



Task 1 Strategic PV Analysis and Outreach

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National Survey Report of PV Power Applications in CHINA 2022





What is IEA PVPS TCP?

The International Energy Agency (IEA), founded in 1974, is an autonomous body within the framework of the Organization for Economic Cooperation and Development (OECD). The Technology Collaboration Programme (TCP) was created with a belief that the future of energy security and sustainability starts with global collaboration. The programme is made up of 6.000 experts across government, academia, and industry dedicated to advancing common research and the application of specific energy technologies.

The IEA Photovoltaic Power Systems Programme (IEA PVPS) is one of the TCP's within the IEA and was established in 1993. The mission of the programme is to “enhance the international collaborative efforts which facilitate the role of photovoltaic solar energy as a cornerstone in the transition to sustainable energy systems.” In order to achieve this, the Programme's participants have undertaken a variety of joint research projects in PV power systems applications. The overall programme is headed by an Executive Committee, comprised of one delegate from each country or organisation member, which designates distinct ‘Tasks,’ that may be research projects or activity areas.

The IEA PVPS participating countries are Australia, Austria, Belgium, Canada, Chile, China, Denmark, Finland, France, Germany, Israel, Italy, Japan, Korea, Malaysia, Mexico, Morocco, the Netherlands, Norway, Portugal, South Africa, Spain, Sweden, Switzerland, Thailand, Turkey, and the United States of America. The European Commission, Solar Power Europe, the Smart Electric Power Alliance (SEPA), the Solar Energy Industries Association and the Cop- per Alliance are also members.

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What is IEA PVPS Task 1?

The objective of Task 1 of the IEA Photovoltaic Power Systems Programme is to promote and facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of PV power systems. Task 1 activities support the broader PVPS objectives: to contribute to cost reduction of PV power applications, to increase awareness of the potential and value of PV power systems, to foster the removal of both technical and non-technical barriers and to enhance technology co-operation. An important deliverable of Task 1 is the annual “Trends in photovoltaic applications” report. In parallel, National Survey Reports are produced annually by each Task 1 participant. This document is the country National Survey Report for the year 2022. Information from this document will be used as input to the annual Trends in photovoltaic applications report.

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COVER PICTURE

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1 INSTALLATION DATA

The PV power systems market is defined as the market of all nationally installed (terrestrial) PV applications with a PV capacity of 40 W or more. A PV system consists of modules, inverters, batteries and all installation and control components for modules, inverters and batteries. Other applications such as small mobile devices are not considered in this report.

For the purposes of this report, PV installations are included in the 2022 statistics if the PV modules were installed and connected to the grid between 1 January and 31 December 2022, although commissioning may have taken place at a later date.

1.1 Applications for Photovoltaics

By the end of 2022, the cumulative installed capacity of renewable energy reached 1,213GW, accounting for 47.3% of the country's total installed capacity of power generation, which was an increase of 2.5% from 2021. Among them, 365GW of wind power and 393GW of solar power.

In 2022, China's new PV installation was 87.41GW(AC), up 59.3% year-on-year. Among them, utility PV installed 36.3GW, up 41.8% year-on-year while distributed PV installed 51.1GW, up 74.5% year-on-year.

In 2022, the new distributed PV installations reached more than half of the annual new PV installations in 2022. In terms of distributed PV types, the new installation of commercial and industrial was 25.86GW, accounting for 50.6% while the residential PV was 25.24GW, accounting for 49.4%. Commercial and industrial distributed PV by tariff advantage and other factors to take over residential PV and became the fastest growing distributed PV.

In 2022, the newly installed capacity of wind power and PV power generation exceeded 120 million kilowatts. Wind power, PV power generation for the first time exceeded 1 trillion kilowatt-hours, reaching 1.19 trillion kilowatt-hours, a year-on-year increase of 21%, accounting for 13.8% of the total electricity consumption of the whole society, close to the national urban and rural residents living in the electricity consumption.¹

1.2 Total photovoltaic power installed

Table 1: Annual PV power installed during calendar year 2022

		Installed PV capacity in 2022 [MW]	AC or DC
	Decentralized	51110	DC/AC
	Centralized	36300	AC
	Off-grid	-	-
	Total	87410	AC

¹ Resource: CPIA (China Photovoltaic Industry Association)

**Table 2: Data collection process**

If data are reported in AC, please mention a conversion coefficient to estimate DC installations.	1.15
Is the collection process done by an official body or a private company/Association?	Data on annual and accumulated PV grid-connected installation capacity in 2022 were published by National Energy Administration. Off-grid installation accounts for a very small scale in China so the data was estimated by PV experts.
Link to official statistics (if this exists)	http://www.nea.gov.cn/
	Additional comments on market and data collection, especially the estimated accuracy of data.

