

# Solar PV Market Research and Industry Competition Report

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**Abstract.** Solar Industrial scale continues to expand. The world installed photovoltaic capacity gradually increased from 135GW in 2013 to 480GW by the end of 2018, achieved 3.5 times growth during five years. There will be still have space for price reduction. With the development of solar cell structure design, micro-nano laser precision machining and other technologies, the per-kilowatt cost of photovoltaic power generation has entered decline channel, and it is expected to realize the affordable online in the future. According to IHS, the price difference between PERC single crystal components and polycrystal components is \$0.055 per watt. Industrial technology has made obvious progress, and single crystal PERC has become the mainstream. The efficiency of the cell is breaking new records. The conversion efficiency of ordinary single-crystal and polycrystalline cells has reached 20.2% and 18.6% respectively, and the efficiency of high-efficiency batteries has reached 21.3% and 19.2% respectively. According to data released by Solarbe, the single crystal PERC technology performs best in cell conversion efficiency and output power compared with other technologies. In the next four years, China's market growth will remain stable at 40-50GW. IHS Markit forecasts that the global market size is expected to remain stable at 100-120GW from 2018, while the growth of the Chinese market will remain stable at 40-50GW in the next four years.

**Keywords:** Solar energy; renewable; pv market; industrial technology; investment factors; component selection.

## 1. Overall development of the global photovoltaic industry

### 1.1. Industrial scale continues to expand

The international energy agency released the report "statistics 2019 on installed capacity of renewable energy"[1], which shows that pv is developing rapidly. The total installed pv capacity in the world increased from 135GW in 2013 to 480GW by the end of 2018, achieved a 3.5-times growth in five years. In 2017, the production scale of all links of the global photovoltaic industry chain has been growing continuously. In terms of polysilicon, global production reached 442,000 tons in 2017, up 19.5% per year. China's output of 242,000 tons increased 24.7 percent per year, ranking first in the world for seven consecutive years. In terms of silicon wafers, the global output reached 105.2GW, up 40.6% per year. The production of silicon wafers in China was 91.7GW, up 41.5% per year. In terms of batteries, the global output was 104.3GW, up 39.1% per year; China's output of 72GW, up 41.2%



per year, remains the largest producer of solar cells. In terms of components, the global component output reached 105.5gw, up 35.4% per year; China's output was about 75GW, up 39.7% per year.

### 1.2. There will be still have room for price reduction

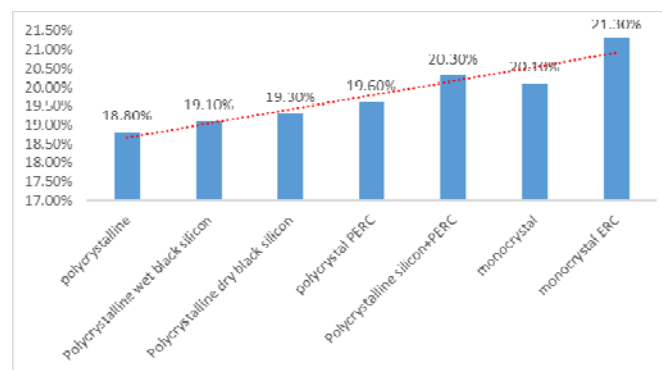
With the development of solar cell structure design, micro-nano laser precision machining and other technologies, the per-kilowatt cost of photovoltaic power generation has entered a decline channel, and it is expected to realize the affordable online in the future. In 2018, global pv module prices fell 32 percent and inverters 18 percent [2].

Polycrystalline silicon has always been the mainstream choice in the global solar cell market due to its simpler manufacturing process and lower price than single crystal. In the past two years, the cost gap between monocrystalline silicon and polycrystalline silicon has gradually narrowed, and the market share of monocrystalline silicon began to rise.

