ASTRONERGY
A CHINT COMPANY

First Choice for Utility-scale Solar Plant

ASTRO 6

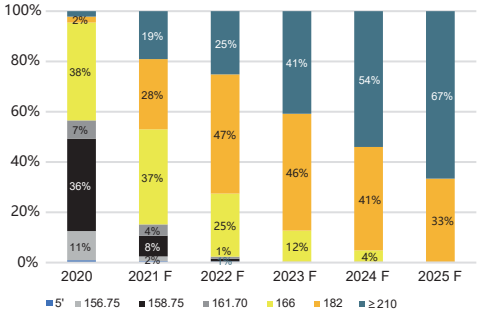
PRODUCT WHITE PAPER

CONTENTS

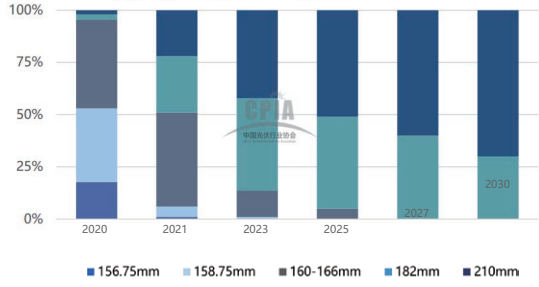
CONTENTS

01 Emergence Background

The global energy system is accelerating the transition to low carbon, and renewable energy such as photovoltaic (PV) power generation has become the mainstream direction of the global energy transition. Due to the continuous reduction of levelized cost of electricity (LCOE), the PV power generation has been sustainadly developed on a large scale, and it has become more competitive with fossil fuel power generation. All parts of the PV industrial chain have reduced LCOE through continuously technological innovation. Among them, high efficiency solar cell and module technologies emerge one after another, and silicon wafer is also undergoing significant changes. According to the forecasts of the industry organizations, the wafer size of crystalline silicon products will evolve to 182mm and 210mm. Therefore, combined with the future development trend of the PV industrial chain, the development of module products with lower LCOE will greatly promote the arrival of a fully parity era of PV power generation.



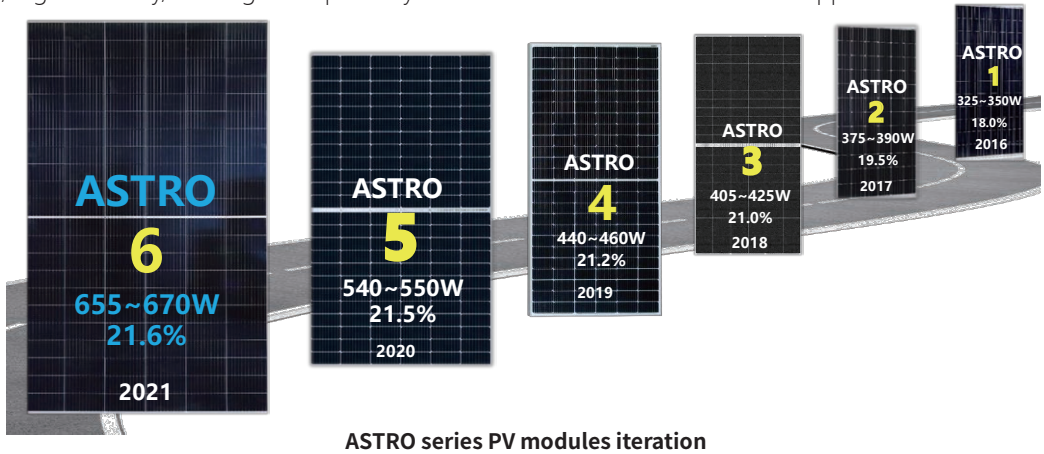
Source: PV InfoLink, August 2021



Source: China PV industry development Roadmap of CPIA 2020 version, April, 2021

Trend in the market share of modules with different wafer sizes

Astronergy (CHINT Solar) has been committed to the research and promotion of PV new technologies and products. The ASTRO series PV modules launched in recent years have achieved continuous breakthroughs in module power and efficiency. Last year, the 545W+ ASTRO 5 product with significantly reduced LCOE was innovatively launched. Its characteristics of high power, high efficiency, high reliability, and high compatibility make ASTRO 5 suitable for various application scenarios.



ASTRO series PV modules iteration

With the gradual improvement of the 210 industrial chain, Astronergy integrates the latest technological achievements and officially launches the ASTRO 6 series PV module products with high efficiency and high power for utility-scale solar power plants. ASTRO 6 further reduce the LCOE, and promote to an era of fully affordable PV power.

02 ASTRO 6 Characteristics

ASTRO 6 incorporates the advanced technologies such as G12 wafer, high efficiency mono-crystalline PERC+ solar cell, Multi-busbar (MBB) with half-cut cell, non-destructive cutting, high density encapsulation and double-layer coatings PV glass, and these technologies make ASTRO 6 have the characteristics of high power, high efficiency, high reliability, lower voltage, lower balance of system (BOS) cost and LCOE.

High Max. Power

610W/670W

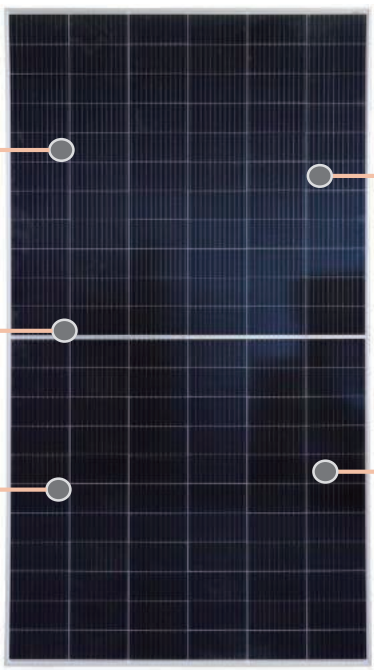
60/66 layout optional

High Module Efficiency

Max. 21.6%

High Quality

Mature design,
Longer warranty,
Lower degradation



Lower Voltage

Voltage decrease 8.3% per module. Compared to 166 module, string power is 64% higher, the number of strings decreases 39% at the same installed capacity.

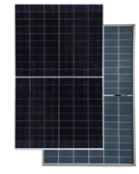
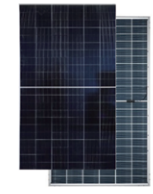
Lower BOS & LCOE

BOS is 5.1% lower and LCOE is 9.6% lower than 166 mono-facial module

ASTRO 6 core advantages

Basic Parameters

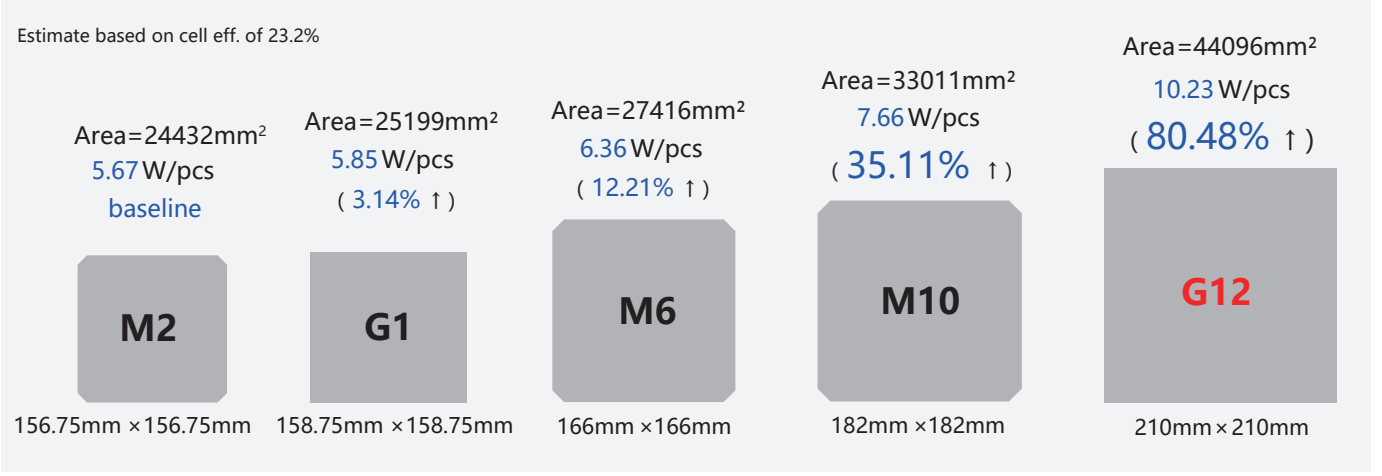
The ASTRO 6 series are divided into two types, ASTRO 6 Semi (mono-facial) and ASTRO 6 Twins (bi-facial), each containing 60 layout and 66 layout.

