produced (Mono perc/Topcon/HJT). Most cell types require the wafer to be exposed to a gas containing an electrically active dopant, and coating the surfaces of the wafer with layers that improve the performance of the cell. Screen printing of silver metallization for electrical contacts is also very common among cell types.
- e. **Module Assembly** – In module assembly facility, procedure involves stringing of cells. Electrical interconnection of the cells placed on sheets of

glass covered with a sheet of polymer encapsulant. A second sheet of encapsulant is placed on top of the face-down cells, followed by a tough polymer back sheet or glass. The whole stack of materials is laminated in an oven to make the module waterproof, then fitted with an aluminium frame, edge sealant, and a junction box in which the ribbons are connected to diodes that prevent any backward flow of electricity. Electrical cables from the junction box convey the current produced by the module to an adjacent module or to the system's power electronics.

2.2 Advanced technology cells:

PV technology has focused on improving efficiency, cutting costs, and meeting regulations. PERC has dominated the market over the past years due to its cost-effectiveness. However, with n-type technology driving efficiency up and costs down, n-type products will take over 70% of the market this year.

At present, TOPCon, and HJT, are the main cell technology routes. TOPCon gained recognition for its high efficiency and lower costs. HJT, despite higher investment and costs, is valued for its low carbon footprint.

2.2.1 Tunnel Oxide Passivated Contact (Topcon):

There are several losses within a solar cell that cause electrons to leak and recombine back into the silicon without forming an electric current. The ultra-thin TOPCon layer helps increase the conductivity of the semiconductor and reduce this loss with a minimal cost increase to the production process. The efficiency of a Topcon cell is in the range of 22.4% to 22.5%

2.2.2 Hetero Junction Cells (HJT)

This technology uses a base of common crystalline silicon with additional ultra-thin-film layers of amorphous silicon on either side forming what is known as a heterojunction. The additional amorphous silicon layers reduce the recombination

at the N-P junction which reduces losses and increases cell efficiency. The maximum efficiency of a HJT cell is 22.7 %

2.2.3 Perovskites

These are emerging solar cells that have a hetero-junction kind of structures which are formed by stacking different layers of semiconducting materials perovskite-structured compound, most commonly a hybrid organic–inorganic lead or tin halide-based material as the light-harvesting active layer. Perovskite materials, such as methylammonium lead halides and all-inorganic cesium lead halide, are cheap to produce and simple to manufacture

So far, the maximum recordable power efficiency achieved for PVSCs is 25.2%, however there is uncertainty prevailing in context of its operational life.

2.2.4 Thin Film PV

Thin-film solar panels are a type of photovoltaic solar panels that are made up of one or more thin layers of PV materials. These thin, light-absorbing layers can be over 300 times thinner than a traditional silicon solar panel.

Thin-film solar cells have built-in semiconductors, making them the solar panels the lightest panels available. However, they don't operate as efficiently as crystalline solar panels, so more thin film solar cells would be required to generate the same amount of electricity.

As thin film solar cells are often only used in large-scale operations, like utility and commercial power plants. They're also popular as portable solar panels because they are so lightweight

3. Components of Solar Modules

A solar photovoltaic (PV) module is made up of several key components, each playing a crucial role in converting sunlight into electricity. The main components are following:

3.1 Solar Cells:

The core component that converts sunlight into electrical energy. Most solar cells are made from silicon, and they come in different types (monocrystalline, polycrystalline, and thin-film).

3.2 Encapsulation

This layer protects the solar cells from moisture and mechanical damage. It typically consists of a transparent polymer material, like ethylene-vinyl acetate (EVA).

3.3 Front Glass Cover

A tempered glass layer on the front of the module provides protection against environmental factors, such as hail and wind, while allowing sunlight to pass through. Usually glasses of thicknesses 2-3.2 mm are used.

3.4 Backsheet

This layer is located on the back of the module and protects the solar cells and internal components from moisture and environmental damage. It also provides electrical insulation.

3.5 Frame

Usually made of aluminium, the frame adds structural integrity and facilitates mounting the module on various surfaces.