Table 3: The cumulative installed PV power in 4 sub-markets

Year	Off-grid [MW]	Grid-connected distributed [MW]	Grid-connected centralized [MW]	Total [MW]
2010	27	190	283	500
2011	20	680	2000	2700
2012	40	1360	1800	3200
2013	40	10950		10990
2014	40	2050	8550	10640
2015	20	1390	13740	15150
2016	10	4230	30310	34550
2017	0	19440	33420	52860
2018	0	20960	23300	44260
2019	0	12200	17900	30100
2020	0	15500	32700	48200
2021	0	29280	25600	54880
2022	0	51100	36290	87410

**Table 4: Other PV market information**

	2022
Number of PV systems in operation in your country	Total installed 87.41GW except for Distributed PV 51.1GW ; utility PV 36.3GW.
Decommissioned PV systems during the year [MW]	N/A
Repowered PV systems during the year [MW]	N/A

Table 5: PV power and the broader national energy market

	Data (2021)	Year (2022)
Total power generation capacities [GW]	2380 GW	2564GW
Total renewable power generation capacities (including hydropower) [GW]	1120 GW	1213GW
Total electricity demand [TWh]	8300 TWh	8640 TWh
New power generation capacities installed [GW]	176.3 GW	199.74GW
New renewable power generation capacities (including hydropower) [GW]	134.02 GW (hyd. 23.49 GW, wind 47.57 GW, PV 54.88 GW, Bio 8.08 GW)	152.25GW (hyd. 23.87 GW, wind 37.63 GW, PV 87.41 GW, Bio 3.34 GW)
Estimated total PV electricity production (including self-consumed PV electricity) in [TWh]	325.9 TWh	432 TWh
Total PV electricity production as a % of total electricity consumption	3.9%	5%
Average yield of PV installations (in kWh/kWp)	1300 kWh/kWp	1500 kWh/kWp



2 COMPETITIVENESS OF PV ELECTRICITY

2.1 Module prices

Table 6: Typical module prices

Year	Lowest price of a standard module crystalline silicon (optional)		Highest price of a standard module crystalline silicon (optional)	Typical price of a standard module crystalline silicon (mandatory)
2022	N/A		N/A	1.9 Yuan/W

2.2 System prices

Table 7: Turnkey PV system prices of different typical PV systems

Category/Size	Typical applications and brief details	Current prices [Yuan/W]
Residential BAPV 5-10 kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity to grid-connected households. Typically roof-mounted systems on villas and single-family homes.	4.2
Small commercial BAPV 10-100 kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity to grid-connected commercial buildings, such as public buildings, multi-family houses, agriculture barns, grocery stores etc.	4.0
Large commercial BAPV 100-250 kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity to grid-connected large commercial buildings, such as public buildings, multi-family houses, agriculture barns, grocery stores etc.	3.8
Industrial BAPV >250 kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity to grid-connected industrial buildings, warehouses, etc.	3.5
Small centralized PV 1-20 MW	Grid-connected, ground-mounted, centralized PV systems that work as central power station. The electricity generated in this type of facility is not tied to a specific customer and the purpose is to produce electricity for sale.	3.8
Large centralized PV >20 MW	Grid-connected, ground-mounted, centralized PV systems that work as central power station. The electricity generated in this type of facility is not tied to a specific customer and the purpose is to produce electricity for sale.	3.6



Table 8: National trends in system prices for different applications

Year	Residential BAPV Grid-connected, roof-mounted, distributed PV system 5-10 kW [Yuan/W]	Small commercial BAPV Grid-connected, roof-mounted, distributed PV systems 10-100 kW [Yuan/W]	Large commercial BAPV Grid-connected, roof-mounted, distributed PV systems 100-250 kW [Yuan/W]	Centralized PV Grid-connected, ground-mounted, centralized PV systems 10-50 MW [Yuan/W]
2022	4.2	4.0	3.8	3.6



2.3 Financial Parameters and specific financing programs

Table 9: PV financing information in 2022

Different market segments	Loan rate [%]
Average rate of loans – residential installations	4.9%
Average rate of loans – commercial installations	3.5%
Average cost of capital – industrial and ground-mounted installations	4%

2.4 Specific investments programs

In 2022, the new installed capacity of distributed PV accounted for more than 58%. Unlike the centralized PV power plant investment main body, distributed PV project development main body is a private enterprise. Due to the small scale of distributed projects alone, financial leasing is the most suitable financing method. For example, Huaneng Tiancheng Financial Leasing, Huaxia Financial Leasing, as representatives of leasing organizations, had financed distributed PV projects for more than 100 billion yuan.

In addition, In 2022, the amount of domestic PV power plants for sale project reached 1.79GW, and the transaction value reached 5.9 billion yuan. PV power plant acquirers are mainly state-owned energy organizations such as SPIC, CHN Energy, Huadian Corporation, Huaneng Renewables etc., of which SPIC acquired the scale of 820MW, accounting for 46% of the total scale.

2.5 Merchant PV / PPA / CPPA

N/A

2.6 Additional Country information

Table 10: Country information

Retail electricity prices for a household [Yuan/W] (mandatory)	0.56-0.62
Retail electricity prices for a commercial company [Yuan/W] (mandatory)	0.50-1.25
Retail electricity prices for an industrial company [Yuan/W] (optional)	0.40-1.80
Liberalization of the electricity sector	Explain in a few lines whether the electricity market is liberalized or not and how.



3 POLICY FRAMEWORK

This chapter describes the support policies aiming directly or indirectly to drive the development of PV. Direct support policies have a direct influence on PV development by incentivizing or simplifying or defining adequate policies. Indirect support policies change the regulatory environment in a way that can push PV development.