Product Type	ASTRO 6 Semi		ASTRO 6 Twins	
	60 Layout	66 Layout	60 Layout	66 Layout
Picture				
Module dimension [mm]	2172×1303	2384×1303	2172×1303	2384×1303
Maximum power (Pmax) [W]	610	670	605	665
Voltage at maximum power point (Vmpp) [V]	34.80	38.23	34.80	38.28
Current at maximum power point (Impp) [A]	17.54	17.54	17.39	17.38
Open-circuit voltage (Voc) [V]	41.90	46.09	41.90	46.09
Short-circuit current (Isc) [A]	18.62	18.60	18.46	18.47
Module efficiency	21.6%	21.6%	21.4%	21.4%
Weight [kg]	32.5	34.8	35.9	38.2
Temperature coefficient of Pmax (γ-Pmp)	-0.34%/°C			
Temperature coefficient of Isc (α-Isc)	0.04%/°C			
Temperature coefficient of Voc (β-Voc)	-0.25%/°C			
Warranty	12-years product warranty, 25-years linear power warranty		12-years product warranty, 30-years linear power warranty	
Power attenuation warranty	First year degradation≤2%, annual degradation≤0.55%		First year degradation≤2%, annual degradation≤0.45%	

03 ASTRO 6 Core Technologies

3.1 G12 Large-size Silicon Wafer

The increase in wafer size increases the power of each cell. Compared with M2 wafer, the cell power of M10-182mm wafer increases by 35.11%, and that of G12-210mm wafer increases by 80.5%. While the number of cells and modules produced per unit of time remains the same, the capacities of the large-size cells and modules are increased due to the increased power of each cells, thus significantly reducing the production cost per watt; moreover, the larger-size wafer improves the module power, greatly promoting the cost reduction of BOS. Therefore, large-size wafers have become an inevitable trend in the development of the PV industry.



Parameters of silicon wafers with different sizes

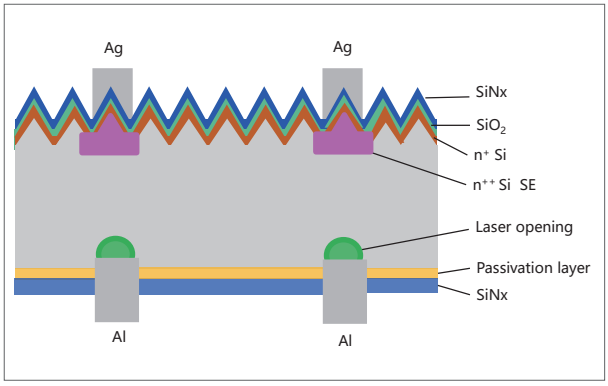
At present, 210mm is the largest size of silicon wafers in the PV industry, and it is estimated to last at least 3 years in the future. This is conducive not only to the standardization of module size, but also to the standardization of downstream PV system design.

As a result, ASTRO 6 directly uses G12-210mm wafers, promoting module power up to 670W.

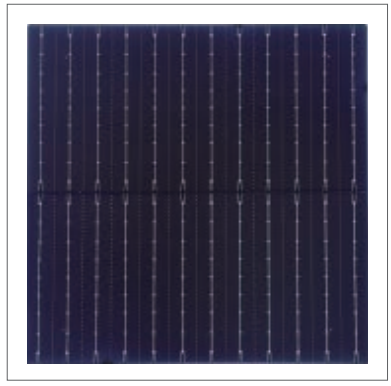
3.2 Super PERC+ 4.0 Solar Cells

ASTRO 6 applies the super PERC+ 4.0 mono-crystalline solar cells with high efficiency, high bifaciality and low attenuation.

On the basis of PERC+ cells technology, the super PERC+ 4.0 solar cells integrate the latest technologies including the optimized front surface passivation, laser doping selective emitter (LDSE4.0), dual printing, high sheet resistance and dense fingers process, optimized rear passivation layer and so on. Meanwhile, the gallium-doped wafer and hydrogen passivation technology are used to further reduce the cell light-induced degradation (LID) and light and elevated temperature induced degradation (LETID), which ensure high reliability of the ASTRO 6 series products.



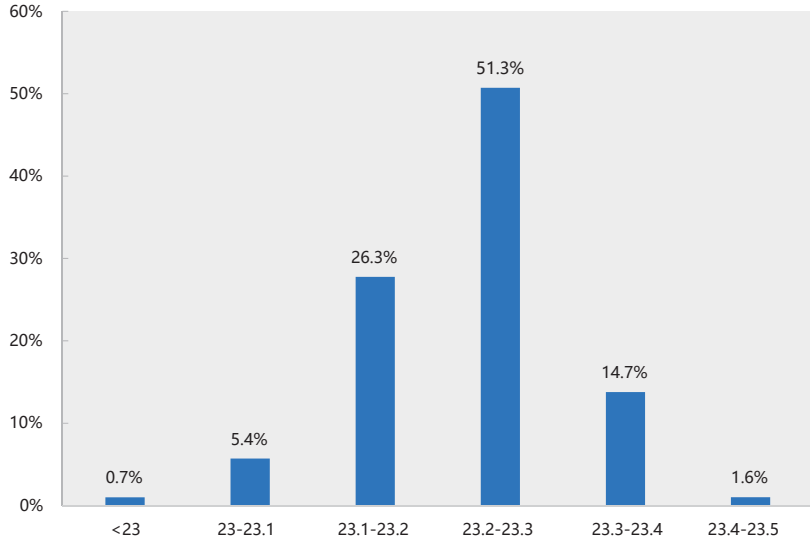
PERC+ cell structure



PERC+ cell front view

PERC+ cell back view

At present, the average efficiency of the Astronergy super PERC+ 4.0 solar cells is 23.2%+ in mass production. The highest efficiency of 23.44% is verified by the national PV industry measurement and testing center of Fujian metrology institute. The high efficiency cells improve the module power and enhance the core competitiveness of ASTRO 6.

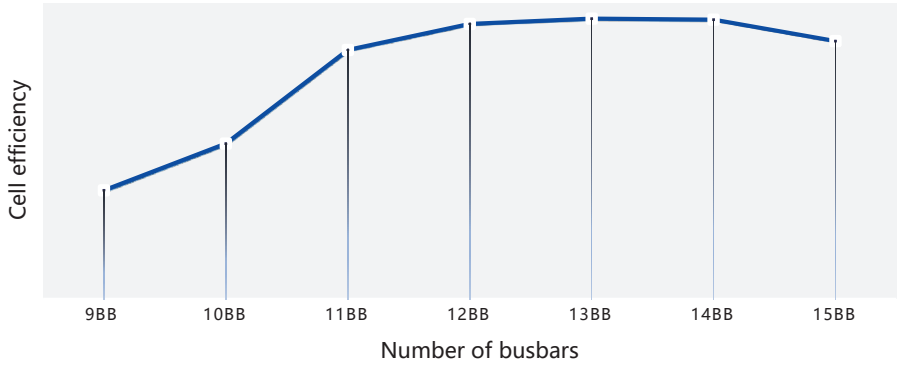


Efficiency distribution of the Astronergy super PERC+ 4.0 solar cells in mass production

3.3 Multi-busbar and Half-cut Technologies

The effect of the number of busbars on the efficiency of G12-210mm cells is simulated and analyzed. Starting from nine -busbars (9BB), the cell efficiency will be gradually improved with the increase in the number of busbars. The efficiency will reach the maximum at 12BB-14BB, and the efficiency will decrease due to excessive shading loss as the number of busbars keeps increasing.

