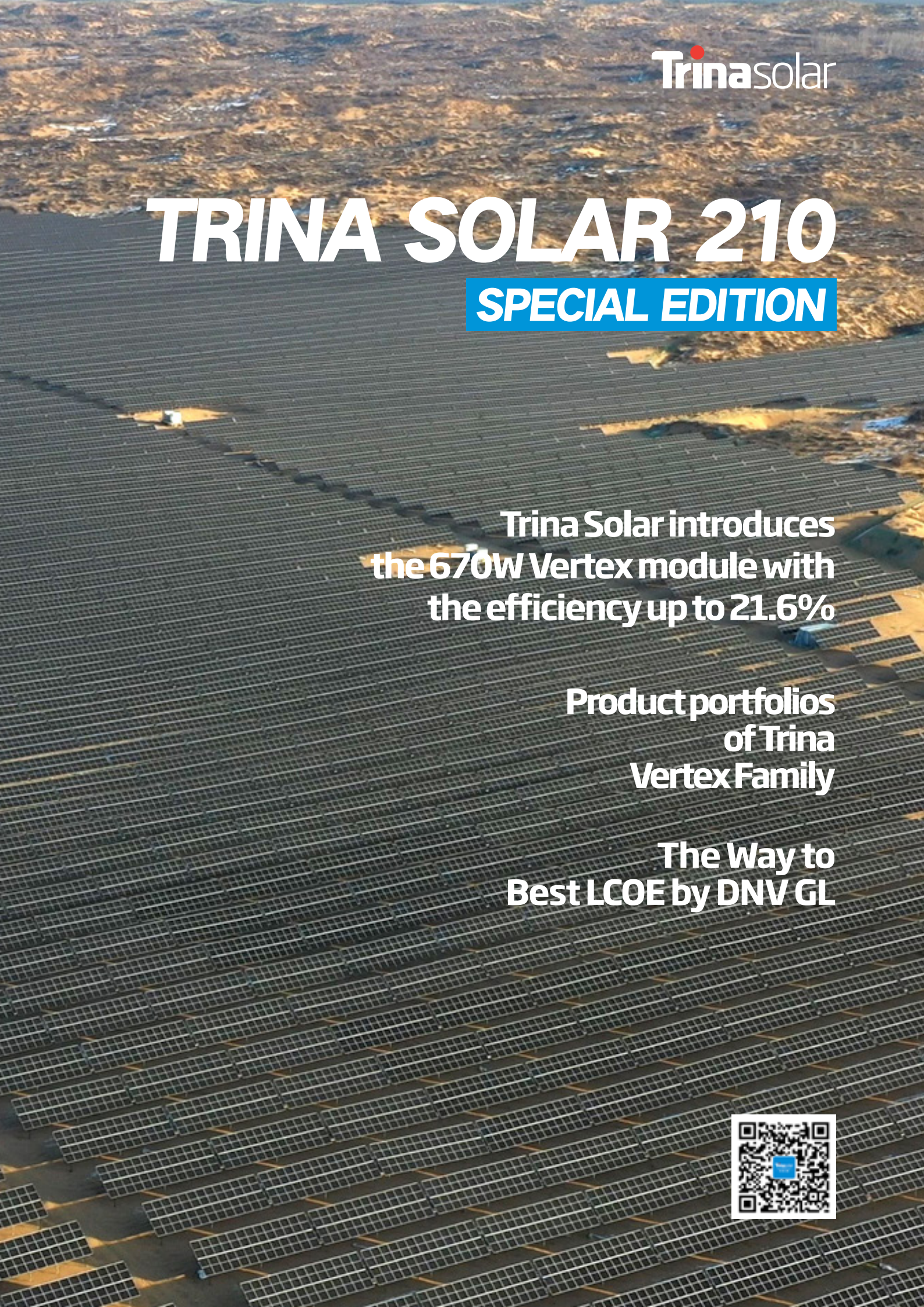

Trinasolar
TRINA SOLAR 210
SPECIAL EDITION
Trina Solar introduces
the 670W Vertex module with
the efficiency up to 21.6%
Product portfolios
of Trina
Vertex Family
The Way to
Best LCOE by DNV GL

CONTENTS

Global orders & strong capacity

Booming demand for 210mm modules

spreading production capacity around the world

Signed **12GW** *orders in half a year since Vertex was launched, covering both* ***utility*** *and* ***rooftop*** *markets*

Cell & module capacity in ***Changzhou***, ***Yancheng***, ***Suqian***, ***Yiwu*** *and* ***Vietnam***, *exceeding* **50GW** *by the end of 2021*

Industry trends

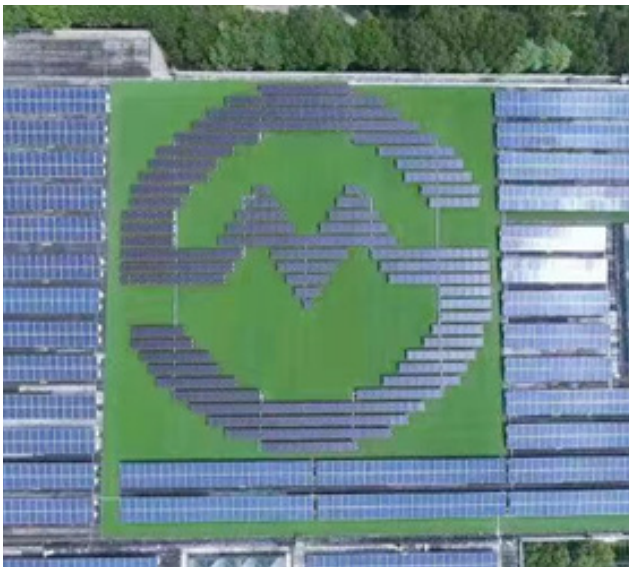
600W+ ultra-high power modules and system integration new technology platform

are to be an important direction for the future development of the photovoltaic industry

This year, many photovoltaic companies released 600W+ ultra-high power photovoltaic modules. With the continuous improvement in productivity, and the solution in low voltage and high string power, there are more possibilities for the decline of BOS and LCOE on the system side. At the same time, this evolving trend has resulted the innovation in both R&D and manufacturing within the supporting industry chain. In the industrial chain, all enterprises collaborate and innovate together to promote the reduction of the cost of electricity, which is an inevitable trend for the development of the industry. On August 9, the " System and application advantages of 600W+ high-module string power output " was held in Shanghai. The representatives from various companies introduced 600W+ inverters and tracking system solutions within their system.

The signing ceremony of the strategic cooperation agreement for the reliability testing of ultra-high power extreme 600W+ modules of the National Solar Photovoltaic Product Quality Supervision and Inspection Center was held at the same time. This marked the start of cooperation and technical services etc. between the National Photovoltaic Quality Inspection Center and Trina Solar in the reliability testing of ultra-high power modules, in order to jointly facilitate Chinese photovoltaic industry transitioning into an ultra-high power era with high quality. This signing ceremony also shows that Trina Solar has never forgotten the important mission of building a high-reliability guarantee system for the Vertex Series Modules and to generate customer value, while pushing for technology improvement and continuous innovation.

During the first summit after the establishment of the 600W+ Photovoltaic Open Innovation Ecological Alliance, the participating companies agreed unanimously that the traditional thinking of photovoltaic companies is being changed. It is becoming more open, inclusive, and confident, moving from a battle for market share to value collaboration, and from isolation to a win-win cooperation. At the same time, the alliance is open to companies from all trades within the industry chain, hoping to attract more outstanding and cooperative companies in the future, and to promote 600W+, a type of inclusive technology, and to add room for value generation within the industry.



The photovoltaic industry has entered the 6.0 era. Compared with lower power modules, the greatest value of 600W+ ultra-high power modules lies in the reduction in BOS and LCOE, which resulted from low voltage and high string power. This also raised many questions about the compatibility of 600W+ modules industry chain among the industry members. This seminar reflected the knowledge, foresight, and strong technical backup of downstream inverter and tracker companies, because they came up with the associated compatibility solutions of 600W+ modules as the ultra-high power modules were launched.

Vertex 600W+ Ultra-High Power Modules Adopt Low-Voltage Design, And The Single String Power Is Increased By More Than 40% At The System End

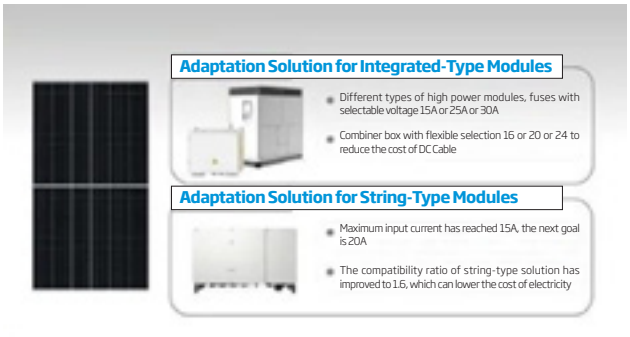
"Trina Solar Vertex 600W+ modules adopt non-destructive cutting, and high-density packaging, and plus MBB technology, laying a solid foundation for high efficiency and high reliability; the product has a low-voltage feature, with a power increase of a single string module by more than 40%; and has a significant

reduction in BOS cost and LCOE cost. By the end of 2020, the production capacity of Vertex modules is expected to be approximately 10GW and 21GW by 2021, while 31GW by 2022." said Shu Yunhua, the deputy director of product management at Trina Solar.

The Sungrow Power Inverter Is Ready for Module 6.0 Era

Modules have entered the 600W+ ultra-high power era. What about the inverters? Would they be compatible? Zhang Yuehuo, the solution director of Sungrow Power Supply Co., Ltd. firmly said: "Of course, the answer is affirmative." After the acceleration and the upgrade of photovoltaic components, under the same 1500V system, the low-voltage and high-current modules have greater advantages. Regarding today's high-power modules, whether they are an integrated type or a string type, Sungrow is ready for it. Since 2019, Sungrow has deployed high-current modules to quickly adapt the market demand in order to achieve mass supply. " The Sungrow Power Inverter Is Ready for Module 6.0 Era!"

Summary: Adaptation Solution for High Power Module Inverter



With the Integration of AI, Huawei Creates A Better LCOE Solution To Suit High-Power Modules

Huawei Intelligent Photovoltaic is an important part of the photovoltaic system ecosystem. Huawei has always maintained a close cooperation and an in-depth technical communication with mainstream photovoltaic module manufacturers, so as to explore the direction of future technological evolution together. Huawei's technological innovation is based on the system level, which integrates with the upstream and downstream of the industrial chain, and ultimately provides customers with lower electricity costs. For example, our intelligent tracker algorithm, from a digital perspective, "perceives" external factors such as radiation, temperature, wind speed, etc., combined with accurate big data and AI intelligent learning algorithms, to make the modules and trackers work and synergize together, to locate the best tracking angle, and to allow each string of the power station to fully release its potential for the best power generation performance. According to actual project calculations, the average power generation can be increased by more than 1%.

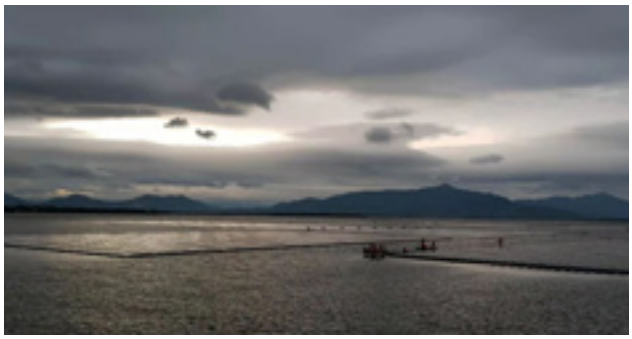
"High-efficiency and high-power" is an inevitable development trend of photovoltaic modules, thus how inverters adapt to the high-power modules becomes a new challenge. One of the important factors of choosing low-voltage and high-current solutions for high-power components is to achieve the long string design in order to reduce the number of strings, thereby reducing the number of PV cables and reducing the cost of PV DC cables. The working current of high-current modules has increased significantly, which brings new challenges to inverter design. Huawei came up with corresponding product planning based on the characteristics of high-current modules, with the integration of multiple innovative designs, and proposed a more optimal and suitable solution of string inverters.

Huawei's new generation of intelligent photovoltaic solutions will continue to lead innovation, and to achieve continuous reduction in the LCOE cost of photovoltaic power generation. As the power and the current of the modules increase, Huawei's next-generation products will be released before mid next year.

