PV Industry Trends

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15th April 2025, IEA PVPS Webinar

Contents

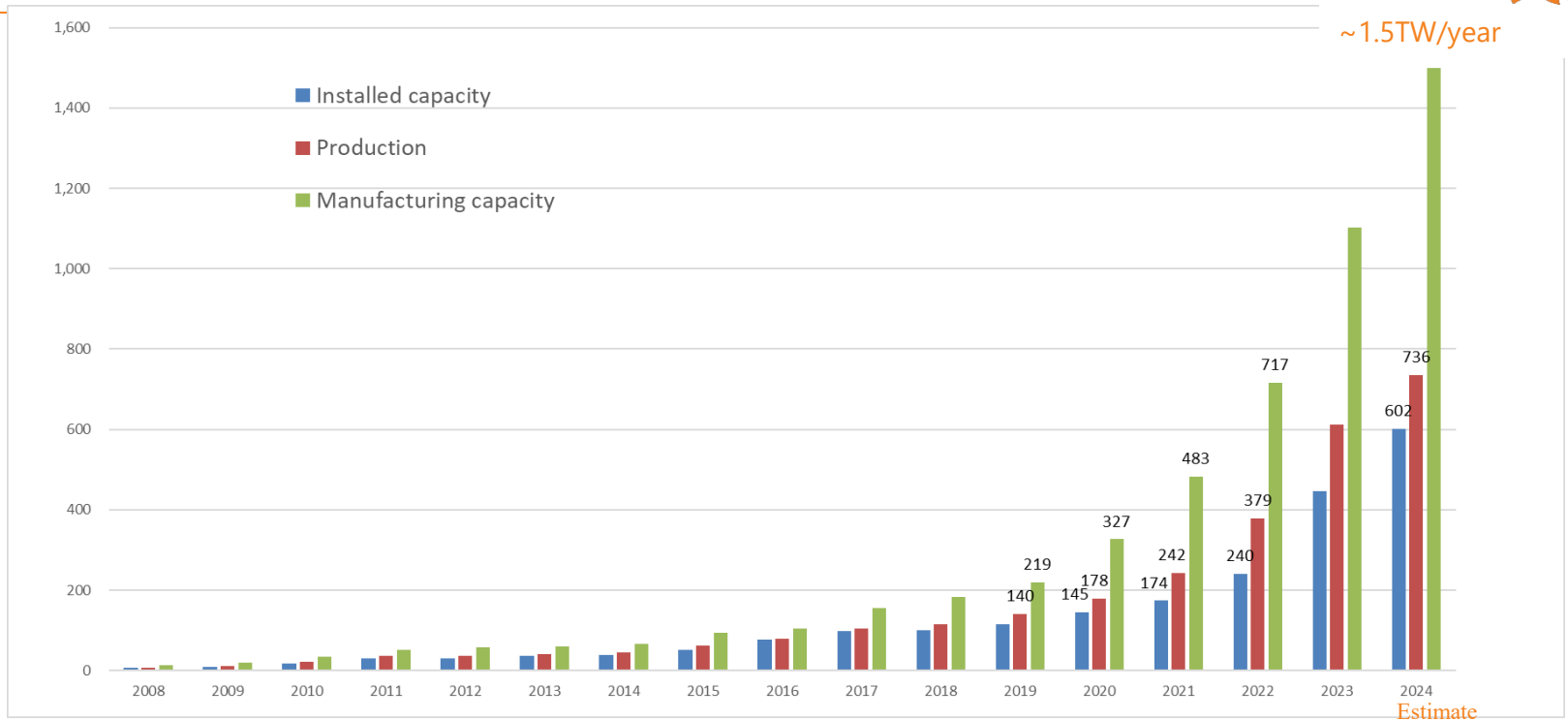
- Status of global PV industry
  - Trends of demand, supply and manufacturing capacity
  - Share by country and global flow of PV modules
  - Policies affecting local production
  - Price development
  - Evolution of PV technologies
  - Summary

Note: detailed analysis of 2024 status is underway to be published in Trends Report 2025

Highlights of the PV Industry 2024, more details will be reported in Trends Report 2025

- PV module production capacity to exceed 1.5 TW/year
- Progress of local supply chains outside of China:
  - India and the US increased production capacity with industrial support measures; trade barriers and incentives
- Due to the supply-demand gap, PV modules fallen below 10 cents/W after May 2024.
  - Chinese government is revising entry criteria and moving to put a stop to disorderly expansion of production capacity
- Change of the PV technology
  - TOPCon is became the mainstream products
  - Efforts to reduce costs are continuing

Installation, PV module production and capacity



- 2023 : 736 GW of production with >1.5 TW/year production capacity
- Capacity enhancement is slowing down in China. Active in USA and India
- Demand supply gap will continue in 2025

Source : IEA PVPS, Trends Report 2024

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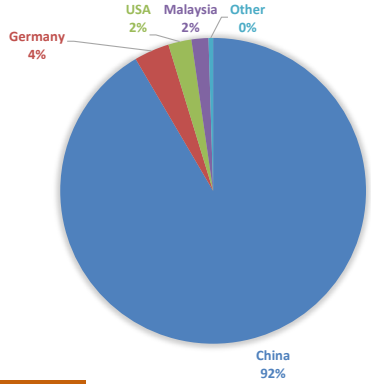
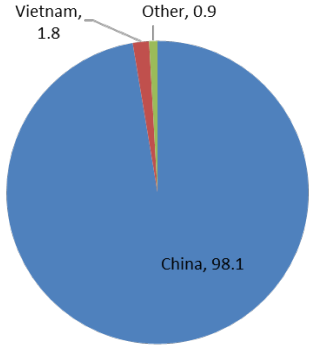
PV Supply Chain and share by country (2023)

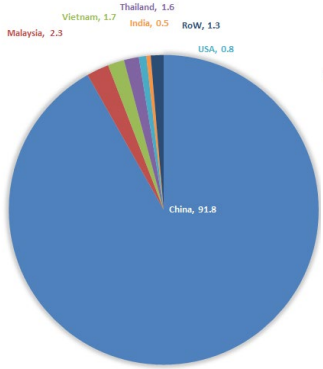
Wafer

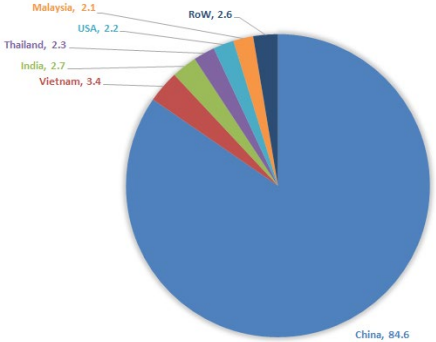
Cell

PV Module









Share of China

2022: 86%
2023 : 92%

2022 : 97.5%
2023: 98.1%

2022 : 84%
2023: 92%

2022 77.8%
2023: 84.6%
2024: 80%

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- China increased the share of production along the value chain
- Inverters, materials such as glass, encapsulants, equipment also China dominates
- Trade barriers and measures for local manufacturing contribute diversification of production sites

Source : IEA PVPS, Trends Report 2024

PV modules : flow of the shipment

Jan . to Nov. 2024
Imported value: 10.5 Billion EUro

TOP5 exporting countries	Share (%)
China	**98%**
Singapore	0.58%
Malaysia	0.30%
USA	0.28%
VIetnam	0.25%

※Removed EU regional trading

Jan. to Dec. 2024
Exported value: 27.9 Bill. USD

TOP5 Exported region/country	Share (%)
EU 27 member countries	39%
Brazil	9%
Pakistan	7%
Saudi Arabia	7%
India	7%

Jan. to Dec. 2024
Imported value: 11.5 billion USD

TOP5 exporting countries	Share (%)
Vietnam	39%
Thailand	24%
Cambodia	11%
Malaysia	8%
India	7%