Considering the 0.1% efficiency gain of 12BB compared with 9BB and other factors including material cost and production yield,the 12BB technology is finally adopted for the Astronergy G12 MBB super PERC+ 4.0 cells.



Simulation of the effect of the number of busbars on the efficiency of G12-210mm cells

Advantages of MBB and Half-cut

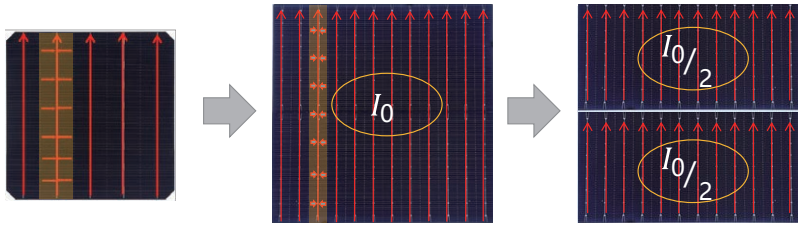
Reduce Electrical Loss

Improve Optical Utilization

Improve Reliability and Power Generation

Reduce Electrical Loss

The MBB technology is designed with multiple busbars. The current is transmitted through the fingers to the busbars, and the denser busbars can effectively shorten the distance of current transverse transmission path, thus reducing the resistance loss. The half-cut technology cuts the full cell into two half cells, which reduces the current of each busbar by half. This results in the thermal loss I^2R of the half-cut module being reduced to 1/4 of that of the full-cell module. Therefore, the MBB and half-cut technologies can effectively reduce the internal electrical loss and improve the efficiency of cells and modules.



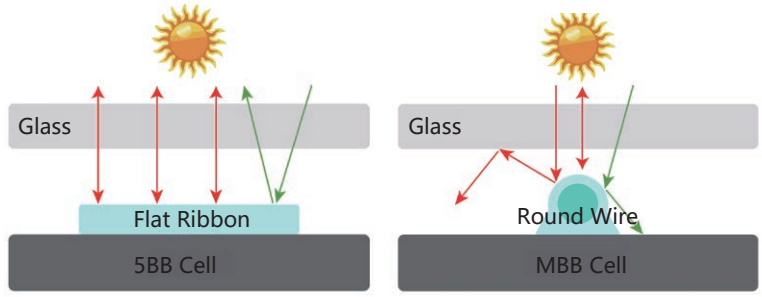
MBB and half-cut technologies improve current collection and reduce internal resistance loss

Improve Optical Utilization

The cell connector adopts round wire instead of flat ribbon. The round wire has less shading loss because the light shining on the wire can be re-reflected back to the cell surface and be absorbed. Combining the round wire with the thinner and narrower finger and busbar design, the shading loss of the front grid pattern is effectively reduced. Compared with the welding area of 5BB, the optical utilization of the MBB is improved by more than 30%.

Using MBB and half-cut technologies,

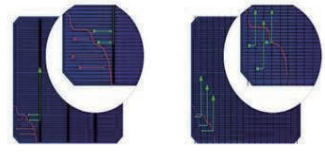
- module power ↑ **about 5%**
- module efficiency ↑ **about 3%**



Comparison of optical utilization of different ribbons

Improve Reliability

The MBB technology can reduce the effects of micro-cracks and broken fingers. The micro-crack of 5BB cell is less likely to cross a busbar due to the large spacing between adjacent busbars. This will cause a circuit break as the current in the micro-crack area cannot be transmitted to a busbar and thus cannot be collected. While the micro-crack of MBB cell is more likely to cross a busbar because of the small spacing between the busbars, then the current in the micro-crack area can still be transmitted to a busbar to be collected. Therefore, the MBB cell has high tolerance to micro-cracks.



Influence of micro-cracks on conventional and MBB cells

The MBB technology improves the mechanical performance of cells and modules. With the increase in the number of busbars, the distribution of the round wires on the cell is more uniform, and the stress distribution on the cell is also more uniform. This disperses the stress of the cells after encapsulated, significantly improving the mechanical performance of the modules.

The half-cut technology can reduce the temperature of the hot spot by about 10-20 ℃ because the cell current is reduced by half, which greatly reduces the risk of the hot spot and improves the reliability and safety of the modules in the practical application.

Improve Power Generation

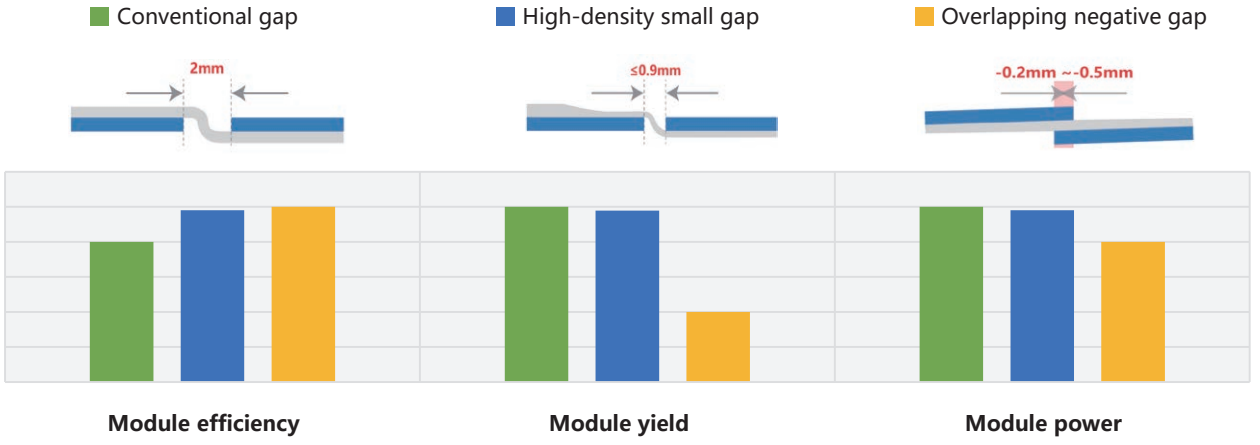
Compared with the 5BB full-cell module, the MBB and half-cut module has a lower nominal module operating temperature (NMOT) and a reduction in module operating temperature of about 2 ℃ due to the reduced internal electrical loss.

The half-cut module has better shading tolerance because of the unique series and parallel structure design. It can reduce the loss of power generation caused by internal mismatch and shading, then improve the economic benefit of power station.

3.4 High-density with Small Cell Gap Encapsulation Technology

The interconnect welding technologies can be divided into the conventional cell gap welding, the small cell gap welding and the negative cell gap welding.

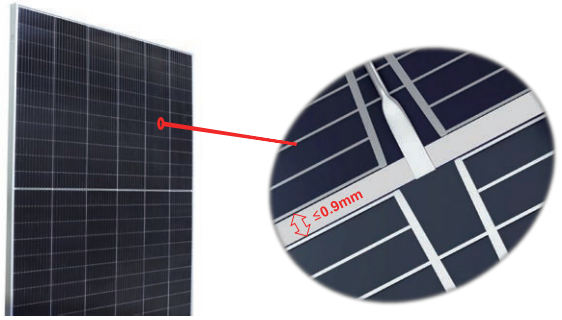
The conventional cell gap welding is easy to achieve in manufacturing process and has a high yield due to the large cell gap of about 2mm. However, the large cell gap reduces the proportion of the effective power generation area in a module, resulting in a slightly lower module efficiency. With the progress of welding technology, the high density encapsulation technologies have emerged in order to further increase the effective power generation area in the module and improve the module efficiency. At present, the high density encapsulation is mainly achieved by the small cell gap welding or the negative cell gap welding.



Effect of different cell gaps welding technologies on the module performances

The negative cell gap welding is done by overlapping a small part (0.2 to 0.5mm) of one cell with another cell. Although the module efficiency is the highest, but there are problems of the high fragment rate and low yield in mass production because of the overlapping between the cells. Moreover, the modules have great risk of micro-cracks in practical application.