Table 16 instructions: in the table below, mark “yes” if there are measures within this category on-going or commenced in your country. If not such measure exists in your country, leave the “-”.

Table 11: Summary of PV support measures

Category	Residential		Commercial + Industrial		Centralized	
	On-going	New	On-going	New	On-going	New
Measures in 2022						
Feed-in tariffs	Yes	-	Yes	-	Yes	-
Feed-in premium (above market price)	-	-	-	-	-	-
Capital subsidies	-	-	-	-	-	-
Green certificates	Yes	-	Yes	-	Yes	-
Renewable portfolio standards with/without PV requirements	Yes	-	Yes	-	Yes	-
Income tax credits	-	-	-	-	-	-
Self-consumption	Yes	-	Yes	-	-	-
Net-metering	-	-	-	-	-	-
Net-billing	-	-	-	-	-	-
Collective self-consumption and delocalized net-metering	-	-	-	-	-	-
Sustainable building requirements	-	-	-	Yes	-	-
BIPV incentives	-	-	Yes	- Yes	-	-
Merchant PV facilitating measures	-	-	-	-	-	-
Other (specify)	-	-	-	-	-	-



3.1 National targets for PV

In 2022, China's intelligent manufacturing and modernization of the PV industry accelerated via a steady and positive development throughout the whole year. This strongly supported approaching the goal of "carbon emissions peak and carbon neutrality", via five key channels of progress: industry scale, innovation, intelligent manufacturing, market growth and subsidy phase-out.

Firstly, the industry scale continued to increase and the output of the PV industry chain set new records in 2022. The production of polysilicon, wafers, cells and modules reached 827 000 tons, 357 GW, 318 GW and 288.7 GW, respectively. This marks a 58.8% year-on-year increase, with the industry's total output value exceeding 1.4 trillion RMB.

Secondly, the innovation of technology improved quickly. The P-type PERC cell average conversion efficiency of the mainstream enterprises in 2022 reached 23.2%. The N-type TOPCon cell technology impacted the scale of mass production, and the average conversion efficiency increased to 24.5%. The output of HJT cells accelerated and the conversion efficiency created a new world record of 26.81%. The research and production lines of perovskite and c-Si tandem solar cells have made new breakthroughs.

Thirdly, the demonstration of intelligent PV has achieved initial success. This refers to the blending and innovation of the PV industry and new information technology, which has been accelerated, including the timely expansion of the third batch of intelligent PV pilot demonstrations. The total systematic solutions of industry, buildings, transportation, agriculture and energy were frequently in focus, and the levels of PV industry intelligent manufacturing, intelligent operation and maintenance, intelligent scheduling and PV/storage hybrid implementation were significantly improved.

Fourthly, the domestic market applications grew continuously. The utility PV base as well as the distributed PV market steadily improved throughout 2022. The new installed capacity of 2022 domestic PV was more than 87 GW, which can effectively support the growth of both domestic and foreign PV markets.

Fifthly, the green certificate trade & market gradually improved while the PV market became fully independent of subsidies in 2022. The government has encouraged power users to sign green certification trading contracts with new energy enterprises for more than one year, locking in longer-term and stable price levels for new energy enterprises. By the end of 2022, 20.6 million green certificates had been issued, corresponding to 20.6 billion kWh of power, which was an increase of 135% compared to 2021. (Each green power certificate generated and traded corresponds to 1000 kWh of renewable power consumed, and renewable generators enterprises obtain the environmental value of green power by trading green certificates.)

China has a strong market reserve for PV power generation. The future development of distributed PV will be combined with the "Rural Revitalization Plan" and the "Clean Heating" national project. Additionally, in the distributed PV building market, the roof area of new buildings in public institutions will be installed to achieve PV coverage rate of 50% by 2025. At the same time, the construction of large PV bases in the Gobi desert region is developing fast. The first batch of wind and PV power bases (97 GW) had been all started by 2022, and by now the second batch of bases have also been started one after another.

It is estimated that China's new installed PV capacity will be 150GW by 2023.



3.2 Direct support policies for PV installations

3.2.1 Development measures of accommodation

Same as in 2021, the incentive policy 2022 of the renewable energy power accommodation continued the RPS responsibility, strictly implementing the requirements for the proportion of renewable energy power in the West-East power transmission and cross-provincial & cross-region power transmission. As for the 2022 non-hydro power accommodation increased by 1.25 percentage points from 2021.

China's energy conservation and emission reduction efforts have explicitly addressed the need to reduce energy consumption intensity and increase the resilience of total energy consumption management. In August 2022, a document from the National Energy Administration was issued, proposing that new renewable energy consumption could be deducted from the total energy consumption of each region in the assessment of energy-saving targets of each provincial government, and that governments and enterprises can utilize incremental consumption of renewable energy to meet the incremental energy demand of local new industries and new economic development. This policy reflects the orientation of green and low-carbon energy consumption from renewable energy to support the high-quality development of industry and economy after disruption.

