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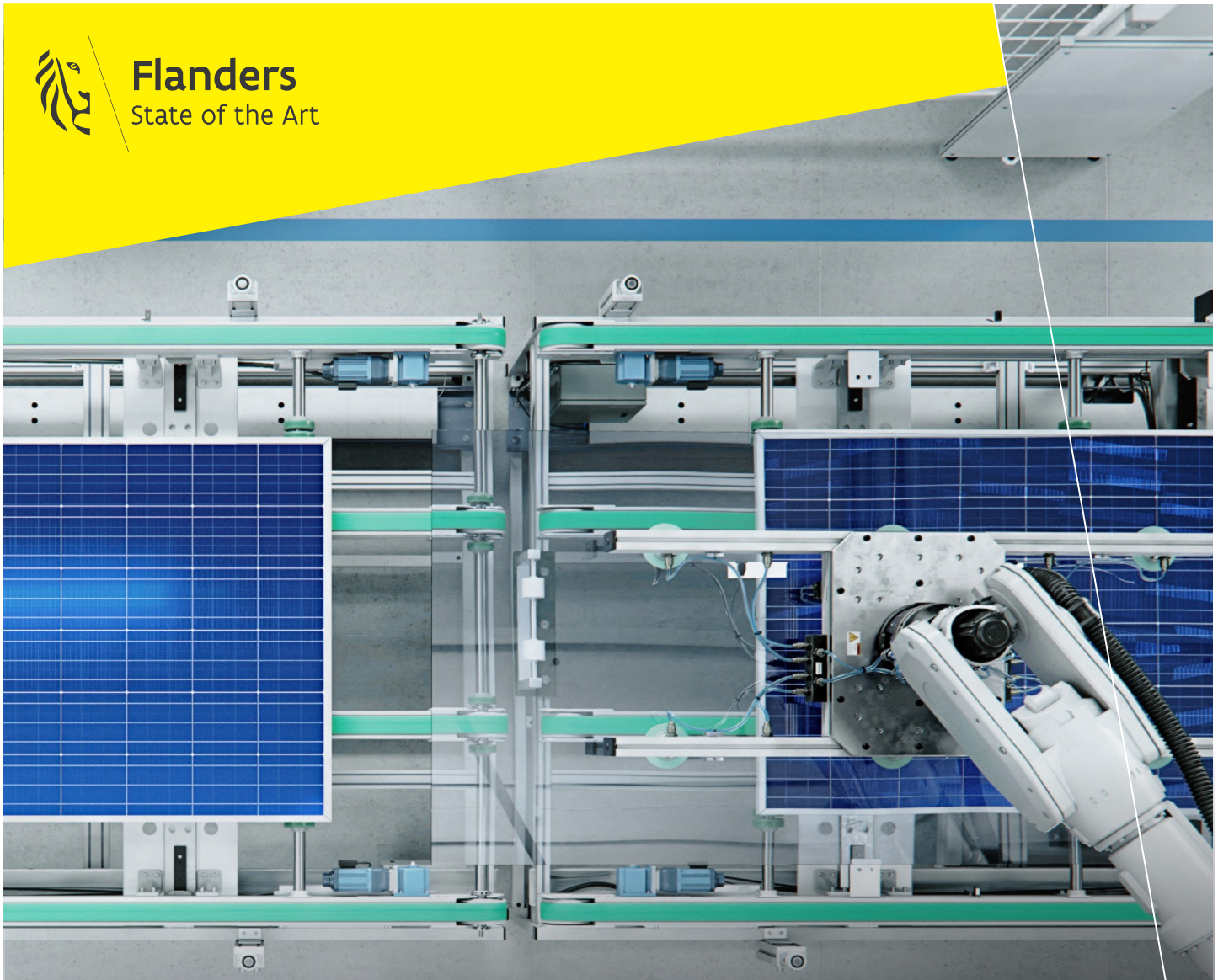

PHOTOVOLTAIC INDUSTRY CHAIN IN CHINA

FLANDERS INVESTMENT & TRADE MARKET SURVEY

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Market Study

CHINA'S PHOTOVOLTAIC INDUSTRY CHAIN

Analysis of the development status and situation

November 2023

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CONTENT

ABSTRACT:
Based on the photovoltaic industry development course of China, the paper analyses the structure and prospect of the Chinese photovoltaic industry combining the developers' present situation.
KEYWORDS: Photovoltaics; PV;

The photovoltaic (hereinafter referred to as PV) industry is one of the strategic emerging industries in China, and its development is of great significance for adjusting energy structure, promoting energy production and consumption revolution, and promoting ecological civilization construction. In recent years, under the dual effects of national policy guidance and technological innovation drive, the PV industry has maintained a rapid growth trend, continued to expand its scale, and continuously updated its technology. Currently, it has gained a leading advantage in the global market. Especially during the 13th Five Year Plan period, the costs of various links in the PV industry chain steadily decreased, with the price of polycrystalline silicon dropping by 24.9%. The prices of silicon wafers, PV cells, and modules all decreased by more than 50%, and the system price decreased by 47.2%, laying an important foundation for the PV power generation industry to achieve affordable grid access.

Currently, China's PV power generation industry has officially abolished central government subsidies and support. In order to further promote the high-quality development of the industry, various links of the PV industry chain focus on reducing costs and increasing efficiency, continuously deepening the upstream and downstream collaboration of the industry chain, and accumulating strength to promote greater development of the PV industry.

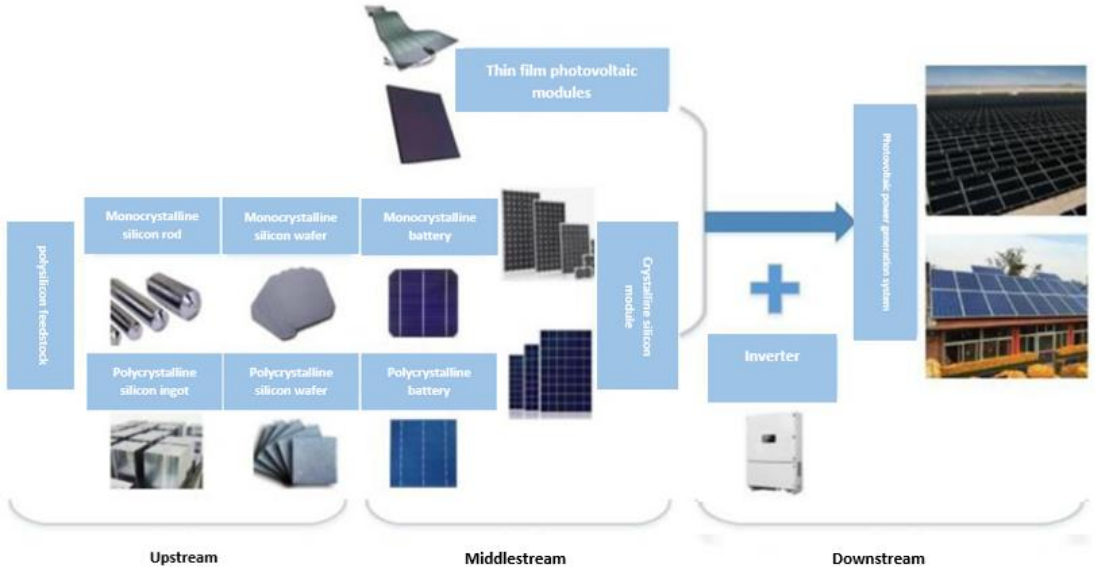

Figure 1 Composition of China's PV Industry Chain

Source: CPIA

1. ANALYSIS OF UPSTREAM LINKS

1.1 POLYCRYSTALLINE SILICON

As a key raw material for PV crystalline silicon cells, solar grade polycrystalline silicon (hereinafter referred to as "polysilicon") is made from industrial silicon after purification and processing. The purity is generally between 99.9999% and 99.999999%, and the conductivity is positively correlated with its purity. Since the 13th Five Year Plan period, driven by the rapidly growing installed capacity of the downstream PV power generation industry, China's polysilicon industry has entered a golden development period of "quantity and price flying together".

1.1.1 Supply and demand: The world's largest polysilicon production base

On the supply side, the development pace of China's polysilicon industry is constantly accelerating, and it has grown into the world's largest polysilicon production base. According to statistics, in 2021, China achieved an annual production of 505,000 tons of polysilicon, a year-on-year increase of 27.5%, accounting for approximately 80% of the global total production. There are two main reasons for the increase in production. Firstly, China has relatively abundant reserves of silicon resources. At present, China has around 150 silicon ore reserves, with the Northwest region being the most abundant, with a total of 1.91 billion tons of ore reserves, accounting for 48% of the country's total ore reserves and a utilization rate of 7%. Secondly, China's self-sufficiency in polysilicon continues to improve. Data shows that the self-sufficiency rate of polysilicon in China has continued to increase from 47.8% in 2010 to 75.4% in 2019, significantly reducing its dependence on foreign countries.