To balance the impacts of module efficiency and yield, ASTRO 6 is encapsulated with a small cell gap of ≤0.9mm combined with hetero type ribbon (HTR), which improves the module efficiency while maintaining high yield. Additionally, adopting the advanced smart welding technology further reduces the risk of micro-cracks, and the production yield and reliability of ASTRO 6 are fully ensured.



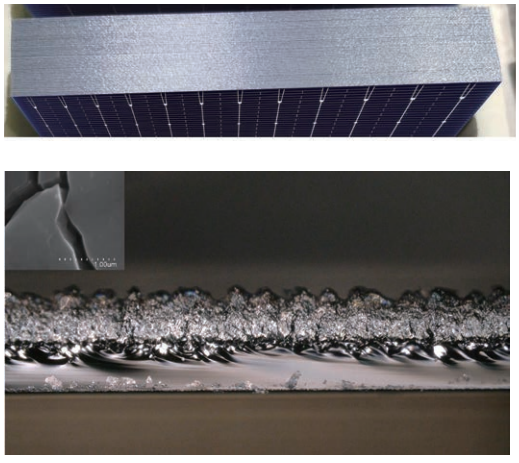
Enlarge image of the high-density with small cell gap encapsulation in ASTRO 6

3.5 Non-destructive Cutting Technology

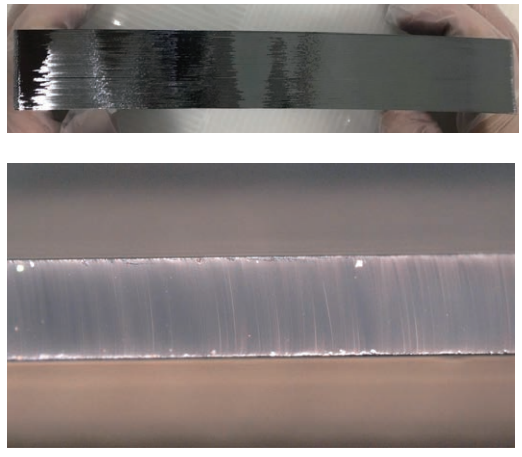
The non-destructive cutting technology improves the reliability and module efficiency of ASTRO 6.

The half-cut technology cuts a full cell into two half cells. The traditional cutting ablates a groove on the cell surface using a laser with high energy density and then mechanically breaks the cell into two halves. This technology will generally produce micro-cracks and damage the cutting surface, which affect the mechanical strength of the cell.

The non-destructive cutting naturally splits the full cell due to thermal stress generated by the laser. The cutting surface expands steadily with the laser moving path, and the cutting edge is very smooth without any micro-cracks. The non-destructive cutting improves the bending strength and reduces fragment rate of cells, thus ensuring the mechanical performance of ASTRO 6.

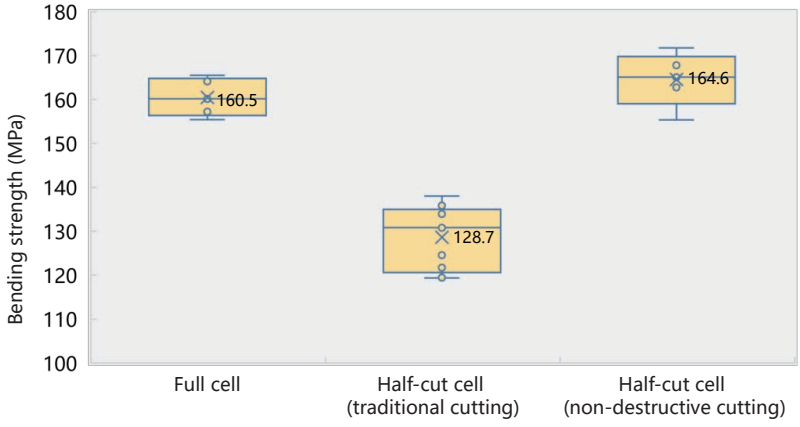


Cross-section of a solar cell after traditional cutting
Rough cutting surface with micro-cracks

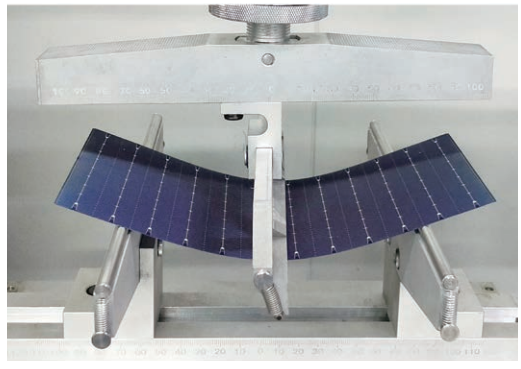


Cross-section of a solar cell after non-destructive cutting
Smooth cutting surface without any micro-crack

The bending strength of the half-cut cell after non-destructive cutting is about 30% higher than that of traditional cutting, and even better than that of the full cell. This result fully demonstrates the reliable mechanical performance of ASTRO 6.

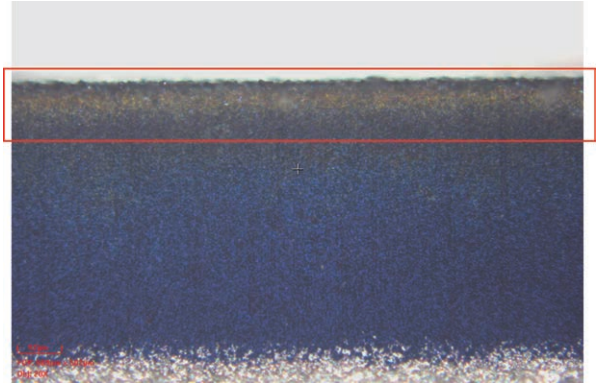


Comparison of bending strength of cells

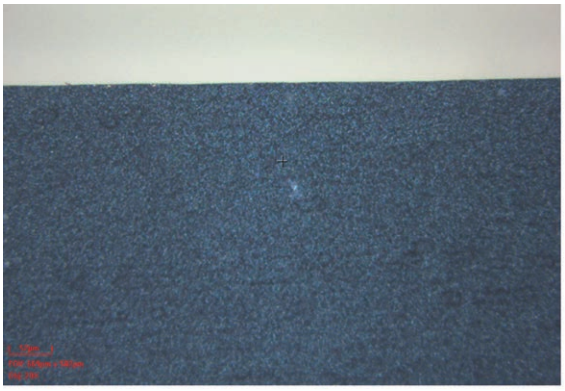


Three-point bending test of cell

The traditional cutting is a high temperature process, a heat affected zone of about 80-150μm width is generated on the cell surface, which damages the electrical performance and reduces cell efficiency by 0.1-0.3%. In contrast, the non-destructive cutting is a low temperature process without generating heat affected zone, which can significantly reduce the loss of cell power caused by cutting. This helps ASTRO 6 achieves the high power and high efficiency characteristics.



Top view of a solar cell after traditional cutting
80-150μm heat affected zone, cutting edge is rough



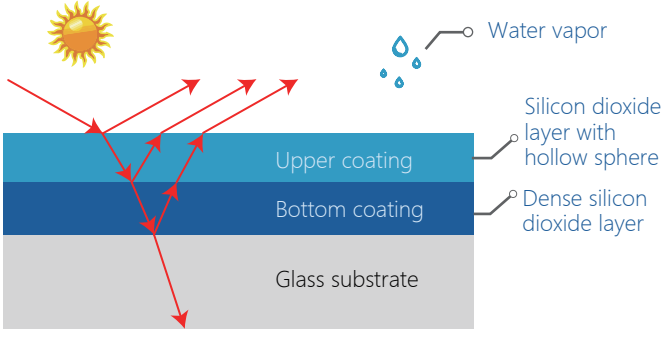
Top view of a solar cell after non-destructive cutting
No heat affected zone, cutting edge is smooth

3.6 Double-layer Coatings PV Glass Technology

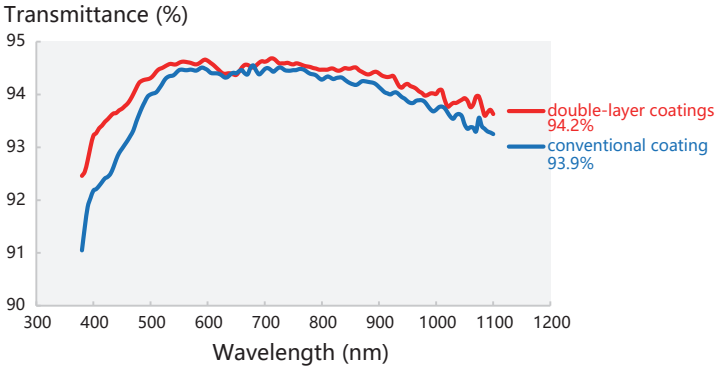
The single-layer coating glass is generally used for PV modules. The single-layer coating is a porous silicon dioxide layer with hollow sphere, therefore, the water vapor is relatively easy to penetrate single-layer coating and directly attack the glass surface, resulting in local hydrolysis. This will cause some quality problems.