Ultra-High Direct AC Ratio, SMA Sunny Tripower Core2 Perfectly Suits 600W+ Modules, And Orders Have Been Scheduled Until The End Of 2020

Vice President Of Sales For Greater China, India And Southeast Asia Of SMA Solar Technology (Shanghai) Co., Ltd. Ms. Wang Ting, introduced that the Sunny Tripower CORE2 launched by SMA this year is a photovoltaic inverter that is perfectly suitable for 600W+ modules. Firstly, this product is designed to be flexible, with a power of 110kW, 12 MPPTs and 24 outputs. Customers can choose to use part of the MPPT or part of the string input as per the project requirement. When the 12-channel input encounters high current, it can still be connected from 120 kilowatts to 140 kilowatts. This direct AC ratio is sufficient and will not affect the cost of BOS. This precisely reflects the design concept of SMA's entire line of products: the products have an ultra-high direct AC ratio, and the ratio of SMA integrated photovoltaic inverter can reach a maximum of 225%.

In addition, Sunny Tripower CORE2 can be applied to a variety of scenarios as per the demand of owners and EPC parties, from large-scale industrial and commercial projects to small ground-based power station projects. Finally, CORE2's integrated platform can be combined with the SMA smart energy management system for unified management and control, and can also be extended and integrated into the energy storage system. It is a highly integrated product. CORE2 was officially put into production and shipped out this month, and the orders have been scheduled till the end of this year. We believe that it will be a string inverter with extremely competitive pricing, competitive functionality, and a strong overall competency in the field of industrial and commercial SMA applications. Besides that, SMA has a complete series of industrial and commercial products, and the inverter power range covers from 50kW to 150kW.



TrinaPro, The Industry's First 600W-Level System Solution

The Senior Director of Optoelectronics System Integration and Optimization at Trina Solar Co., Ltd., Ms. Qu Xiaojuan, said that Nclave trackers are fully prepared for ultra-high power modules. Firstly, we utilized multi-point drive to make the whole system more stable. Meanwhile, we strengthened the structural design to improve the durability of key connection joints, and reduced the risk of bending and torsion tremor caused by changes in module size and weight, in order to ensure the wind-induced stability. Secondly, as the open circuit voltage of the components decreases and the current increases, we further improve the adaptability of the electrical parameters to truly reduce the cost of BOS. Thirdly, we designed the best tracking angle and installation scheme through intelligent control algorithms. Fourthly, the system of Nclave can offer customers with a remote monitoring window to minimize the cost of the future product lifespan for customers. From these aspects, as the power of modules increases, it will become the strong driving force for the upgrade of the entire system. Therefore, the TrinaPro system is a byproduct of Trina's continuous attention to the latest technology and the integration of both new and existing technology.

Foreseeing The Future, Arctech Solar Has Laid Out The Adaptation Plan For High-Power Components And Trackers In Advance

In response to the current trend of component power reaching 600W, and even getting higher and higher, Arctech Solar actually had precisely foreseen this coming as early as two years ago, and made preparations and study in order to come up with a adaptation plan for high-power modules and trackers in advance. Yang Ying, chief engineer of the R&D center of Jiangsu Arctech Solar New Energy Technology Co., Ltd., said: "Targeting the mainstream high-power modules represented by Trina Solar, we have conducted various key parameter analysis and calculations for the tracker. For the installation of high-power modules in single-row and vertical installation, Arctech Solar's competitive product Skyline Tracker System has had a suitable solution. And for the installation of high-power modules in dual-row and vertical installation, both the SkySmart trackers and the SkySmart II trackers at Arctech Solar's are perfectly compatible. Especially SkySmart II trackers, it is considered as the most compatible trackers ever designed for high-power components."

Trina Solar's Vertex Ultra-High Power Modules Received The First-Grade Certificate As Being A Photovoltaic Leader

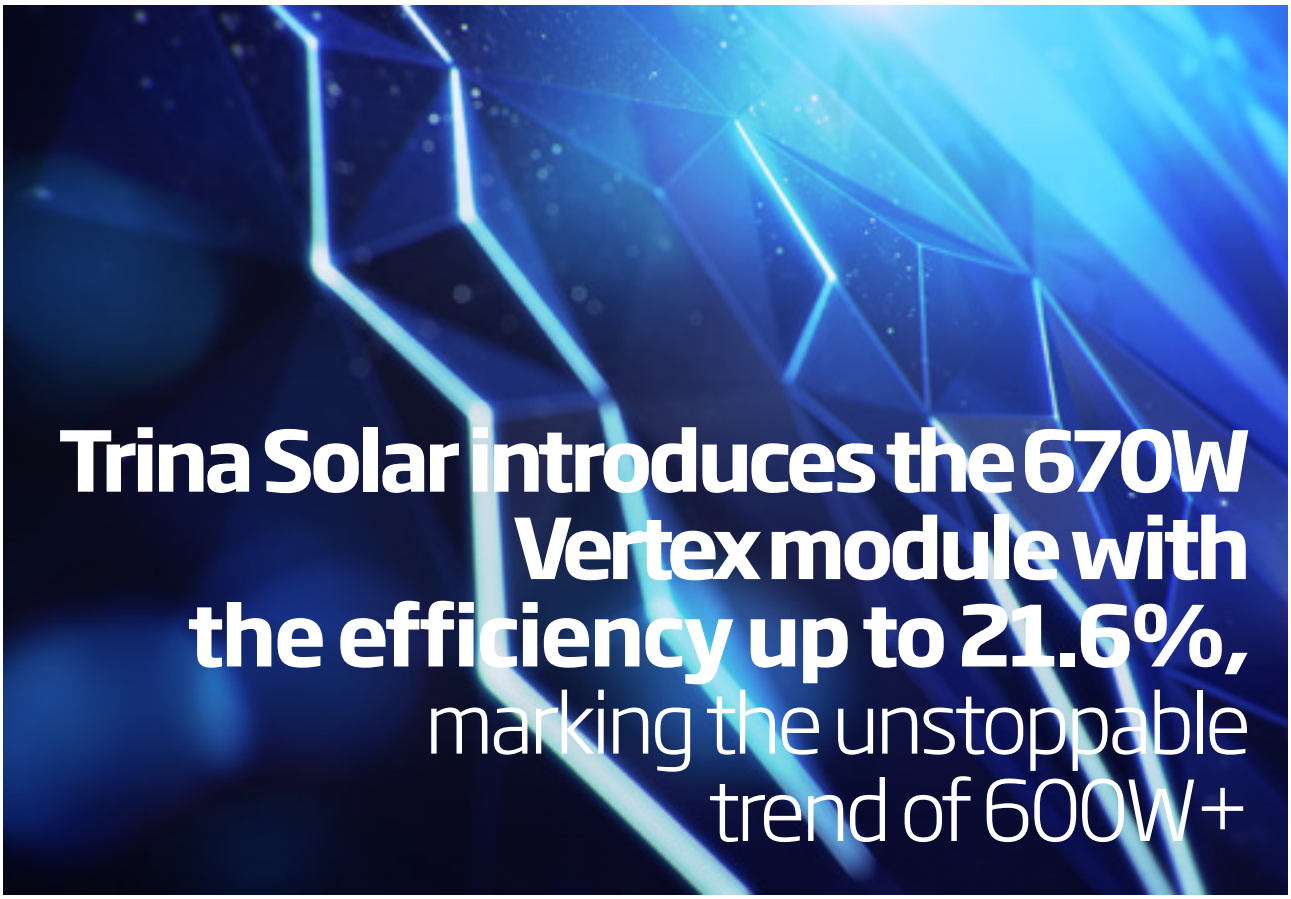
Recently, China General Certification Center (CGC Jianheng) issued and awarded officially the "New Standard Basic Certification" and "FrontRunner Frontier Technique Product certification" for Trina Solar Vertex ultra-high power modules. The general manager of CGC Jianheng, a member of 600W+ Photovoltaic Innovation Open Innovation Ecological Alliance, Mr. Zhou Gang said: "Trina Solar was one of the first customers of CGC Jianheng's most advanced module laboratory in Jiaxing. We are extremely honored to witness the development of Trina Solar's 500W and 600W+ modules. This time we were also very fortunate to be able to award Trina Solar with their first domestic "front-runner" certification."

600W+ Ultra-High Power Modules And New Technology Platforms For System Integration Are Important Directions For The Future Development Of The Photovoltaic Industry

The special edition of "Photovoltaic 6.0 Era: Photovoltaic Industry under the 600+W Wave" was officially released. The special edition covers the endeavors, technological innovations, breakthroughs and collaborations of industry-leading companies. It aims to clearly demonstrate all aspects of the industry under the photovoltaic era. And new technological ideas can quickly be turned from thoughts to reality. Li Junfeng, the first director of the National Climate Change Strategy Research and International Cooperation Center, Qiu Xin, vice president of Risen Energy Co., Ltd., Zhang Dongbing, deputy director of the National Solar Photovoltaic Product Quality Supervision and Inspection Center, and Zhou Gang, general manager of the solar energy division of Beijing Jianheng Certification Center, and representatives of various inverters and trackers companies witnessed the release of this special edition.

During the meeting, Director Li Junfeng said that the photovoltaic industry should always put the customer value generation first, and our customers are all mankind. This year's COVID-19 brought everyone a new inspiration: that is to take a different path, and that is the path of sustainable development. Director Li also mentioned that nothing is as popular as photovoltaics. About 198 countries around the world have developed photovoltaics, and photovoltaics has become a market of 100 GW per year nowadays. This market is full of opportunities, and when such a fragmented market is being tied into a large system, many innovations will be produced. Finally, Director Li also hoped that the new generation of photovoltaic industry members could have more innovations, and explore their own life paths while bringing change to the industry.

When opportunities and challenges are both presented, **there will be an unstoppable trend to establish an open and innovative photovoltaic ecosystem. 600W+ ultra-high power modules and system integration new technology platforms are important directions for the future development of the photovoltaic industry**. Companies in the alliance will work together to build products, systems and standards based on a new technology platform, committed to maximizing the value of 600W+ ultra-high power components and solutions on the application end, in order to establish a new pattern of collaboration and win-win solution.



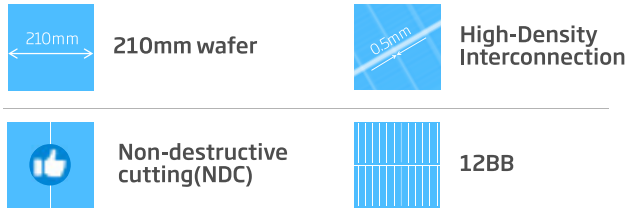
Trina Solar introduces the 670W Vertex module with the efficiency up to 21.6%, marking the unstoppable trend of 600W+

At the PV Module Tech Conference on March 11, 2021, Trina Solar Co., Ltd. ("Trina Solar") officially unveiled a new generation of ultra-high power Vertex module with a single panel power of 670W. The series has obtained the IEC certification from the TÜV Rheinland after passing complete reliability test, and realized the mass production. This marks an even higher milestone in the PV 6.0 era and demonstrates that 600W+ is unstoppable in the future.

According to Dr. Zhang Yingbin, Trina Solar's head of product strategy and marketing department, the 670W Vertex series inherits the non-destructive cutting, high-density interconnection and other high-precision technologies of the 210mm modules; with the ultra-high module power, the single string power gets 34% higher than that of other 500W+ modules in the industry. In addition, 670W Vertex modules maximize the container space utilization in transportation, as a result of which the 12% up in the loading power and 5 - 7% down in the installation cost, creating more room for reduction of the LCOE and BOS cost.

The 670W Vertex modules inherit the four 210 key technologies

As a type of 210mm module, Trina Solar's 670W Vertex bears non-destructive cutting, high-density interconnection, multi-busbar (MBB) and other forward-looking innovative technologies, with low voltage, high string power and other core features, presenting efficient and reliable product performance. The MBB and high-density interconnection improve the module efficiency to up to 21.6%, while the non-destructive cutting pioneered by Trina Solar significantly reduces the risks of cell micro crack and power loss.



Leading Advantages, 34% higher power generation

Increasing in power of the single string is the core factor to reduce the BOS cost. At the launch of the 670W Vertex, Dr. Zhang Yingbin explained that in large-scale power plants (-20℃), the 670W Vertex has 28 modules on each string. Compared to other 500W+ high-power modules in the industry, the 670W Vertex module achieves a total power increase of up to 18,760W per string, 34% higher than that of the 500W+ modules.

Module	Per Module Power	Module Quantity /String	Total Power per String
Vertex	670W	**28**	**18760W**
Reference Module	540W	26	14040W

-20 degrees below zero , 1500V system
location: Minnesota 40°40'00.00"N 122°29'00.00"W

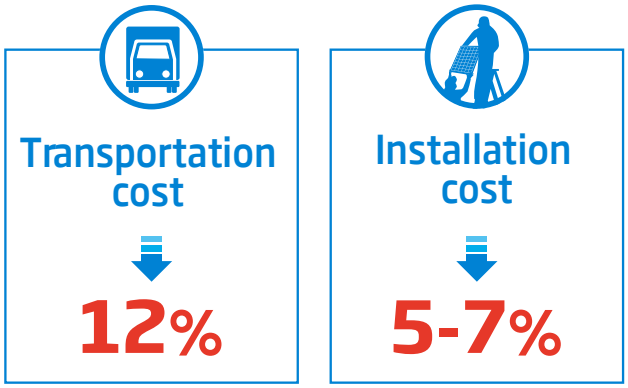
670W Vertex module is suitable for large-scale power plants, especially the low-cost power plants which are very sensitive to investment costs, because the 670W modules can reduce the non-silicon cost of silicon wafers and cells for the upstream supply chain, and reduce the cost of trackers, pile foundations, cables and labor for the downstream. Compared to other 500W+ modules in the industry, BOS cost savings are at least 0.08-0.09 yuan per watt, hence with a significant overall advantage.