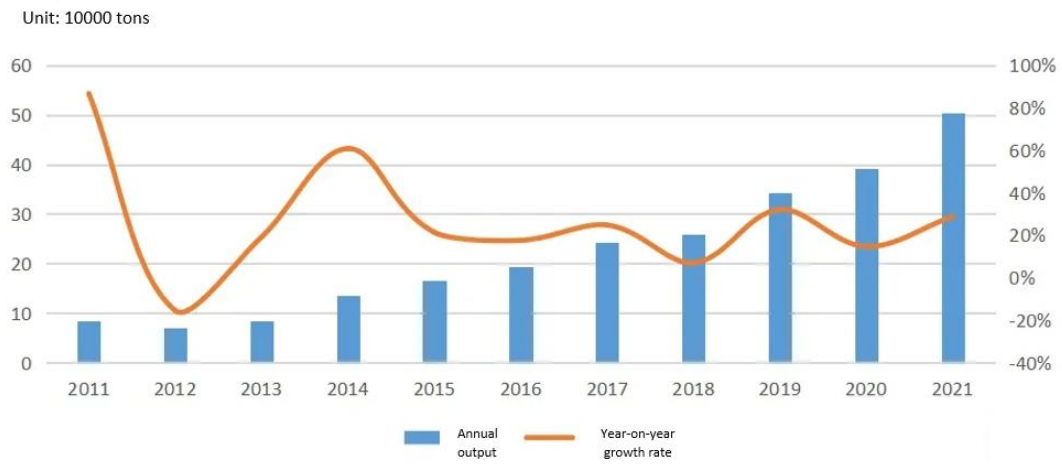

Figure 2 Changes in China's annual polysilicon output from 2011-2021
Source: According to the public data

On the demand side, the rapidly expanding PV market has strongly stimulated the demand for polysilicon. In the domestic market, the continuous construction of large-scale PV base projects in China during the 14th Five-Year Plan period will drive the stable growth of the silicon material market. In the overseas market, the negative strategies adopted by overseas countries in response to the COVID-19 led to significant production reduction and withdrawal of overseas production capacity, which, to a certain extent, accelerated the transfer of the global polysilicon industry to China and promoted the development of China's polysilicon market.

It is worth noting that due to the significant growth of downstream PV power generation installation and the mismatch of production expansion cycles in various links of the supply chain, there was a supply imbalance in China's silicon material market in 2021, and the market transaction price continued to rise, which was transmitted to the entire PV industry chain. In 2022, the transaction prices in the silicon material market continued to rise, and as of the end of April, they had maintained an upward trend for 15 consecutive weeks. The supply of polysilicon continued to be in a tight balance, causing downstream links, especially module prices, to rise under pressure and approach the ceiling of affordable cost for grid-connection. In order to reduce the negative impact of upstream price fluctuations on corporate profits, since the second half of 2020, PV companies have been increasing their new and expanded silicon material production capacity. According to incomplete statistics, if all the newly announced and expanded production projects are put into operation, the growth rate of polysilicon production capacity will be higher than the end market demand, which is not conducive to the healthy development of the industry.

1.1.2 Technology: Polysilicon mainly prepared by trichlorosilane method

At present, the mainstream production technology for polysilicon in China mainly includes two methods: trichlorosilane method and silane method, with the product forms being rod-shaped silicon and granular silicon, respectively. According to the "Roadmap for the Development of China's PV Industry (2021 Edition)" released by the China Photovoltaic Industry Association (hereinafter referred to as CPIA), in 2021, the rod-shaped silicon produced by the trichlorosilane method in China accounted for approximately 95.9% of the total national production, making it the most mainstream polysilicon production method in China. The technology and production techniques of trichlorosilane method have promoted the continuous decline of average costs in the polysilicon industry, contributing positively to the continued decline in the cost of PV power generation.

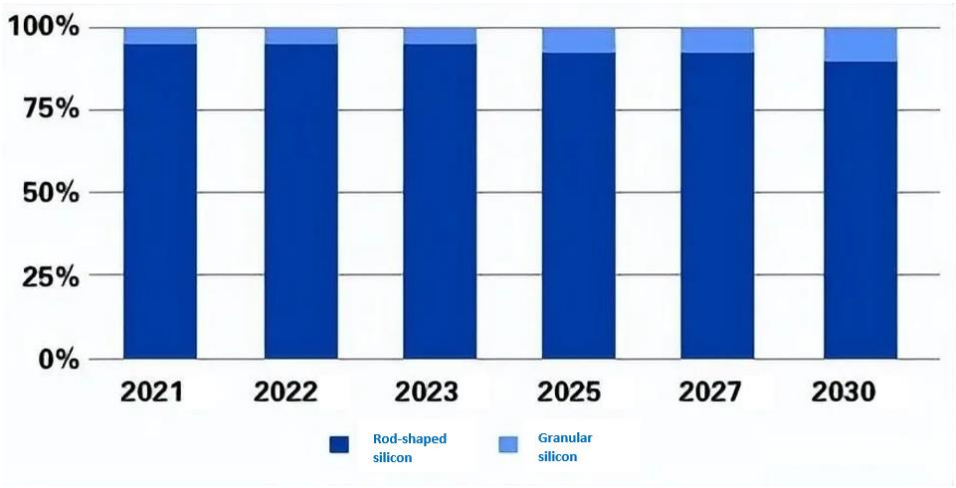

Figure 3 Market share of rod-shaped and granular silicon in China
Source: CPIA

The silane method is one of the main technological directions for producing polysilicon. This technology mainly obtains high-purity silicon material by decomposing silane, and its production process is more convenient for continuous production. The theoretical production cost is reduced by about 20% to 30% compared to the trichlorosilane method, and the tail gas is easier to recover and utilize. The comprehensive power consumption is saved by 40% to 50% compared to the trichlorosilane method, providing more options for seeking lower costs in high electricity price areas. Due to the relatively active (low safety factor) silane gas used in this process and the difficulty in controlling impurities such as hydrogen and carbon, mass production is currently not possible. Data shows that in 2021, the annual production of granular silicon accounted for approximately 4.1% of the market share in the national silicon material market, an increase of 1.3% year-on-year.

At present, there are relatively few enterprises in China that use silane method to produce polysilicon. Only GCL-ET can achieve large-scale production, while other enterprises have made slow progress and have not yet entered the commercialization stage. According to the pre-increase announcement released by GCL-ET, its granular silicon production capacity in 2021 is 30000 tons, of which 20000 tons have been fully produced. Customers include multiple enterprises such as TZE, JinKo Solar, JA Solar, and LONGi. At present, the granular silicon projects established by GCL-ET in Xuzhou, Jiangsu, Leshan, Sichuan, and Baotou, Inner Mongolia have all started construction or expansion, and actively engage in technical cooperation with other leading enterprises, hoping to accelerate the cultivation of the granular silicon industry ecosystem.

From the perspective of market performance and technological development level, in the future, the preparation of polysilicon in China will still be mainly based on trichlorosilane method, and the market share of granular polysilicon by silane method is expected to further increase. Other new processes and methods need to pass market inspection and recognition in terms of safety, environmental protection, quality, large-scale production, and cost in order to have a foothold in the polysilicon market.

1.1.3 Market: domestic Matthew Effect prominent, and the discourse power in global market constantly increasing.

As the upstream link of the PV industry chain, polysilicon belongs to a technology and capital intensive industry, with relatively high industry barriers and high requirements for entering enterprises. At present, China's leading enterprises have taken a leading position globally in terms of production capacity, technology, and preparation processes, and their global market discourse power is constantly increasing. The Matthew Effect is strengthening, and industry differentiation is becoming increasingly evident. According to data released by CPIA, in 2021, there were 8 enterprises in China with polysilicon production of 10000 tons or more. The average production of top 5 enterprises exceeded 85,000 tons, a year-on-year increase of 27.5%. By leveraging their first-mover advantages and economies of scale in technology research and development, as well as production technology upgrades, leading enterprises are accelerating their advantage transformation and gradually occupying more orders in market competition, thereby achieving higher profit margins.

At the same time, despite the continuous emergence of new entrants in the industry, under fierce competition, enterprises with weak research and development capabilities and poor competitiveness have been rapidly eliminated due to their inability to obtain orders, and the market reshuffle continues.

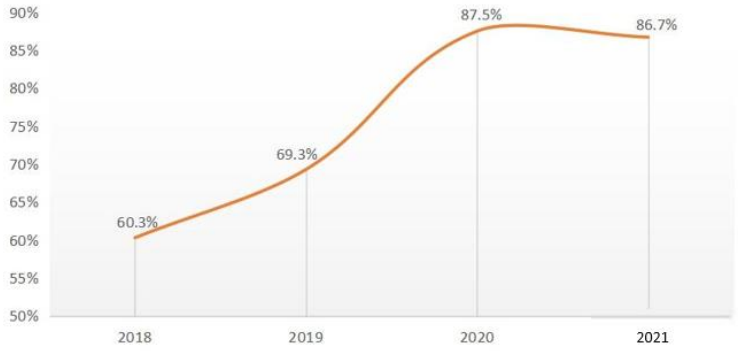

Figure 4 Domestic market share of total production of top 5 polysilicon enterprises
Source: CPIA

In 2022, the national production of polysilicon reached 827,000 tons, a year-on-year increase of 63.4%. Among them, the top five enterprises account for 87.1% of the total domestic polysilicon production. In 2023, with the release of polysilicon enterprises' technological transformation and new production capacity, the production is expected to exceed 1.24 million tons.