ASTRO 6 adopts the advanced double-layer coatings glass technology. The upper layer of the double-layer coatings is a closed-hole film, which improves the transmission of light; the bottom layer is a dense silicon dioxide layer, which can effectively isolate the water vapor. In addition, so as to achieve a better anti-reflection effect, the upper and bottom coatings have different refractive index, and this makes the refractive index gradually decreases from the air side to the cell. The average transmittance of double-layer coatings glass is more than 94.2% in the wavelength range from 350nm to 1100nm, which is about 0.3% higher than that of the conventional PV glass.

As a result, by using the double-layer coatings glass technology, ASTRO 6 not only has a higher optical utilization, but also greatly improves the environmental durability of the products.



Structure diagram of double-layer coatings PV glass

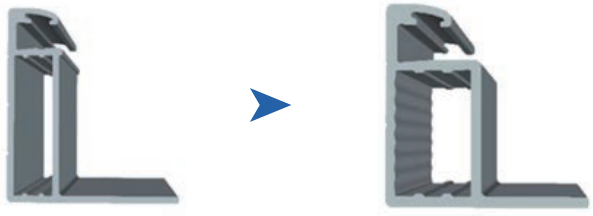


Comparison of transmittance of different PV glass

04 Performance Assurance of ASTRO 6

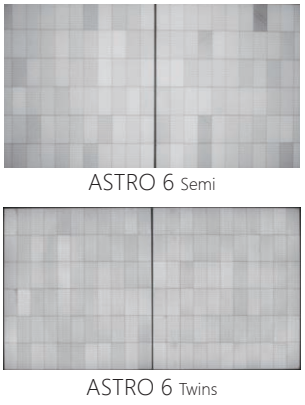
4.1 Optimization of Mechanical Load Performance

The main factors affecting the mechanical load performance of modules are the cell quality, glass and frame. ASTRO 6 is developed by various optimized designs to fully ensure the mechanical load performance of the product, firstly, all of the cells used in ASTRO 6 are EL tested by the fully automatic AI equipments to ensure that each cell is without any crack. Secondly, the advanced non-destructive cutting technology is used to ensure that the cutting surfaces of half-cut cells are smooth and no new micro-cracks are added, and the bending strength of the half-cut cells are even slightly better than that of the full cells.Thirdly, the frame is not only manufactured with stronger materials, but also the design is optimized. As shown in the following figure, the width and thickness of frame are optimized; and the contact area between frame and glass is increased to prevent glass breaking away the frame; some texturing stripes are also designed on the frame upper surface (face A), which increase friction with mounting clamps and reduce the risk of module falling off. Finally, the use of tempered glass is combined to ensure the high mechanical load performance of ASTRO 6.

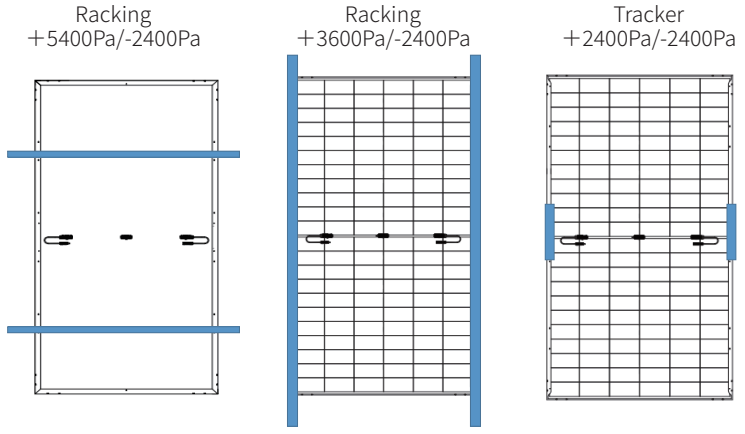


Conventional frame structure **ASTRO 6 frame structure**

The ASTRO 6 series modules were tested under the mainstream testing conditions of mechanical load. There are only a few cracks in ASTRO 6 Semi and virtually no cracks in ASTRO 6 Twins shown in EL images, and the power degradation of all the modules is <3%, and there is never any appearance problem such as glass breaking away frame or module bursting, etc. In short, those results confirm that ASTRO 6 fully meet the requirements of mainstream mechanical load performance under the mounting of fixed racking or tracking.



EL images of ASTRO 6 series after mechanical load test



Mechanical load performance of ASTRO 6 in different installation modes

The result of the test sequence of static mechanical load after DH1000 tested by TÜV Rheinland shows that the power degradation values of ASTRO 6 Semi and ASTRO 6 Twins are only 1.5%-2.8%. This result fully verifies the high reliability of ASTRO 6.

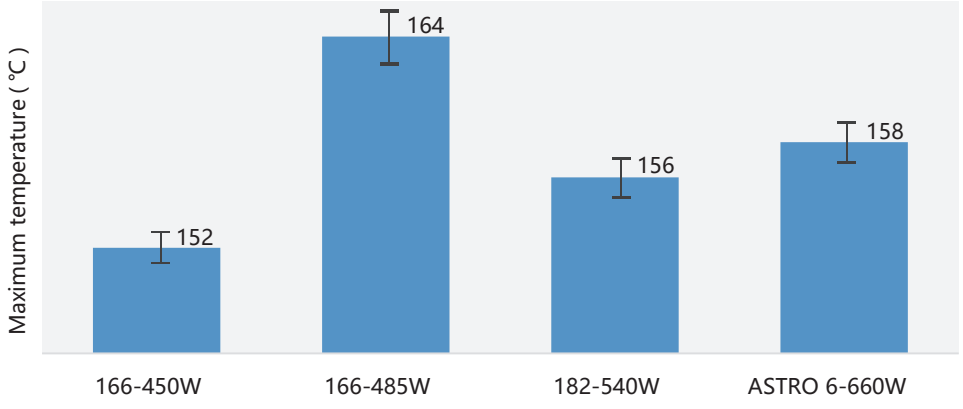
Testing Organization	Module Type	Power Loss	Test Condition
TÜV Rheinland	ASTRO 6 Semi	1.51%	**DH1000+Static mechanical load** (5400Pa positive load and 2400Pa negative load, 4 point mounting with clamps)
		2.76%	
	ASTRO 6 Twins	1.80%	

4.2 Risk Assessment of Hot Spot

The cause of module hot spot is that the defective or shaded cell limits and consumes the power generated by other normal cells in the same cell string protected by a bypass diode, resulting in the formation of heating unit and generating hot spot. The main influence factors of hot spot are the leakage current of the cells, the power of the cell string where the hot spot cell is located, and the reverse bias voltage on the hot spot cell. The photocurrent is the secondary factor. Therefore, the key to preventing hot spot is the quality of the cells and the design of the module circuit.

In order to reduce the risk of hot spot in ASTRO 6, some hot spot control technologies are adopted. Firstly, the leakage current of the cells used in ASTRO 6 is controlled by optimizing the cell process and implementing strict quality control. Secondly, the circuit with low voltage per cell string protected by a bypass diode is designed. The number of cells in a cell string protected by a bypass diode is 20 and 22 for 60 and 66 layouts, respectively, both less than that of the mainstream 72 and 78 layouts. Fewer cells reduce the voltage of a cell string. Thirdly, the half-cut technology is used to reduce the photocurrent per half-cut cell. All of these technologies ensure that ASTRO 6 has a relatively low hot spot temperature.