3.2.2 Development measures of the construction and management PV installation

On large-scale PV base projects, the focus in 2022 was to promote construction of large-scale wind and PV power base projects in the desert, Gobi, desert areas. The first batch of 97GW base projects scheduled by the end of 2021 will be completed in 2022 and 2023, and most of these PV projects will be connected to the grid in 2023. The National Energy Administration announced the list of the second batch of base projects, which have been started one after another in 2022.

The distributed PV is a multi-pronged approach of "County-Scale PV Promotion", industrial and commercial distributed, and residential PV. With the advancement of the power market and the adjustment of time-sharing tariff policy, more "PV+" fusion industry and business models will appear. For most of the central and eastern provinces, renewable energy is not included in the energy consumption control policies, RPS responsibility and the backdrop of declining PV product prices all contribute to the advancement of distributed projects.

3.2.3 Development measures of Feed-in tariffs

With the end of national feed-in tariff subsidies for residential PV in 2022, PV power generation achieves full grid-parity. The feed-in tariffs for newly filed PV projects are in accordance with local coal benchmark prices. But at the end of 2022, as individual provinces such as Shandong and Hebei, set the daytime noon, when PV power output is at its maximum, as a deep valley tariff (with feed-in tariffs of only a few cents per kWh), which significantly affected the tariff revenue of both existing and new items.

3.2.4 Development measures of PV energy storage

For new PV projects, energy storages were required from 2022. Most provinces required 15-20% capacity, 2 hours of electrochemical storage. New energy storage business models are encouraged to be stand-alone storage or to participate in electricity market trade in conjunction with owned power sources.



3.2.5 Development measures of Green Certification

Green certificate issuance expanded to all renewable energy in 2022. For the policy environment in which new renewable energy consumption is not included in the total energy consumption control of each region, green certificates are the only vouchers that recognize renewable energy electricity. Green certificates are issued by the national unified green certificate qualified platform, and the code of the certificate contains information on the technology category, project information, electricity output, time and so on.

In 2022, driven by the "Carbon Peak & Carbon Neutrality" policy, the domestic demand for green certificates expanded rapidly and the trading volume increased, which played a role in promoting green power consumption and consumption.

By the end of 2022, the cumulative number of green certificates subscribed reached 10.31 million papers, and in December 2022, the average price of green certificates for affordable PV power generation was (1 MWh) 41.2 yuan.

3.2.6 BIPV development measures

From 2019, the Chinese government started to support BIPV from energy and environmental policies. In March 2022, Ministry of Housing and Urban-Rural Development of PRC unveiled 《Green Buildings and Energy Efficiency Development Plan for the 14th Five-Year Plan Period》 (2021-2025), proposing "BIPV Action", to actively promote the distributed and integrated application of PV in urban and rural buildings as well as in municipal utilities. It's expected to install more than 50GW of new BIPV during the 14th Five-Year Plan period. Under the support of relevant policies of the state and provinces and cities, BIPV shows a good development trend, and PV modules also develop in the direction of building materials and components.

3.2.7 Merchant PV development measures

In May 2022, the State Council of PRC issued 《the Notice on the Implementation Program for Promoting the High-Quality Development of New Energy》, which explicitly proposed to improve the fiscal and financial policies to support the development of new energy. Firstly, it should optimize the use of financial funds, and utilize the National Renewable Energy Development Fund; Secondly, it should improve the financial support measures, and support eligible financial institutions to provide green loans to meet the capital needs of new energy enterprises; Thirdly, it is necessary to enrich green financial products and services, increase the support of green bonds and green credit for new energy projects, and explore the inclusion of new energy projects in the REITs support pilot.



3.3 Self-consumption measures

Table 12: Summary of self-consumption regulations for small private PV systems in 2022

PV self-consumption	1	Right to self-consume	Yes
	2	Revenues from self-consumed PV	Savings on the electricity bill + bonus (some provincial level)
	3	Charges to finance Transmission, Distribution grids & Renewable Levies	Yes
Excess PV electricity	4	Revenues from excess PV electricity injected into the grid	Yes
	5	Maximum timeframe for compensation of fluxes	Real-time
	6	Geographical compensation (virtual self-consumption or metering)	None
Other characteristics	7	Regulatory scheme duration	20 years
	8	Third party ownership accepted	None
	9	Grid codes and/or additional taxes/fees impacting the revenues of the prosumer	None
	10	Regulations on enablers of self-consumption (storage, DSM...)	Yes
	11	PV system size limitations	6 MW
	12	Electricity system limitations	None
	13	Additional features	None

3.3.1 Development measures of green Electricity demands

From 2022, the government proposes that new renewable energy is not included in the total energy consumption control and the low-carbon renewable electricity is encouraged to be used. This is an important means for governments to reach the assessment goal of "energy consumption control+ carbon emission control" policy. As a result, enterprises are encouraged to self-consume PV green power.

In June 2022, with the development of CBAM, many domestic export enterprises, in order to avoid the carbon tax, use PV green power, and install distributed PV to increase the proportion of self-consumption of PV green power. The above policy has increased the application of commercial and industrial distributed PV and green power self-consumption.