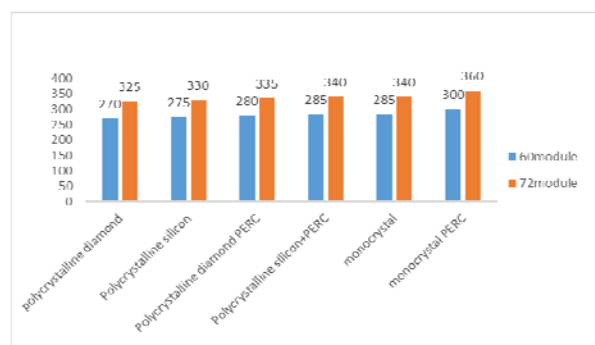
### 1.3. Industrial technology has made obvious progress, and single crystal PERC has become the mainstream

At present, the efficiency of the cell has reached new heights, and the laboratory efficiency has been advanced continuously. The conversion efficiency of ordinary single-crystal and polycrystalline cells has reached 20.2% and 18.6% respectively, and the efficiency of high-efficiency batteries has reached 21.3% and 19.2% respectively. The development of heterogeneous junction (HIT), back electrode (IBC), N - type double - sided technology has been accelerated. In terms of system links, tracking system, 1500V system and other technologies have been more and more widely used in the construction of photovoltaic power stations.

According to the data released by Solarbe [3], the efficiency level and module power of the mainstream solar cells in the market in 2018 are shown in the figure below.



**Fig. 1** efficiency level of mainstream silicon solar cells in 2018 market



**Fig. 2** power level of mainstream silicon solar modules in the 2018 market

**Table. 1** The test results of PV Magazine

Company		Jolywood	Risen	NSP	LONGi	LONGi	Aiduo	Aiduo
Module type		JW-D60N-305	RSM60-6-270P	D6M305E3A	LR6-60PE-310M	LR6-72BP-360M	AD280-60S	AD265-60P
module model and characteristics		Mono n-Pert double glass bifacial	Poly	Mono PERC	Mono PERC	Mono PERC BIFACIAL	Mono	Poly
Date of publication		17-Sep	17-Nov	18-Feb	18-Mar	18-Mar		
Time of test		Aug 2017 to Oct 2017	Aug 2017 to Oct 2017	18-Jan	18-Feb		17-Jul	17-Jul
Power		305*	270	310	310	360	280	265
Cell		60	60	60	60	60	60	60
Poly			x					x
Mono				x	x	X	x	
Perc				x	x	X		
Pert		x						
p-type			x	x	x	X	x	x
n-type		x						
double glass		x				X		
framed			x	x	x	X	x	x
bifacial		x				X		
1,000 V			x	x	x		x	x
1,500V		x				X		
<b>Average Grade</b>		<b>81</b>	<b>76</b>	<b>81</b>	<b>87</b>	<b>78</b>	<b>66</b>	<b>67</b>
Grade Weights	Visual inspection (10%)	46	75	100	100	100	63	100
	EL image inspection (10%)	100	77	100	100	100	100	61
	Low irradiance efficiency loss (25%)	89	73	82	75	57	63	62
	Pmax temperature coefficient (25%)	78	72	66	81	83	56	56
	PID loss (30%)	81	81	81	93	77	67	72

#### 1.4. In the next four years, China's market growth will remain stable at 40-50gw

In the past eight years, China's photovoltaic industry has grown at an unprecedented rate, with a cumulative installed capacity of 175GW. State subsidies have stimulated the growth of the domestic market, while also rapidly strengthening the domestic manufacturing base. IHS Markit forecasts that the global market size is expected to remain stable at 100-120gw from 2018, while the growth of the Chinese market will remain stable at 40-50gw in the next four years.