Complete reliability test, 12% falls in transportation cost and 5-7% falls in installation cost

At the launch conference, Trina Solar once again introduced the reliability the 670W product performed in transportation and installation.

Packaging & Transportation

For 600W+ series products, Trina Solar innovated the packaging method to vertical placement, so that the width of the modules is no longer limited by the height of the container.



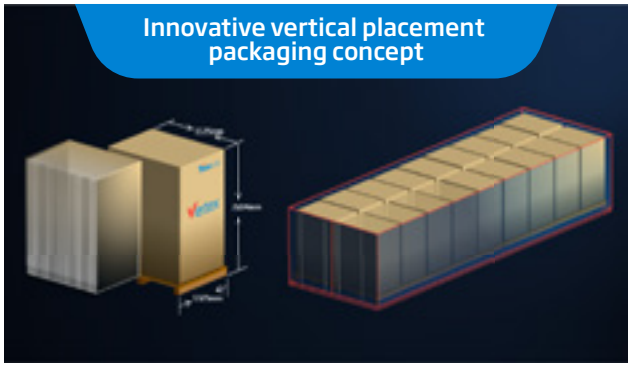
Such packaging makes the best use of the container's internal capacity. Compared with the traditional ways, the loading power increases by 12%, which introduces a 12% cost reduction in transportation. In terms of safety, first of all, the factory packaging is completed by automatic equipment to ensure safety and efficiency; secondly, in the process of transportation, the modules pallets are closely arranged inside the container, to avoid shaking; finally, stable and reliable transfer was achieved at the project site to ensure safe delivery to the customers.

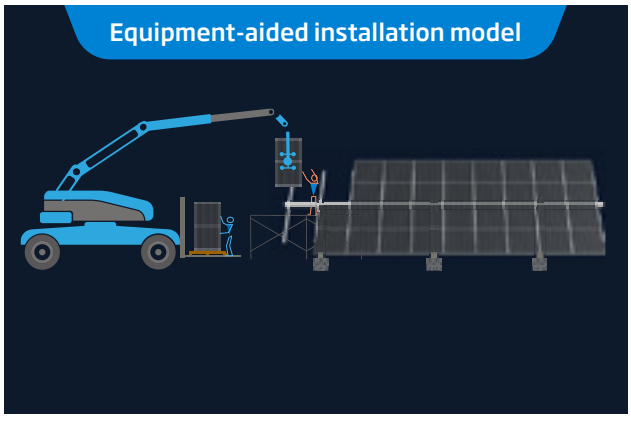
Installation

For the stage of unpacking and installation, Trina Solar provides simple and easy-to-use auxiliary tools with standard configuration, which can be used as the support of the box body to ensure the safety in the entire unpacking process. Many empirical studies have proved that 670W modules also support traditional installation methods. Meanwhile, the number of modules can be reduced by about 24% for 100-megawatt power plant thanks to the substantial increase in module power over 100W, leading to the overall installation cost reduction by 5% to 7%. In addition, Trina Solar has started to develop automatic installation machine, retaining only the delicate manual operations such as fastening screws. This will undoubtedly improve the installation efficiency, reduce the labor costs, and drive down the LCOE.

Mechanical loading performance

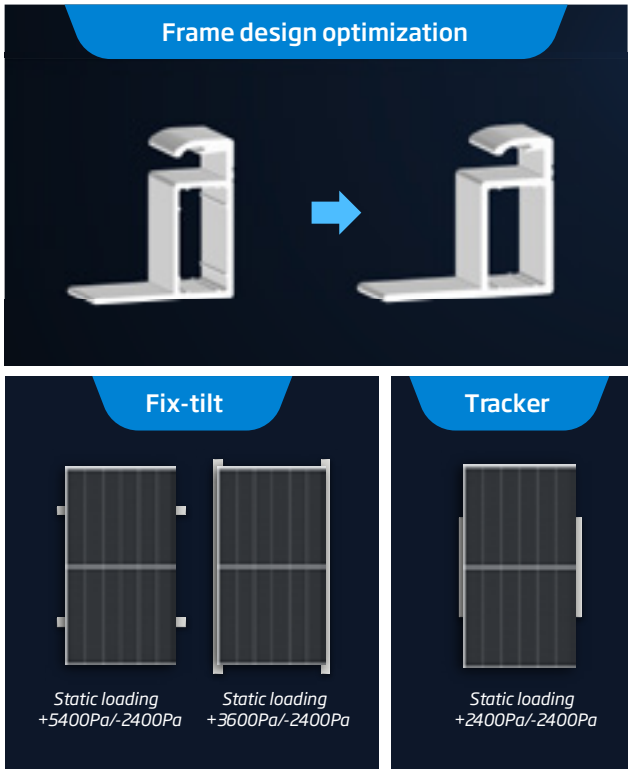
The load capacity of Trina Solar's 670W modules is also tested. On one hand, the optimized frame design and material selection prevents the deformation even when the module area increases, and reduces the risk of micro crack. On the other hand, the non-destructive cutting ensures that each cutting surface of the cell is smooth and crack-free. Owing to these measures, the loading capacity of the 670W Vertex module can adhere to the industry mainstream standard of 5400 Pa positive load and 2400 Pa negative load.





The entire industry chain, inverters, trackers, glass supply, is ready to embrace the PV 600W+ era

At the beginning of this year, Huawei, Si-Neng, and Sungrow launched inverters compatible with the 600W+modules, and TBEA, GOODWE, Ginlong, Kstar, SMA and some other inverter manufacturers also announced their products compatible with high-power 210mm modules. Obviously, these 18.4A



- 18.5A inverters will also be fully compatible with 670W modules.

Almost at the same time, eight world-leading PV tracker manufacturers - Arctech Solar, Array Technologies, GameChange Solar, IDEEMATEC, Nextracker, PVH, Soltec, TrinaTracker - announced trackers of full compatibility with 210mm ultra-high power modules.

In early March, glass manufacturers such as Xinyi, Flat, CNBM, Kibing and China Southern Glass also brought the news that they have broken through the bottleneck of width in PV glass raw materials production and started to fully adapt to the large-size 210 modules.

The 210mm modules, integrating high efficiency, high reliability, high power generation and low cost have been increasingly favored by the market, with tenders for large-size modules accounting for more than 78%. By the end of 2021, 210 modules production capacity is expected to achieve 120 GW in the entire industry. At Trina Solar, 210 modules will account for 70% to 80% of its overall shipments this year. As ultra-high power 600W+ modules becoming an unstoppable trend in the PV industry, the industry will continue to deliver more support for the innovative 210 solutions both upstream and downstream.

As Dr. Zhang Yingbin said, "As a leader in the industry, Trina Solar has been driven by innovative, reliable quality and customer value. The ultra-high power Vertex 670W module launched this time reveals higher feasibility in reducing the BOS cost and LCOE, which will help achieve the renewable energy goals and accelerate the PV industry's pace to embrace the era of grid parity. This is profound importance for China's PV industry to once again lead the world."

210 products for ground and rooftop applications

Product portfolios of Trina Vertex family

Utility

Vertex 550W | Vertex 600W | Vertex 670W | TrinaTracker

Vertex 670W

Vertex 550W

High customer value

- Lower LCOE (Levelized Cost Of Energy), reduced BOS (Balance of System) cost, shorter payback time
- Lowest guaranteed first year and annual degradation
- Designed for compatibility with existing mainstream system components
- Higher return on Investment

High reliability

- Minimized micro-cracks with innovative non-destructive cutting technology
- Ensured PID resistance through cell process and module material control
- Resistant to harsh environments such as salt, ammonia, sand, high temperature and high humidity areas
- Mechanical performance up to 5400 Pa positive load and 2400 Pa negative load

High energy yield

- Excellent IAM (Incident Angle Modifier) and low irradiation performance, validated by 3rd party certifications
- The unique design provides optimized energy production under inter-row shading conditions
- Lower temperature coefficient (-0.34%) and operating temperature
- Up to 25% additional power gain from back side depending on albedo

TrinaTracker

High reliability

- "Four better"
- Compatible with all modules
- Better structural components
- Better drive solution
- Better wind engineering research

More yield gain

- "Three higher"
- Scattered radiation yield gain is higher
- Bifacial modules have higher yield gain
- Avoid shadows and increase yield gain

Low Costs

- "Two lower"
- Lower BOS cost
- Lower O&M cost

Integrated Service

- "one stop"

Non-utility

Vertex S 400W+ | Vertex 500W+

Vertex S 400W+

Universal solution for residential and C&I rooftops

- Designed for compatibility with existing mainstream optimizers, inverters and mounting systems
- Perfect size and low weight. Easy for handling. Economy for transporting
- Diverse installation solutions. Flexible forsystem deployment

Outstanding Visual Appearance

- Designed with aesthetics in mind
- Excellent cell color control by dedicated cell blackening treatment and machine selection.
- Thinner wires that appear all black at a distance

High Reliability

- 15 year product warranty
- 25 year performance warranty with lowest degradation;
- Minimized micro-cracks with innovative non-destructive cutting technology
- Ensured PID resistance through cell process and module material control
- Mechanical performance up to 6000 Pa positive load and 4000 Pa negative load

Small in size, big on power

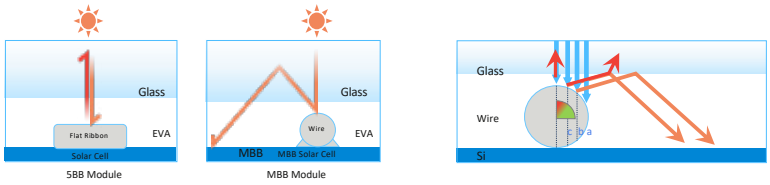
- Small form factor. Generate a huge amount of energy even in limited space.
- Up to 20.5% module efficiency with high density interconnect technology
- Multi-busbar technology for better light trapping effect, lower series resistance and improved current collection
- Reduce installation cost with higher power bin and efficiency
- Boost performance in warm weather lower temperature coefficient(-0.34%) and operating temperature

Vertex 500W+

Technical Characteristics

MBB - MODULE EFFICIENCY IMPROVEMENT 0.4%~0.6%

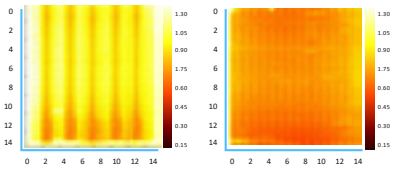
- Optical performance:
  1%~1.5%
  Power improvement

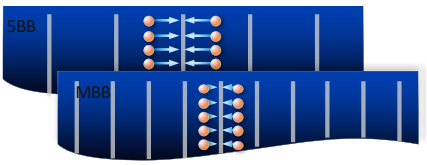


Shading reduction

Light trapping effect

- Electrical performance:
  1%~1.5%
  Power improvement

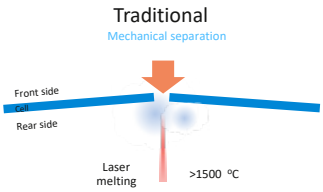


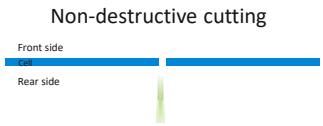


Distribution of resistance on PI (photoluminescence) test

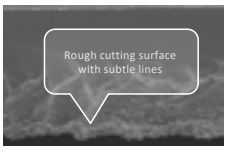
50% shorten current path Comparing to 5BB