3.4 Collective self-consumption, community solar and similar measures

3.4.1 Development measures of power generation, transmission, loading, and storage integration

In 2022, China's PV power integration continued to improve, with the annual PV power accommodation rate reaching 98.3%, up 0.3 percentage points year-on-year. The government accelerated the construction of the electricity market and actively promoted the participation of emerging players in market-oriented transactions. Such as Shanxi Province Energy Administration issued the first "power generation, transmission, loading, and storage integration management measures" and "virtual power construction and operation management implementation measures", to clarify the access standards, operation and revenue model of the virtual power, forming an operational power generation- transmission-loading-storage integration experience.

3.5 Tenders, auctions & similar schemes

In November 2022, a new version of the Measures for the Development and Construction of PV Power was released, with core elements: PV power generation projects have a unique identification code for lifecycle monitoring through archiving; The capacity of PV power should be filed in accordance with AC in principle; PV power should obtain an electricity business license within six months of grid connection; Grid enterprises should improve internal approval processes, and enhance power generation and transmission coordination; Encourage PV power plants to rebuilt, proposing that the modules' efficiency of the existing power plants should reach the benchmark level (16% for monocrystalline modules and 15% for polycrystalline modules), to promote the upgrading and rebuilding of the existing power plants, and the modules' efficiency of the new projects fully reach the benchmark level (20.5% for monocrystalline modules and 17% for polycrystalline modules).

3.6 Other utility-scale measures including, floating and agricultural PV

3.6.1 Development measures of offshore PV

In 2020-2022, China successively released offshore PV support policies. Seven coastal provinces began to shift their PV application to offshore, and successively released specific measures to support the development of offshore PV. For example, Shandong Province released a total planning installed capacity of 42GW, of which 11.25GW of offshore PV is planned for 2022. Adopt fishery/PV hybrid and Wind/PV hybrid to accelerate the development of pile-fixed offshore PV project, which is expected to reach capacity of over 3GW. At the same time, considering the layout of offshore wind power sites, start floating PV demonstration, to create a "wind and PV hybrid " integrated development model.



3.7 Social Policies

2022 is the first year that China's residential PV grid parity. According to the data released by the National Energy Administration, in 2022, the new installation of residential PV is 25.25GW, a year-on-year growth of 17%, accounting for 29% of the annual new installation. By the end of 2022, China's residential PV cumulative installation is 67GW, while the new additions of national residential PV project amounted about 1.022 million households, and the cumulative installation is about 3.446 million households. The average single-household capacity of new residential PV installations in China in 2022 is 24.9kW. The main business models include full self-investment by the head of household, bank loans, cooperative construction, operational leasing and financial leasing currently, with the leasing model accounting for more than 95% .

3.8 Retroactive measures applied to PV

By the end of 2022, as the new energy penetration further increases and the spot market is carried out, the net load trough phenomenon of the midday power occurs in some provinces. Midday power supply exceeds demand, leading to midday time-share tariff adjustments, such as Shandong and Hebei setting the deep valley tariff during daytime peak PV power output, with the feed-in tariff is only a few cents per kWh, which greatly affects the tariff revenue of existing and new projects, as well as drop revenue of self-consuming industrial and commercial distributed PV projects. But this adjustment has brought about a market space for PV energy storage.

3.9 Indirect policy issues

3.9.1 Rural electrification measures

In June 2022, the National Development and Reform Commission, the National Energy Administration and other nine ministries and commissions jointly issued a plan, presenting that vigorously promote the integration of PV power generation multi-scene development, and implement the "Thousands of PV households Program", coordinating rural roofs with conditions or rural centralized sites to carry out distributed PV, and build about 1,000 PV demonstration villages, which is the important way to achieve China's rural revitalization.

3.9.2 Support for electricity storage and demand response measures

2022, China's PV energy storage develops fast, more than 20 provinces have issued new energy storage policy. The new installed capacity of PV energy storage projects commissioned in 2022 reaches 2,204 MW/4,520 MWh.

The utility PV base installed capacity of 30GW, should configure the proportion of energy storage for 10-20% and duration of energy storage for 2-4 hours. Distributed PV midday generation period is valley tariff. When the PV power generation exceeds the load at midday, the excess power is fed to the grid at a lower price. Therefore, distributed PV projects installed with energy storage can transfer the PV power generation at midday to the high tariff period for self-consumption or fed back to the grid through energy storage, which enhances the revenue of the project.

In addition, the existing power plants energy storage is also worthy attention. In certain western provinces, PV penetration has accounted for more than 30%, becoming the main power source.



But the PV utilization is still very low, existing the curtailment of solar, so the government introduced the existing PV energy storage policy with PV Power Guaranteed Acquisition for more generation hours and hourly trading opportunities.

3.9.3 Support for encouraging social acceptance of PV systems

The government, associations and enterprises work together to improve the public awareness of PV through workshops and popularization of science, such as LONGi's slogan "SOLAR FOR SOLAR, SOLAR FOR ALL", and the Tsinghua University team's nationwide publicity tour and research on "1 kW per capita".

3.9.4 Other support measures

In August 2022, the U.S. Inflation Reduction Act (IRA) went into effect. With the introduction of implementation rules in 2023, the global PV industry chain is being reshaped. The IRA-like policies of other countries have been introduced one after another, directly affecting the overseas layout of China's PV industry.