3.6 Junction Box

This is where the electrical connections are made. It contains diodes that help prevent backflow of current and improve performance in shaded conditions.

3.7 Wiring

Connects the solar cells to the junction box and the inverter, facilitating the flow of electricity.

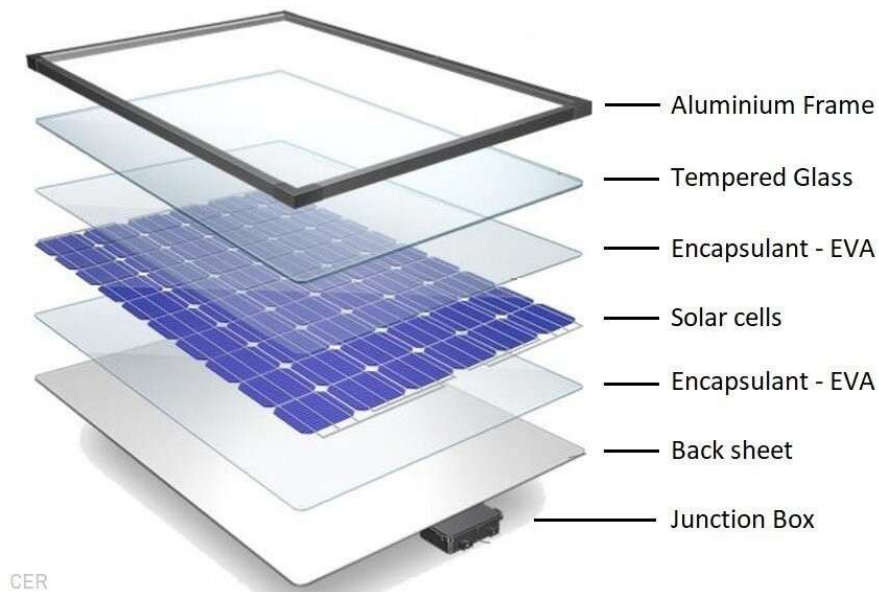


Figure2: Components of Solar PV module

Each of these components is designed to work together to ensure the efficiency, durability, and performance of the solar PV module.

Chapter-III: Solar Panel Manufacturing Capacity

1. PV Capacity in the World

As per International Energy Agency (IEA) report, around 80% of the global PV manufacturing industry is currently concentrated in China, while India and United States each hold 5% share. Europe accounts for about 1%. Module manufacturing capacity in China at the end of 2023 was 861 GW with further planned addition of 500 GW in 2024¹. It is estimated that the China's estimated wafer, cell and module capacity that will come online in 2024 is sufficient to meet annual global demand now through to 2032.

The rapid growth of Chinese PV industry is attributed to (1) WTO membership opening foreign markets to Chinese exports (2) Technology transfer from western countries to China; leading to delivery of turnkey production lines. (3) Entrepreneurs entered the innovation system because of the high expectations of profitable business opportunities. (4) Local government facilitation with cheap capital, land, etc (5) Investment in R&D, leading to increasing technological competencies. Factors that cumulatively led to the Chinese renewable industry is brought out in [2,3].

The global solar cell and module manufacturing industry is currently operating at a utilization rate of approximately 50%, according to the IEA's Advancing Clean Technology Manufacturing report. This massive capacity has led to tumbling prices in the international markets. As Chinese manufacturers cut prices to stay ahead of

¹ <https://www.reuters.com/business/energy/china-solar-industry-faces-shakeout-rock-bottom-prices-persist-2024-04-03/>

² <https://eprints.whiterose.ac.uk/178109/3/%23%20Revised%20manuscript%20-%20clean%20version.pdf>

³ <https://www.epjpv.org/articles/epjpv/pdf/2024/01/pv20240013.pdf>

competition, the prices of Chinese panels are estimated to be 60% cheaper than US panels.