NDC - SMOOTH SURFACE WITHOUT MICRO CRACK



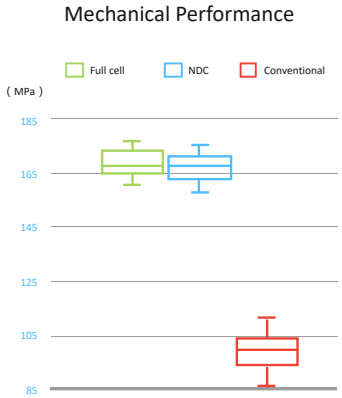


Low Temperature
Non-destructive cutting(NDC) Process

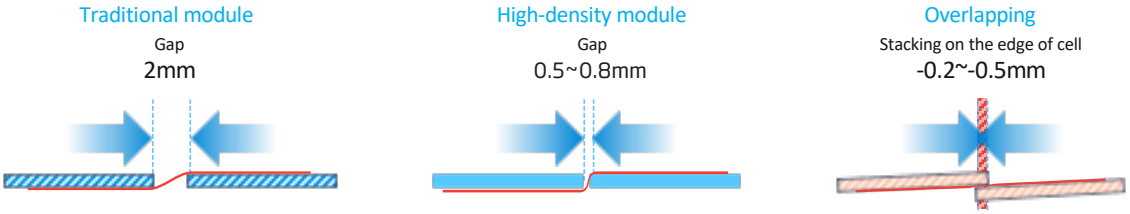


Section after traditional cutting

Section after NDC



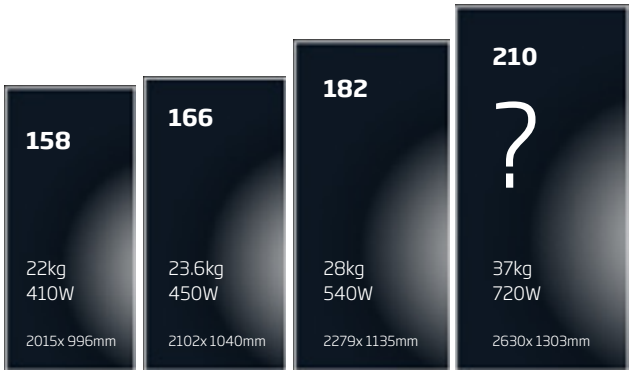
HIGH-DENSITY INTERCONNECTION - MODULE EFFICIENCY IMPROVEMENT 0.3%



Adding customer value
analyzing the advantages of 210 series applications

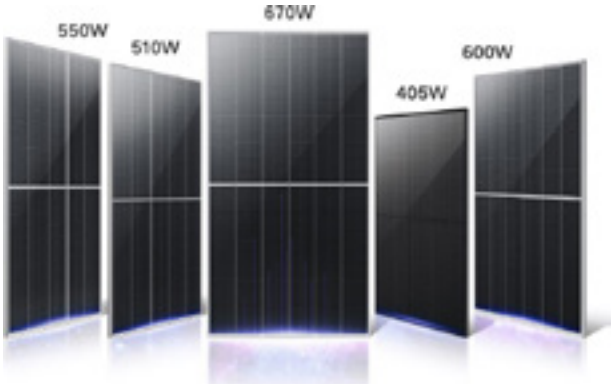
210mm series: a wide-range of solutions

Over the last year, we have seen an increase in the size of silicon wafers, arriving at modules that deploy the 210mm silicon wafers (210 series ultra-high power module). As the size of silicon wafers has increased over the last year, we've seen a correolation in power. The diagram below shows this growth with wafers increasing in size from 156mm to 210mm while power in the 72-cell module is 540W for the same layout.



So, does a 210mm wafer deliver 720W? Yes but power is not the only consideration. The structure would need to be 2.6m long and 1.3m wide and weigh up to 37kg.

It's worth noting that 210mm module is just the size of the silicon wafer and components using them can come in variety of cell designs. In December, the 600W+ Photovoltaic Open Innovation Ecological Alliance companies announced a compact 210mm module delivering 400W. The unit is virtually the same size as the smaller 166mm 60-cell module but delivers 30W more power. Moreover, 400W would normally require the much larger 72-cell, 158mm unit. The cutting-edge technology in 210mm silicon wafers not only boosts power but also allows more opportunity to optimize designs.



This is evidenced in the five 210mm modules already announced with power ranging from 400W to 670W, with applications for a variety of design scenarios. This paper discusses the advantage of using the 210mm module through the analysis of the pain points in different market segments, as well as how different product lines impact customer value.

Comparing distributed models in the market

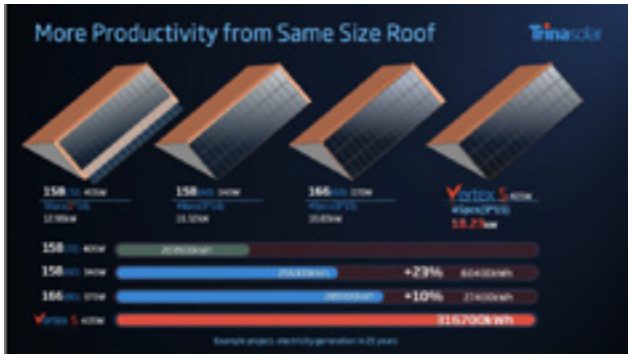
According to some market predictions, about half of all photovoltaic projects will run a distributed model. In terms of product selection, these projects will significantly differ from large-scale power stations.

Residential scenarios:

If a 72-cell module is applied in a rooftop design as shown in

the diagram below, only two rows of modules can be arranged. 60-cell modules fit better given to the size restraints. This is precisely why smaller modules dominate the market. **Fully covering the rooftop is an essential factor in choosing products for household set-ups.**

In this case, the capacity of a compact 210mm module of 400W will be 12% higher than that of the 158mm module, and a 10% increase compared to the 166mm module. The higher power module will deliver better returns for this kind of project.



Commercial scenarios:

There are similar requirements for distributed rooftop commercial designs. The number of modules dictates the use of trackers, cables, connectors, and so on. Therefore, high-power modules have their advantages. Meanwhile, the layout of the roof also requires a flexible design for greater capacity.

Consider a design for a 10,000-square-meter commercial premise with colored steel tiles. Using string-type 1,000V inverters in a tiled installation setting, the comparison of 158mm, 166mm and 210mm modules is as follows:

Item	158 modules	166 modules	210 modules
Module power	(405W)	(445W)	(495W)
Photovoltaic structure	0.15	0.14	0.13
Cables and connectors	0.04	0.036	0.032
Site construction and installation	0.282	0.269	0.257
Works for other equipment and utilities	0.7	0.69	0.68
BOS cost	1.172	1.135	1.099
Difference in BOS cost		-0.037	-0.073

Compared to the 158mm modules, there is a 6.6% increase in capacity over the same roof area with the 210mm modules, saving 7 cents per Watts in BOS cost. The rooftop is better utilized, and the rate of return is significantly higher.

The 400W and 500W version of the 210mm modules fit roofs of different sizes. Their electrical parameters are also similar to those of conventional 166mm modules, and they can work well with a wide-variety of inverters available today. Simply put, they are flexible and easy to use.

Comparing power stations

For power stations, customer value is reflected in cost control. Different types of modules impact not only the overall cost of the system but also the energy yield. Currently, mainstream modules are classified by their power levels based on PERC monocrystalline cell technology, with just tiny differences in energy yield. Instead, a greater focus is placed on cost reduction through increasing power, using fewer modules and improving system layouts.

Comparing power stations at different latitudes:

The 210mm modules of 550W, 600W and 670W are primarily designed for large-scale power stations, where the 550W model is in mass use. Data collected from Hebei Energy Engineering Design Institute and Shandong Electric Power Engineering Consulting Institute highlights the variation in performance at different latitudes as follows:

Design Institute	Solution	Differences (Yuan/W)		
		210 vs 166		
Hebei Energy	String	Guangdong	Shandong	Heilongjiang
		0.102	0.119	0.172
Shandong Institute	Central	Guangdong	Henan	Inner Mongolia
		0.110	0.090	0.120

Design Institute	Solution	Differences (Yuan/W)		
		210 vs 182		
Hebei Energy	String	Guangdong	Shandong	Heilongjiang
		0.030	0.042	0.071
Shandong Institute	Central	Guangdong	Henan	Inner Mongolia
		0.020	0.040	0.030

The end cost of the three low-voltage modules significantly drops with increasing power. Comparing the 550W module with the 155mm 450W module, the decreases range between 0.1 and 0.17 yuan/W. And compared to the 182mm 540W module, cost falls anywhere from 0.03 to 0.07 yuan/W.

A staff member from a well-known local design institute said: "According to the test data from the three latitudes, high-power modules can indeed save costs. The amount is region-dependent; in higher latitudes, the saving is more significant as more trackers, pile foundations and cables are used."

Yu Long, a photovoltaic engineer from the New Energy Division of Shandong Electric Power Engineering Consulting Institute, said: "The three commonly seen modules are developed based on the varying latitudes. The conclusion is clear: modules with

higher power help reduce costs. The combination of high-power modules and large low-voltage strings can effectively reduce the cost of power stations."

Comparing composite projects:

For projects such as agricultural solar lighting, fishing solar lighting and tidal flats, pile foundation costs are usually very high due to various factors such as farming facilities and water depth. The construction is also complicated, which leads to high labor costs. The initial investment is usually much larger than, say, photovoltaic projects. **For composite projects, it is critical to reduce the scale of pile foundations.**

We compared four composite projects in a variety of locations. These projects have different pile lengths based on four scenarios and the comparison is as follows:

Type	Pile length (m)	Solution	Location	Difference（Yuan/W）	
				210 vs 166	210 vs 182
Agricultural solar lighting	5	Central	Guangdong	0.089	0.026
Agricultural solar lighting	6	String	Hebei	0.121	0.045
Fishing solar lighting	10	String	Jiangsu	0.146	0.042
Fishing solar lighting	12	String	Anhui	0.185	0.069

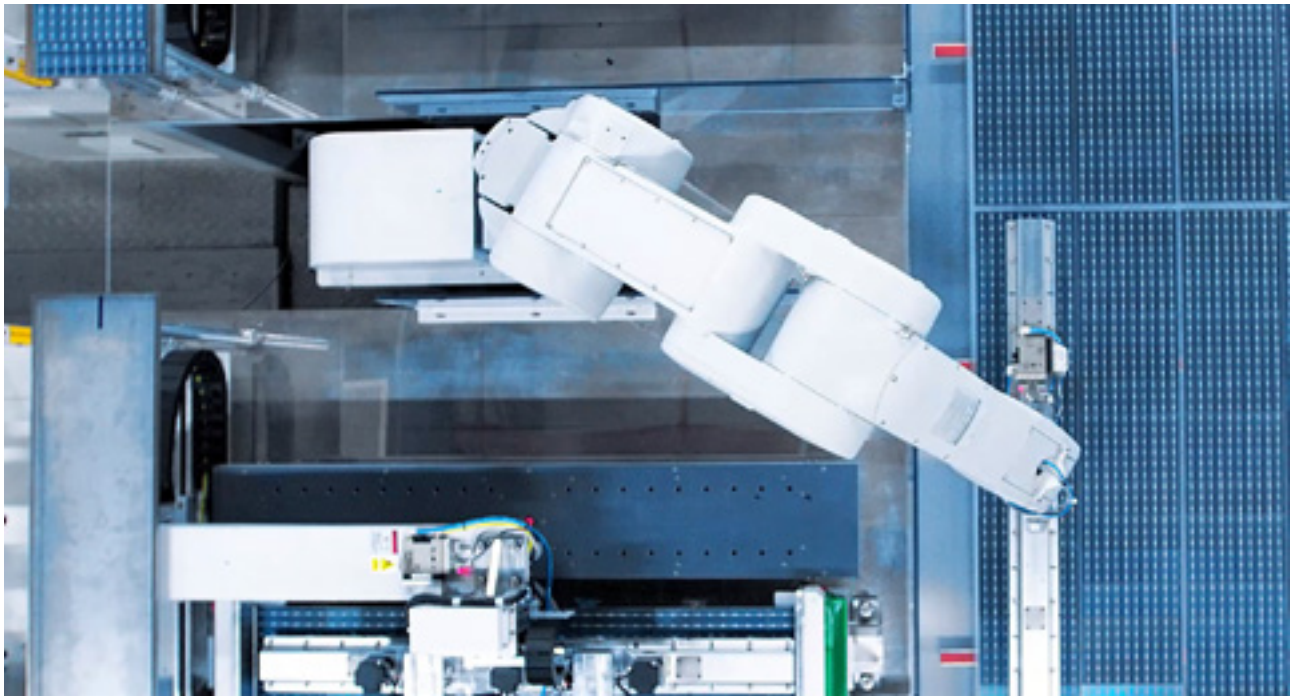
Feng Zhuowen, Chief Engineer of Hunan Institute of New Energy, said: "Projects with agricultural solar lighting and fishing solar lighting have high costs because of the use of pile foundatiosn and trackers. The 210mm module works best to reduce the project cost significantly by lowering the the number of pile foundations. With lower per-watt power cost comes a higher rate of returns."

210mm series further increases customer value

All set-ups – whether they are domestic or commercial, regular power stations, agricultural or fishing solar lighting – have different pain points. Solutions using the 210mm module are suitable for a wide range of scenarios, even in a market that is highly segmented.

After more than a year in development, there is an arsenal of products in the 210mm series. The 400W and 500W modules are flexible for household distributed projects, while the 550W and 670W modules work very well with power stations via their high-power low-voltage settings. Irrespective of the setting, customer value is increased – something that has been proven by more than a dozen institutions.