※Crystalline Silicon only

Jan. to Nov, 2024
Imported value: 2.8 billion USD

TOP5 exporting countries	Share(%)
China	**77%**
Vietnam	15%
Malaysia	3%
Singapore	2%
Hong Kong	2%

- USA: Trade barriers and UFLPA prevented importing PV modules from China.
- US imports PV modules from SE Asian countries
- India increased share in 2024

Source ：RTS Corporation based on customs statistics as of mid-February 2025

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Support measures for domestic PV supply chain

	Manufacturing	Domestic products	Barriers for import
	- Tax credit for production under IRA (incentive for produced amount and incentive for CAPEX), Augst 2022 - ??? Trump Administration???	- Bonus tax credit for domestic content for projects - ??? Trump Administration???	- AD and CVD (2012, 2014) - Safeguard Duty(2019) - Sec.301 Punitive tariffs on Chinese imports (2018) - **Uyghur Forced Labor Prevention Act (UFLPA) (2020)** - Anti Circumvention (2022) - **CVD for MY, TH, VT and KH (Oct 2024)**
	- PLI program (incentive for produced amount), Selection in 2021 and 2022	- **ALMM (qualification) (2021 -), mandate for solar cell from April 2026** - Domestic content for SECI auctions - Auctions for production and projects	- **Basic Custom Duty (BCD)(Apr. 2022)** - AD and CVD for materials for PV modules (EVA:2019, BS:202、Glass:2019, 2017)
	- EU Innovation Fund (CAPEX) - Incentive by member countries (DE, NL, ES, FR, HU, PR....)	- Resilience Auction based on Net Zero Industry Act -	- Ban on distribution of products produced using forced labor guideline being developed)

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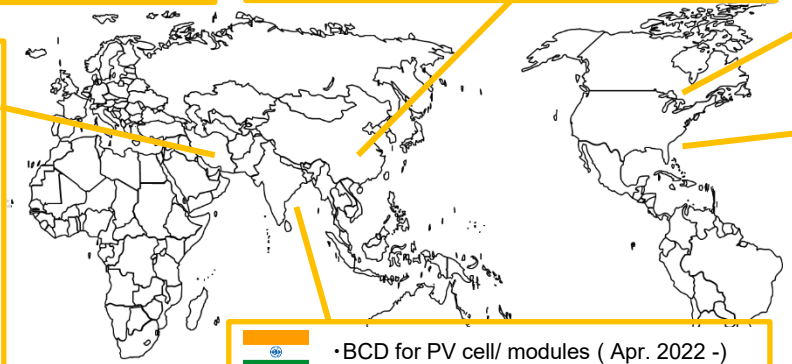
Trade issues affecting production bases



- Glass for PV modules AD・CVD (from 23 July 2020 -)
- Counter measures for US section 301
- PolySi from USA and South Korea AD・CVD (Jan 2020 -, 5 years)
- PV module from China AD・CVD (2015-, extended)
- Metal Si AD・CVD (2019- , 5 years extentsion
- Added Tax for Chines PV product is under consideration
- Cell/ PV module from China AD
- PV module from Vietnam, Malaysia, Thailand, Croatia, JordanvAD
- Minimum price for imported solar cells (Jan 2023
- Section 301 Tax for China
- Safegurd for imported PV products SD (2018-、4 years rs extension in 2022)
- PV cell/module from China and Taiwan AD・CVD (2012, 2015 and under review)
- Unti-circumvention for PV cell/module from Malaysia, Thailand, Vietnam and Cambodia (June 2024-)
- CVD for PV cell/module from Malaysia, Thailand, Vietnam and Cambodia (announced in Oct 2024)
- BCD for PV cell/ modules (Apr. 2022 -)
- EVA AD (Apr. 2019 -, extended)
- PV Glass from China AD (Aug. 2017-)
- PV glass from Malaysia AD (Feb 2019-)
- F-based BS AD (June 2022-)
- China AD (Under investigation, July 2023)

AD：Antidumping

CVD：Unfair subsidy

SG：Safegurd

Source：RTS Corporation as of August 2024

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US Trade barriers for PV products

Duties	China	4 South East Asian countries*	India
Safeguard tariffs	14%	14%	14%
Anti-dumping Duty (AD)	10.86 - 90.56%	Preliminary tariff: 14.72 - 855.23%	-
Countervailing Duty (CVD)			-
Section 301 Sanctions tariff	50%	-	-
Tariffs under the International Emergency Economic Powers Act (IEEPA)	20%	-	-
Reciprocal Tariff (RT)	84%	24 - 49%	27%

- The USA sources PV products from 4 Southeast Asian countries, but ADs and CVDs are expected to be imposed (collection of deposits has already begun).
- With support from the Inflation Reduction Act (IRA), plans to establish factories in the US are on going
- However, some companies are suspending their investment plans, citing the lack of transparency of future IRA under the 2nd Trump administration.
- India, which has relatively low tariffs, is stepping up its export offensive to the US.

	Total provisional AD + CVD	Reciprocal Tariff	AD+CVD+ RT+Safegurd tariff (2025)
Cambodia	262.44 - 855.23%	49%	325.44 - 918.23%
Malaysia	14.72 - 22.54%	24%	52.72 - 60.54%
Thailand	91.44%	37%	142.44%
Vietnam,	81.03 - 363.84%	46%	141.03 - 423.84%

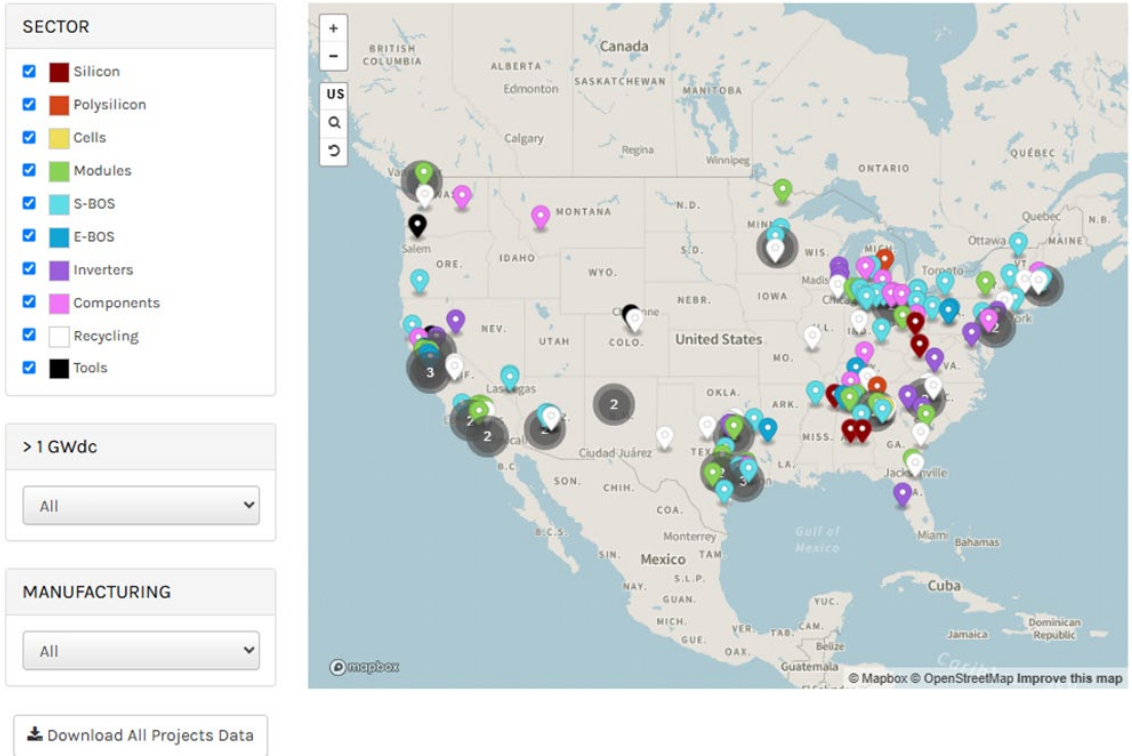
PV supply chain in the USA

- The United States is supporting manufacturing PV products through incentives under the Inflation Control Act (IRA) and implementing imposing multiple tariffs for imported products from specific countries
- With the support of the IRA, the production capacity of solar cell modules is rapidly increasing. Solar cell production has also resumed since 2019 for the first time in five years.
- Meanwhile, polysilicon production capacity is decreasing after Norway's REC Silicon gave up on restarting operations at its Moses Lake plant in Washington state.
- Focusing production in USA: Corning (USA), Suniva (USA), and Heliene (Canada) have announced a partnership to produce all polysilicon, wafers, solar cell cells, and modules in the United States