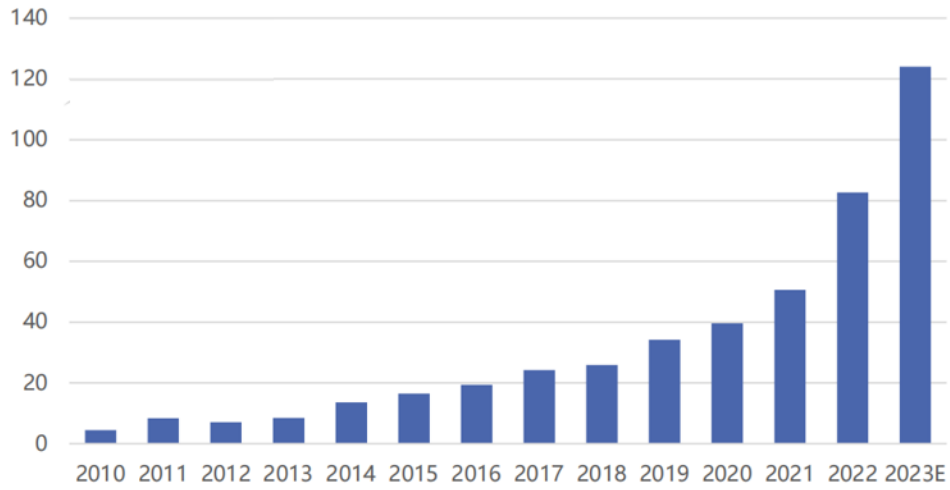

Figure 5 National Polysilicon Production from 2010 to 2023
Source: CPIA

Chinese manufacturers have continuously increased their global market share and become increasingly competitive. From a global market perspective, in 2017, China's polysilicon production capacity and output exceeded half of the global total for the first time. China's polysilicon enterprises, especially new ones, have increasingly obvious global market competitive advantages in technology, equipment, energy conditions, prices, and other aspects. According to the global ranking of polysilicon manufacturers released by Bernreuter Research, as of 2020, China's polysilicon production accounted for approximately 80% of the global total. Seven of the top ten polysilicon manufacturers in the world come from China, and the global market bargaining power is gradually strengthening.

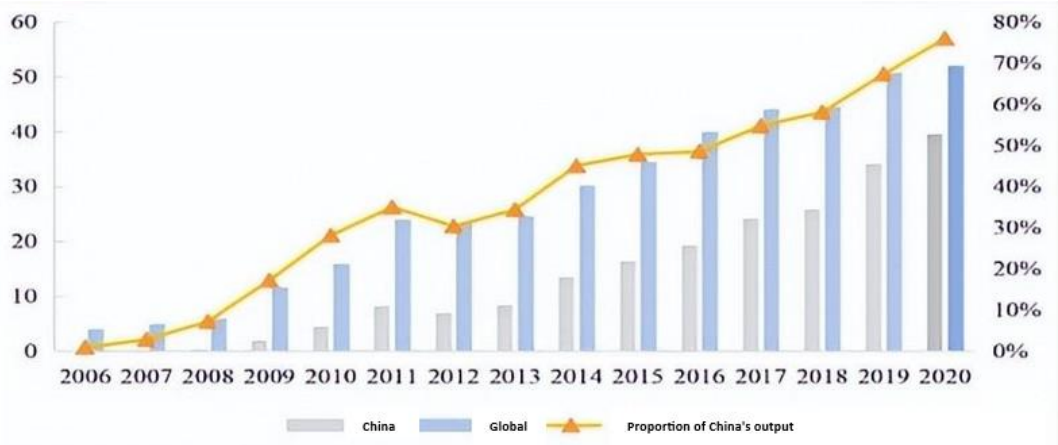

Figure 6 Global Proportion of Polysilicon Production Capacity in China from 2006 to 2020
Source: CPIA

1.2 SILICON WAFER

After melting ingots or pulling crystal slices, polysilicon materials can be made into polysilicon wafers and monocrystalline silicon (hereinafter referred to as "monosilicon") wafers respectively, which can be used to manufacture crystalline silicon cells. Currently, China's silicon wafer industry has taken a leading position globally in terms of technology, scale, and other aspects.

1.2.1 Supply and demand: China is the major production market in the global silicon wafer industry.

On the supply side, in recent years, the production capacity and output of China's silicon wafer market have continued to rise. In 2022, the production capacity of silicon wafers in mainland China was approximately 650.3GW, a year-on-year increase of 59.7%. The output was 357GW, a year-on-year increase of 57.5%, accounting for 97.4% of global silicon wafer output and occupying an absolute dominant position in the global silicon wafer industry. It is expected that the national silicon wafer production will exceed 535.5GW in 2023.

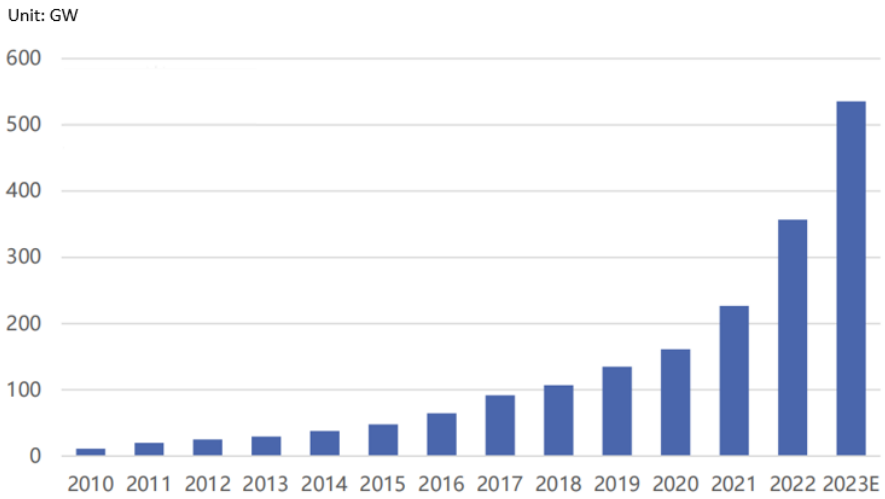

Figure 7 National Silicon Wafer Production from 2010 to 2023
Source: CPIA

In terms of import and export, in 2022, China's silicon wafer export volume was about US $5.07 billion, a year-on-year increase of 106.9%, and the export volume was about 36.3GW, a year-on-year increase of 60.8%, accounting for approximately 9.8% of China's silicon wafer production. Affected by the increase in raw material prices, the price of silicon wafers has also increased, leading to a significant increase in the export value of silicon wafers. In addition, with the acceleration of companies' access to outbound market, the export volume of silicon wafers has also increased significantly.

1.2.2 Technology: accelerated process of large-sized and thinned silicon wafers

The production process of silicon wafers is mainly divided into crystal production and slicing processes. Among them, the crystal production process can be divided into rod pulling and ingot casting according to different production methods. The rod pulling technology is mainly divided into two forms: suspension zone melting method and direct pulling method. Currently, the mass-produced solar grade monosilicon rods are all produced through direct pulling method. Ingot casting technology is one of the main technologies for preparing solar crystalline silicon, mainly divided into full melt casting method (represented by Rietech-Solar) and semi-melt casting method (represented by GCL-ET).

For a long time, polysilicon has occupied a major market share in China's silicon wafer market due to its cost advantage. With the continuous improvement of silicon material production process and diamond wire cutting technology, single crystalline silicon wafers have successfully achieved a significant reduction in production costs, highlighting their advantages in photoelectric conversion efficiency, crystal quality, and electrical performance. According to statistics, the market share of monosilicon wafers (P-type and N-type) in China has increased from 20% in 2016 to 94.5% in 2021. At the same time, as of the end of 2021, the market share of polysilicon wafers in China was about 5.2%, a year-on-year decrease of 4.1 %. It should be noted that although the market share of polysilicon wafers has significantly decreased and is in a continuous decline channel, they will still maintain a certain share in the segmented market and will not be completely replaced by monosilicon wafers.

During the price rise in 2022, companies realized the importance of the silicon wafer process, prompting some companies to accelerate their vertical integration operation. At the same time, downstream silicon wafer companies have strengthened their supply chain control capabilities by locking in long-term orders. And with companies such as JinKo, Tongwei, and CHINT laying out TOPCon cells, the demand for N-type silicon wafers will gradually increase from 2023 onwards. According to the "Development Roadmap of China's Photovoltaic Industry (2022-2023)", it is predicted that the market share of N-type silicon wafers will increase from 10% in 2022 to 25.5% in 2023, and the market share of N-type silicon wafers will continue to increase.

Currently, China's PV power generation industry has entered the era of grid parity. In order to further reduce costs and increase efficiency, and meet the requirements of enterprises for project profitability, the silicon wafer process has a clear trend towards large-sized and thinned development.

Large size, which refers to the ability to produce higher power silicon wafers per unit time, is an important measure to increase production and reduce the cost of non silicon per watt in silicon wafer manufacturing. According to CPIA data, in 2020, the domestic market share of 182mm and 210mm silicon wafers was only 4.5%, which rose to 45% in 2021 and rapidly increased to 82.8% in 2022, and is expected to account for nearly 95% in 2023. Large size silicon wafers are gradually occupying the mainstream market. At the same time as the increase in module power, the trend of large-sized silicon wafers also

significantly increases the fragmentation rate of products, and increases the possibility of uneven distribution issues in suede size, diffusion square resistance, and coating thickness. To some extent the preparation process threshold has been raised.