## 2. Performance Testing of some manufacturers' Modules

### 2.1. PV Magazine tested some products of different manufacturers

PV Magazine is designed to help investors to test the main performance of products during the purchase of photovoltaic modules, and to guide manufacturers to improve production according to product testing problems. The test was conducted at GSolar laboratory in xi 'an, China. In order to ensure the quality of the test, PV Magazine selected CEA as an independent third-party expert to monitor all steps of the test procedure. The test results are shown in the following table [4] :

The test results show that the lr6-60pe-310m product of longkiloye company has the highest score and the best performance under the same test conditions. Ad280-60s products of aido company have the lowest score and the worst performance.

### 2.2. PV Magazine published the test results of different outdoor technical materials in February 2019

This test was published by PV Magazine in February 2019 in xi 'an, China. It was a performance test for different technical materials of individual manufacturers.

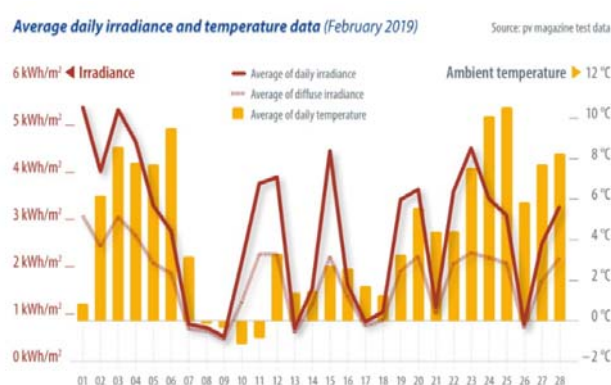


Fig. 3 Average daily radiation and temperature of the test site

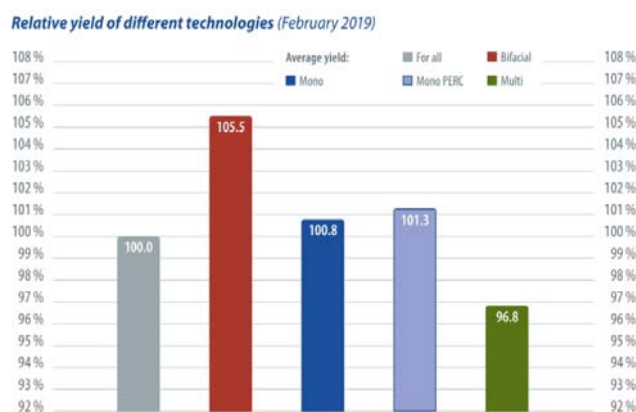


Fig. 4 relative yields between materials with different technologies

In conclusion, under the same irradiance and temperature conditions, the battery module technology with double-sided single crystal PERC has the highest output capacity compared with other technical products.

### 2.3. TUV certified laboratory in Germany

The following test results are publicly released by the German TUV certification laboratory. The test is initiated by the manufacturer and funded voluntarily. The fair and transparent test is conducted for their products under the same experimental conditions [5].

Results	Schott Solar SCHOTT POLY 290	Sharp NU-180E1	Mitsubishi Electric PV-TD185MF5	Conergy PowerPlus 225P	Sovello SV-X-195-fa1	Perfect Solar PS230-6P-TOP
Made in	Germany	Japan	Japan	Germany	Germany	Germany/OEM (original manufacturer in Taiwan)
Size (millimeters)	1,685 mm x 1,281 mm x 50 mm	1,318 mm x 994 mm x 46 mm	1,658 mm x 834 mm x 46 mm	1,651 mm x 986 mm x 46 mm	1,650 mm x 951 mm x 46 mm	1,663 mm x 997 mm x 39 mm
Weight	41.5 kg	16.0 kg	17.0 kg	19.6 kg	18.6 kg	22.0 kg
Cell type	Polycrystalline 6-inch cells	Monocrystalline 6-inch cells	Polycrystalline 6-inch cells	Polycrystalline 6-inch cells	String-ribbon cells	Polycrystalline 6-inch cells
Module type	glass/EVA/cells/EVA/glass	glass/EVA/cells/EVA/foil	glass/EVA/cells/EVA/foil	glass/EVA/cells/EVA/foil	glass/EVA/cells/EVA/foil	glass/EVA/cells/EVA/foil
Specified performance	290 watts	180 watts	185 watts	225 watts	195 watts	230 watts
Output tolerance (negative, positive, in percent)	(-0%, not specified)	(-5%, +10%)	(-3%, not specified)	(0%, 2.5%)	(0%, +2.6%)	(-3%, +3%)
<b>Individual evaluation</b>						
Performance parameters (20%)	+++	+	+	+++	++	+
Aging behavior (25%)	+++	++	++	+	+	+
Documentation (15%)	+++	+++	+++	+++	+++	+
Electrical safety (25%)	+++	+++	+++	+++	++	++
Processing (10%)	++	+++	+	++	o	++
Warranty and ease of installation (5%)	+	+++	++	+++	+++	++
<b>Overall evaluation</b>						
Results within the requirements of IEC 61215 and IEC 61730	yes	yes	yes	yes*	yes	yes
Overall evaluation (maximum 100 points)	91.3	90.7	89.0	88.1	84.3	80.0
Scores	excellent (-)	excellent (-)	good (+)	good (+)	good	good (-)