2. Manufacturing Capacity in India

Echoing the favourable policy environment created by the Indian government, PV manufacturing has grown rapidly in India in the last two to three years. From 2020 to now, the nameplate capacity for both cells and modules in India has increased substantially. The module manufacturing capacity grew from around 11.5 GW in March 2022 (as per ALMM enlistment) to around 22.4 GW in March 2023 (as per ALMM enlistment) and around 67 GW in August 2024 (around 54.7 GW enlisted in ALMM and additional around 12 GW applied for enlistment in ALMM). The cell capacity has increased from 3 GW cell capacity in 2020 to around 8 GW in August 2024.

Out of the 54.7 GW solar module manufacturing capacity enlisted in ALMM as of August 2024, around 13.6 GW (~25%) is capable of producing TOPCon modules, around 3.2 GW (~6%) is based on CdTe Thin Film technology and balance is mostly based on Mono-PERC technology with a minor portion of around 0.3 GW based on multi-crystalline technology. Top 10 manufactures account for 72.38 % of total module production capacity of 54.7 GW enlisted in ALMM as of August 2024 and 100 % of cell production.

Driven by the government initiatives and policies, it is estimated that the cell and module manufacturing capacities in India would cross 70 GW and 100 GW respectively by 2026-27.

3. Policy Initiatives in India to promote domestic manufacturing

In order to meet the requirement through domestic manufacturing, the following steps have been taken by the government:

3.1 PLI Scheme

To build an ecosystem for manufacturing of high efficiency solar PV modules in India and thus reduce import dependence in the area of Renewable Energy, Government of India launched a Production Linked Incentive (PLI) Scheme⁴.

The PLI Scheme is being implemented in two tranches as follows:

Tranche-I:

The Union Cabinet approved the Production Linked Incentive (PLI) Scheme for National Programme on High Efficiency Solar PV Modules, for achieving manufacturing capacity of Giga Watt (GW) scale in High Efficiency Solar PV Modules on 7th April, 2021. Ministry of New & Renewable Energy (MNRE) issued the Scheme Guidelines for Production Linked Incentive Scheme on 'National Programme on High Efficiency Solar PV Modules' on 28th April, 2021, with an outlay of Rs. 4,500 crore. Letters of Award were issued by IREDA (implementing agency) in November and December, 2021 to three successful bidders for setting up of **8,737 MW** capacity of fully integrated Solar PV Module manufacturing units within PLI scheme outlay of ₹ 4,500 crore.

Tranche-II:

Subsequent to the Union Cabinet approval dated 21.09.2022, Ministry of New & Renewable Energy, on 30.09.2022, issued Scheme Guidelines for implementation of Tranche-II of the PLI Scheme for High Efficiency Solar PV Modules, with an outlay of Rs. 19,500 crore.

Under this tranche, Letters of Award (LoAs) have been issued by SECI (implementing agency) to 11 bidders in April 2023 for setting up **39,600 MW** of fully

⁴ <https://mnre.gov.in/production-linked-incentive-pli/>

/ partially integrated solar PV module manufacturing which are at different stages of construction / development as per following details:

Tranche – II				
Investment by Solar Manufacturers under Tranche-II of PLI Scheme for High Efficiency Solar PV Modules				
Sl. No.	Name of Manufacturer	Extent of Integration being set up	Manufacturing capacity being set up (MW)	Total Investment envisaged (Crore Rs.)
1	Indosol Solar Private Limited (TopCon)	P+W+C+M	6,000	18,000.00
2	Reliance New Solar Energy Limited (HJT)	P+W+C+M	6,000	17,756.00
3	FS India Solar Venture Private Limited (Thin Film)	P+W+C+M	3,400	7,275.00
4	Waaree Energies Limited (HJT)	W+C+M	6,000	9,000.00
5	Avaada Electro Private Limited (	W+C+M	3,000	4,500.00
6	ReNew Solar (Shakti Four) Private Limited	W+C+M	4,800	12,900.00
7	JSW Renewable Technologies Limited	W+C+M	1,000	1,600.00
8	Grew Energy Private Limited	W+C+M	2,000	3,550.00
9	VSL Green Power Private Limited	C+M	2,400	1,912.20
10	AMPIN Solar One Private Limited	C+M	1,000	730.00
11	TP Solar Limited	C+M	4,000	4,434.00
	TOTAL		39,600	81,657.20