In 2022, the European Union launched The European Green Deal, and put forward the "Sustainable Product Initiative" (SPI), which is consistent with Chinese PV industry concept of green manufacturing. There is substantial progress in Ecodesign, PV module recovery and recycling in 2022.

3.10 Financing and cost of support measures

The tariff surcharge collected in 2022 is nearly 10 billion (RNB) for renewable energy tariff subsidies. The State Grid and the Southern Power Grid have set up the Beijing and Guangzhou Renewable Energy Development Settlement Service Co., Ltd. respectively, to co-ordinate and resolve the issue of renewable energy power generation subsidies. The principle of the establishment of the two companies is to undertake policy-oriented operations and, on the basis of State financial allocations, subsidize the funding gap, which will be resolved through special financing in accordance with market-oriented principles. In addition, green certificates and RPS are all playing a role in bridging the subsidy funding gap.

3.11 Grid integration policies

In 2022, the national utilization rate of PV power generation reached 98.3%, basically the same as the previous year. Mainly because:

First, Policy Guarantee. Adhere to the coordinated development of installed capacity and accommodation rate, put 5 hydro-pumped storage plants into operation and start 6 new projects, plus new energy storage and other means to ensure the renewable energy accommodation.

Second, the layout and structure continue to be optimized. The utility PV base and the distributed PV are emphasized. Planning guidance the new installations of utility PV base mainly layout to North, Northeast and Northwest, the distributed PV mainly layout to East, South and Central China. In practical terms, it is seen that 70% and 90% of the new utility PV base and the distributed PV, respectively, are within the scope of the plan.



Third, strengthening the construction of power grids and improving their balancing and regulating capacity. In 2022, completed the new energy supporting power grid project investment of more than ten billion yuan, completed a number of ultra-high voltage transmission projects, and improved the cross-provincial allocation capacity of new energy power, which improved the accuracy of new energy power forecasting and deepened Demand Side Responds on the load side.



4 INDUSTRY

4.1 Production of feedstocks, ingots and wafers (crystalline silicon industry)

Table 13: Silicon feedstock, ingot and wafer producer's production information for 2022

Manufacturers (or total national production)	Process & technology	Total Production	Product destination	Price
Total	Silicon feedstock [Tonnes]	116.6.*10 ⁴	Sichuan, Inner Mongolia, Yunnan, Jiangsu, Qinghai, etc.	(optional)
Total	mc-Si ingots [GW]	600	Hebei, Jiangsu, Henan, Inner Mongolia, Ningxia, Yunnan, Sichuan	(optional)
Total	mc-Si wafers [GW]	650.3	Hebei, Jiangsu, Henan, Inner Mongolia, Ningxia, Yunnan, Sichuan	(optional)

Source : CPIA,2023.5

China's PV manufacturing scale maintains rapid expansion in 2022. There are 14 Chinese polysilicon enterprises in production, with an effective capacity of 1.166 million tons, and the capacity of the top ten enterprises accounted for 88%; polysilicon production reached 857,000 tons, an increase of 69.4% year-on-year, and the top one in terms of production is Sichuan Tongwei. Wafer production was 371.3GW, up 63.9% year-on-year.



4.2 Production of photovoltaic cells and modules (including TF and CPV)

Total PV cell and module manufacture together with production capacity information is summarised in Table below.

Table 14: PV cell and module production and production capacity information for 2022

Cell/Module manufacturer (or total national production)	Technology (sc-Si, mc-Si, a-Si, CdTe, CIGS)	Total Production [MW]		<u>Maximum</u> production capacity [MW/yr]	
		Cell	Module	Cell	Module
Wafer-based PV manufactures					
Sichuan Tongwei	mc-Si	A 49.2*10 ³		B 70*10 ³	
Longi Green Energy	mc-Si	36.2*10 ³	48.2*10 ³	50*10 ³	85*10 ³
Aiko solar	mc-Si	33.7*10 ³		36*10 ³	
Trina Solar	mc-Si	33.6*10 ³	45.4*10 ³	50*10 ³	65*10 ³
Jinko Solar	mc-Si	32.7*10 ³	43.9*10 ³	55*10 ³	70*10 ³
JA Solar	mc-Si	31.5*10 ³	40.1*10 ³	40*10 ³	50*10 ³
Thin film manufacturers					
Hanergy	CIGS			600	
Sun Harmonics	CIGS			100	
CNBM(Chengdu)Optoelectronic Materials	CdTe			150	
Advanced Solar Power (Hangzhou)	CdTe			120	
Cells for concentration					

Source : CPIA,2023.5



In 2022, the total cell production capacity of mainland China reached 505.5GW, a year-on-year growth of 40.2%, and the output was about 330.6GW, a year-on-year growth of 67.1%. PV cell n-type technology advantage was obvious, TOPCon capacity layout accelerated. By the end of 2022, China already had about 15 PV companies with TOPCon capacity and more than 12 with HJT. In addition, cell companies reduced the amount of silver by developing multi-BusBar technology. P-type cells was changed from 9BB to 11BB and 16BB in 2022. Cells have shifted to larger sizes, and from the wafer size it appears that 182mm+210mm accounted for 45% of the total in 2021, and had jumped to 82.8% by 2022.