With subsidies falling next year, we are entering an era of flat rates and we may find ourselves in a price war. Module prices will likely remain high, though, and there is a chance that the photovoltaic industry may well slow down as prices fall. But innovative products like the 210mm series will likely offset any decline and help drive the industry forward.



The way to best LCOE (I)
System value assessment for Trina 210 Vertex bifacial-dual-glass module with single-axis tracker

Since establishment from 1997, Trina Solar has been driven by innovative, reliable quality and customer value. Since the release of the first advanced Vertex 210mm modules in February 2020, the product line has been stacked with different products including Vertex S 400W, and the Vertex series of 500W, 550W and 600W and beyond, which fit well with the applications of residential, commercial and large scale power plant, as well as multiple scenarios of agriculture and fisheries .

In the era of grid parity, the Vertex series have a prominent edge in Levelized Cost of Energy (LCOE). Foreign and domestic leading design institutes and well-known third-party organization DNV GL have evaluated the LCOE advantage and value of Vertex 210mm modules, notably the bifacial dual-glass Vertex series. The report finds that the 545W bifacial dual-glass Vertex module has the best Levelized Cost of Energy (LCOE), and performs significantly better than the conventional 166mm, 450W and 182mm, 535W modules in terms of BOS costs.

High-power, high-efficiency modules are getting inevitably popular in the era of grid parity. With its top-notch research and development of ultra-high-efficiency modules, Trina Solar has led the industry into the 600W+ era, with a host of high-power, high-efficiency, high-yield and highly reliable products. More discussions are surrounding how ultra-high-power modules can best preserve customer value by reducing cost. Trina Solar's innovative "low voltage, high string power " design concept has drawn attention from the industry. To further prove this as the best LCOE reduction strategy, Trina Solar invited DNV GL to evaluate such design in terms of BOS costs and LCOE. Through the comprehensive and objective evaluation system and methodology by an independent third party, the design concept of "low voltage, high string power" can be demonstrated to the industry and customers.

Assumption for assessment

To fit different solar projects, the assessment took place in typical photovoltaic sites in Spain and Texas, US, with the coordinates and climate as follows:

In these locations, DNV GL compared the BOS costs and LCOE

Coordinates of the projects

	GHI [kWh/m²] monthly	DHI [kWh/m²] monthly	T [°C]
Source	Satellite derived [4]	Satellite derived [4]	Satellite derived [4]
Period	1994 – 2019	1994 – 2019	1994 – 2019
Jan	80	29	10.7
Feb	99	36	12.1
Mar	148	52	14.9
Apr	176	62	17.1
May	213	72	20.8
Jun	234	69	25.2
Jul	245	64	27.5
Aug	218	62	27.7
Sep	164	54	24.3
Oct	122	45	20.2
Nov	85	31	14.5
Dec	71	26	11.6
Total	1,856	603	18.9

	GHI [kWh/m²] monthly	DHI [kWh/m²] monthly	T [°C]
Source	Satellite derived [4]	Satellite derived [4]	Satellite derived [4]
Period	1999 – 2018	1999 – 2018	1999 – 2018
Jan	96	27	5.4
Feb	108	32	7.5
Mar	156	49	12.8
Apr	183	58	17.6
May	205	70	22.4
Jun	217	68	27.3
Jul	225	62	29.3
Aug	203	59	28.9
Sep	162	51	24.1
Oct	130	39	17.8
Nov	98	27	11.4
Dec	83	26	5.6
Total	1,865	567	17.5

Local weather information

of the bifacial dual-glass 166mm, 450W module, 182mm, 535W module, and the Vertex bifacial dual-glass 210mm-545W module, based on fixed 100MW AC capacity, with the same DC/AC ratio design at the power station. In terms of system design, the projects adopted a single-row, one portrait mounted, single-axis (1P) tracker, equipped with a string inverter. The ground cover ratio (GCR) is fixed to ensure the consistent shadow occlusions on the bifacial module. Such design aims to maintain control over climate and project design, while objectively comparing merely to impact on costs and LCOE based on a different module. To make the comparison more meaningful, the trackers and inverters used are all mainstream products. The costs of the three tested sytem are based on local costs so that it is consistent, comprehensive and objective when comparing the on-grid tariff as well as the costs of operation and maintenance.

Parameters of power station design and 3D simulation diagrams as below:

Layout design of the power station in Spain

Layout design of the power station in the US

Module power	450 W	535 W	545 W
Module		bifacial	
Dimensions L x W [mm]	2111 x 1046	2256 x 1133	2384 x 1096
# modules	244,350	205,389	201,600
Modules/string	27	27	35
Inverter		Sungrow SG250HX (string inverter)	
Inverter capacity		225 kWdc	
# inverters		445	
Tracker		NexTracker (1 module portrait)	
Tracker length [m]	85.1	92.2	77.4
# trackers	3,017	2,536	2,880
Modules per tracker	81 (3 strings)	81 (3 strings)	70 (2 strings)
Transformers		44 x 2.5 MW 1 x 1.5 MW	
DC Capacity		110 MWdc	
AC Capacity		100 Mwac	
DC/AC ratio		1.1	
Pitch [m]	6.55	7.00	7.41
Ground cover ratio (GCR)		32.2%	

Parameters of the power stations

Assessment results:

In the Spanish project site, while compared to the 166mm bifacial dual-glass, 450W module, Trina Solar's Vertex 210mm bifacial dual-glass 545W can save the initial investment by 2.16 Euro cents per watt, reducing LCOE by about 3%. Compared to the 182mm bifacial dual-glass, 535W module, the initial investment is down by 0.2 Euro cents per watt, reducing LCOE by 0.3%.

For the project site in the United States, while compared to the 166mm bifacial dual-glass, 450W module, Trina Solar's Vertex 210mm bifacial dual-glass 545W can save the initial investment by 4 US cents per watt, reducing LCOE by about 3.9%. Compared to the 182mm bifacial dual-glass, 535W module, the initial investment is down by almost 1 US cents per watt, reducing LCOE by 0.5%.

	Spain			USA		
	450 W	535 W	545 W	450 W	535 W	545 W
Module		0.1932			0.3200	
Inverter		0.0257			0.0279	
Tracker & mounting	0.1000	0.0896	0.0885	0.126	0.1124	0.1115
EPC cost	0.5268	0.5079	0.5052	0.9533	0.9222	0.9132
Development	0.1137	0.1138	0.1138		0.1567	
CAPEX	0.6406	0.6217	0.619	1.1099	1.0788	1.0699
CAPEX compare 450 W		-2.9%	-3.4%		-2.80%	-3.60%
Land	0.0017	0.0016	0.0017	0.0034	0.0033	0.0033
O&M fee		0.015			0.0082	
Asset management		0.002			0.0015	
OPEX		0.0187			0.0130	
	Euro €/kWh			USD $/kWh		
LCOE	0.0366	0.0357	0.0356	0.0451	0.0437	0.0435
LCOE compare 450 W		-2.5%	-2.8%		-3.0%	-3.5%

Comparison of estimate costs

Through the comparisons, Trina Solar's Vertex can significantly reduce costs, LCOE in particular, thanks to its superbly efficient power generation capacity and its low-voltage, highstring power design. On the one hand, the 210mm modules' 545Wultra-high power can reduce the numbers of modules in the setup. On the other hand, the iconic low-voltage design in Vertex 210mm module can string up more modules with the 1,500V voltage, which can boost the single string power with fewer strings connected. In turn, it can save the material and labor costs of DC cable work, and thus lowering the initial investment.

The above calculations match with the existing mainstream 1P trackers. DNV GL further elaborates, "With the further optimization and extension of the tracker length, the 545W Vertex 210mm-Module will save more in BOS cost and LCOE than the other two modules, giving it more edge." Currently, the 600W+ Alliance and mainstream tracker makers are either developing or launching more optimized trackers for these modules.

With the close partnership in the 600W+ Photovoltaic Open Innovation Ecological Alliance members, along with the design mindset of low voltage , high string power, modules, trackers, inverters as well as solutions are all in place. This is a critical step for the photovoltaic industry to reach the best LCOE.

In conclusion, Trina's Vertex 210mm module and its low-voltage high-string power design can significantly save the system's BOS cost and LCOE. It sets a new cost-saving standard, ultimately ensure the project's earnings and maximize customer value, making PV solar energy more cost competitive.

* For more information about the assessment report on Trina's Vertex modules, please contact Trina's local sales representatives. And please follow "The Way to Best LCOE" series.

The way to best LCOE (II)
DNV GL's technical report: reducing LCOE by 3.72%,
Trina Solar pioneers in better system value by 210 Vertex modules conjoining single-axis 2 portrait installation (2P) tracker

CHANGZHOU, China, Jan. 24, 2021 /PRNewswire/ -- DNV GL, the international leading design institutes and the well-known third-party organization, just reported the value of Trina Solar's 600W+ Vertex Bifacial Dual-Glass Module with Single-Axis 2 portrait installation (2P) tracker, calculating their systematic advantages of BOS and LCOE, resulting the continuous BOS saving up to 6.32% and LCOE reduction by 3.72% compared with the 166mm bifacial dual-glass module. The assessment was carried out at two PV sites in Spain and the US, given their geographical representation.

This is DNV GL's second run Assessment on Trina Solar's 210 Vertex modules following the first round in early December 2020.

Steady Value Improvement on 210 Vertex Modules with Tracker

As the PV industry accelerates its entry into the era of grid parity, the Vertex series have a prominent strength in LCOE thanks to the continued efforts to cost reduction and efficiency improvement by Trina Solar. The assessment performed in last December found that Trina Solar's 545W bifacial dual-glass Vertex module with single-axis 1 portrait installation (1P) tracker has the best LCOE, a drop of 3.5% compared with conventional 166mm-450W and 182mm-535W modules in terms of BOS costs.

DNV GL's Technical Report (II) confirms the value of Trina's Vertex modules according to the assessment results of Vertex module with single-axis 2 portrait installation (2P) tracker. Vertex's innovative "low voltage, high string power" design boosts the single string power while lowering the initial investment and the cost at each stage.

Assessment Results: reducing BOS up to 6.32% and LCOE by 3.72%

The assessment of Vertex module with single-axis 2 portrait installation (2P) tracker took place in typical PV application sites in Spain and Texas, US, with the coordinates and climate as follows:

Seville, Spain (37.27°, -5.74°) Texas, USA (34.36°, -99.89°)

Coordinates of the projects

	GHI [kWh/m²] monthly	DHI [kWh/m²] monthly	T [°C]
Source	Satellite derived /4/	Satellite derived /4/	Satellite derived /4/
Period	1994 - 2019	1994 - 2019	1994 - 2019
Jan	80	29	10.7
Feb	99	36	12.1
Mar	148	52	14.9
Apr	176	62	17.1
May	213	72	20.8
Jun	234	69	25.2
Jul	245	64	27.5
Aug	218	62	27.7
Sep	164	54	24.3
Oct	122	45	20.2
Nov	85	31	14.5
Dec	71	26	11.6
Total	1,856	603	18.9

	GHI [kWh/m²] monthly	DHI [kWh/m²] monthly	T [°C]
Source	Satellite derived /1/	Satellite derived /1/	Satellite derived /1/
Period	1999 – 2018	1999 – 2018	1999 – 2018
Jan	96	27	5.4
Feb	108	32	7.5
Mar	156	49	12.8
Apr	183	58	17.6
May	205	70	22.4
Jun	217	68	27.3
Jul	225	62	29.3
Aug	203	59	28.9
Sep	162	51	24.1
Oct	130	39	17.8
Nov	98	27	11.4
Dec	83	26	5.6
Total	1,865	567	17.5

Monthly GHI&DHI data

In the above locations, DNV GL compared the BOS costs and LCOE of the bifacial dual-glass 166mm-450W module and 182mm-535W module with the Vertex bifacial dual-glass 210mm-545W module with single-axis 2 portrait installation (2P) tracker, based on fixed 100MW AC capacity, with the same DC/AC ratio design at the power station. In terms of system design, the projects adopted a single-axis 2 portrait installation (2P) tracker, equipped with a string inverter. The ground cover ratio (GCR) is fixed to ensure the consistent shading on the bifacial module.

Such design aims to maintain control over the influence of external factors and system configuration on the same site, to objectively compare costs and LCOE based on different modules. The comparison of the costs of the three tested groups are all based on local equipment, construction and installation, labor costs, grid interconnection fees, costs of operation and maintenance, land cost, and financial cost, so that the calculation is consistent, complete and objective.