Thinning, which means reducing the thickness of silicon wafers to reduce silicon consumption and material costs, has become a hot technological development direction in the silicon wafer process. According to the "Proposal on Reducing Silicon Material Costs through Technological Innovation and Product Specification Innovation" released by TZE Co., Ltd., for example, the full specification monosilicon wafers in the industry chain have been comprehensively upgraded from 175 μm to 160 μm in thickness, which is expected to save 6.8% of silicon material usage, significantly reduce the initial cost of silicon wafers, and enhance market competitiveness. It should be noted that the thinner the silicon wafer, the higher the risk of fragmentation, which may lead to the loss of backend process yield and the decrease in reliability of PV products. The industry needs to continue to promote technological research and development or improve relevant solutions in order to truly achieve the large-scale application of thin silicon wafers.

Overall, in the future, the development of silicon wafers will continue to revolve around two aspects: cost reduction and efficiency enhancement, improving power generation efficiency while reducing project electricity costs and expanding profit margins in all aspects.

1.3 MARKET: THE "DUOPOLY" PATTERN LEADS THE DEVELOPMENT OF THE INDUSTRY

As a capital intensive industry, silicon wafer leading enterprises rely on their scale advantages to build a high first mover advantage in technology, cost, market channels, and other aspects, strongly occupying market share. As a result, small and medium-sized enterprises gradually stop production and withdraw from the silicon wafer business due to the continuous reduction of production capacity and operating rate, decrease in product competitiveness, pushing continuous increase of industry concentration. According to statistics, in 2021, there were 7 enterprises in China with a silicon wafer production capacity of over 5GW. Among them, CR5 (referring to the market share of the top 5 companies in terms of business scale) accounts for 84%, and the average annual production of top 5 exceeds 38GW, a year-on-year increase of 64.2%. In 2022, the proportion of production of CR5 decreased to 66%. But in 2022, there were 14 enterprises with a production capacity of over 5GW, which means the number of enterprises has doubled.

Currently, most of China's silicon wafer production capacity is concentrated in leading enterprises such as TZE and LONGi. According to the annual reports released by the two companies, LONGi's annual production of monosilicon wafers was 85.06 GW in 2022, stably ranking first in global monosilicon wafer shipments for 9 consecutive years.

As of the end of 2022, the total production capacity of TZE monosilicon wafers reached 140 GW, and the export market share of monosilicon wafers ranked first in the world.

The company's sales in 2022 were 68 GW, a year-on-year increase of 29.6%, ranking first in the world in sales.
The high production capacity of the two companies not only ensures a fault overtaking other companies in the market, but also ensures their own high profit margins.

1.4 ANALYSIS OF DEVELOPMENT TREND

1.4.1 Further concentration of global industrial operation in upstream links towards China

In recent years, the global layout of the silicon material and silicon wafer industry has continued to shift to China. On one hand, thanks to continuous technological updates and iterations, China has significant advantages over overseas countries in terms of technology, cost per KW-h, and product quality in the silicon material and silicon wafer production. The relatively low level of electricity prices and labor costs, coupled with the continuous downward trend in per KW-h cost caused by scale effect, have highlighted China's production advantages. On the other hand, affected by the COVID-19, overseas silicon material and silicon wafer enterprises were forced to reduce, suspend or close production, which also played a certain role in promoting the transfer of global production capacity.

1.4.2 The continuous expansion of silicon material production capacity may lead to overcapacity

Since 2021, there has been a continuous supply imbalance in the silicon material market, with market transaction prices continuing to rise and transmitted to the entire PV industry chain, putting pressure on downstream costs.

In order to avoid market volatility risks as much as possible, industry chain related enterprises have deployed new and expanded silicon material production capacity to lock in the supply scale and price of silicon materials in advance. According to incomplete statistics, the total amount of production expansion plans announced in China's silicon material sector alone in 2021 has exceeded 1.6 million tons. If all these production capacities are implemented as scheduled, as an industry with relatively small elasticity in capacity, the polysilicon industry may experience oversupply and overcapacity.

1.4.3 Transfer of production to low-electricity-priced areas seeking cost reduction

The production cost of the silicon material mainly consists of electricity bills, industrial silicon costs, depreciation fees, labor costs, etc. Among them, electricity costs account for the highest share, about 30%. Affected by this, in order to further reduce production costs, in recent years, the silicon material and silicon wafer industries have continued to shift to western regions such as Xinjiang, Sichuan, Inner Mongolia, and Ningxia, where electricity prices are relatively low, in order to reduce electricity costs and improve market competitiveness by saving electricity bills.

2. ANALYSIS OF MIDSTREAM LINKS

2.1 PV CELLS

PV cells are the core part of the PV industry chain, and their PV conversion rate and power generation performance directly determine the overall power generation level and profitability of PV power generation projects. Compared to other processes, the update and iteration of PV cell technology and production processes are still at a relatively fast level. The breakthrough of some technological routes in key fields may lead to disruptive changes in the market landscape of PV cell segment. In recent years, with advanced conversion efficiency and excellent power generation performance, China's PV cell products have continuously expanded their market scope and led the industry in global development.

2.1.1 Supply and demand: scale driven by domestic and foreign market demand continues to rise

On the supply end, with the continuous construction of large-scale wind power and PV bases, the domestic market demand for PV cells in China continues to grow, driving the continuous increase in domestic production capacity. According to statistics, in 2021, China's annual production of PV cells reached 198 GW, a year-on-year increase of 46.9%. In 2022, the national production of PV cells was approximately 318GW, with a year-on-year growth of 60.7%.

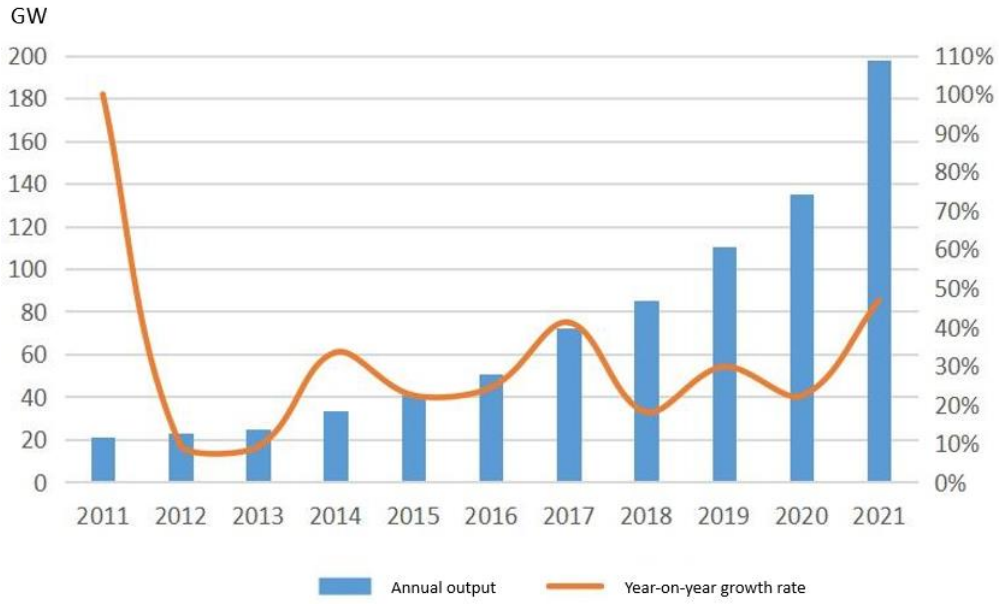

Figure 8 Change of China's Annual Production of PV cells from 2011-2021
Source: According to the public data

On the demand side, in addition to meeting the domestic market, the export scale of China's PV cell products continues to increase. According to statistics, in 2021, the export volume of PV cells in China was about 10.3 GW, a year-on-year increase of 14%, and the total export amount reached US $1.37 billion, a year-on-year increase of 38.2%.

In 2022, the export volume of PV cells was 23.8 GW, amount of US $3.74 billion, a year-on-year increase of 130.7%, setting a new historical high. The top five export markets were Turkey, India, Cambodia, Thailand, and South Korea, accounting for 75% of the export market. Among them, the export volume to Turkey was US $890 million, accounting for 24% of the market share, ranking the first.

2.1.2 Technology: Difficult to predict the final result of multi-track "fighting"

From the perspective of development cycle, from the initial BSF to the current TOPCon, HJT and other high-efficiency cells, every round of technological upgrading has brought new changes to the development pattern of the cell industry and even the entire PV power generation industry. Currently, PV cells in China are mainly divided into two categories based on material types: crystalline silicon cells and thin film solar cells. Among them, crystalline silicon cells have become more mature in terms of technology and manufacturing processes. As of the end of 2021, their domestic market share is about 95%, occupying an absolute advantage.

Crystalline silicon cells are mainly based on monosilicon or polysilicon wafers, using optoelectronic materials to absorb light energy and undergo photoelectron conversion reactions. According to industry estimates, the theoretical conversion efficiency limit of crystalline silicon cells is about 29.43%, and there is currently no technology available to achieve it. According to the different types of surface passivation technologies, crystalline silicon cells are mainly divided into P-type and N-type, with the difference mainly in the two stages of silicon wafers and cells. Specifically, P-type are made by doping gallium in silicon wafers and diffusing phosphorus elements on P-type silicon wafers; N-type are made by doping phosphorus in silicon wafers and diffusing boron elements on N-type silicon wafers.