P+W+C+M: Manufacturing of Polysilicon+Ingot-Wafer+Cell+Module

W+C+M: Manufacturing of Ingot-Wafer+Cell+Module

C+M: Manufacturing of Cell+Module

3.2 Tariff Barrier for import of cheaper Panels and Cells

In order to provide level playing field to domestic solar PV cell and module manufacturers, from 30th July 2018 to 29th July 2021, the Government, had imposed Safeguard Duty on import of solar cells and modules. The Safeguard Duty rates gradually tapered down from 25% in July 2018 to 14.5 percent in July 2021.

Basic Customs Duty (BCD) of 40% on import of solar PV modules and 25% on import of solar PV cells was implemented with effect from 01.04.2022. Imposition of safeguard duty and BCD on imported PV modules and cells were the key enablers for domestic PV manufacturing. The BCD of 40% on modules and 25 % on cells created a level playing field for the Indian manufacturers compared to their Chinese counterparts.

3.3 Other Incentives/Policies

In order to promote local manufacturing of solar panels, the Government has taken a number of steps, including⁵:

(i) Modified Special Incentive Package Scheme (M-SIPS) Scheme of Ministry of Electronics & Information Technology: The scheme mainly provides subsidy for capital expenditure – 20% for investments in Special Economic Zones (SEZs) and 25% in non-SEZs. The Scheme was open to receive applications till 31st December, 2018.

(ii) Preference to ‘Make in India’ in Public Procurement in Renewable Energy Sector: Ministry of New & Renewable Energy (MNRE) vide its Order No. 283/22/2019-GRID SOLAR dated 09.02.2021, inter-alia, prescribed that in public procurement of items in respect of which there is sufficient local capacity and local competition, only Class-I local supplier shall be eligible to bid. Class-I local supplier means a supplier or service provider, whose goods, services or works offered for procurement, has local content equal to or more than 50%. Solar PV modules are one of the products identified as having sufficient local capacity and competition.

⁵ <https://pib.gov.in/Pressreleaseshare.aspx?PRID=1779724>

(iii) Domestic Content Requirement (DCR): Under some of the current schemes of the Ministry of New & Renewable Energy (MNRE), namely CPSU Scheme Phase-II, components B&C of PM-KUSUM and PM Surya Ghar: Muft Bijli Yojana, wherein government subsidy is given, it has been mandated to source solar PV cells and modules from domestic sources.

(iv) Discontinuation of Customs Duty Concession benefits: Ministry of Finance (Department of Revenue) vide its Gazette Notification No. 7/2021-Customs dated 01.02.2021, has rescinded its earlier Notification No. 1/2011-Customs dated 06.01.2011 thereby withdrawing the benefit of concessional customs duty on the items imported for initial setting up of the solar power projects with effect from 02.02.2021.

(v) Approved Models and Manufacturers of Solar Photovoltaic Modules (ALMM)⁶: Ministry of New and Renewable Energy (MNRE) issued “Approved Models and Manufacturers of Solar Photovoltaic Modules (Requirement for Compulsory Registration) Order, 2019” on 02.01.2019. Only the models and manufacturers included in ALMM List-I (of solar PV modules) are eligible for use in Government Projects/ Government assisted Projects/ Projects under Government Schemes & Programmes/ Open Access / Net-Metering Projects, installed in the country, including Projects set up for sale of electricity to Government under the Guidelines issued by Central Government under section 63 of Electricity Act, 2003 and amendment thereof.