The site system is configured as follows:

Module power	166 - 450 W	182 - 535 W	210Vertex - 545 W
Module type		Bifacial dual glass module	
Dimensions L x W [mm]	2111 x 1046	2256 x 1133	2384 x 1096
# modules	244,350	205,389	201,600
Modules/string	27	27	35
Inverter		Sungrow SG250HX (string inverter)	
Inverter capacity		225 kWdc	
# inverters		445	
Tracker		Arctech Tracker (2 portrait)	
Tracker length [m]	56.75	61.45	58.07
# trackers	2263	1902	1920
Modules per tracker	108(4 strings)	108 (4 strings)	105 (3 strings)
Transformers		44 x 2.5 MW 1 x 1.5 MW	
DC Capacity		110 MWdc	
AC Capacity		100 Mwac	
DC/AC ratio		1.1	
Pitch [m]	13.10	14.00	14.82
Ground cover ratio (GCR)		32%	

Site system configuration

Assessment results in the Spanish project:

While compared to the 166mm-bifacial dual-glass-450W module, Trina Solar's 210 Vertex bifacial dual-glass-545W can save the BOS up to 6.32%, reducing LCOE by about 3.19%. Compared to the 182mm-bifacial dual-glass-535W module, the BOS is down by 1%, with better performance in terms of LCOE.

Assessment results in the US project:

While compared to the 166mm bifacial dual-glass-450W module, Trina Solar's 210 Vertex bifacial dual-glass-545W can save the BOS up to 6.06%, reducing the LCOE by about 3.72%. Compared to the 182mm-bifacial dual-glass-535W module, the BOS is down by 1.2%, reducing LCOE by about 0.5%.

	Spain Project Euro €/Wp			US Project USD $/Wp		
	450 W	535 W	545 W	450 W	535 W	545 W
Module		0.1952			0.3200	
Inverter		0.0257			0.0279	
Tracker & mounting	0.1089	0.0957	0.0932	0.1216	0.1071	0.1043
BOS	0.3164	0.2991	0.2964	0.6118	0.5841	0.5747
BOS compare 450W		-5.47%	-6.32%		-4.53%	-6.06%
EPC cost	0.5096	0.4923	0.4897	0.9518	0.9041	0.8947
Development	0.1070	0.1034	0.1028	0.1584	0.1537	0.1521
CAPEX	0.6166	0.5957	0.5925	1.0902	1.0577	1.0468
Land	0.0017	0.0016	0.0017	0.0031	0.0030	0.0030
O&M fee		0.015			0.0082	
Asset management		0.002			0.0015	
OPEX		0.0187		0.0128	0.0127	0.0128
	Euro €/kWh			USD $/kWh		
LCOE	0.0364	0.0953	0.0952	0.0451	0.0437	0.0435
LCOE compare 450 W		-3.01%	-3.19%		-3.28%	-3.72%

Comparison of estimate costs

DNV GL reports: Higher Systematic Value, lowest LCOE with Trina Solar's Products

After the Assessment on Vertex module with single-axis 1 portrait installation (1P) tracker, DNV GL confirms Trina's value again according to the assessment results of Vertex module with single-axis 2 portrait installation (2P) tracker. First of all, Vertex's innovative "low voltage, high strings power" design can interconnect more modules with the 1,500V voltage, which can boost the single string power. Secondly, the ultra-high power can reduce the numbers of modules in the setup. In turn, it can save the material and labor costs of DC cable work, and thus lowering the initial investment by reducing transportation, manual installation and civil work costs. Last but not least, with superior power generation performance, Vertex are able to maximize value for customers by ensuring a minimum LCOE.

Since establishment from 1997, Trina Solar has been driven by innovative, reliable quality and customer values. Since the release of the first advanced 210 Vertex modules in February 2020, the product line has been enriched with different products including Vertex S 400W, and the Vertex series of 500W, 550W and 600W and beyond, which fit well with the applications of residential, commercial and large scale power plant, as well as multiple scenarios of agriculture and fisheries. As planned by Trina Solar, the capacity of PV modules will be no less than 50GW by the end of 2021, and it will continue to strengthen the capacity of advanced modules with large-size cells in the future.

* For more information about DNV GL's Technical Report on Trina Vertex BOS & LCOE, please contact Trina's local sales representatives by sending the mail to VertexValue@Trinasolar.com

And please follow up "The Way to Best LCOE" series in the future.

The way to best LCOE (III)
BOS costs reduced by 6.3%,
DNV GL report on Trina Solar Vertex 210mm modules' advantages with fixed tilt underlines value in both BOS and LCOE

In February 2021 the internationally authoritative third-party organization DNV GL began the third round of assessment of the BOS cost and LCOE of Trina Solar's 210mm Vertex modules. The assessment took place in Aomori prefecture, Japan. In the assessment, the BOS cost and LCOE were compared between two sets of 210mm Vertex module and 182mm module both with landscape-fixed tilts. **Trina Solar's Vertex 210mm 545W mono-facial modules can cut the BOS cost by up to 6.3% and LCOE by 5.8% compared with the 182mm 535W mono-facial modules**, the report said, and the Vertex 210mm 600W mono-facial module performs just as well in reducing BOS and LCOE (5.6%) compared with the 182mm 585W module.

Where the assessment took place

In Aomori prefecture on the island of Honshu, with coordinates and conditions as follows:

40.815450°, 141.084902°.

At the site, with the 166mm 450W mono-facial module as the benchmark, DNV GL compared the BOS cost and LCOE of the Vertex 210mm 545W mono-facial module and the 182mm 535W mono-facial module, as well as the Vertex 210mm 600W mono-facial module and the 182mm 585W mono-facial module with landscape-fixed tilts. In this assessment, the capacity of the AC side was 10 MW with the same DC/AC ratio, and adopting the four-row landscape-fixed tilts commonly used in Japan and with mainstream string inverters. In order to objectively compare the impact of different types of modules on the BOS cost and LCOE, the project as a whole used similar meteorological data and design input conditions. The five comparisons were all based on local costs to be consistent, comprehensive and objective when comparing local construction cost, on-grid tariffs, operational and maintenance costs, and land costs.

Month	Aomori Project		
	GHI [kWh/m²/month]	DHI [kWh/m²/month]	Ambient Temperature [℃]
Jan	48	32	-0.9
Feb	66	42	-0.6
Mar	105	63	2.4
Apr	141	71	7.2
May	157	78	12.4
Jun	145	79	16.0
Jul	127	79	20.2
Aug	125	70	22.0
Sep	110	55	19.1
Oct	89	45	13.2
Nov	55	32	7.1
Dec	40	27	1.6
Annual	1,208	671	10.0

Local GHI & DHI and ambient temperature data

Module power					
Module type	Mono-facial module				
Module dimensions (L x W [mm])					
Module quantity					
Modules/string					
Inverter					
Inverter capacity					
Inverters					
Structure type					
Axis tilt					
Transformer rating & quantity					
Transformers rating & quantity					
DC/AC capacity					
AC/DC capacity					
DC/AC ratio					
Pitch [m]					

Parameters of the power plants

Assessment results: BOS fell 6.3%, and LCOE fell 5.8%, maximizing customer value

Vertex's innovative low-voltage design connects more 1,500V modules so that significant BOS cost savings and LCOE reduction are achieved on the fixed tilt by greatly reducing the number of module strings by connecting 8-9 more modules in a single string than is the case with182mm modules. First, it can cut material and labor costs involving DC cables and racking system, and thus reduce initial investment. Second, the ultra-high power can reduce the numbers of modules in the setup and speed up construction, further reducing total investment costs. Finally, with superior power generation, Vertex is able to maximize value for customers by ensuring minimum LCOE.

According to the assessment in Japan, Trina Solar's Vertex 210mm 545W mono-facial module can reduce BOS by up to 6.3% and reduce LCOE by 5.8% compared with the 182mm 535W mono-facial module, and the Vertex 210mm 600W mono-facial module performs just as well in reducing BOS and LCOE (5.6%) compared with the 182mm 585W module.

Comparison of estimate costs

The DNV GL report thus found that Trina Solar's Vertex 210 mm module cuts costs in many ways.

As the PV industry embraces grid parity, the Vertex series has a prominent edge in LCOE as a result of Trina Solar's continued push to reduce costs and improve efficiency. This assessment followed two rounds of assessment of Trina Solar Vertex modules by DNV GL, in January and December.

The assessment in December found that **the 545W bifacial dual-glass Vertex module with single-axis (1P) tracker** has the best LCOE, 3.5% less, and performs significantly better than the conventional 166mm-450W and 182mm-535W modules in BOS costs. (https://mgr.trinasolar.com/en-glb/resources/newsroom/mathe-way-best-lcoe-ii)

DNV GL's assessment in January focused on the LCOE advantage and value of the **Trina 600W+ Vertex Bifacial Dual-Glass Module with Single-Axis 2 portrait installation (2P) tracker**. The report found that Trina Solar's Vertex 210mm bifacial dual-glass module can cut BOS by up to 6.32% and LCOE by 3.72% compared with the 166mm bifacial dual-glass module. (https://mgr.trinasolar.com/en-glb/resources/newsroom/mathe-way-best-lcoe-i-%E2%80%93-system-value-assessment-trina-600w-Vertex-bifacial-dual)

In the report of this third assessment, DNV GL again confirmed the value of Trina's Vertex modules, being able to maximize value for customers by ensuring minimum LCOE.

Over the coming five years Trina Solar will strive to forge further ahead as a world leader in smart energy and distributed energy solutions, involving PV, energy storage and hydrogen energy industries. In this way it will contribute to the development of a clean, low-carbon, safe and efficient energy system and the development of renewable energy to achieve the goal of carbon neutrality.

Promoting standardization of the Industry

The development status of large-size module supply chain: getting compatible with 210mm size

Source: PVInfoLink

On June 24th, Canadian Solar, Runergy, SolarSpace, JA Solar, JinKo Solar, LONGI and Luan issued a joint initiative, calling for the establishment of a unified size standard (182mm) for M10 silicon wafers. It is expected that vendors, who had been in a dilemma about the size of their expanded products, would follow the leading companies in adopting the size of 182mm as the mainstream size. Unexpectedly, the 600W+ Ecological Alliance was announced on July 9th, which covers the whole PV industry chain, including the G12 (210mm) vendors in the module field such as Trina Solar, Risen Energy and Huansheng Solar PV. In addition, JA Solar from the 182 Alliance also appears in the 600W+ Ecological Alliance.

Vendors	Strategy
182 Alliance	On June 24, major progress was made in the competition of module size: Runergy, SolarSpace, JA Solar, JinKo Solar, LNGI and Lu'an Group issued a joint initiative to promote the 182mm size. This has finally settled the industry's 18Xmm speculation. In spite of capacity expansion of glass and the major supply chain, module validation is still some way off and the M6 is expected to remain a mainstream cell from the second half of this year to early next year. Actual production of 182mm wafer will not climb quarterly until next year, but the uniform size of 182mm is expected to accelerate the iteration from the M6 to the next generation size.
600W+ Photovoltaic Open Innovation Ecological Alliance	On July 9, the 600W+ Photovoltaic Open Innovation Ecological Alliance for Open Innovation was established, which brought together more than 74 companies in a short time. It contains wafer, cell, module, equipment, auxiliary materials, PV glass, PV backsheet, and inverter vendors in terms of manufacturing end, and attracts organizations in the fields of certification, design institute, terminal engineering, transportation, power station development, and research institute, forming a comprehensive alliance covering the upstream, midstream and downstream of the industrial chain. At present, more alliance companies have started to put 210mm silicon wafer into production, or plan to shift the direction of production expansion to 210mm next year.

On June 24th, Canadian Solar, Runergy, SolarSpace, JA Solar, JinKo Solar, LONGI and Luan issued a joint initiative, calling for the establishment of a unified size standard (182mm) for M10 silicon wafers. It is expected that vendors, who had been in a dilemma about the size of their expanded products, would follow the leading companies in adopting the size of 182mm as the mainstream size. Unexpectedly, the 600W+ Ecological Alliance was announced on July 9th, which covers the whole PV industry chain, including the G12 (210mm) vendors in the module field such as Trina Solar, Risen Energy and Huansheng Solar PV. In addition, JA Solar from the 182 Alliance also appears in the 600W+ Ecological Alliance.

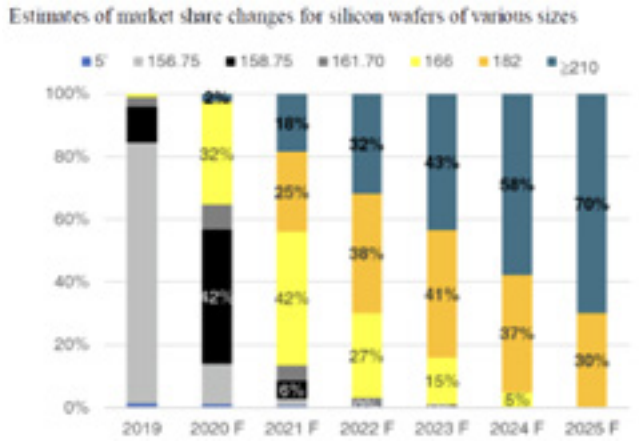
PV InfoLink conducted a trend analysis based on the current development status of the large size module's supply chain:

Two major cell vendors, Tongwei and Aiko, this year chose the production expansion strategy of 210mm with downward compatibility, and in order to meet the needs of major customers, Runergy and Headway followed the strategy. From this year to next year, the size of the cell tends to be uniform, with 210mm as the main feature, allowing downward compatibility. Considering the cost performance, there is not much upgrading from G1, M4 or 166mm production line to 182mm or above in the market. At present, only JA Ningjin and JA Shanghai have made major transformation, while other vendors mainly focus on new production expansion line.