Products	Manufacturing capacity in USA	
	2023	2024
Polysilicon	71,000t/year	51,000t/year
Ingot and wafer	-	-
Solar cell (crystalline Si)	-	2.0/year
PV module (crystalline Si)	9GW/year	42.5GW/year
PV module (thin film)	6GW/year	10.6GW/year

Source：US DOE, “U.S. Domestic Solar Photovoltaic Manufacturing Map Data” etc, compiled by RTS Corporation

US manufacturing map for PV supply chain



https://www.energy.gov/eere/solar/solar-manufacturing-map

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Support policy and measures for local manufacturing in India

- India is promoting the creation and development of a domestic industry through the Production Linked Incentive (PLI) system to support the establishment of factories, as well as the Already Produced and Manufacturers (ALMM) system for solar cell modules, which is essentially a local content requirement system, and Basic Customs Duty (BCD).
- By 2024, India's production capacity for PV modules is expected to grow to about twice the size of the country's market, and the country is on track to become an exporter of PV modules.

Measures to promote local manufacturing

Measure to promote local manufacturing	Production linked Incentive (PLI)
Measure to promote local products in the domestic market	Approved list of models and manufacturing (ALMM)
Trade barriers	基本関税（Basic Custom Duty）
	AD and CVD

Manufacturing capacity and planned capacity

Products	2024	2030
PolySilicon	0	15,5000t/year
Ingot and wafer	>0	28 GW/year
Solar cell	5.8 GW/year	60GW/year
PV modules	64.5GW/year	129GW/year

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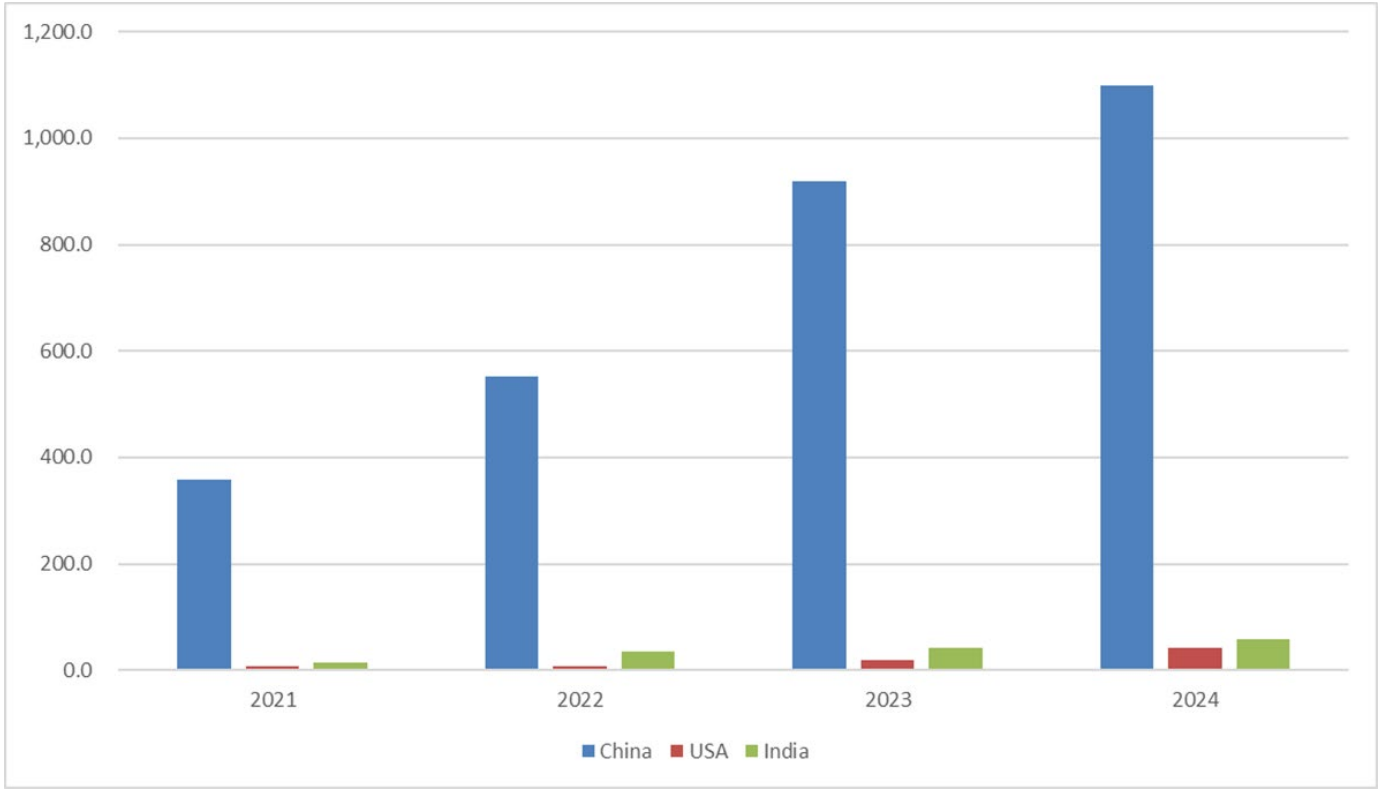
PV module manufacturing capacity of China, USA and Inidia



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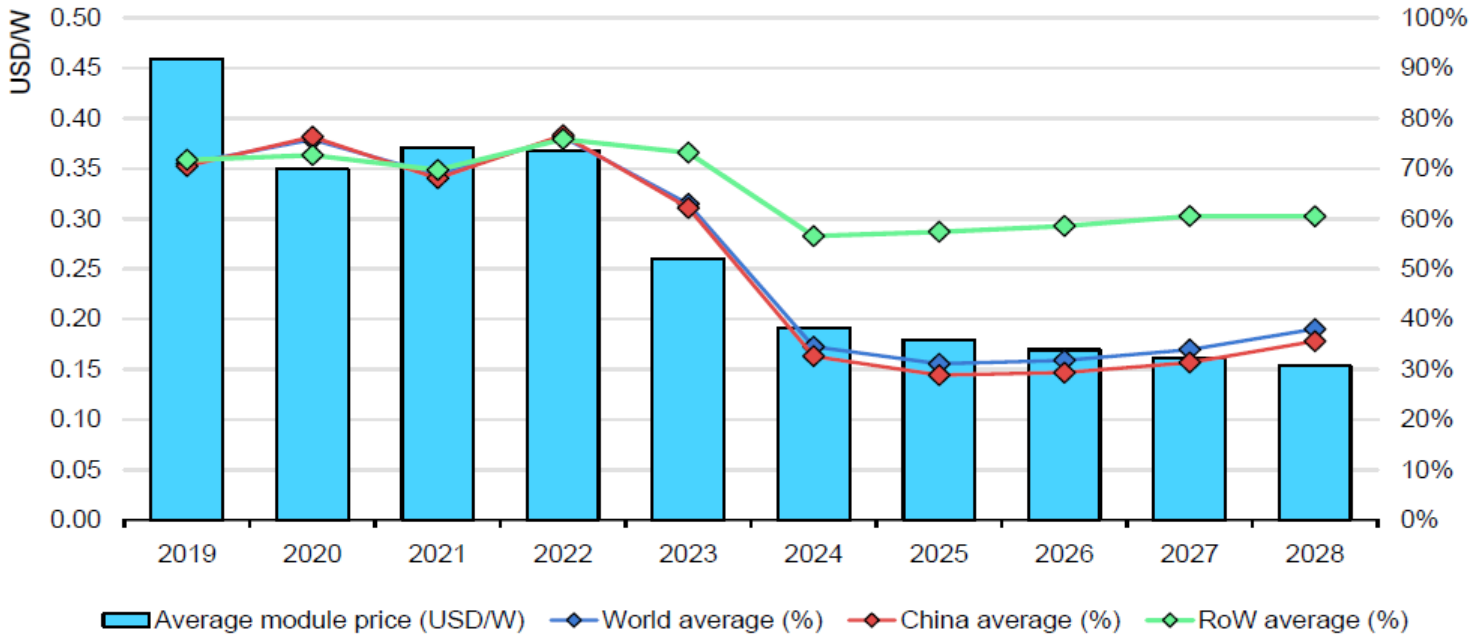
Outlook for PV module price by IEA