In 2022, the total production capacity of PV modules in mainland China reached 551.9GW, and the total production reached 294.7GW. Module power was further improved, mainstream products reached more than 500+W, and the unification of module size became the key. Based on M10 silicon wafers, the mainstream 72 cell module size was 2278*1134mm; based on G12 silicon wafers, the mainstream 60-cell module size was 2172*1303mm. The share of bifacial modules was 37.4% in 2021, and the share increased to 40.4% in 2022.

Different application scenarios have given rise to different types of PV modules. Coastal mudflats and offshore PV plants drive the development of modules with salt spray, corrosion and wind resistance properties. Northwest desert PV plant pushes the development of modules adapted to high day/night temperature differences and strong UV protection. PV plants in wastewater plant and mountainous drive the development of modules with flexible support structure. The integration of PV buildings promotes the development of modules with building materials and colorful module.

In 2022, China's PV product exports totaled about \$51.25 billion, an increase of 80.3% year-on-year. Among them, the export value of wafers was \$50.7 billion, and the export quantity was about 36.3GW; The value of cell export was \$3.81 billion and the export quantity was about 23.8GW; The value of module exports was \$42.36 billion, a year-on-year increase of 72.1%, and the export quantity was about 153.6GW, a year-on-year increase of 55.9%. Module export value and quantity both hit record highs.

In 2022, China's new PV installed capacity reached 87.41GW, up 59.3% year-on-year, of which the utility PV base was 36.3GW and the distributed PV was 51.1GW. The distributed accounted for 58.5% and the installations accounted for more than half for two consecutive years. Among them, the residential PV new installation was 25.25GW.

4.3 Manufacturers and suppliers of other components

4.3.1 PV inverters (for grid-connection and stand-alone systems) and their typical prices

The brand pattern of China's domestic inverter industry had been basically formed in 2022, and there were about 20 more active enterprises. Among them, there were more than 18 enterprises with production over 5GW, including Sungrow, Huawei, Ginlong, Growatt, Goodwe and so on. Influenced by the significant increase in distributed installations, the inverter market developed to be dominated by string inverters, with its share rising to 78%. China's inverter exports was \$8.99 billion in 2022, up 75% year-on-year, with the largest market in Europe.

In 2022, China's distributed PV installed capacity continued to rise, and the international residential energy storage market was developing rapidly, although the core components chip, IGBT power devices and other overall incremental volume was still insufficient, but the supply had been eased, making the price of inverter products relatively stable.



4.3.2 Storage batteries

According to incomplete statistics from the National Energy Administration, by the end of 2022, the installed capacity of new energy storage projects had been put into operation nationwide amounted to 8.7 million kilowatts, with an average storage duration of about 2.1 hours, representing an increase of more than 110% compared with 2021.

Among the new energy distribution storage, the demand for PV project distribution storage was also strong in 2022, with the application of PV+storage projects taking up the most share. According to relevant organizations information, in 2022, the new PV energy storage project installation was 2204MW/4520MWh. Among them, the Xinjiang Autonomous Region had the strongest demand, and the Tibet Autonomous Region with the existing PV storage triggered the attention of the industry.

In 2022, among the installed new energy storage, lithium-ion battery storage accounted for 94.5% , compressed air storage accounted for 2%, liquid flow battery storage accounted for 1.6%, and lead-acid battery storage accounted for 1.7%.

4.3.3 Supporting structures

In 2022, module price increased, resulting in a lower cost share of other systems, and the cost of the support structure system (including foundation) and installations accounted for about 10%-12% of the investment cost of the power plant. The share of tracking support structure system in power plant systems will recover to 12-18% in 2023 compared to 2022. support structure and installation costs accounted for about 5.6-8% of the total investment in distributed commercial and industrial power plants.

Global shipments of leading tracking support structure companies are clustered in the U.S. and Europe. China accounted for three of the top fifteen, for Arctech, Versol Solar, Powerway. In 2022, the use of tracking system was the optimal choice in typical affordable ground-based utility PV base projects in China, which can bring considerable power generation gains.

4.3.4 BIPV products

With the support of relevant policies of the state and provinces and cities, the combined application of PV power generation system and building has shown a good development trend, and PV modules are also developing in the direction of building materialization and componentization. Many domestic manufacturers have also launched PV products that are integrated with buildings. For example, manufacturers of crystalline silicon-based PV modules for buildings, such as LONGi and Trina Solar, have developed rooftop PV components based on crystalline silicon-based technology to realize the integration of PV modules with building roofs and facades. CdTe thin-film PV module manufacturers such as Advanced Solar Power (Hangzhou) and CNBM (Chengdu) Optoelectronic Materials have also launched PV modules suitable for building facades, which can achieve colorful and patterns according to the needs of the building, and the adjustable light transmission of the modules can better meet the needs of indoor lighting.

In addition, Perovskite thin-film PV companies, based on the material advantages, developed PV module products with colors and textures that more closely matched architectural aesthetic requirements. These products are being gradually and steadily mass-produced, and the technical challenges of long product life and high stability are being solved.



5 PV IN THE ECONOMY

This chapter aims to provide information on the benefits of PV for the economy.