4. Export and Import of Modules and Cells in India

⁶ <https://mnre.gov.in/approved-list-of-models-and-manufacturers-alm/>

The total import and export of solar modules of cells and modules in India for the period from 2018-19 to 2023-24 are as follows:

	2018-19	2019-20	2020-21	2021-22		2022-23		2023-24	
	Cell & Module (HS Code: 85414011)	Cell & Module (HS Code: 85414011)	Cell & Module (HS Code: 85414011)	Cell (HS Code: 85414011)	Module (HS Code: 85414012)	Cell (HS Code: 85414200)	Module (HS Code: 85414300)	Cell (HS Code: 85414200)	Module (HS Code: 85414300)
Import (in Million USD)	2159.72	1684.32	571.67	1137.86	3263.20	1310.28	943.52	1853.05	4353.51
Export (in Million USD)	121.08	212.69	76.81	28.95	83.52	1.12	1031.37	54.67	1969.13
Import (from China) (in Million USD)	1694.04	1307.03	494.87	1069.88	3075.32	581.45	874.89	1035.98	2850.74

Source: Export-Import Databank of Department of Commerce

(<https://tradestat.commerce.gov.in/eidb/default.asp>)

Chapter-III: Cost of Solar PV Module

1. Price trends of Cell & Module Ex-Factory basis in China

The prices of solar PV modules have been on a declining trend from the start of CY 2023 and are prevailing at all-time lows. As brought out earlier, around 80% of the global PV manufacturing industry is currently concentrated in China and the pricing of China market for PV modules has become a benchmark for PV module pricing.

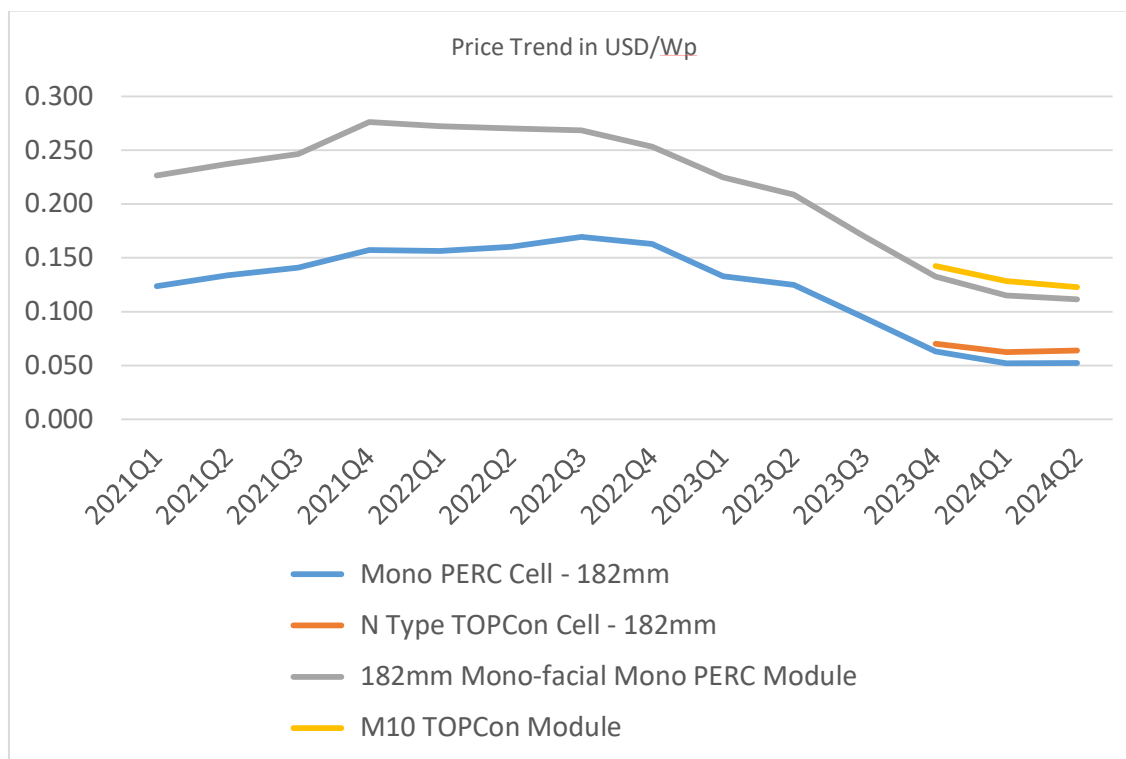


Figure 3: Price Trend of Solar Cells and Modules in China

It can be observed that the price decline in China is significant and the latest pricing reports state that the N Type TOPCON cell prices have fallen below 0.04 USD/Wp and corresponding module prices are priced at around 0.09 USD/Wp.