As oversupply continues, the price of PV module is predicted to remain low. Also, the operating rate of the facilities in the entire world continues to be low.



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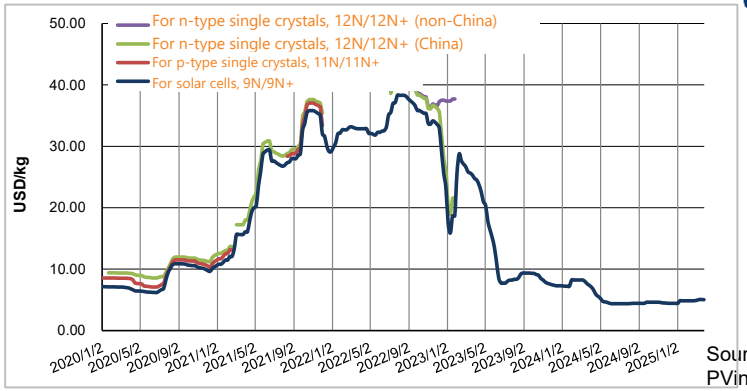
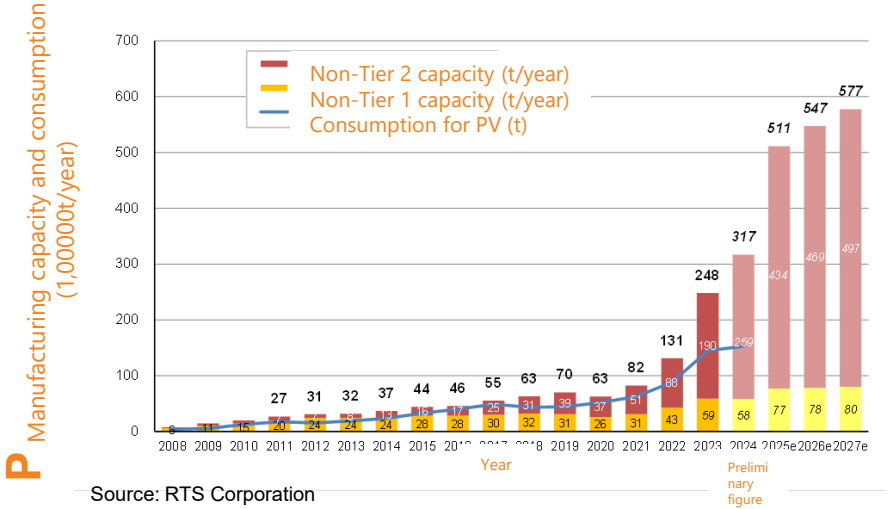
Source: International Energy Agency (IEA), "Renewables 2023" (January 2024)

Trends of spot price : Polysilicon

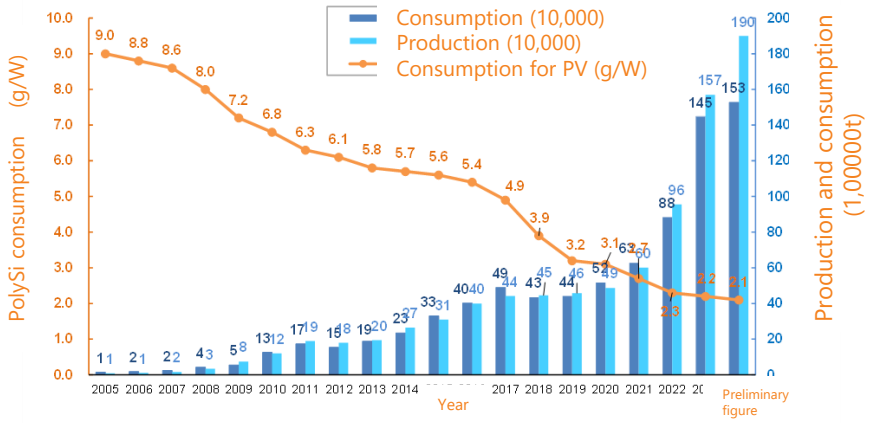
- Recently demand is increasing due to a rush to install in China in preparation for new policy
- However, as the Chinese market is expected to shrink after June, reducing inventory is being prioritized over increasing production
- Production adjustments are ongoing across the industry, with the goal of restoring prices to healthy levels after Q2
- Thinner wafers and reduced polysilicon usage also contribute significantly to price declines



Source : PVinsights



Source: RTS Corporation

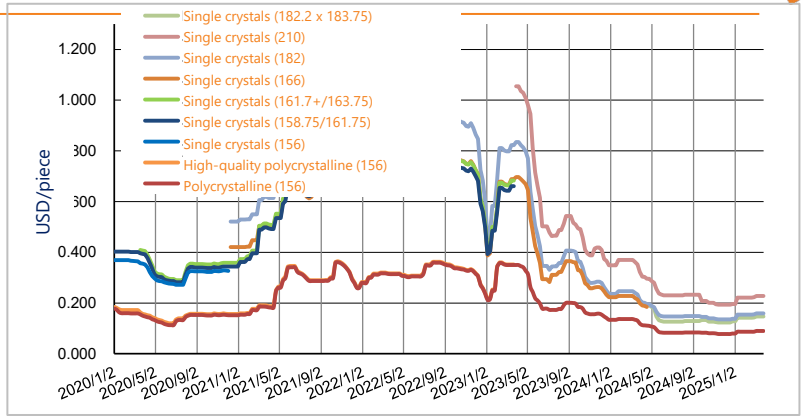


Source: RTS Corporation

Trends of spot price : Wafer and Solar cell

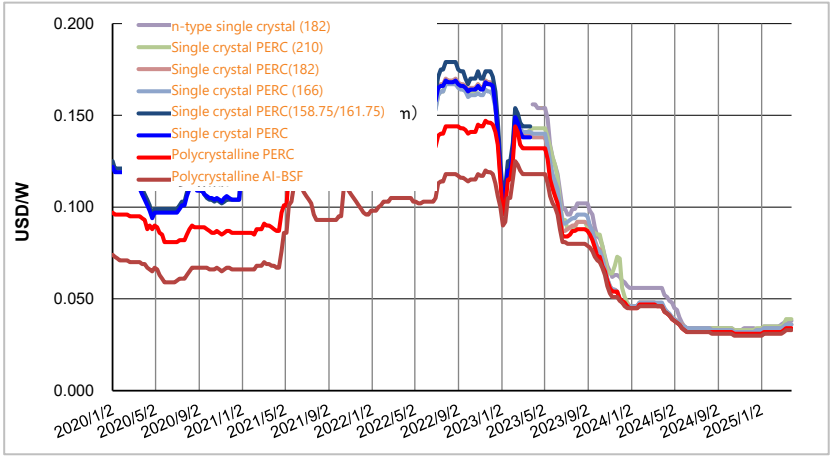
Silicon wafers (USD/Piece)