The preparation process of P-type is relatively mature and has now achieved mass production, including two types: BSF cell and PERC cell. BSF is the first generation of PV cells in China, with a mass production conversion efficiency of about 19.8%, basically reaching the theoretical limit level. Data shows that with the emergence of more efficient cell technology, BSF's market share has continued to decline in recent years, with a global market share of approximately 8.8% by the end of 2020, facing elimination.

The production process of PERC is relatively mature and has been occupying the main position in China's newly added production capacity since 2018, making it the mainstream type of PV cells at the current stage. Data shows that as of the end of 2021, the mass production conversion efficiency of PERC has reached 23.1%, an increase of 0.3 % compared to 2020, approaching its theoretical efficiency limit of 24.5%. In order to

improve the conversion efficiency of PERC, the industry has further upgraded the technology based on PERC, achieving a conversion efficiency limit increase of 0.2% to 0.3%. Its product is known as PERC+ in the industry.

The preparative technology of N-type cells is relatively complex, and the mass production process is not yet fully mature, including various types such as TOPCon, HJT, IBC, etc. The development prospects are promising in the industry. Currently, TOPCon and HJT are mainly in the pilot and semi-pilot stages, and IBC is still unable to achieve mass production. The conversion efficiency of N-type has basically exceeded the theoretical limit of PERC conversion efficiency, and technological innovation is still in a dense and active period, which is regarded as the main development direction of the next stage of PV cell technology. According to CPIA, the market share of N-type cells (TOPCon and HJT) increased to 8.3% by the end of 2022. It is expected to exceed 20% in 2023.

TOPCon cells have not yet achieved large-scale production due to the combined influence of multiple factors. Firstly, the production cost of TOPCon is RMB 0.08 - 0.09/watt higher than that of PERC, especially in terms of non-silicon costs. The amount of slurry used in TOPCon production is more than twice that of PERC technology, and the market competition is at a disadvantage. Secondly, the production process of TOPCon cells is relatively complex, with 12 processing steps (9 for PERC and 4 for HJT) and the process flow has not yet been finalized, resulting in a relatively low yield of TOPCon products and inability to meet commercial requirements, which to some extent increases the cost of per KW-h.

In the long run, the industry is very optimistic about the development potential of TOPCon. Currently, the highest conversion efficiency of TOPCon is 25.7% announced by JinKo Solar in April, 2022. The mass production conversion efficiency is around 24.5%, and its theoretical conversion limit is 28.7%, which has great potential for improvement. At the same time, TOPCon's production process has great compatibility, which can be directly modified by adding diffusion, etching, and deposition processes on the PERC production line, achieving a significant improvement in conversion efficiency, extending the service life of existing equipment, and reducing the sunk cost of initial investment.

HJT cells are prepared by depositing amorphous silicon thin films on crystalline silicon. At present, only Maxwell, Shenzhen S.C, and Jinchen have the ability to complete the entire production line. HJT's production capacity is relatively small, but its development potential is optimistic in the industry. On the one hand, the mass production efficiency of HJT exceeded 24% in the first half of 2021, with a current peak of 25.62%. There is still considerable room for improvement from the theoretical limit of 27.5% conversion efficiency. On the other hand, with the improvement of domestic substitution capabilities for low-temperature silver slurry and equipment, new breakthroughs are expected to be made in downstream metallization technologies such as silver coated copper and electroplating. At that time, HJT's production costs will be further reduced, promoting continuous improvement of market competitiveness.

The characteristic of IBC is that all positive and negative electrodes are arranged on the back of the cell, which is the most complex process and the most difficult structural design preparation method in current commercial crystalline silicon cells. This also leads to relatively high technical and financial barriers for IBC cells. In the early stages of research and development, the laboratory conversion efficiency of IBC has exceeded 25%. The average production efficiency of China's first mass production scale IBC and module production line, built by the Yellow River Upstream Hydropower Development Co., Ltd of State Power Investment Corporation, has exceeded 24%. From a structural perspective, its front side is unobstructed by grid lines, which can achieve greater utilization of incident photons compared to other types, thereby obtaining higher current and ensuring higher conversion efficiency of the product. It's remarkable that the front gridless structure not only brings higher conversion efficiency to IBC, but also significantly increases the technical difficulty of the preparation process. Therefore, enterprises that can take the lead in achieving technological breakthroughs and mass production of IBC cells are expected to enjoy technological benefits.

PV Cell Type		PV Cell Definition	Limit Efficiency	Mass Production Efficiency
P-type Cell	BSF	Aluminum Back Surface Field (AlBSF) cells, which deposit a layer of aluminum film on the backlight surface of the silicon wafer after the p-n junction is prepared to improve the efficiency of crystalline silicon cells.	20%	19.8%
	PERC	Passivated emitter and rear contact, using special materials to form a passivation layer on the back of the cell as a back reflector, increasing the absorption of long wave light and increasing the potential difference between p-n electrodes, reducing electron recombination, and improving efficiency.	24.5%	23.1%
N-type Cell	TOPCon	Tunnel oxide passivated contact, an ultra-thin layer of silicon oxide is prepared on the back of the cell, and then a thin layer of doped silicon is deposited. The two together form a passivation contact structure.	28.7%	24% - 24.5%
	HJT	Heterojunction technology involves the presence of both crystalline and amorphous silicon in cells, and the presence of amorphous silicon can better achieve passivation effects.	27.5%	-
	IBC	Interdigitated back contact, placing both positive and negative electrodes on the back of the cell to reduce the shadow loss caused by the reflection of a portion of the incident light from the electrodes placed on the front.	Over 25%	-

Table 1 Comparison of Crystalline Silicon Cells Technology Routes

Source: CPIA

Thin film solar cells are produced by depositing a layer of thickness not greater than 20 μm on substrates such as glass and flexible polymers thin film, and making solar cells formed by PN junctions (or PIN junctions) in this thin film, mainly including various types such as silicon-based thin films, copper indium gallium selenium (CIGS), cadmium telluride (CdTe), gallium arsenide (GaAs), perovskite cells, and organic thin film cells. Compared with crystalline silicon cells, the advantages of thin film solar cells lie in their production being not affected by the supply and demand situation of the silicon material market, and having lower production costs, relatively low attenuation, and less material consumption, making them more suitable for PV building integration.

Perovskite cells are composed of silicon and synthetic perovskite thin film layers in series, which are relatively low-cost and have sufficient material supply. According to industry estimates, the single-layer theoretical efficiency of perovskite cells can currently reach 31%, and the conversion efficiency of perovskite stacked cells, including crystalline silicon and perovskite double layer stacked cells, can reach 35%. The cost is only about 5% of that of crystalline silicon cells, and once its technology stabilizes, it will have a significant market advantage. At present, the technology of perovskite cells is not yet mature, and the uniformity of their thin films cannot reach stability under mass production conditions. Industry enterprises are mostly in the small-scale experimental stage.

While promoting the updating and iteration of existing technologies and striving to explore new technological innovations, PV cell companies are also trying to improve photoelectric conversion efficiency, reduce manufacturing costs, and enhance competitiveness in product market through various methods such as dual glass (increasing power), half cut (reducing power loss), shingled panel, and multi-busbars.

2.1.3 Market: Continuous competition triggered by technological iteration

As a still growing industry, the market share of PV cells is relatively dispersed, and the optimization and upgrading of technology routes during the cycle will drive significant changes in the ranking of enterprises. Affected by this, the gross profit margin of enterprises in this stage is relatively low, and their bargain power towards upstream and downstream is relatively weak.

Enterprises have strengthened their vertical integration operation, and industry concentration has continued to increase. Since 2021, there has been a sustained imbalance between supply and demand in the upstream silicon material sector, leading to a continuous increase in market prices and spreading throughout the entire PV industry chain. In order to avoid the impact of market fluctuations in other links, since the second half of 2021, multiple specialized PV cell companies have begun to strengthen vertical integration to reduce initial costs, enhance market competitiveness, and stabilize market share. In addition, compared to other links, the industry concentration of PV cells is relatively low. According to statistics, in 2021, there were 7 enterprises in China with a production capacity of over 5 GW of cells, and the CR5 reached 53.9%, a year-on-

year increase of 0.7%. The average production capacity of TOP5 exceeded 2.1GW, a year-on-year increase of 67.2%, showing a continuous upward trend.

Currently, the PV cell sector in China is in the early stages of market turmoil. The current mainstream PERC technology enterprises have touched the technological ceiling and are seeking breakthroughs or changing routes to continue to occupy the main market share. Otherwise, they may be eliminated from the market. At the same time, efficient cells represented by N-type are becoming increasingly mature with technological innovation, attracting more enterprises to lay out mass production lines and accelerating the pace of promotion.

It is noticeable that there are multiple parallel technological routes in the current PV cell process, many of which are still in the stage of exploration and breakthrough. In order to lock in the market in advance, enterprises usually choose to bet on the layout of their production lines first. For enterprises with relatively weak financial strength and relatively backward technological research and development capabilities, the initial investment of tens of millions may have a significant impact on their survival.