The selection of module for production expansion changed greatly before and after the SNEC. Prior to the SNEC, models for production expansion were at the discretion of each vendor alliance. 182 Alliance selects 182mm in size, while 210 Alliance selects 210mm, compatible downward. However, as the SNEC

identified the trend toward larger modules, many of the 182 players in the Q3 began planning the production capacity of 210mm and downward compatible, and even started actively discussing the corresponding equipment. The vendors that will put 210mm into mass production next year will mainly include Trina Solar, Risen Energy, Huansheng Solar PV, and Canadian Solar, which has just released new products recently.

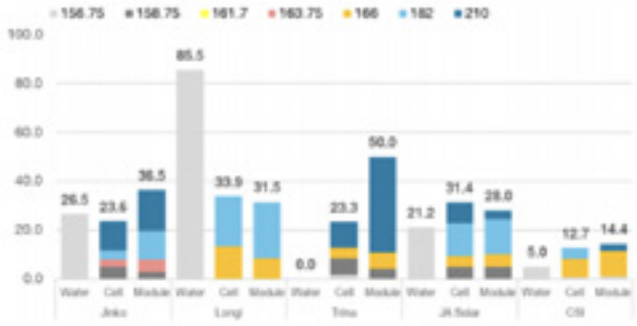
At present, such major vendors as JinKo Solar and LONGI have plans to expand the production of 182mm modules. However, due to the waiting for certification and the ramp up of production capacity in the first half of the year, as well as the limited production capacity of large-size glass in the whole year, the market share of 182mm modules in 2021 will not be too large.



The yield rate of 210mm modules needs to be improved. The capacity of 5-row modules is not limited by the glass capacity. Therefore, the mainstream products for this year and next year will be 500W-550W modules. In contrast, the capacity of the 6-column 600W modules is heavily influenced by glass, and the issue of shipping container must also be addressed, so its development is not expected to accelerate until the second half of 2021.

This year, specialized cell vendors and vertically integrated vendors have successively released the news of large-scale production expansion of monocrystalline PERC cells, and the top 5 vertically integrated vendors have also all released a relatively large cell and module expansion plan for the next year.

In terms of modules, the trend of large size requires module vendors to continuously expand production capacity. From the situation in the second half of this year, getting compatible with 210mm size has become standard, and leading vendors will also be ready for larger sizes likely in the future.



Standardization of 210 mm size wafer module will benefit the entire industry chain

On November 27th, Trina Solar, Risen Energy, Zhonghuan Semiconductor, Tongwei, Huansheng Photovoltaic, Runyang New Energy Technology, Canadian Solar, Wuxi Shangji Automation jointly proposed to promote the standardization of 210mm silicon wafer and module size in the photovoltaic industry. The eight companies jointly suggest to use the silicon wafer size following the SEMI standard within the 210-220mm size range: 210+/-0.25mm as the only size. And at the same time revise the SEMI and existing modules size in PV industry association according to the wafer size.

After studying the eight photovoltaic companies in the list of joint initiatives, reporters from SOLARZOOM found that these companies have made some outstanding performance in silicon materials, silicon wafers, cells, modules, equipment, and racks etc., which basically represent the highest technology and production capacity... It is of great significance for such a group of companies to jointly promote standardization in the industry at this moment.

Advantages of the large size and comparison of price-performance ratio

Since 2019, the cost reduction of the photovoltaic industry has entered into a new stage: the large-size of silicon wafers, cells, and modules. The benefits of large-size of silicon wafer cells and high-power modules are well-known: flux value, dumpling effect, and the cost savings of the number of blocks that drive the cost reduction of large-size silicon wafers, cells, modules, and BOS.

Flux value refers to the increase in production capacity brought about by large-size products, thereby reducing the cost of labor, depreciation, and three types of expenses (operating expenses, management expenses, financial expenses) per unit of output; the dumpling effect refers to during the use of large-size silicon wafers to produce modules, the increase in the amount of auxiliary materials such as the frame, glass, backplane, EVA, ribbon bus bars, pallets and packaging materials in transportation is less than the increase in the area of the modules, which brings about savings in module

Total cost calculation of large-size products value chain			
	182(530W) VS 166(445W)	210(545W) VS 166(445W)	210(545W) VS 182(535W)
Silicon material	0.0009	0.0011	0.0002
Non-silicon cost of silicon	-0.0278	-0.0473	-0.0195
Silicon wafer (=Silicon material + Non-silicon cost)	-0.0269	-0.0462	-0.0193
Non-silicon cost of cell	-0.0188	-0.0321	-0.0134
Cell (Silicon wafer + Non-silicon cost of cell)	-0.0457	-0.0784	-0.0327
Non-silicon cost of module	-0.0247	-0.0279	-0.0032
Module (Cell + Non-silicon cost of module)	-0.0704	-0.1062	-0.0359
BOS	-0.0291	-0.0745	-0.0454
Power station system(=module + BOS)	-0.0995	-0.1808	-0.0813
Logistics	-0.0089	-0.0102	-0.0013
Total cost of value chain (power station system + Logistic)	-0.1084	-0.1910	-0.0826

encapsulation and transportation costs; cost savings related to the number of blocks refers to during the process of module production and power station construction process, the costs of junction box, potting, combiner box, DC cable, installation and construction are only related to the number of modules, so the use of large-size products will increase module area and power, which decreases the costs of module production per watt and power station construction significantly.

The significance of standardization of 210mm size silicon wafer

Since the beginning of this year, the standardization of 182mm size first appeared in June. At that time, the silicon wafer size was only defined, and the module size that ultimately reflected customer value was not considered. (From the product specifications of the three main module manufacturers, the module sizes are 2274*1134; 2256*1133; 2285*1136). This time, the 210-camp represented by Trina Solar proposed the standardization of the advanced 210-size, including the specifications and recommendations for the size of silicon wafers and module design (whether double-glazed modules or backplane modules), suggesting no other sizes should be used in the range of 210mm-220mm.

We know that the ultimate goal of the photovoltaic industry is to reduce the cost of electricity. The cost reduction effect of the 210mm size has been explained above.

What is the cost reduction effect of standardization of 210-size?

Through the standardization of 210mm size silicon wafer, the size of the silicon wafer and module etc., the industrial chain can achieve the best scale effect, powerfully help upstream and downstream enterprises improve production efficiency,

optimize supply, and drive industry technological innovation, while reducing the cost of industry chain manufacturing, the initial investment of photovoltaic systems and LCOE (levelized cost of energy) of power generation, to achieve grid parity.

The 210mm size silicon wafer and module size standardization proposition is the first-ever attempt for the industry to standardize the entire industry chain, including module products. This initiative is not only from the perspective of the industry chain, but also from the standpoints of the users. **The unified module size effectively solves the pain points of customers, greatly reduces the uncertainty in the design process, and improves the efficiency while selecting racking structure, inverters, cables, combiner boxes, etc. and enhances the flexibility of module supply. At the same time, the installation efficiency of modules and racking structure can be improved, and the design and EPC costs can be reduced. It can be seen that the unified module size standard is the gospel of customers.**

After the size is standardized, when the investor has multiple power stations under construction, and the supply of modules cannot be ensured, there will be greater supply flexibility. The owner can have flexible deployment between projects or between each bidding section of a project according to the degree of project tension, without affecting the grid connection of the owner's project.

The standardized size can ensure the consistency of the mounting holes during the racking structure design, effectively speeding up the design and processing progress of the **racking structure**, and providing a guarantee for the rapid advancement of the owner's project. Therefore the versatility of the racking structure is improved. When the project capacity has to be reduced due to external reasons, the racking structure purchased by the owner will not be wasted and can also be used for other projects.

At the same time, the value of standardization is also reflected in the development, operation and maintenance of power stations, which is conducive to the reduction of the types of spare parts (modules, fuses, cables) on-site, and facilitates operation and maintenance management. It is more user-friendly and more versatile for projects that are preparing to use array automatic cleaning robots. It ensures accuracy during installation, and can reduce the rework, and the damage or impact on module performance.

The significance of standardization is also reflected in the design of inverters, racking structure and trackers, and the financialization of optical power storage. The extreme cost reduction of the photovoltaic industry and the increase in the competitiveness of the price of solar storage power per kilowatt-hour will inevitably be accompanied by "standardization" for a long time. Based on the significant advantages of the 600W+ ultra-high power module system, the standardized module size will bring more long-term value to customers in the design of downstream power stations.

From the perspective of the supply chain, standardization is beneficial to improve the stability of the supply chain and reduce the cost of the industrial chain. The upstream and auxiliary material suppliers such as glass, silicon wafers, junction boxes, etc. are produced under unified standards, which will greatly reduce the loss caused by switching production lines and the inventory cost due to different specifications, so that the production of the 210 mm size modules' entire industry chain will be more ordered and effective.

The diversification of photovoltaic module sizes not only led to the low matching degree in supply chains, but also added a lot of direct and hidden costs. Many glass manufacturers and modules manufacturers have also put forward their demands for uniform specifications as much as possible. When the glass supply gets tight, the industry still loses more than one million square meters of glass production capacity every month due to the switch of different sizes of product specifications; and hundreds of thousands of square meters of glass have become stranded inventory due to the cancellation of customer orders. Not only that, due to the diversification of the size of photovoltaic modules, glass manufacturers need to stock a variety of specifications of glass, these glasses cannot be used between different module factories, bringing a lot of inventory costs to glass companies, affecting the supply capacity and delivery in time. After the standardization of size, the inventory and supply of glass and all modules related to the size and specifications of the backplane, EVA, junction box and other non-silicon auxiliary materials can be optimized.

The cost reduction effect of "standardization" is not only reflected in the optimization of module material inventory and supply, but also in the production and manufacturing process of the overall industrial chain, including silicon wafer pulling, slicing, cell manufacturing and module manufacturing. Even if the manufacturing equipment is compatible, different tooling and fixtures must be configured to meet different cell or module sizes (tooling cost is estimated at 5-7 million RMB/GW). The greater impact is on the loss of production capacity when switching between products of different, inventory costs of products of different specifications, and processing costs of downgraded products. According to preliminary estimates by industry insiders, it usually takes 10-12 hours to switch between different products in cell and module manufacturing. In addition to the loss of yield and efficiency per switch, the cost of each switch is about 0.003-0.005 ￥/W, with its 1GW correspondent cost of 3-5 million ￥/run.

Compared with the previous products, the 210mm size module products and system solutions based on the new technology platform have significant advantages in terms of materials, design, process and system. With the standardization of large size silicon wafers, solar cells, and module sizes, the industry chain will achieve a better scale effect, improve production efficiency, and reduce the cost of industrial chain manufacturing, photovoltaic system initial investment and LCOE of power generation. Through the unification of standards, the entire industry chain will work together to create higher-quality photovoltaic products, bring higher value to customers, and reduce the LCOE of power generation. This standardization initiative is of great significance to the photovoltaic industry and will lead the industry to a new level.

World's leading photovoltaic inverter brands to launch products compatible with 210 ultra-high power modules, **streamlining PV supply chain**

The world's leading photovoltaic inverter brands have announced the market launch of inverters compatible with the 210 Ultra-High Power Modules. Mass production of the inverters is due to begin in March 2021, and the price is expected to remain at a level compatible with that of other types of inverters.

The full launch of inverters that support 210 modules underlines the environmental and technological interdependency of 210 Ultra-High Power Modules and the 600W+ Photovoltaic Open Innovation Ecological Alliance, both of which were initiated by Trina Solar, a leading global PV and smart energy total solution provider. The new inverters advance the application of 210 ultra-high power module products on the system side.

On Jan 29 Huawei Digital Technology (Suzhou) Co Ltd said that it would mass-produce inverter models: SUN2000-196KTL-H3 for Chinese market at the end of March 2021 and SUN2000-215KTL-H3 for other global markets at the end of May 2021. Both models will increase the maximum current per MPPT to 100A, to be compatible with the high current characteristics of 210 modules and further reduce the levelized cost of energy (LCOE) of photovoltaic power plants.

On Feb 3 Sineng Electric Co Ltd said a new string inverter (model SP-250K-H) had been launched that will be compatible with the 210 modules and will be on the market in March.

On February 5 Sungrow Power Supply Co Ltd said that centralized inverters (model SG3125HV) and string inverters (domestic model SG225HX; international model SG250HX) now in supply are fully compatible with 210 Ultra-High Power Modules.

SMA said that all central inverters and 2 types of String inverters SHP 150 & STP 110 now in supply and fully compatible with 210 ultra-high power modules.