- Prices fell sharply from 2023.
- Prices has continued to fall until around June in 2024, then remain flat at the bottom
- In 2025, prices will tend to rise slightly due to increased demand in China



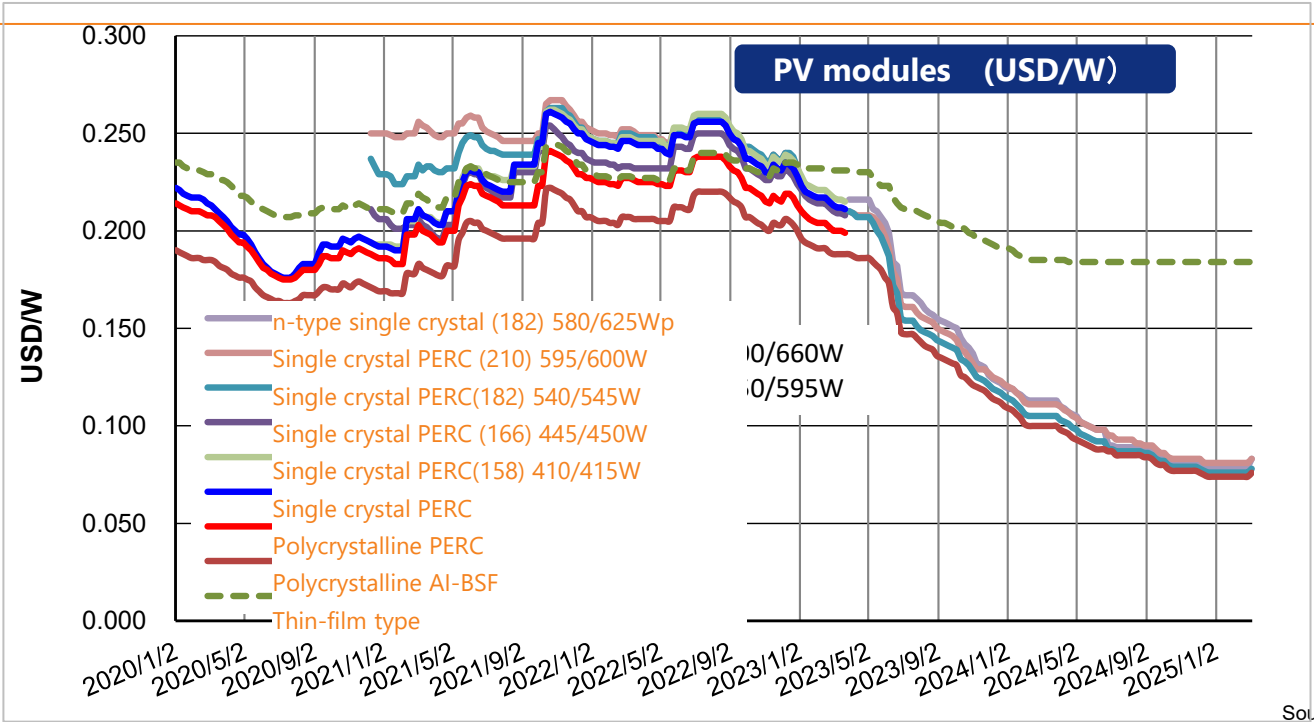
Solar cells (USD/W)

- Demand is increasing, but with the market uncertain after June, companies are cautious about increasing production.
- Demand is concentrated in 210RN wafers, so the price increase for this standard is notable.
- Some companies are expected to increase production in April.



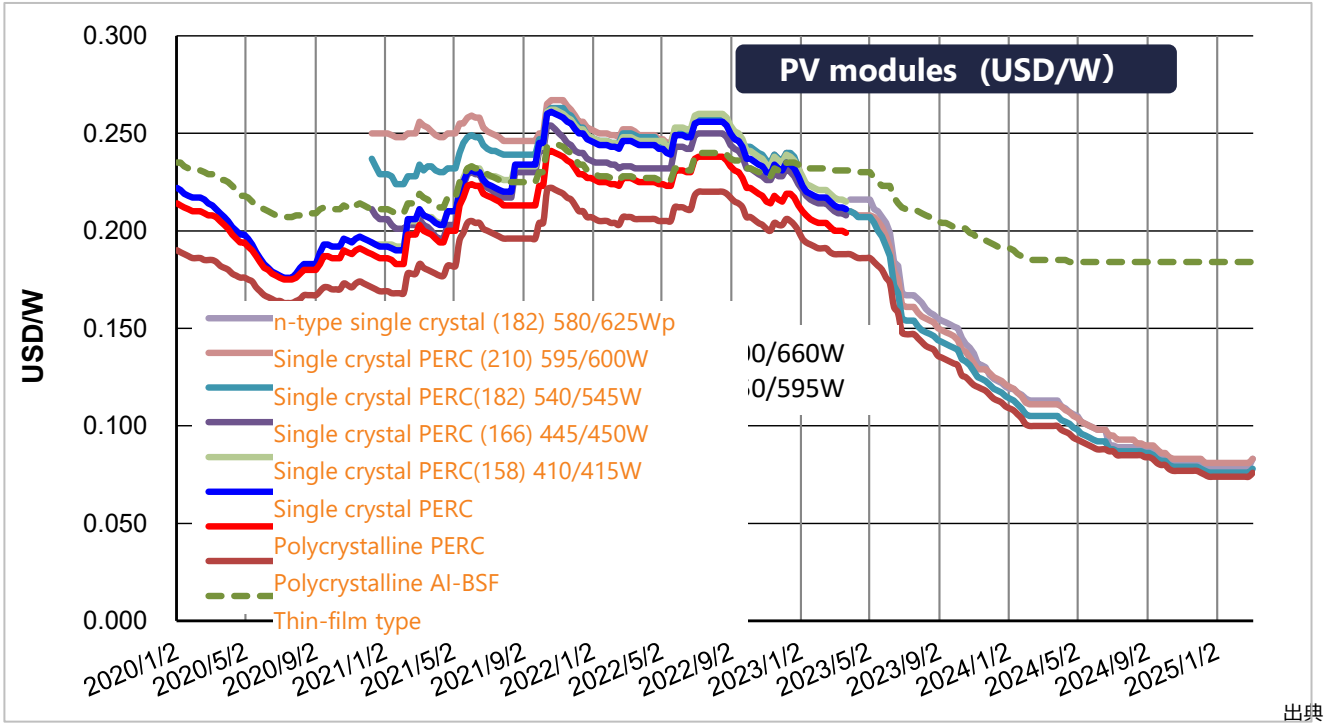
Source : PVinsights

Trends of spot price : PV module



Source : PVinsights

- PV module prices will also fall from 2023.
- Lower price level contributed the global expansion of the PV system installation, especially in emerging and developing countries, but the major PV module manufacturers are exhausted by the fierce price competition
- Major manufacturers are facing loss of profit due to lowering prices while shipping volume increased