2.2 PV MODULES

PV modules, commonly known as solar panels, can enhance the tolerance and performance of the PV cells to the surrounding environment, effectively increasing their service life. Correspondingly to PV cells, PV modules can be mainly divided into two categories: crystalline silicon modules and thin film modules. Due to its none technology-intensive nature, the PV module segment in the PV industry chain has little say.

2.2.1 Supply and demand: annual production ranked 1st globally for 15 consecutive years

On the supply side, the supply capacity of China's PV module industry continues to improve. According to statistics, the annual production of PV modules in China in 2022 was 288.7GW, and the export volume reached 153.6GW, a year-on-year increase of 55.8%. In 2022, China's newly installed PV capacity reached 87.41GW. With the continuous increase of global and Chinese newly installed PV capacity, the domestic and export demand for PV modules will also continue to increase, thereby promoting the growth of demand for PV cells.

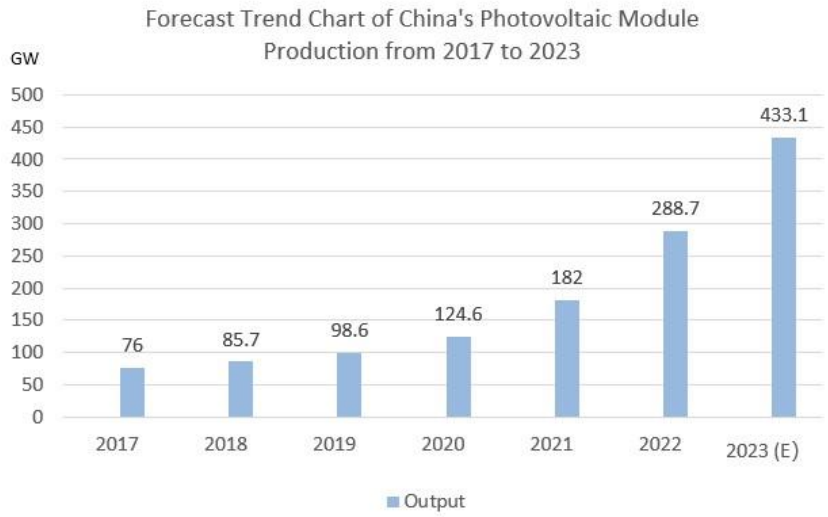

Figure 9 Forecast Trend Chart of China's PV Module Production from 2017-2023
Source: CPIA

On the demand side, in the domestic market, the demand for PV cells continues to expand. In overseas markets, fluctuations in the policy environment have a certain impact on market demand. On the one hand, the overseas business landscape of China's PV module enterprises continues to expand.

With regard to industrial scale, as of the end of 2022, the global module production capacity and output reached 682.7 GW and 347.4 GW, respectively, with year-on-year growth of 46.8% and 57.3%, continuing to maintain rapid growth.

From the perspective of module industry scope, the focus of global PV module production and manufacturing is still in Chinese Mainland, with the capacity of Chinese Mainland reaching 551.9 GW, accounting for about 80.8% of the global total capacity. The production reached 294.7GW, accounting for approximately 84.8% of the global total output.

The export value of PV modules in China in 2021 was US $24.61 billion, accounting for 86.6% of the total export value of PV products (silicon wafers, cells, modules), with a year-on-year increase of 44.8 %. In 2021, the export volume of PV modules was approximately 98.5 GW, a year-on-year increase of 25%, accounting for approximately 54.2% of China's module production.

In 2022, the export value of PV modules in China was US $42.36 billion, a year-on-year increase of 72.1%, accounting for 82.7% of the total export value of PV products (silicon wafers, PV cells, modules). The export volume of PV modules is about 153.6 GW, a year-on-year increase of 55.9%, accounting for approximately 53% of China's module production.

2.2.2 Technology: Taking multiple measures to deepen cost reduction and increase efficiency

With the deepening of technological development, in recent years, the power generation performance of PV modules in China has been continuously improving. According to CPIA data, as of the end of 2021, the maximum power of PV modules in China has reached 700 watts, an increase of 100 watts compared to 2020. In order to maximize the advantages of high-efficiency cells, the current iteration of PV module technology mainly focuses on improving unit power generation and reducing power loss, divided into multiple methods such as dual glass, half cut, shingled panel, and multi-busbars.

Dual-glass refers to the process of replacing a traditional back panel with a glass or transparent back panel when packaging a solar panel, so that the back of the panel can also absorb ground reflected light and scattered light in the air to improve the conversion power of the PV cell, thereby reducing the electricity cost of PV projects. In different scenarios, the power generation efficiency of dual glass modules is 5% to 19% higher than that of traditional single-sided modules. As of 2021, the market share of dual-glass modules in China was 37.4%, an increase of 7.7% year-on-year. According to industry estimates, by 2023, the market share of dual-glass modules is expected to reach the same level as traditional single-sided modules.

Half cut refers to using a laser to cut the cell into two identical half pieces along the main grid line, and then welding them in parallel. Compared with ordinary cells, the power of a half cut module is reduced by half, and the current flowing through the panel is also reduced by half, resulting in a significant reduction in internal current loss. Meanwhile, thanks to the unique series connection structure of PV cells, the bypass diode of the half-cut module can quickly create an alternative path to guide current away from shadow positions in the event of solar obstruction, which helps reduce current loss, reduce CTM (Cell to Module Loss), and improve module service life. As of 2021, China's half-cut module market accounted for 86.5%, an increase of 15.5% year-on-year, becoming the current mainstream packaging model.

Shingled panel refers to the process of using a laser to cut and weld small cells into a string using conductive adhesive instead of traditional soldering tape. Due to the fact that the cells of the shingled panel module are connected through front and back stacking, there are no longer metal grid lines on the surface of the panel, and there is also a "zero spacing" between the cells. According to industry calculations, under the same version comparison, shingled panel module can accommodate 5% more cells compared to other types of module, greatly improving the conversion efficiency and significantly improving performance stability. At the same time, the equipment required in the manufacturing process of laminated tile components, such as laminated tile colloid printing machines, typesetting machines, laser slicing machines, as well as auxiliary materials such as conductive silver glue and screen printing, are all added to the conventional module production and can only be used for shingle manufacturing, resulting in a significant increase in the production cost, which will to some extent reduce their technological advantages in improving efficiency.

Multi-busbars (MBB) refers to increasing the number of busbars in crystalline silicon cells from 2-3 to at least 4 to improve the conversion efficiency and overall performance of the module. It should be noted that on the one hand, due to the limited area of the module, the dense busbars will reduce the light receiving area of the cell. On the other hand, the increase in busbars will also lead to an increase in the cost of silver paste used for manufacturing busbars. Therefore, the specific design for the busbars needs to strike a balance between power generation efficiency and cost, shading and conductivity.

Although modules are not the core factor affecting power generation, the decrease in module costs plays an important role in driving the continuous decline in the consumption cost of PV power generation projects. According to CPIA data, during the 13th Five Year Plan period, the cost of PV modules in China decreased from RMB 3.3 per watt to RMB 1.57 per watt, driving the initial investment to decrease from RMB 7.3 per watt to RMB 3.99 yuan per watt. This has laid an important foundation for the rapid increase in the installed scale of PV power generation in China.

As a note, with the technological breakthroughs in high-efficiency cells and the rapid increase in market share, the market has put forward higher requirements for modules in aspects such as string welding and packaging. For example, how to reduce silver slurry consumption through multi busbars technology, how to further improve welding accuracy to improve module reliability, and how to further enhance packaging density to isolate water vapor can all have a significant impact on the product quality, industrialization speed, and even power generation performance of N-type modules.

2.2.3 Market: The trend of vertical integration development among enterprises is strengthening

The PV module segment is basically close to the end of the PV manufacturing industry chain. As a typical labor-intensive industry, its requirements for capital and technology are not high, and its market share is relatively scattered.

The concentration of the industry is gradually increasing, and the trend of vertical integration in enterprises is strengthening. In recent years, the concentration of China's PV module industry has continued to increase. According to the module shipment data in 2022, enterprises with a scale of over 40GW are LONGi, Trina Solar, JinKo, and JA Solar, with a total shipment volume up to 170GW, accounting for about 60% of the country's total shipment volume. The gap in shipment volume among the top four enterprises has gradually narrowed, from 12GW in 2021 to 6GW in 2022. With the rapid decline in the prices of the PV industry chain in 2023, competition among enterprises will enter a white-hot stage.

In the past two years, the market price rise caused by the imbalance between supply and demand in upstream links has gradually transmitted to the entire industry chain, driving module costs to approach the ceiling of affordable grid connection, and continuously putting pressure on profit margins. In order to reduce front-end costs and stabilize market share, especially since the second half of 2021, multiple PV module companies such as JinKo and LONGi have gradually accelerated their vertical integration and

extended their expansion to upstream links. They hoped to reduce operational risks by building a full industry chain integration structure covering silicon materials, silicon wafers, cells, and modules.