2. Price of cell and modules in India

Unlike China, there are no agencies analysing the cell and module pricing trends and the pricing trends of Indian market can only be assessed from the various market contracts that are happening. After analysing the discovered prices of PSU tenders, it is found that the pricing of domestically manufactured modules was always higher than that of the Chinese pricing. Domestically manufactured modules with imported cells were higher by an average of 0.06-0.07 USD/Wp and the pricing difference was further more in case of modules manufactured with domestic cells.

It may be noted that the wafer for production of cells is imported from China for the domestically manufactured cells, as the manufacturing of wafers and silicon ingot is in early stages of production in India. Thus, the pricing of PV modules is indirectly dependent on the pricing of solar PV chain products in the Chinese market.

3. Analysis of solar module cost in India

There are two modalities of domestic manufacturing of PV modules i.e. i) Modules manufactured with imported cells from China and ii) Modules manufactured with domestic manufactured cells. The Audit committee noted that the dynamics for cell to module manufacturing and wafer to module manufacturing are different and hence decided to analyse the pricing of the following considering Mono-PERC technology:

- A. Pricing of Balance of System (BoS) for modules
- B. Pricing of Cell
- C. Pricing of Module

A) Pricing of BoS for modules

After various discussions with stakeholders, the cost of BoS for the module is estimated to be around 0.075 USD/Wp.

182 mm Module Components	Type - Glass with Rear White Backsheet Monofacial	USD/Wp
Backsheet	TPF	0.008
Encapsulant	EVA – Front	0.01
Encapsulant	EVA – Back	0.01
Glass	ARC 3.2 mm – Front	0.015
Frame	Aluminum - Monofacial Module	0.02
Junction Box	182 mm Module - 25 A, 300 mm Cables, 1,500 V	0.005
Cell Ribbon	Φ 0.3 mm Wire	0.005
Interconnection Ribbon	4 Ribbons (0.04 mm)	0.001
Potting Material	AB Silicone 6:1	0.0001
Frame Sealant	White Silicone	0.002
Other Materials	Inputs and Consumables	0.004
TOTAL		0.075

B) Pricing of Cell

The committee estimated the cell pricing for the imported cells and domestically manufactured cells with wafer being imported which is detailed as below:

B.1 Imported Cell

Landed cost of imported Cell

	Component of Cost	Imported Cell
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		(USD cents/W _p)
A	Cost in China	4.00
B	Add: Transport (foreign component)	0.50
C	Add: BCD (@ 25%) of (A+B)	1.125
D	Add: Surcharge (@10%) of (A+B+D)	0.56
E	TOTAL COST	6.19

B.2. Domestically manufactured cell

The cost price of domestically manufactured cell is estimated as below based on the market data and various inputs gathered from the manufacturers:

SI No	Components of cost	Cost (USD cents/W _p)
A1	Average wafer price (including breakage in process)	3.14
A2	Pasties, Silver and Aluminium	1.05
A3	Chemical and Gases	0.78
A4	Other Misc	0.48
A	Total Raw Material cost (A1+A2+A3+A4)	5.45
B	Factory Cost (Man-power/electricity/OH)	1.87
C	Depreciation over 3 years	1.96
D	Finance Cost	1.24
E	Total Cost (A+B+C+D+E)	10.52

The committee noted that the significant portion in the pricing of cell is the depreciation expense and financing cost assumption, which are not uniform and cannot be easily ascertained.

The committee further estimated the selling price of the solar PV cells/modules considering margin of 20% to account for profit and other costs, over the above costing.

C) Pricing of modules

C.1 Modules manufactured with imported cells from China

In this case, the modules are manufactured with the cells imported, mostly from China. Considering the landed cost of cell as 0.062 USD/Wp and the BoS cost of modules of 0.075 USD/Wp, the cost of PV module works out to around 0.137 USD/Wp. The selling price of modules including the profit margin works out to around 0.164 USD/Wp which is broadly in line with the discovered prices of modules manufactured with imported cells.