The hot spot temperatures of different modules are compared. The result shows that the risk of hot spot on ASTRO 6 is within a safe and controllable range, the maximum hot spot temperature of ASTRO 6 differs from the 182 module by only about 2 ℃, even better than that of the 78 layout 166 module (166-485W).

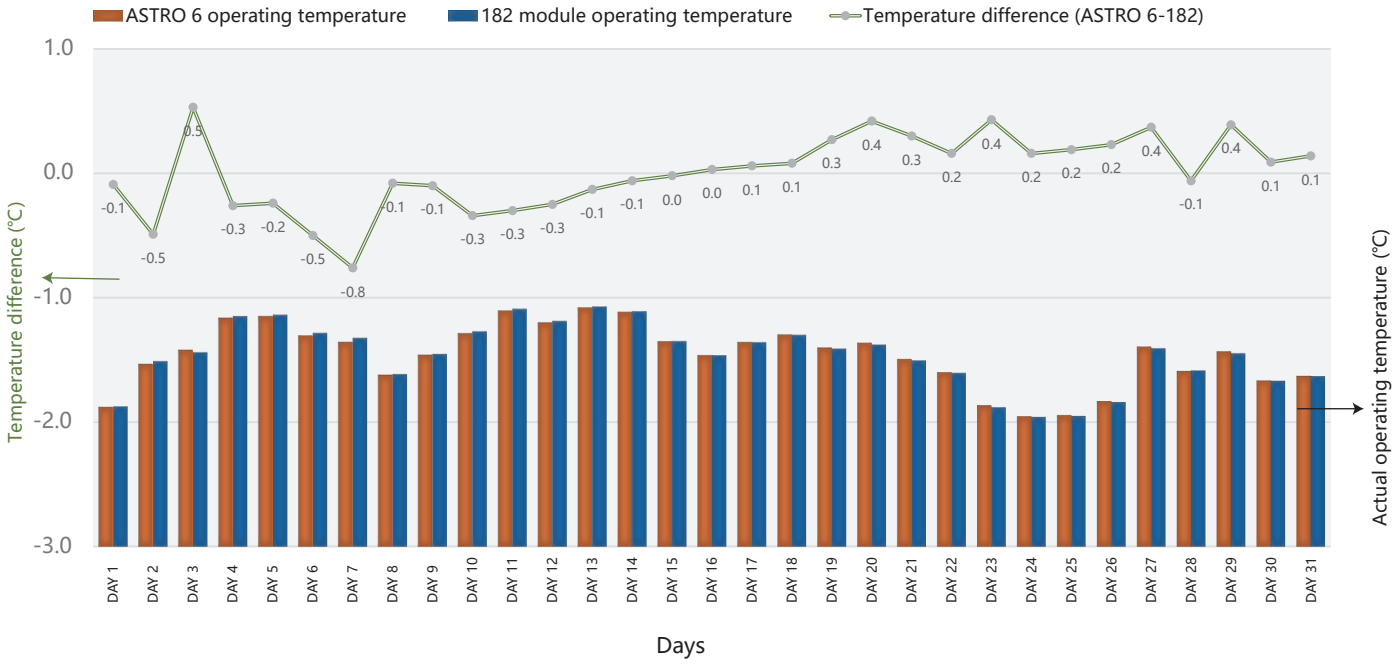


Maximum temperature of hot spots of different modules

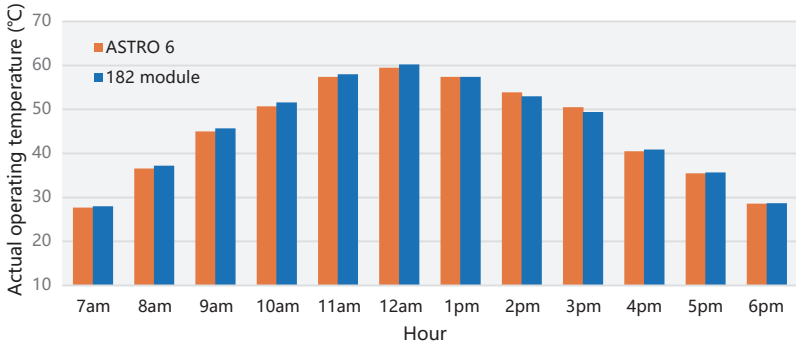
4.3 Comparison of Operating Temperature

The size of the silicon wafer does not affect the current density of the cells, so there is no obvious difference in current density between 166, 182 and 210mm cells when the efficiency of PERC+ cells is the same. However, the larger the cell size, the greater the current that flows to the round wires and string connectors. Therefore, in order to reduce the thermal loss of high current, the number of busbars in ASTRO 6 is increased to 12, and the sizes of the round wire and string connector are both optimized to reduce resistance.

In the outdoor demonstration, the operating temperatures of ASTRO 6 and 182 module are real-time monitored in a summer month and a typical sunny day. the results show that the difference of actual operating temperatures between ASTRO 6 and 182 module is about ±0.8℃, which is very small, basically negligible. Therefore, there is no risk of high operating temperature for ASTRO 6.



Comparison of operating temperature between ASTRO 6 and 182 module in a summer month



Comparison of operating temperature between ASTRO 6 and 182 module on a typical sunny day

Project location: Haining, Zhejiang Province, China. Fixed tilt:20°, ground clearance:1.2m

4.4 Analysis of High Current Cable Loss

The current at the maximum power point (Impp) of ASTRO 6 is around 17.4A, which is higher than that of most modules on the market. Does the high current result in lower power generation due to the increased cable loss? The cable loss is represented by Joule heating (I^2R, R is the resistance of all DC cables), which can be calculated in the following formula:

$$P_{loss} = \frac{{I_m}^2 \times L \times r}{P_m \times N} \times 100\%$$

- **Im:** operating current of modules
- **L:** length of all DC cables
- **r:** resistance per meter of DC cables
- **Pm:** module power under Standard Test Conditions (STC)
- **N:** number of modules used in the power station

Based on the estimation of 1MW installed capacity, the cable losses of different modules are compared in the following table. The cable loss of ASTRO 6 is 0.3% higher than that of 166 module and about 0.2% higher than that of 182 module when 4mm² cable is used. In order to reduce the cable loss of ASTRO 6, 6mm² cable can be used. At this time, the cable loss of ASTRO 6 is basically the same as 166 module, slightly better than 182 module. There are many factors affecting the power generation in an actual power station, and the difference of 0.2-0.3% of the cable loss has little effect on power generation. In other words, the cable loss caused by the high current of ASTRO 6 has very slight effect on the LCOE.

Due to the significant reduction in cable usage for ASTRO 6, even if ASTRO 6 uses more expensive 6mm² cable, the cable cost is still slightly lower than that of 166 module used 4mm² cable. For ASTRO 6, the cost of using 6mm² cable is about 35% higher than that of using 4mm² cable. Therefore, the 4mm² or 6mm² cable should be selected flexibly based on the actual project situation.