出典：PVinsights

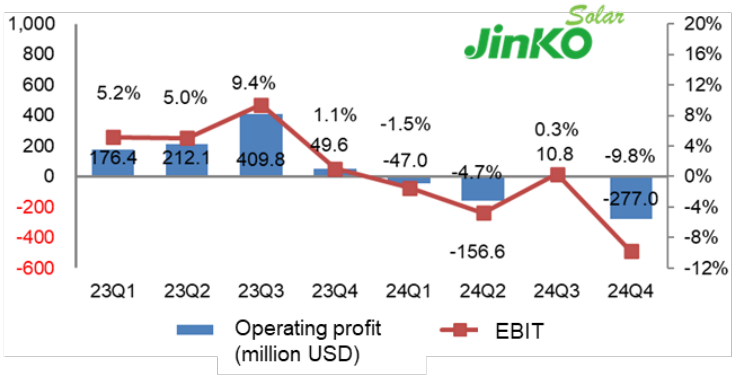
- PV module prices will also fall from 2023.
- Lower price level contributed the global expansion of the PV system installation, especially in emerging and developing countries, but the major PV module manufacturers are exhausted by the fierce price competition.
- China announced in November 2024 that bidding below cost price in module procurement bidding will be a violation of the law, which is acting as a deterrent to price competition

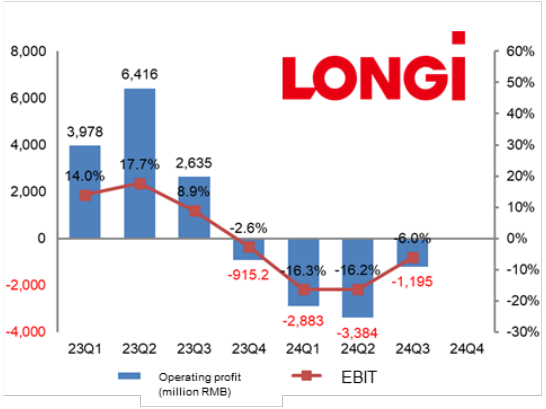
2024 rankings of PV module shipment by supplier

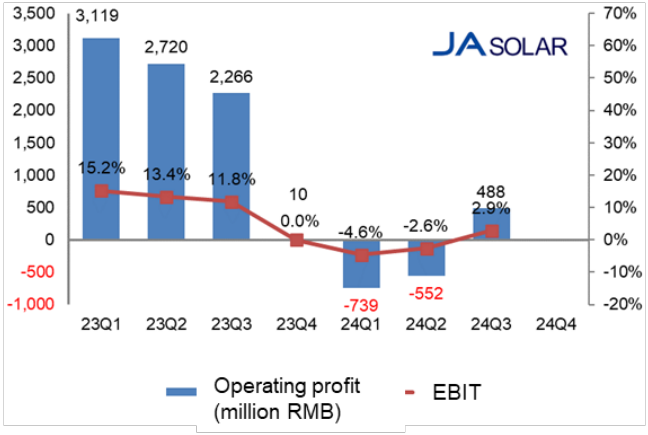
	2024（GW）		2023（GW）		2022（GW）	
1	JinkoSolar	90 - 100	JinkoSolar	78.5	LONGi Green Energy Technology	46.76
2	LONGi Green Energy Technology	76 – 80	LONGi Green Energy Technology	67.5	JinkoSolar	44.5
3	JA Solar Technology	75+	Trina Solar	65.2	Trina Solar	43.09
4	Trina Solar	75+	JA Solar Technology	55.3	JA Solar Technology	39.75
5	Tongwei	48 – 50	Tongwei	31.11	Canadian Solar	21.1
6	Zhejiang Chint Electrics（Astronergy）	40.2	Canadian Solar	30.7	Risen Energy	13.5
7	Canadian Solar	30.9 - 31.4	Zhejiang Chint Electrics（Astronergy）	28.0	Zhejiang Chint Electrics（Astronergy）	13.5
8	GCLSI	25 – 26	Risen Energy	18.99	First Solar	*9.3*
	DAS Solar	25 – 26	DAS Solar	17.7	Hanwha Solutions	9
10	Yingli Solar	22+	GCLSI	16.4	DAS Solar	8.5

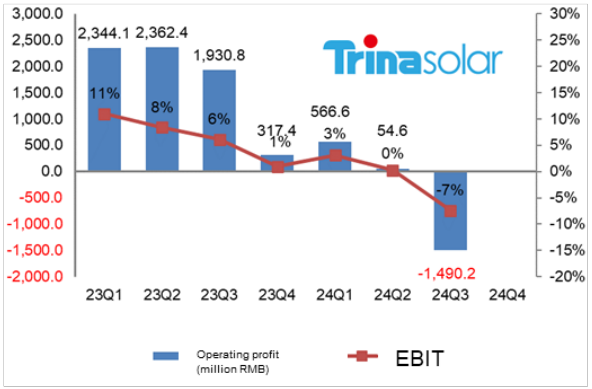
Source：RTS Corporation, including estimated number

Operating profit and EBIT of top 4 PV manufacturers









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Efforts to re-develop healthier industry in China: “Norm” for PV Manufacturing Industry

- The Ministry of Industry and Information Technology (MIIT) of China announced draft of “Norm for PV Manufacturing Industry‘’
- The draft specifies performance standards for polysilicon, solar cell modules, and inverters
- Draft requirement of PV module manufacturing

		Existing factory		Capacity Addition/ New Capacity	
		2021 version	2024 draft	2021 version	2024 draft
P-type mono	**Minimum Efficiency**	**19.6%**	**21.2%**	**20%**	**21.8%**
	Degradation ratio after 1 year	≦ 2.5%	≦ 2%	≦ 2.5%	≦ 2%
	After 2 years	≦ 0.6%	≦ 0.55%	≦ 0.6%	≦ 0.55%
	After 25 years	≦ 17%	≦ 15%	≦ 17%	≦ 15%
	Total electricity consumption	≦ 40MWh/Mwp	≦ 25MWh/Mwp	≦ 40MWh/Mwp	≦ 25MWh/Mwp
N-type mono	**Minimum Efficiency**	**-**	**22.3%**	**-**	**23.1%**
	Degradation ratio after 1 year	-	≦ 1%	-	≦1%
	After 2 years	-	≦ 0.4%	-	≦0.4%
	After 25 years	-	≦ 11%	-	≦11%
	Total electricity consumption	-	≦ 25MWh/Mwp	-	≦25MWh/Mwp