C.2 Modules manufactured with domestically manufactured cells

Considering the cost of domestically manufactured cells as 0.105 USD/Wp and the BoS cost of modules of 0.075 USD/Wp, the cost of PV module works out to be around 0.18 USD/Wp. The selling price of modules including the profit margin works out to around 0.216 USD/Wp. The discovered prices are found to be higher than the estimated prices.

4. Factors contributing to higher prices of module manufactured with domestic cells

It has been observed that the price of solar modules with domestically manufactured cells are higher than that the prices of solar modules manufactured

with Chinese manufactured cells even after accounting for the BCD. The committee discussed the reasons for the same with the stakeholders and major factors are as outlined below:

A. Scale Issues:

The Audit team noted that production costs are varying w.r.t the size of the plant. Plants of GW scale will have very different economies of scale than a plant of 200 MW scale. The economics of scale has a significant influence on the costing.

B. Technology Obsolescence/Transition:

The Audit team noted that the solar PV manufacturing industry had undertaken rapid technological strides in the recent past. The technological churning has led to transitions from poly crystalline to mono crystalline, mono- Passivated Emitter and Rear Contact (PERC), Tunnel oxide passivated contact (TOPCon), Heterojunction (HJT), in very fast succession allowing a technological shelf life of 3-4 years. This requires substantial investment by the manufacturers to be relevant in the market. This fast change and accordingly change in customer preference for better efficient, newer technology also creates risk for the financing agencies, which may raise the cost of borrowing. Also, the manufacturers try to recover the costs upfront/early (higher depreciation) leading to front loading thereby resulting in higher costs.

C. Plant Utilization:

Plant utilization rates also directly impact the per unit cost of the module/cells. A manufacturer with a higher utilization rate can charge a lower rate than a manufacturer with a lower utilization rate.

D. Technological adaptation time:

Whenever a process line based on new technology is started, it takes time to tune the plant parameters to obtain the desired efficiency and other parameters of the product which may take time, thereby exposing the manufacturer to risk of default of commitment to buyers or the government. Specifically it was expressed by the manufacturers that the wafer to cell technology needs the substantial learning time.

E. Supply and Demand Factors in India:

The Team observed that present manufacturing capacity and likely capacity addition in module manufacturing and cell manufacturing in India as under:

i) Module Manufacturing

- As on August 2024 date, the solar PV module manufacturing capacity of India stands at around 67 GW (around 54.7 GW enlisted in ALMM and additional around 12 GW applied for enlistment in ALMM). Considering, market share of 15-20% of roof top solar, solar pumps etc., only 80% of the total ALMM capacity is available for utility scale solar projects which works out to be around 54 GW.
- Further, an operational factor or plant utilization factor of 70-75 % may be considered on the ALMM capacity after accounting breakdown, preventive maintenance, low demand etc.
- On further assuming 70: 30 ratios for Domestic to export order, the domestic utility PV manufacturing shall be around 38 GW as on August 2024.

ii) Cell Manufacturing

- As on date, the cell manufacturing name plate capacity of India Stands at around 8 GW and the wafer manufacturing capacity stands at around 2 GW. The manufacturing of polysilicon capacity is NIL.

iii) Future prospects in module and cell manufacturing

PLI shall be the primary driver for capacity addition across the PV module value chain.

The estimates of domestic solar manufacturing up to FY 2026-27 indicate over 100 GW of module manufacturing capacity, over 70 GW of Cell manufacturing, 40 GW or more of Ingot-Wafer manufacturing and 20-40 GW of polysilicon production in India.

However, the progress in PLI Tranche I has been minimal till date. Timely execution and capacity addition by 2026 seems highly unlikely. However, considering the low capital cost of module lines and low lead time in setting up module manufacturing units, manufacturers are more inclined towards addition in module manufacturing capacity first. The other components of supply chain i.e. polysilicon, ingot-wafer & solar cell, may take time to implement.