Module Type	166-455W	182-545W	ASTRO 6-660W	ASTRO 6-660W
Maximum power (W)	455	545	660	660
Impp (A)	10.96	13	17.45	17.45
DC cable crosssection area (mm²)	4	4	4	6
Resistance (mΩ/m)	4.375	4.375	4.375	2.917
Cable length (m/MW)	9765	7980	6090	6090
Cable loss	0.5%	0.6%	0.8%	0.5%
Cable cost	baseline	-18%	-38%	-3%

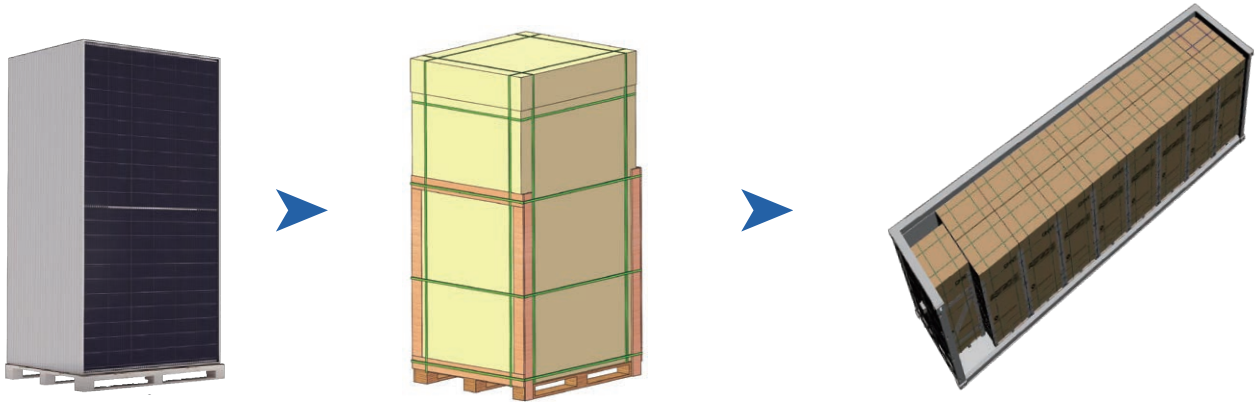
Note: The cable length is an estimate and varies slightly for specific projects

Comparison of cable losses and cable costs of different modules

05 Packaging, Unpacking and Transportation Solutions of ASTRO 6

In view of the large-size characteristics of ASTRO 6, the method of " vertical packing and reinforcement using protecting planks" is introduced to ensure the safety of packing and unpacking. Meanwhile, the placement of ASTRO 6 packaging in 40HC container is no longer restricted by the module width. The schematic diagram is as follows. Each packaging contains 31 pcs modules placed vertically and tightly. In order to ensure the reliability of packaging, both the modules and the enclosure carton are fixed with vertical and horizontal packing straps, furthermore, the packaging is reinforced using anti-dumping protecting planks. The dimension of one packaging is about 1.14m×1.34m×2.50m, therefore, the packaging is fully compatible with 40HC container, which can be placed directly side-by-side in the container.

The loading power in 40HC container of ASTRO 6 is 12% higher than that of 166 module and about 3% higher than that of 182 module. It is calculated that the transportation cost of ASTRO 6 has been reduced by 11.8% compared with 166 module. In brief, the Innovative vertical packaging of ASTRO 6 improves the utilization of the internal capacity of the container, and provides a large space of cost reduction for the logistics.

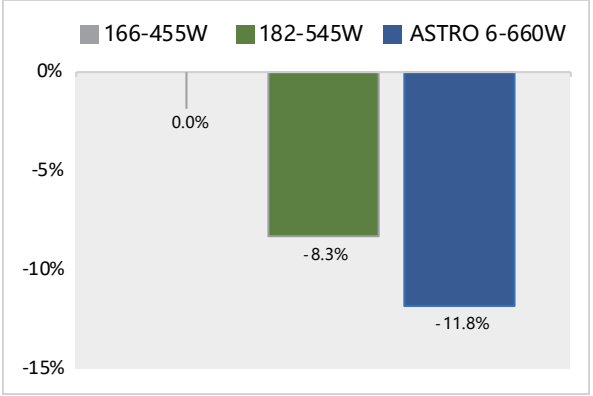


Vertical packing | Strengthen the packaging with protecting planks | Placement in 40HC container

Packing and transportation of ASTRO 6

	166-455W	182-545W	ASTRO 6-660W
Modules per 40HC container (pcs)	682	620	**527**
Pallets per 40HC container (pcs)	22	20	**17**
Power per module (W)	455	545	**660**
Power per 40HC container (W)	310310	337900	**347820**
Gain to 166 module (%)	0	↑8.9%	↑**12.1%**

Comparison of module power per 40HC container of different modules



Comparison of clause D shipping costs of different modules

In view of the problem of inconvenient unpacking of large-size module, a reliable and simple unpacking solution for ASTRO 6 is provided. After placing the packaging on a relatively flat hard ground using a crane or forklift,

firstly, remove the packing materials including stretch films, packing straps, protecting planks, upper cover plate and enclosure carton.

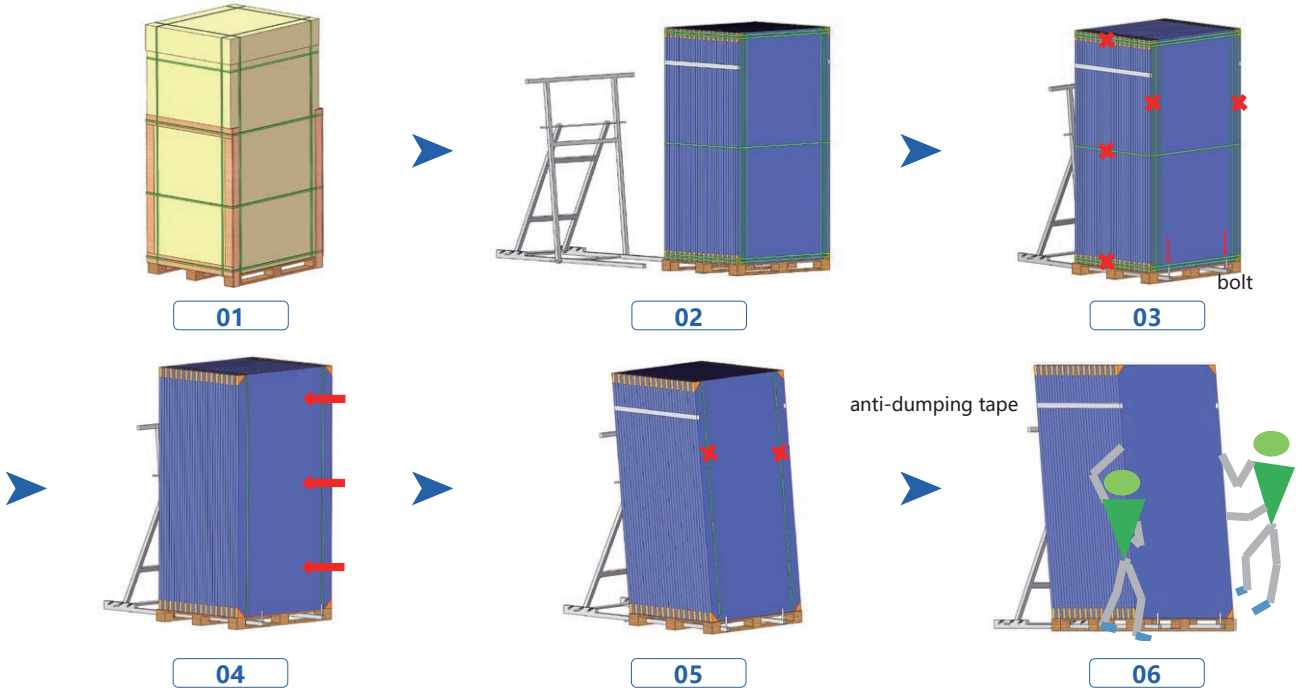
Secondly, insert an auxiliary unpacking rack into the bottom of the pallet and place the rack against backside of modules; then insert two bolts of about 150mm in length into the front holes of the rack to prevent the rack from shifting.

Thirdly, cut off all the horizontal packing traps and the outer four vertical packing traps, still retain two vertical packing traps located on the inside to prevent the modules from dumping.

Fourthly, slowly push the modules against the rack.

Fifthly, cut off the remaining two vertical packing traps after ensuring the safety of unpacking status.

Finally tear off the anti-dumping tapes on both sides of the modules. Pay attention to tearing only one piece of module-thick tape at a time, and then take out the modules in sequence and complete the unpacking.



Auxiliary unpacking process of ASTRO 6 in vertical packaging

ASTRO 6 can be installed in a traditional method or mechanically assisted. Due to the high power characteristics of ASTRO 6, the number of ASTRO 6 is reduced about 31% than that of 166 modules and about 17% than that of 182 modules at the same installed capacity. The reduction in the number of modules will significantly reduce the installation cost.