5.1 Labour places

Table 15: Estimated PV-related full-time labour places in 2022

Market category	Number of full-time labour places
Research and development (not including companies)	0.35 million
Manufacturing of products throughout the PV value chain from feedstock to systems, including company R&D	1.96 million
Distributors of PV products and installations	0.14 million
Other	0.35 million
Total	2.8 million



5.2 Business value

Table 16: Rough estimation of the value of the PV business in 2022 (VAT is excluded)

Sub-market	Capacity installed [MW]	Average price [Yuan/W]	Value	Sub-market
Off-grid	-	-	-	-
Grid-connected distributed	51100	4.78	244,258,000,000	-
Grid-connected centralized	36300	4.03	146,289,000,000	-
Value of PV business in 2022				390,547,000,000



6 INTEREST FROM ELECTRICITY STAKEHOLDERS

6.1 Structure of the electricity system

China is divided into three major power grid companies according to region, namely State Grid, China Southern Power Grid and Inner Mongolia Power Group. The operation area of State Grid Corporation of China covers 26 provinces (autonomous regions, municipalities directly under the Central Government) in China, and the power supply scope accounts for 88% of the land area. China Southern Power Grid covers five provinces and regions, and is connected with the power grids of Hong Kong, Macao and Southeast Asian countries. The power supply area is 1 million square kilometers, and the power supply population is 272 million. Inner Mongolia Power (Group) Co., Ltd. is a wholly state-owned super large power grid enterprise directly under the Inner Mongolia Autonomous Region. It undertakes the task of power supply for industrial, agricultural and animal husbandry production in eight cities (leagues) and urban and rural residents' lives of 14 million in the region, while supplying power to North China, Yulin in Shaanxi, and Mongolia across provinces, regions and borders.

In 2022, the proportion of China's power structure was as follows: thermal power accounted for the largest share of 66%, followed by hydropower, accounting for 15%; wind power accounted for 9%; PV power accounted for 5%; and nuclear power accounted for 5%.

6.2 Interest from electricity utility businesses

With the "Carbon Peak & Carbon Neutrality" target, the Chinese government announced that "accelerate a new type of power system that is clean and low-carbon, safe and abundant, economical and efficient, supply-demand synergistic, flexible and intelligent". By the end of 2022, China's installed capacity of wind power and PV power accounted for about 29.6% of China's total power capacity (10 years ago was 4.9%), and new energy generation accounted for 12.5% (10 years ago was 2%). China has built the world's largest and highest-voltage national interconnected power grid, the world's highest-voltage AC/DC transmission project, the world's first flexible DC grid and the world's largest electric vehicle charging network. The rapid development of the power system meets the needs of the rapid development of new energy sources such as PV.

At the same time, new technology such as virtual power plants, microgrids, hybrid energy systems, electric vehicles, etc., provided the possibility of loads transmission in time and space and controllability, and met the demand balance of the power system at different lever duration. The transmission grid composed of extra-high voltage AC and DC as the backbone, together with 500KV/750KV was continuously enhanced. In the process of increasing the degree of electrification in various industries, P2X technology has been widely noticed, in which renewable energy electrolysis of water to produce green hydrogen is a key technology for deep decarbonization of energy and power systems.

6.3 Interest from municipalities and local governments

Chinese provincial governments released the regional "14th Five-Year Plan" Renewable Energy Development Special Plan, putting forward the province's target of renewable energy installation before 2025. Among them, the plan clearly defined PV installation target, which



was the most important target to guide the provinces. For example, Jiangsu province proposed that before 2025, PV installed capacity will reach 35GW, which means that Jiangsu in the next few years, the new installed capacity will reach 10GW per year. Zhejiang province's new public buildings, new plant roof PV coverage will reach 30%, and the province's PV installed capacity will reach 27.5GW, of which the distributed installed capacity will reach half.



7 HIGHLIGHTS AND PROSPECTS

7.1 Highlights

In 2022, China's new installed capacity of PV, distributed and residential installed capacity made a new record in the total installed capacity. China's new installed PV capacity was 87.41GW, an increase of 59.3% year-on-year; of which, the distributed installed about 51.1GW, accounting for 60% of all new installations. Residential PV installation reached 25.3GW, up 16.9% year-on-year, accounting for 28.9% of all new installations. PV power generation amounted to 427.6 billion kWh, a year-on-year increase of 30.8%. The average utilization rate of PV power generation reached 98.34%, basically the same as last year.

In 2022 China had many achievements in the field of PV core technology research and development, refreshing the laboratory efficiency of crystalline silicon cells 14 times (including 10 times for n-type cell technology) and made the world's highest record for silicon-based solar cell efficiency of 26.81%.

Capital market boosted PV development in 2022 with 15 companies listed.

7.2 Prospects

Guided by the national goals of achieving "carbon peak" by 2030 and "carbon neutrality" by 2060, the Chinese government has made it clear that by 2030 China's non-fossil energy sources will account for 25% of primary energy consumption; and that the total installed capacity of wind power and PV will reach more than 1,200GW. By then, wind and PV power installations will exceed coal power, with an installed capacity of 30-40%, becoming the first major power source. The share of wind and PV power generation will reach 17-25%.

China's new PV installations are forecast to reach 150-180GW in 2023.