It can be seen that the module manufacturing capacity is ramping up first to cater to the demand whereas the cell and wafer manufacturing capacity is not sufficient to cater to the domestic demand. Further, it may be noted that only manufacturers listed under ALMM are eligible to cater to the domestic market. The supply demand mismatch resulting in a low competition for domestically manufactured cells may be a factor leading to higher pricing.

Chapter-IV: Key Findings and Observation

1. Comparison of Solar module prices

Considering landed cost of around 6.2 USD cents/Wp for imported solar cell, cost of around 10.5 USD cents/Wp for domestically manufactured solar cell, considering balance of supply cost as around 7.5 cents/Wp, and considering margin of 20% to account for profit and other costs over and above the cost of solar cell and the cost of balance of supply, pricing of solar PV modules manufactured from imported solar cells and pricing of solar PV modules manufactured from domestically manufactured solar cells, works out as under:

Cost of solar PV module manufactured from imported cell	Cost of solar PV module manufactured from domestic produced cell
~ 16-17 Cents/Wp	~ 21-22 Cents/Wp

2. Estimated tariff based on fair prices of solar modules

The Audit Team also calculated the estimated levelized tariff for the Solar Power Plants in above two cases. As most of the project developers are coming up with 40% DC overloading, the panel cost has been considered with 40% over-loading. Further, based on discussion with developers, Team has taken the cost of Balance of System as ₹ 1.5 crore/MW without overloading and ₹2.0 crore/MW with 40% overloading.

For estimating the levelised tariff in above two cases, following financial parameters have been considered:

- i. Debt: Equity: 75:25
- ii. Return on Equity: 14.0% (on post –tax basis; tax rate=25.17%)
- iii. Interest on Loan: 9%
- iv. Depreciation: 5% for first 15 years and 1.5 % for remaining 10 years
- v. O&M: ₹3 lakh/MW with annual escalation of 3.84%
- vi. Discount rate: 9.73%
- vii. CUF:25%

	Solar Power Plants with PV module manufactured from imported cell	Solar Power Plants with PV module manufactured from domestic cell
Project Cost without overloading	₹ 2.87 cr/MW	₹ 3.30 cr/MW
Project Cost with 40% overloading	₹ 3.96 cr/MW	₹ 4.5 cr/MW
Levelised Tariff (with 40% overloading)	₹2.48/unit	₹2.79/unit

3. Key Findings

- i. Multiple PV Module / Cell technologies co-exist in the market. Prices are sensitive to the technology and amount of domestic content
- ii. The cost of solar modules manufactured from solar cells imported from China is lower than the cost of solar modules manufactured using solar cells produced domestically, even after accounting for the custom duties
- iii. There is good competition in module manufacturing business ensuring the efficient price discovery. There are very limited domestic solar cell

manufacturers (2-3 nos.) from whom the domestic solar module manufacturers can procure domestically manufactured solar cells for making solar modules compliant to Domestic Content Requirement (DCR) norms. This is leading to oligopolistic nature of market.

- iv. The rapid technological changes in cell technology pre-empts the manufacturers to recover the investments before the obsolescence of the technology. As a result, cell manufacturers want to recover the capital by front loading aided by the high demand environment and thus leading to higher pricing. Fear of technological obsolescence is leading to the claiming of much higher depreciation (around 2-3) as against 6-8 years, leading to higher prices, which could be rationalised.
- v. Comparison of module prices with respect to China may not be appropriate. The lower cost of modules and cells in China could be attributed to supply glut prevailing in China due to various geopolitical issues and oversupply. Besides, the low cost of production in China is attributed to various input subsidies for the industry, low cost of financing, recovery of investments and huge scale of economics.

4. Broad Observations cum recommendations

Higher prices of domestic cells may be a short-term phenomenon. Further, the higher margins will lead to more investments and along with PLI initiative, the cell manufacturing capacity will increase as we progress. With increase in cell manufacturing capacity and more players in the market, there will be competition among the players thereby resulting in efficient price discovery of domestically manufactured cells.