	166-455W	182-545W	ASTRO 6-660W
Maximum power (W)	455	545	660
Number of moudles (pcs/MW)	2198	1835	1516
Fewer modules than 166 module (%)	0%	17%	31%
Fewer modules than 182 module (%)		0%	17%

Comparison of the numbers of different modules at the same installed capacity

06 Advantages of BOS & LCOE of ASTRO 6

Based on the case study of a 100MW project located in Los Angeles, USA with the 1500V centralized inverters, 1P single-axis trackers and DC/AC ratio of 1.33 design. The 455W 166 mono-facial modules, 545W 182 bi-facial modules and 660W ASTRO 6 bi-facial modules are compared. Because of the low voltage characteristics of ASTRO 6, the voltage per ASTRO 6 is about 8.3% lower than that of the 166 and 182 modules, so the number of ASTRO 6 modules in a single string can be increased by 3 pcs. Combined with the high power characteristics of ASTRO 6, the string power of ASTRO 6 can reach up to 19.8KWp, which is 61% higher than 455W 166 module and 35% higher than 545W 182 module.

The calculation results of BOS and LCOE of different modules are compared as follows. Compared to the 455W 166 module, ASTRO 6 can significantly reduce the cost of module handling and installation by about 27%, the cost of DC cables and electrical equipment by about 13%, and the cost of mounting structure and installation by about 6%, finally the BOS cost is decreased by about 5.1%. compared to 545W 182 module, the BOS cost of ASTRO 6 is also lower. Combined with the high power generation characteristics of ASTRO 6 bi-facial module, its LCOE is 9.6% lower than the 455W 166 mono-facial module, and 0.8% lower than the 545W 182 bi-facial module. The advantages of BOS and LCOE of ASTRO 6 are due to its characteristics of high efficiency, high power and low voltage.

Module Type		166-455W Mono-facial	182-545W Bi-facial	ASTRO 6 -660W Bi-facial
Modules per string	pcs	27	27	30
Power per string	KWp	12.29	14.72	19.8
BOS	Module handling and installation	baseline	-14%	-27%
	DC Cable & electrical equipment	baseline	-1%	-13%
	Mounting structure and installation	baseline	-7%	-6%
	BOS cost	baseline	-3.5%	-5.1%
	LCOE	baseline	-8.9%	-9.6%

Comparison of BOS and LCOE of different modules

07 Industrial Chain Compatibility of ASTRO 6

The large-size technology can significantly reduce the production costs of the entire PV industry chain, and then reduce the LCOE. After about a year, the industrial Compatibility of 210 products has been greatly improved.

Silicon wafer: Zhonghuan Semiconductor and Shangji Automation have fully equipped with 210mm silicon wafers production capacity, of which Zhonghuan Semiconductor will reach 50GW in 2021.

Glass: In March 2021, the major glass manufacturers such as Xinyi, Flat, CNBM, Kibing and China Southern Glass announced that they have broken through the bottleneck of width in PV glass raw materials production and now the PV glass is compatible with the large-size 210 module. The capacity of PV glass for 600W+ modules will exceed 50GW in 2021 and more than 120GW in 2022.

Inverter: At the beginning of 2021, Huawei, Si-Neng and Sungrow, the world's three leading inverter manufacturers, all issued statements that the inverters, which are perfectly compatible with the high power and high current 210 module, will be mass-produced in March. CHINT Power, Goodwe, Ginlong, Kstar, SMA and other inverter manufacturers also announced that the inverters compatible with the high power 210 module are already available and the new high current inverters are being designed. So far, these inverters have also been launched.

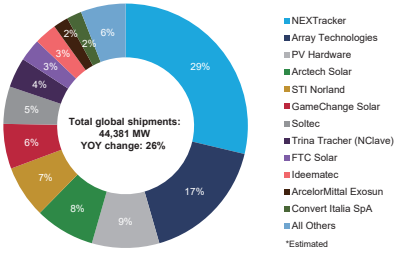
Inverter Manufacturers	Product Type	Module Compatibility	Time of Launch
Huawei	SUN2000-196KTL-H3	210 module	March 2021
Si-Neng	SP-250K-H	210 module	March 2021
Sungrow	SG225HX、SG250HX	210 module	Launched
CHINT Power	CPS SCH250KTL-DO/800	210 module	Q2,2021

Inverter manufacturers and products suitable for ASTRO 6

Tracker: Seven of the world's top 10 PV tracker manufacturers, Array Technologies, GameChange Solar, Ideematec, Nextracker, PVH, Soltec, Trina Tracker, have launched their new trackers that are fully compatible with the 210 large-size module, and all of these trackers have been available before the first quarter of 2021.

Tracker Manufacturers	Brand/Product Type	Module Compatibility	Time of Launch
Array Technologies Inc	DuraTrack HZ v3	210 module	Q1,2021
GameChange Solar LP	GENIUS TRACKER ™ 1P; GENIUS TRACKER ™ 2P	210 module	Q1,2021
Ideematec Deutschland GmbH	H4 PLUS TM	210 module	Q3,2020
Nextracker Inc	Nextracker products	210 module	Q4,2020
PV Hardware	Independent row: Monoline ™ (all its versions 1V, 3H and 2V); Multi-row: Axone ™ , Axone Duo™	210 module	Q1,2021
Soltec	SF7 & SF8	210 module	Q1,2021
Trina Solar	TrinaTracker (Vanguard™/Agile™)	210 module	Q2,2020

Tracker manufacturers and products suitable for ASTRO 6



Source: Wood Mackenzie, 2021

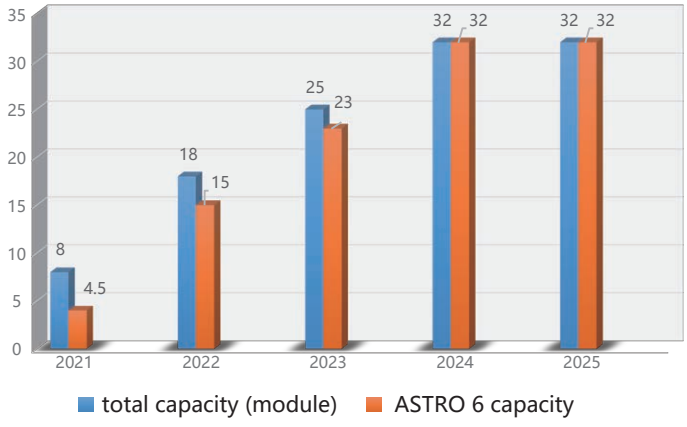
Global PV tracker market share rankings by shipment, 2020

In short, now the 210 industrial chain and PV ecological system are matured, the core parts including silicon wafers, solar cells, modules, glass, inverters, trackers and other raw materials have been well supported.

08 Summary and Prospect

The 600W+ high efficiency large-size ASTRO 6 product has been launched in time, which has now obtained the IEC and UL certification and will soon be promoted to the market on a large scale. The Yancheng base located in Jiangsu Province has a capacity of 3.5GW for 210mm cells and modules, respectively. The module capacity of ASTRO 6 will be increased to 4.5GW by 2021, and upto 32GW+ by 2025. As with ASTRO 5, ASTRO 6 is also a preferred product for utility-scale and large distributed PV power stations, which provides more product choices to customers.

Astronergy will continue to carry out technological innovation, improve the product efficiency and further reduce LCOE of PV power generation. These will not only bring higher value returns to customers, but also promote the rapid development of PV industry and help to achieve the goals of carbon peaking and carbon neutrality at an early date.



Module capacity planning for Astronergy from 2021 to 2025 (GW)

Yancheng phase one 3.5GW
New factory of large size cells and modules

Thailand phase one 1GW
Global layout

Haining phase four 3-5GW
Biggest capacity in one house

Other Production Bases

Tier 1 Bloomberg

Underwritten by International Insurer

DNV GL Top Performer

ctc Green Building Materials

Max. Module Eff
21.6%

Max. Module Power
670W

Astronergy/Chint Solar

Astronergy_Chint Solar

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