The ranking of top enterprises is relatively fixed, and the elimination of small and medium-sized enterprises is accelerating. As an industry with obvious attributes of B2C, leading enterprises in PV modules have attracted market share to accelerate towards to them by leveraging their advantages in scale, brand, channels, financing, supply chain, cost control, and other aspects. In order to enhance product competitiveness and further seize market shares, multiple leading companies in the module sector have proposed brand standards that are higher than the national quality assurance requirements. As stated by LONGi in 2018, the warranty period of its module products has been extended from 25 years to 30 years, and light attenuation rate in the first year is controlled at 2%. JinKo clearly stated that its dual glass monocrystalline modules and N-type modules have a quality guarantee period of 30 years, with N-type modules having attenuation of no more than 1% and a linear attenuation of no more than 0.4% in the first year.

At the same time, the pace of elimination of small and medium-sized enterprises is accelerating. Constrained by relative disadvantages in terms of channels, funds, and scale, on the one hand, the technological level of production capacity of small and medium-sized enterprises is relatively lagging, equipment and products are accelerating depreciation, so that market share loss is gradually accelerating. On the other hand, currently, large-sized cells represented by 182mm and 210mm will gradually occupy an absolute advantage in the market. Larger sized cells still need to undergo market validation in terms of technology, cost, and other aspects, and cannot achieve mass production. Therefore, the existing production line does not need to be upgraded in the short term, which will also prevent specialized small and medium-sized enterprises from occupying an advantageous position when competing with vertically integrated leading enterprises on the same platform and gradually being eliminated by the market.

2.3 PV AUXILIARY MATERIALS

A complete PV module is composed of battery cells, frames, PV glass, adhesive films, backsheets, etc. The parts other than battery cells are generally referred to as PV auxiliary materials, and their performance also has a significant impact on the overall power generation performance of the project.

Adhesive film is an important material in the packaging process of PV modules, and its characteristics such as transparency, bonding strength, and aging resistance have a significant impact on the sealing performance and service life of the modules. As of 2021, the global market share of China's top 4 PV film industry has exceeded 83%, occupying an absolute dominant position. Currently, PV films are mainly divided into types such as EVA films (including transparent EVA films and white EVA films), POE films, and EPE films (mixed with EVA and POE). According to statistics, as of the end of 2021, the domestic market share of transparent EVA reached 51.8%, the domestic market share of white EVA

film was about 23.1%, and the domestic market share of POE film was about 23.2%. Driven by the growing demand for high-efficiency cells in the market, the market share of high-quality adhesive films such as white EVA film with higher transparency and POE film with better PID resistance is expected to further increase.

In addition, the technology threshold of the PV film industry is relatively high, and high requirements are put forward for vinyl acetate content, MI (melt index), etc. For example, the MI of ordinary PV grade EVA needs to be higher than 25%, while the MI range of white EVA materials is between 6% and 15%, indicating a significant gap in their standards. Currently, the number of Chinese enterprises with PV grade EVA production capacity is only a single digit, and 70% of the market demand relies on overseas imports. There are no enterprises with PV grade POE production capacity in China. The import dependence of PV grade EVA resin in China is as high as 65%. Domestic imported EVA products are mainly from overseas companies such as Hanhua Total, LG, and Singapore TPC.

3. ANALYSIS OF DOWNSTREAM LINKS

3.1 INVERTERS

PV inverters are mainly used to convert direct current produced by PV modules into frequency adjustable alternating current through boost circuits for grid connection. Their performance has a direct impact on the power generation efficiency and stability of the system, and is one of the important links in PV power generation systems. Over the past decade, the rapid development of the downstream PV power generation industry has driven the rapid growth of the PV inverter industry. It has not only achieved the localization of main materials, but also made China a major inverter production country in the world.

3.1.1 Supply and demand: The production scale is growing year by year, and the shipment volume depends on the installation demand for PV power generation.

On the supply side, currently, China has become a major producer of inverters in the global market. According to data, the production of China's inverter industry in 2022 is about 146.7GW, and the demand is about 84.3GW. The market size of inverters in China is approximately RMB 32.02 billion, with a production value of approximately RMB 69.75 billion. Hebei Province is the largest inverter market in China, accounting for 8.96%. From the perspective of market structure, PV inverters account for the heaviest proportion, accounting for 52.75%. The inverter industry has a high concentration and fierce market competition. The top two manufacturers, Huawei and Sungrow Power, have a market share of 23% and 21% respectively.

On the demand side, the shipment volume of the inverters completely depends on the installation demand of the PV power generation project. In the domestic market, the

rapid increase in installation capacity of the PV power generation industry has driven the market demand for PV inverter products and maintained a long-term growth trend. In the global market, Chinese PV inverter enterprises have significant advantages in technology, cost, quality, etc., with a large market development space.

3.1.2 Technology: continuous upgrade in single unit power and enlargement of power density has ushered in an critical period of development opportunities for energy storage inverters.

Inverter products in China can be mainly divided into three types: centralized inverters, string inverters, and distributed inverters. The main difference lies in the differences in power generation efficiency, flexibility, and application scenarios caused by the different number of PV modules.

With the rapid increase in the installation scale of distributed power plants, in recent years, string PV inverters that require more flexible application scenarios have gradually become the mainstream of enterprise capacity increment, and their market share continues to increase. According to statistics, as of 2021, the market share of centralized inverters and string inverters in China's PV inverter market was 27.7% and 69.6% respectively, while the market share of distributed inverters was as relatively small as 2.7%. The industry believes that with the continuous increase in power and decrease in cost, the string inverters market penetration is expected to further increase.

The single unit power is becoming larger, and the cost of electricity per KW-h continues to decrease. In order to meet the needs of cost reduction and efficiency improvement in PV power generation projects in the era of parity, the single unit power of inverter products will continue to increase and drive the cost of inverter per watt to continue to decrease. According to industry estimates, compared to a 1 MW array, the use of a 2.5 MW inverter can reduce the initial investment of a 100 MW power plant by RMB 10 million, which is equivalent to a RMB 0.1/watt decrease in electricity cost, and the DC losses are consistent.

The PV power generation industry in China is still in a stage of rapid development. From the perspective of the power grid, inverters will become more intelligent, continuously improving ability to perceive and control electricity, providing better support for traditional power grids to absorb and adapt to new energy electricity. From the user's perspective, inverters will provide stronger technical support for the safe and efficient operation of power plants. From the module side, the inverters will iterate in a timely manner according to market demand to ensure the high-quality development of the PV power generation industry.

At the same time, with the gradual acceleration of the development pace of the energy storage industry, energy storage inverters have also arrived in an important period for development opportunities. The function of energy storage inverters is mainly to convert AC power into DC power and transmit it to the battery for charging and storage. In remote areas or isolated island power grids, they can provide uninterrupted current support for users. The industry believes that energy storage inverters can reach 2-3 times

the price of ordinary PV inverters. The relatively large profit margin combined with strong demand in the energy storage market will promote the significant development of energy storage inverters.

3.1.3 Market: The scale of string inverters continues to expand, and competition is approaching white heat.

In recent years, most of the newly entered enterprises in the domestic PV inverter industry have focused on string PV inverter products, while traditional centralized inverter manufacturers have also successively launched various string products. The competition among enterprises in the string PV inverter market is gradually fierce. Among them, companies represented by Huawei and Sungrow Power mainly produce string inverter products, with both occupying a dominant position in the entire PV inverter industry. According to industry estimates, the market size of string inverters in China has reached tens of billions of RMB.

From the perspective of segmented fields, currently, China's centralized inverter field has achieved full competition, with a high degree of homogenization in technology and products, and product prices approaching costs. Sungrow Power and Huawei are leading the industry, with multiple enterprises such as TBEA, SINENG, Kehua, and KSTAR closely following. The market pattern is basically determined, and the focus of market competition has shifted from products to sales channels, brand value, and other aspects. The market share of string inverters is relatively dispersed, and companies such as Ginlong Solis and Goodwe are facing fierce market competition. Leading companies are gradually widening the gap with their advantages in technology, cost, channels, operation and maintenance.

3.1.4 Analysis of development trend

- As a B2C type industry with low technological barriers and high capital requirements, in order to meet the development needs of the downstream PV power generation industry, the PV inverter industry will quickly adjust its product structure to keep up with market changes, improve its market competitiveness, and seize market share. For example, the rapid increase in market share of large-sized cells represented by 182mm and 210mm has effectively accelerated the development pace of high-power string inverters.

- With the expansion of the installed range of PV power generation in China, special environments such as plateaus, deserts, and seaside places require higher performance of PV inverter products, such as resistance to wind and sand, and corrosion resistance, to ensure that projects have better power generation performance and longer power generation cycles. At the same time, in order to ensure the safe and stable operation of the new power system, PV inverters will continuously improve their adaptability to the power grid in terms of leakage protection, SVG, LVRT, DC component protection, insulation impedance protection, PID protection, lightning protection, reverse connection protection, etc.

4. IMPORT & EXPORT STATUS OF CHINA'S PV INDUSTRY

4.1 HISTORICAL DATA

In 2022, the total export value of domestic PV products (silicon wafers, cells and modules) was about US $51.25 billion, a year-on-year increase of 80.3%.Among them, the export volume of silicon wafers was about 36.3GW, a year-on-year increase of 60.8%. The export volume of cells is about 23.8GW, a year-on-year increase of 130.7%. The export volume of PV modules was about 153.6GW, a year-on-year increase of 55.8%, with both export volume and volume reaching historic highs.