**Fig. 5** The test results indicated that Schott Solar's SchottPOLY290 and sharp's nu-180e1 had the highest score and the best performance compared with other tested products.

## 3. Influencing factors of photovoltaic power station investment and main equipment selection

### 3.1. Factors influencing the investment of photovoltaic power station

The investment of photovoltaic power station varies greatly according to the specific situation of each power station. If the financial cost of the preliminary work is not considered, the main factors affecting the power station are as follows:

Voltage level and distance. The higher the voltage level, the higher the investment of sending and substation; Size. The larger the scale, the lower the investment per watt. Bracket installation mode. Fixed, different kinds of tracking, the difference of single watt investment is between 0 and 2 yuan /W (domestic price estimate). Site conditions. If it is a ground power station, the topographic and geological conditions of the site will have a great impact on the basic cost. If it is distributed, concrete roof and color steel tile roof bracket, the cost of the foundation is greatly different. Basic form. Concrete foundation, spiral steel pile foundation and floating foundation of different kinds are adopted. The difference of investment per watt is between 0 yuan and 2 yuan /W. Land costs (roof lease costs). It has a great impact on project investment, and the specific situation of different projects varies greatly.

### 3.2. Selection of photovoltaic equipment

Selection and arrangement of solar modules. Mainly consider the manufacturer's production scale, industry performance, manufacturing level, technology maturity, operational reliability, future technology development trend. A single photovoltaic module of the same area should be selected with a large peak power, so as to reduce the occupation area, reduce the line loss, the number of module installation, the use of integrated lines and the amount of construction. The whole power station should try to choose components of the same manufacturer, the same specification and the same batch to ensure relatively good efficiency consistency, and the attenuation rate of components is basically stable.

Support base and system selection. Bracket foundation selection. The main consideration is to meet the calculation requirements of foundation bearing capacity, foundation resistance to overturning, pulling and sliding, and to ensure the stability of the upper mechanism. At present, reinforced concrete independent foundation, reinforced concrete strip foundation and prestressed cement pipe pile foundation are mainly used in China. The main advantages of reinforced concrete foundation are that the construction is less difficult, the plane positioning of foundation and the top elevation of foundation are easy to control, and the anti-overturning and anti-sliding property is good, which can ensure the accuracy of the best inclination Angle. The disadvantages are long construction period, large ground damage, earthwork excavation, backfill, template configuration, rolling steel bar and other large quantities. The application of prestressed cement pipe pile foundation in places with relatively poor geological conditions, such as coastal beaches, is mainly characterized by pre-supported finished products, fast construction speed, less damage to the ground, and small amount of engineering; The disadvantage is that it requires high skills and experience of piling operators, and the foundation plane positioning and top elevation are not easy to control, which increases the workload and difficulty of later construction adjustment. The two forms have obvious advantages and disadvantages of interchangeability.