Disclosure of manufacturing cost of PV module by CPIA

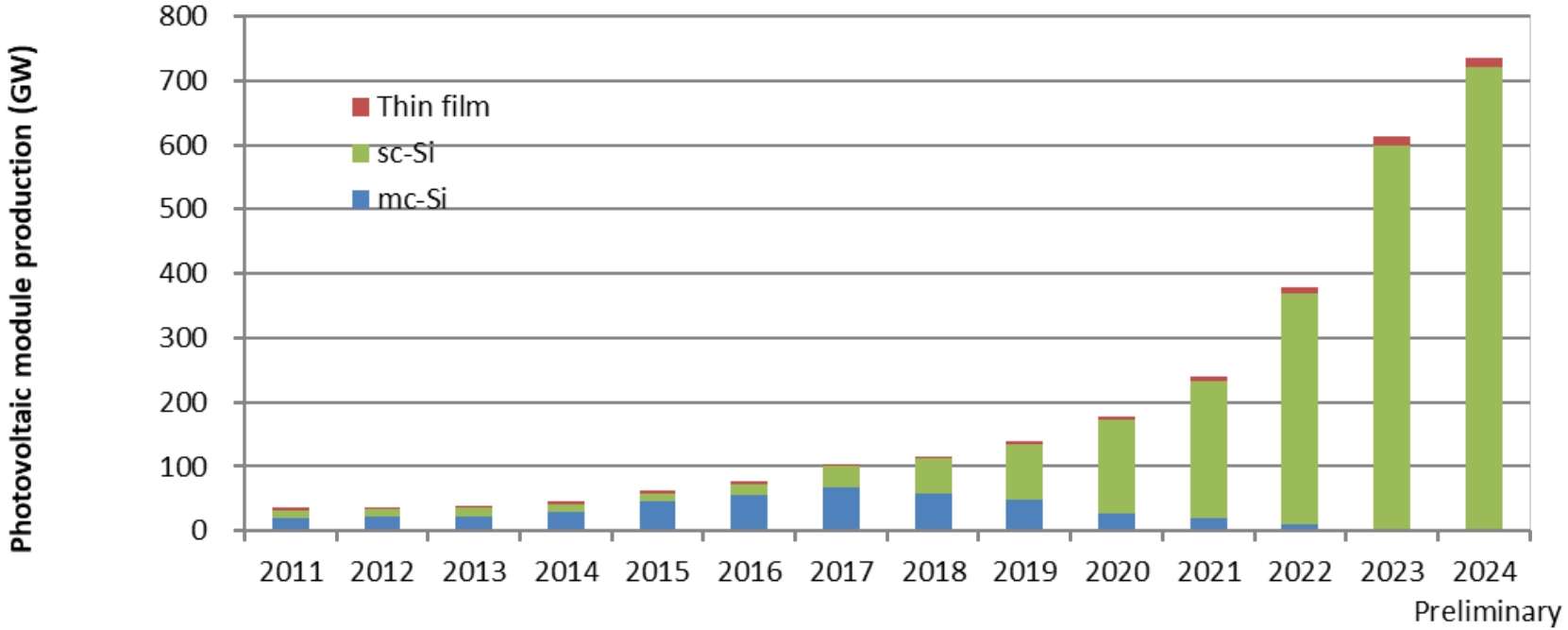
- CPIA expressed that bidding below cost in China violate the Tender Law of the People's Republic of China
- CPIA disclosed the cost price: 0.69 RMB/W (9.5 US cent/W), including tax, excluding transportation and miscellaneous expenses of standard PV module (double-glass, n-type PV modules using M10/ G12R wafers as of Nov. 2024
- The "cost" announced by the CPIA will be considered the "minimum price" for bidding in China
- CPIA also requested to appropriate transportation costs (0.015 RMB/W/km in December 2024) to be taken into account in addition to the "cost."

PV module cost disclosed by CPIA (as of Dec. 2024)

	Cost w/o Tax	Unit	Items
Polysilicon	34.368	RMB/kg	Metal Silicon, SiHCl3, Silicon rod, electricity, labor, etc.
Wafer	0.124	RMB/W	Crucibles, hot zone parts, power, electricity, diamond wire, etc.
Cell	0.263	RMB/W	Silver paste, silk screen, electricity, labor costs, etc.
PV module	0.605	RMB/W	Silver glass, sealing material, frame, labor cost, etc.
Total	**0.692**	**RMB/W**	**Total cost ; PV module cost plus minimum additional cost**

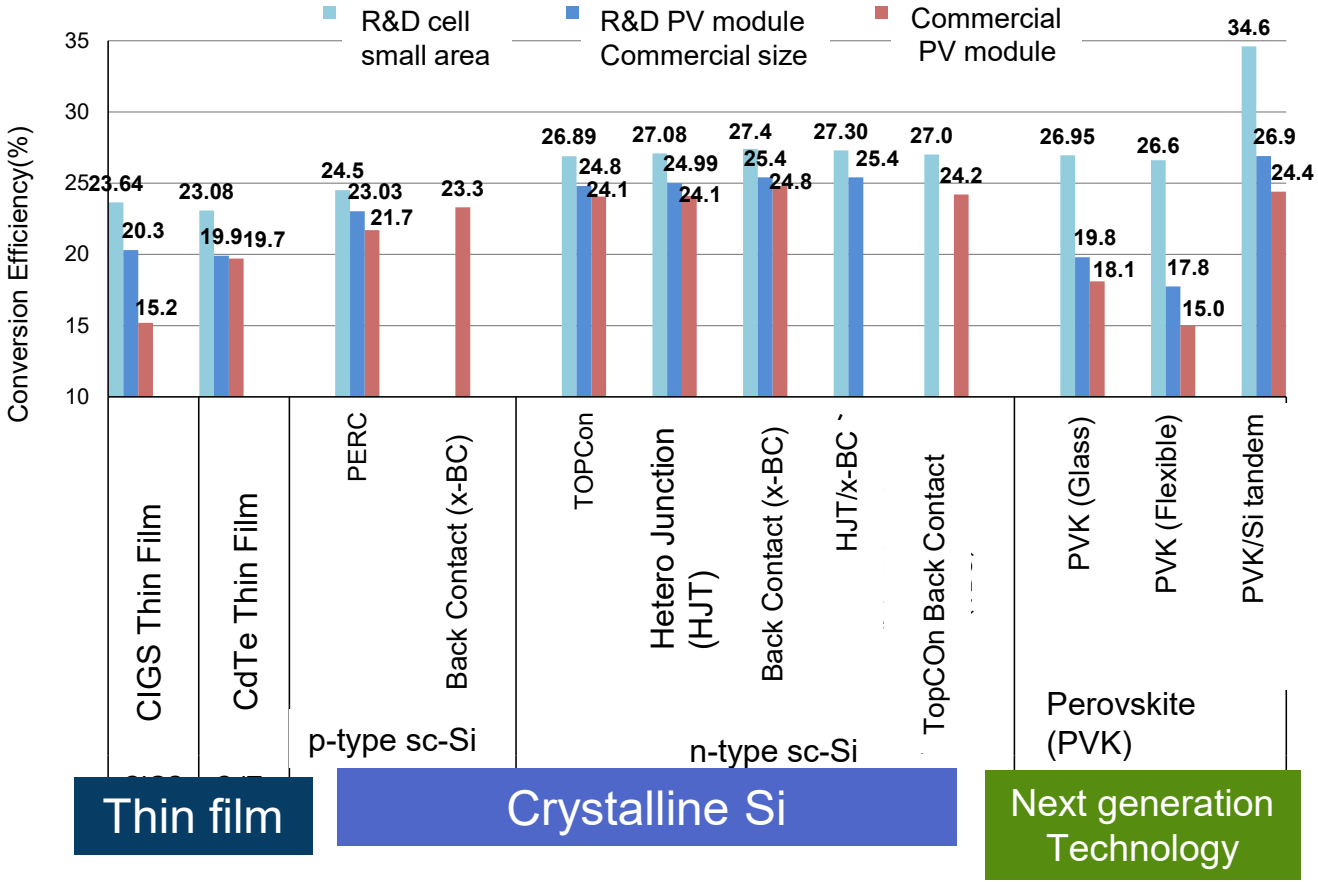
Source :CPIA, compiled by RTS Corporation

Technology Trends



- Single crystalline Silicon (sc-Si) dominates the market
- Thin-film has a small share ~2%, mainly CdTe thin-film PV module by First Solar
- TopCon became the main stream product in 2024