According to the statistics of the CPIA, in 2022, China's PV product exports to markets on various continents achieved varying degrees of growth, with the European market experiencing the largest growth rate, accounting for nearly half of China's exports, with a year-on-year increase of 114.9%. By category, silicon wafers and cells are mainly exported to Asia. In terms of module exports, the Netherlands maintains its position as the largest market for China's PV module exports, while the Polish and Portuguese markets rank in the top 10.

According to calculations by the European Commission, the total cost of PV manufacturing in China is 35% lower than that in Europe, 20% and 10% lower than that in the United States and India, respectively. Taking PV module manufacturing as an example, the cost savings of PV modules produced in China are more than 50% compared to those produced in the United States and the European Union.

Although Europe imported up to 86.6GW of PV modules from China in 2022, an increase of 116% compared to 2021, the newly added PV installed capacity was only 41GW, an increase of 47% compared to the previous year. This means that at least half of the modules are still in stock.

There are various reasons why European PV installation is slower than import, we believe that, including labor shortage, environment, land, fire protection, etc., but the main factor is still labor.

4.2 FORECAST FOR 2023

The export performance of China's PV products in 2023 is impressive. According to data, from January to July 2023, the export value of China's PV products reached US $32 billion, a year-on-year increase of about 6%, reaching a new historical high. According to the Secretary General of the PV Branch of the China Chamber of Commerce for Import and Export of Mechanical and Electrical Products, it is expected that due to the

increasing demand for PV installation in Southeast Asia, Europe, America, Latin America, and other regions, enterprises will accelerate their going overseas process. Affected by factors such as the shortage of N-type cells and the significant increase in global PV installation expectations by the International Energy Agency, the export volume of China's PV products is expected to approach US $60 billion for the entire year of 2023, an increase of about 20% year-on-year.

Since the beginning of this year, China's silicon wafer exports have achieved stable growth. Data shows that from January to July 2023, China's export of silicon wafers reached US $3.074 billion, a year-on-year increase of 15.04%. China's silicon wafer export market is mainly concentrated in Southeast Asian countries.

Rank	Country	Export Amount (USD)	Year-on-year increase
1	Vietnam	781 million	16.15%
2	Thailand	780 million	79.25%
3	Malaysia	700 million	-1.97%

Figure 10 Top 3 Markets of China's Silicon Wafer Exports (January - July 2023)

China's cell exports continue to grow. Data shows that from January to July 2023, the export value of cells was US $2.726 billion, a year-on-year increase of 35.42%, and the export volume was 22.65GW, a year-on-year increase of 80.86%. Türkiye, India and Cambodia are the top three export markets of China's cells.

Rank	Country	Export Amount (USD)	Year-on-year increase
1	Turkey	904 million	107.74%
2	India	581 million	40.13%
3	Cambodia	422 million	132.99%

Figure 11 Top 3 Markets of China's PV Cell Exports (January – July 2023)

However, the growth rate of China's PV module exports has slowed down. Data shows that from January to July 2023, China's export value of PV modules was US $26.12 billion, a year-on-year increase of 2.1%. The export volume was 123GW, a year-on-year increase of 30.4%.

Rank	Country	Export Amount (USD)	Year-on-year increase
1	The Netherlands	7.213 billion	5.08%
2	Brazil	2.28 billion	-22.15%
3	Spain	1.539 billion	-18.18%

Figure 12 Top 3 Markets of China's PV Module Exports (January - July 2023)

The export volume of inverters in China has maintained rapid growth. Data shows that from January to July, China's inverter export value was 6.917 billion US dollars, a year-on-year increase of 71.51%. The Netherlands, Germany, and South Africa have become the top three export markets for Chinese inverters.

Rank	Country	Export Amount (USD)	Year-on-year increase
1	The Netherlands	2.278 billion	126.98%
2	Germany	686 million	181.06%
3	South Africa	450 million	453.22%

Figure 13 Top 3 Markets of China's Inverter Exports (January - July 2023)

4.3 CHINESE PV ENTERPRISES GOING OVERSEAS

The traditional business model for Chinese PV enterprises to go overseas is to sell their products to first tier distributors overseas. In this model, domestic companies are separated from overseas markets and overseas distributors control sales channels, resulting in ineffective "internal competition" among domestic companies. So far, building a local sales network in Europe has become a common choice for large and medium-sized PV manufacturers to go overseas. In terms of specific mode of power station business, there are currently three common development modes for PV power stations overseas: self-owned operation, EPC, and BT (Build-Transfer).

Self- owned operation refers to manufacturers building power stations themselves and operating them on their own grid. The EPC mode is mainly aimed at the owners of self-owned power plants. Through bidding, a company is entrusted with the general contracting of the design-procurement-construction process of the power plant. The BT model refers to the direct transfer of constructed power stations by enterprises to local industrial funds and investment companies to obtain profits. Generally, self-owned power plants are selected in relatively stable countries with overall good returns, while in countries in Central and Western Europe, the BT model is mainly adopted.

4.4 POSSIBLE IMPACTS OF POLICY ENVIRONMENT

4.4.1 Internal

In June 2021, the National Development and Reform Commission announced that starting from 2021, for newly registered centralized PV power stations, the central government will no longer provide subsidies and implement grid parity. According to data, in 2021, China's new installed capacity of distributed PVs reached 29.28GW, surpassing the centralized installed capacity of 25.6GW for the first time. It can be seen that in the future, PV power generation will shift from centralized PV power generation to distributed PV power generation.
At present, PV power generation is about to break away from its dependence on subsidies, and the enormous pressure of parity targets is forcing PV manufacturing enterprises to accelerate the reduction of PV LCOE, and the application of new technologies is constantly accelerating.

4.4.2 External

As early as 2018, the European Commission formulated the "EU 2050 Strategic Long Term Vision", which proposed that the proportion of renewable energy generation in the EU should reach 32% by 2030. In recent years, the changes in the international geopolitical situation have further accelerated Europe's vision of seeking energy independence. On May 18, 2022, the EU passed the REPowerEU plan, which stated that the EU's PV installed capacity should exceed 320GW by 2025 and 600GW by 2030.

On March 16, 2023, as part of the Green Deal Industrial Plan, the European Commission officially announced the two cornerstones of the green industry plan, the Net Zero Industry Act and the European Critical Raw Materials Act.

By 2030, the EU plans to provide at least 10% of key raw materials annually, process 40% of key raw materials, and recycle 15% of key raw materials from within the EU. The overall strategic net zero technology manufacturing capacity is close to or at least 40% of the EU's annual deployment demand. In addition, the above proposal sets that the annual consumption of strategic raw materials from a single third-party country should not exceed 65%, and related products from countries above 65% will be downgraded in bidding evaluation, and the purchaser of this product will have more difficulty obtaining government subsidies.

The impact of this bill on Chinese PV enterprises is not as significant as the market reaction, and it should not have a substantial impact on Chinese companies for two to three years. In the current situation, the EU needs to develop clean energy such as PV wind power, as well as Chinese PV products.

Although the proposal for the European Net Zero Industry Act has almost no substantial impact on domestic enterprises in the short to medium term, global presence may be one of the feasible strategies for Chinese PV enterprises under the hidden concerns of import restrictions. During the legislative process of the Net Zero Industry Act, Chinese PV enterprises will still choose to build factories in Europe.

5. CONCLUSION

1. China's PV industry has entered the era of comprehensive parity, with increasing national policies and financial support, and the industry's momentum is stable and improving;

2. Upstream silicon material is in short supply and demand, and excess profits will still be maintained in the short term. However, price decline will become a long-term trend. Therefore, achieving cost reduction and efficiency increase through technological innovation such as thinning is still the future development direction of the enterprise;

3. The advantages of N-type cells are becoming increasingly evident, and TOPCon and HJT technologies will become the focus of industrial investment and market attention in recent years;

4. The leading enterprises in the industry chain have gradually stabilized their voice in the market, and barriers and entry barriers have gradually increased, making them increasingly unfriendly to new players;

5. By the end of 2021, the proportion of distributed PV power stations surpassed that of centralized power stations. With the continuous iteration and improvement of distributed technology, it can be foreseen that the increment and penetration rate of the distributed PV market in 2023 will continue to increase, embracing a historic opportunity of explosive development;

6. Since the beginning of this year, the prices of PV modules have continued to decline, which may be related to overcapacity. However, the downward trend in prices since June has worsened, indicating that the industry reshuffle has begun. Due to their cost advantages, resource advantages, and integration advantages, leading enterprises are more competitive compared to other enterprises in the industry. Enterprises with a vertical integration self-sufficiency capacity of 80% have better delivery guarantee capabilities.

7. In the near term, EU's Net Zero Industry Act and European Critical Raw Materials Act will not have substantial impact on Chinese PV enterprises. But under the hidden concerns of import restrictions, Chinese PV enterprises will continue going overseas.

5.1 INDEX OF CHINESE ENTERPRISES MENTIONED ABOVE:

GCL-ET https://www.gcl-et.com/
TZE https://en.tzeco.com/
JinKo https://www.jinkosolar.com/en
JA Solar https://jasolar.com/html/en/
LONGi https://www.longi.com/en/
Rietech-Solar http://www.rietech-solar.com/
Tongwei https://en.tongwei.com.cn/
CHINT https://www.chintsolar.com/
Maxwell https://www.maxwell-gp.com/
Shenzhen S.C, http://www.chinasc.com.cn/
Jinchen http://www.jinchencorp.com/
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