Selection and installation of inverter. For large and medium-sized grid-connected photovoltaic power station projects, large-capacity centralized grid-connected inverter is generally selected. Generally, the larger the capacity of a single inverter is, the lower the unit manufacturing price is and the higher the conversion efficiency is. The DC input range of the inverter should be wide, and it should have certain anti-interference ability and instantaneous overload ability when the solar radiation is low in the morning and evening. Under certain overvoltage, the system should be able to operate normally. In the case of failure, the inverter must be automatically de-aligned from the main network, and can be automatically re-connected after the system voltage and frequency return to normal through delay. The inverter should have AC overvoltage protection, undervoltage protection, overfrequency protection, underfrequency protection, anti-island protection, ac-dc overcurrent protection, overload protection and high temperature protection.

### 3.3. Comparison and analysis of system voltage of 1500V and 1000V

Since the 10th international solar energy industry and photovoltaic engineering exhibition was held in Shanghai, China in 2016, experts put forward that "from the perspective of the system, higher input and output voltage levels can reduce the ac and dc side line loss and transformer low-voltage side winding loss, and the system efficiency of the power station is expected to increase by 1.5% to 2%. At the same time, the power density of equipment (inverter, transformer) increases, the volume decreases, and the workload of transportation and maintenance also decreases, which is conducive to the cost reduction of photovoltaic system.

The Solar Utility Pro of Germany gaomi 1500V photovoltaic tester can find:

When the input voltage of the dc side is increased by 1500V, more components can be connected in series, reducing the number of parallel circuits, increasing voltage and reducing current to reduce power loss.

The use of dc side cables is reduced. At the same time, the unit power density of electrical equipment (bus box, dc cabinet, inverter) is increased, the workload of transportation, installation, maintenance and other aspects is reduced, and the cost of human resources is reduced.

Problems and challenges existing in 1500V:

Higher requirements for system security and reliability. The 1500V system requires higher safety performance. Direct current and alternating current are different. There is no zero crossing. In addition, the voltage of 1500V system will reduce the electrical reliability and increase the risks such as PID of photovoltaic modules.

More stringent requirements on parts technology and cooperation ability. For 1500V system voltage components, better quality, more stringent and demanding junction boxes, backboards, connectors, etc., and higher requirements for inverters, more complex topological structures and power devices with higher voltage levels as well as dc switching equipment are required.

With the popularity of the whole life cycle electricity cost, affordable access to the Internet and other concepts, the 1500V dc system has become the future development direction of the photovoltaic industry consensus, and from the perspective of the global market, the 1500V system has become a necessary condition for large photovoltaic projects to reduce cost and increase efficiency.

#### 4. Conclusions

##### *4.1. Single crystal PERC technology is adopted to achieve optimal output capacity*

According to the statistics of Solarbe photovoltaic network, single crystal PERC technology performs best in terms of cell conversion efficiency and output power. Meanwhile, according to PV Magazine certification institution, performance test of different technical materials in xi'an outdoor test field in February 2019 showed that the double-sided single-crystal PERC technology products were adopted in the same test field, and the relative productivity output was optimal compared with single-crystal silicon, polycrystal silicon and single-crystal PERC technology products.

##### *4.2. Reasonable selection of equipment types to ensure the design and operation life of 25 years*

The overall layout of photovoltaic power stations should be economical and convenient for maintenance. Choose photovoltaic modules with high efficiency, large power and stable performance, reasonably choose the arrangement mode of modules, choose bracket system and foundation according to engineering characteristics, choose appropriate cable section through cable length and capacity calculation, reduce line loss, reliable grounding system of the whole station, and all parameters should meet the design operation life of 25 years.

#### References

- [1] Information of the international energy agency report of 2019.
- [2] Information of IHS statistics 2016-2017 global component price trend.
- [3] The data released by Solarbe website.
- [4] The table of PV Magazine Test.
- [5] The data from TUV laboratory in Germany.