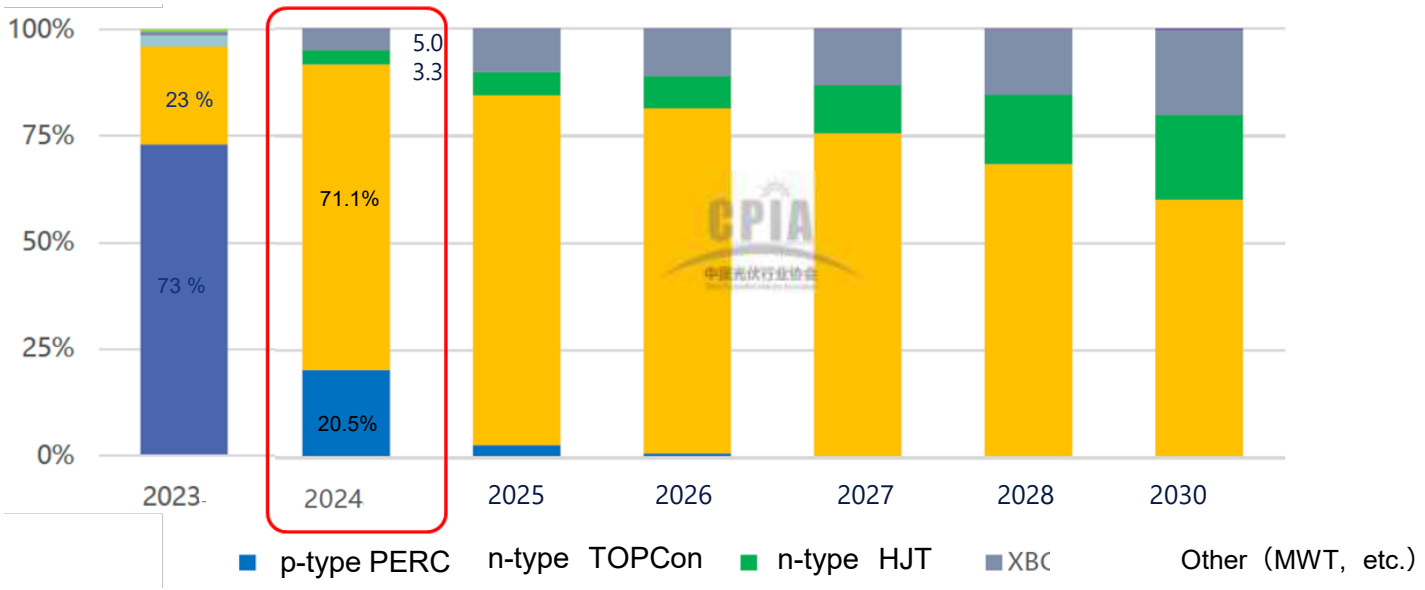
Comparison of highest efficiencies by technologies (2024)



Source：RTS Corporation

Share of PV cell technology and outlook by CPIA

- Most of the solar cell production lines that started operating in China in 2024 were "n-type" technology
- Production capacity in 2024: TOPCON 833GW/year, HJT 50GW/year, XBC 55GW/year



Source：CPIA, Shanghai HIUV New Material, compiled by RTS Corporation

Technology drives further cost reduction

Mono-Si, N-type, Thinner and larger, square → rectangular
P-type → n-type
Thinner P-type: ~150μm
N-type: 100~130μm
182mm（M10）/
≧210mm（G12）
182mm×18X/19X/210mm (182R/210R)

Cell cutting,
½,
1/3…1/6+Shingle,
Damage-less cutting,
Half cut ingot

Multi Busbar
（MBB/SMBB - Super MBB）
Busbar less
（0BB（multi-wire, smart wire（SWCT, ZBB）
Electrodes
（LECO,LEF）

Novel interconnection
（High-density cell interconnection）
Shingle, Tiling),Paving/Gapless/ narrowed-spacing

Bifacial
(Glass/Glass, Glass/BS

Internal cell connection

MPPT control (with MLPE)

Higher efficiency（post-PERC): HJT, TOPCon, xBC, Tandem：PBK/Si or CIGS or OPV、III-V/Si, etc.

BIPV, Glass-less PV (light-weight, bendable), colored or printed

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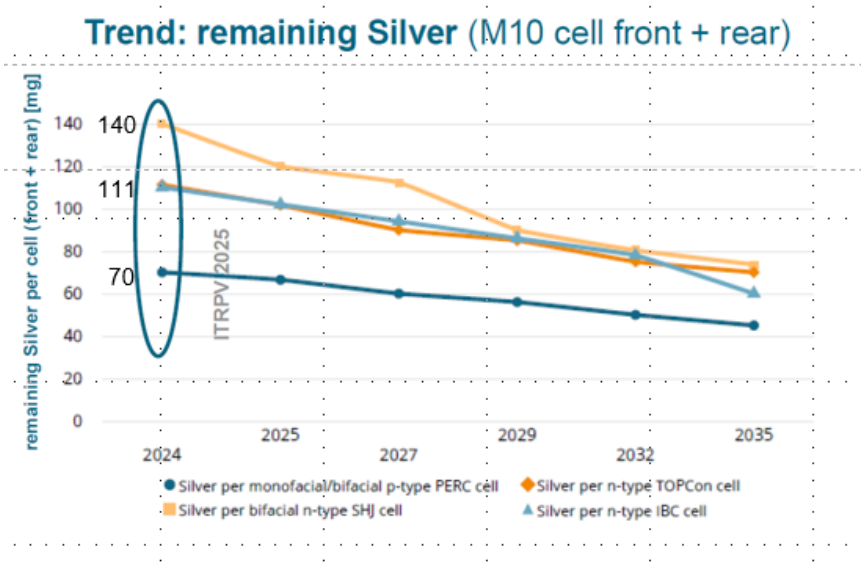
Cost reduction opportunities: standard size

- 6 major companies* reach agreement in December 2023 on standard size for large 700W modules with 210mm cells
- It is proposed to comply with the existing industry consensus dimensions (module size: 1,303mm x 2,384mm, vertical hole spacing on the long side of the module: 400mm/1400mm), and that a hole spacing of 790mm
- *6 companies = Trina Solar, Astronergy, Canadian Solar, Risen Energy, TCL Zhonghuan, TW Solar (Tongwei)
- 700W+ Photovoltaic Open Innovation Ecological Alliance established on December 15, 2023 after launching joint initiative on standardization and application of 700W+ photovoltaic module design

Cost reduction opportunity: Silver consumption

- In 2024, estimated silver usage for PV is ~20% of world consumption of Silver (used for contact)
- N-type cell technology consumes more silver
  - ⇒ Silver consumption levels by top manufacturers (Tier 1) :
    PERC: 7-8 mg/W, TOPCon: 12-16 mg/W, HJT: 17-20 mg/W
- Cu replacement is one of the solutions: Ag-coated Cu

https://tradingeconomics.com/commodity/silver



Rectangular wafers adopted by major manufacturers

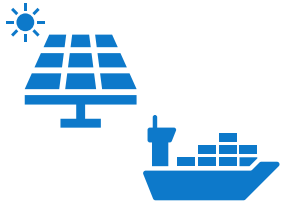
- Major manufacturers are adopting rectangular waferse, mainly for utility scale PV.
- As of Dec. 2023, 5 manufacturers use 182 x 210mm 210R wafers (66 full-size equivalent)
- Rectangular wafers are also used in small 54-cell and 48-cell modules for roofs
- The width of the short side is unified at 1,134 mm

Source：Astronergy(Chint Group)

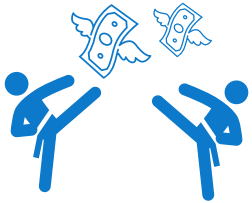
Summary:

- ✓ PV manufacturing capacity reached 1.5 TW/year in 2024
- ✓ India and USA increased manufacturing capacity with the policy and support measures in 2024 while China continues to dominate supply chain (polysilicon, wafer, cell, modules and other materials + manufacturing equipment and inverters) but
- ✓ Global PV industry has over capacity and PV module manufactures are suffering from lowering profit
- ✓ There are space for cost reduction with standardization, materials, new technologies, while sustainable investment is key and new technologies are need to ensure reliability
- ✓ The industry needs to prepare TW/year market

Issues in the PV industry



Oversupply



Price competition

Lowering margin

Forced labor issues

Intensifying trade tensions

Reduced dependency on specific country

Support and protection of local industry

Preparing for TW annual market

出典：㈱資源総合システム作成

Thank you for your kind attention !

感谢您的关注

끝까지 경청해 주셔서 감사합니다

ご清聴ありがとうございました

Acknowledgement for the support of PVPS activities

NEDO New Energy and Industrial Technology Development Organization

Acknowledgement :
PVPS Task1　Colleagues

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