GoodWe, Ginlong, Kstar and other inverter makers have also announced the availability of inverters compatible with the 210 Ultra-High Power Modules of that can support them, and say they plan to launch new high-current inverters.

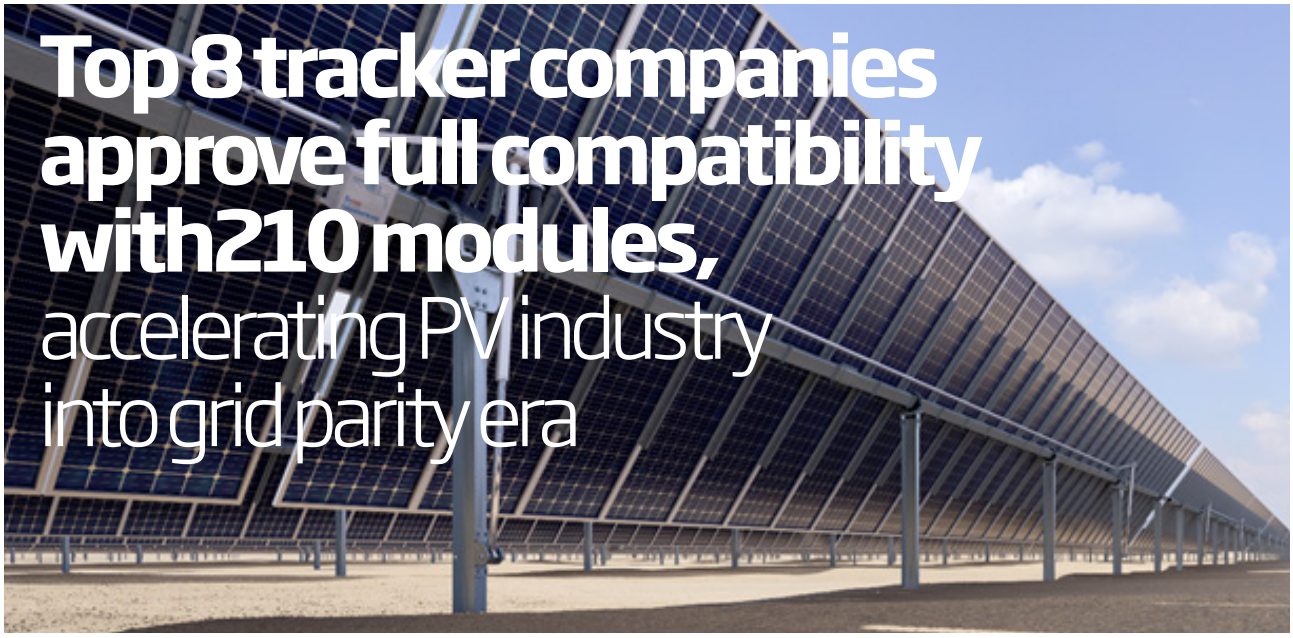
All this brings new vitality to the entire photovoltaic industry. A year ago Trina Solar released its first 210 modules, signaling a new era in the entire photovoltaic industry. While pushing for advances in module technology and increasing power, supporting products such as inverters and tracking systems have also been fully upgraded to fit into the 600W+ era.

Centralized inverters and a string inverter have both passed market testing. The compatibility of the 210 inverters and modules could result in more value in the application process. Specifically, low-voltage, high-current modules can realize a longer string, thereby reducing the number of strings and the cost of PV DC cables, lowering LCOE, highlighting the power generation gain and cost advantages of high-power modules.

In June 2020 industry-leading silicon wafers, batteries, modules, inverters, tracker systems, materials, EPC, design institutes, professional research institutions and owners jointly established the 600W+ Photovoltaic Open Innovation Ecological Alliance. The upstream and downstream collaboration mechanism of the industrial chain was thus formed, with more than 66 members.

As an important link in the photovoltaic industry chain, inverters and tracker systems have entered the 210 era, leading to more seamless collaboration, suggesting a more mature 210 industry chain and PV ecological system.

Top 8 tracker companies approve full compatibility with210 modules, accelerating PV industry into grid parity era



Recently, eight world's leading photovoltaic tracker makers, **Arctech Solar, Array Technologies, GameChange Solar, IDEEMATEC, Nextracker, PVH, Soltec, TrinaTracker**, have successively issued compatibility approvals for 210 Ultra-High Power solar modules, in recent months, the latest on Feb 3rd 2021, significantly promoting smooth chain collaboration in the industry and the reduction of LCOE, thus accelerates the pace of entering grid parity era.

The companies approving compatibility with 210 modules are as follows:

Company Name	Brand/Product Type	Module Compatibility	Time of Approval
Array Technologies Inc.	DuraTrack HZ v3	210 modules	Q1, 2021
GameChange Solar LP	GENIUS TRACKER ™ 1P/ GENIUS TRACKER ™ 2P	210 modules	Q1, 2021
IDEEMATEC Deutschland GmbH	H4PLUS ™	210 modules	Q3, 2020
Nextracker Inc.	Nextracker products	210 modules	Q4, 2020
PV HARDWARE SOLUTIONS, S.L.U	Independent row: Monoline ™ (all its versions 1V, 3H and 2V); Multi-row: Axone ™ , Axone Duo ™)	210 modules	Q1, 2021
SOLTEC ENERGIAS RENOVABLES S.L.	SF7 & SF8	210 modules	Q1, 2021
Trina Solar Co., Ltd.	TrinaTracker (Vanguard ™ /Agile ™)	210 modules	Q2, 2020

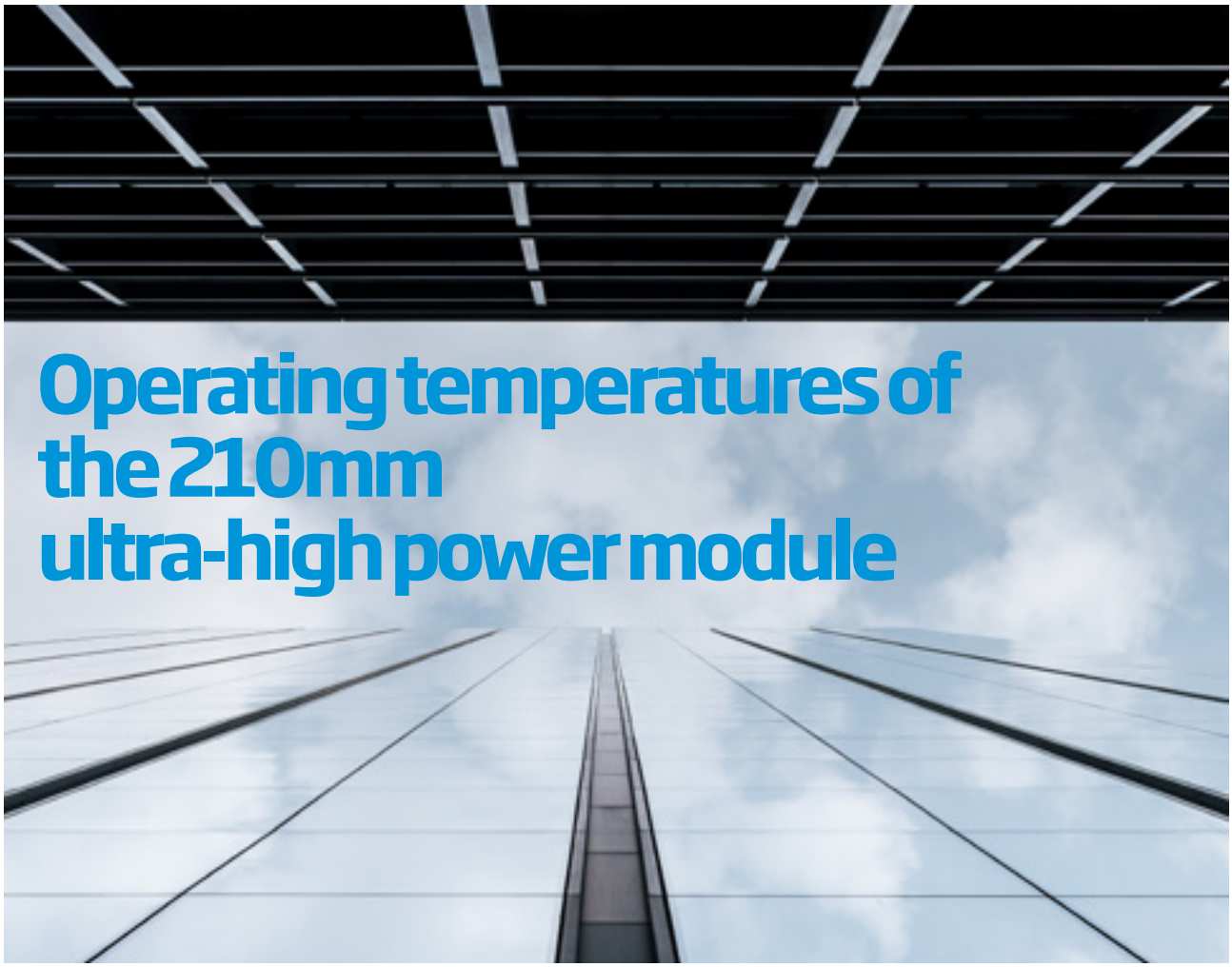
(Arranged in alphabetical order)

The tracker and module compatibility approvals from these global leaders in the tracker field demonstrate their recognition of the 210 modules' high value and strong support in terms of comprehensive collaboration to facilitate the grid parity globally. On the other hand, the compatibility with ultra-high power modules will also raise the tracker's system value and contributes to reducing costs in various scenarios.

Specifically, modules with low voltage design can realize a longer string, thereby reducing the number of strings and the cost of PV DC cables, reducing the LCOE, highlighting the power generation gains and cost advantages of high-power modules. In addition, low voltage modules facilitate land reduction in system design, consequently reducing tracker BOS. In addition, labor costs can be cut when the quantity of tracker shrinks. Ultimately, the combination of the 600W+ trackers and modules achieve a high power generation, low system costs and minimized system loss.

Apart from increasing system value, the compatibility of trackers with 210 ultra-high-power module deepens industrial win-win cooperation mechanism, which prominently started one year ago, Trina Solar released its first 210 modules, signaling a new era in the industry. Then in June 2020, industry-leading makers of silicon wafers, cells, modules, inverters, tracker systems, materials, EPC, as well as design institutes and professional research institutions and power plants jointly established the 600W+ Photovoltaic Open Innovation Ecological Alliance, with more than 66 members up to now. Followed by recent full product launches by top inverter manufacturers such as Huawei, Sungrow, Sineng, SMA and others that support 210 modules. (https://www.trinasolar.com/en-glb/resources/newsroom/maworlds-leading-photovoltaic-inverter-brands-launch-products-compatible-210) The upstream and downstream collaboration mechanism of the industrial chain was thus formed.

Compatibility of trackers is another industry-wide strategic move that advances the application of 210 ultra-high-power module products on the system side. As the important links in the photovoltaic industry chain, inverters and trackers' entrance to the 210 era, signifies the more seamless 210 industry chain collaboration, more mature PV ecological system and remarkable customer values.



Operating temperatures of the 210mm ultra-high power module

Trina's 210mm ultra-high power modules bear a huge potential to reduce the cost of Balance of System(BOS) and Levelized Cost of Electricity (LCOE) as ultra-high power and low voltage design. However, the high working temperature of such PV modules due to high current design has always been a concern. Based on the comprehensive research and outdoor test by Trina's engineering team, under the same installation and cooling condition, the working temperature of 210 mm and 182 mm modules are nearly same as the cells only change the area with the same PERC structure and the efficiency.

The operating temperature is worth to study as it affects the performance of photovoltaic modules. As the temperature rises, the open-circuit voltage (VOC) will decrease while the short-circuit current (ISC) increases slightly. As the fill factor (FF) drops, the photovoltaic conversion efficiency and power of the solar cell decreases. In an energy yield simulation by the PVsyst software in Changzhou, **Trina Solar** found that there is an energy loss of 0.20% for every 1℃ of operating temperature increase.

Two factors that turn out the operating temperature is not negatively affected by the high-current output in the 210 mm module:

First, the cell's current density is determined by its structure and efficiency. The 210 mm and 182 mm cells have the same PERC structure and the efficiency is almost the same. With similar packing materials and under the same optical environment, the current density of such modules is almost no difference. The increase in current in the 210mm ultra-high-power module is driven by a larger cell (current = current density x cell area). Despite this larger current, efficiency remains the same with a steady current density and larger cell area.

Furthermore, for the same module efficiency, the amount of unutilized heat – the solar energy which cannot be converted into electric energy – is the same in terms of unit area. With the same installation and heat dissipation conditions, the operating temperatures for 210mm ultra-high power modules and 182mm modules are roughly the same. That means there is no risk of rising operating temperatures.

What is the actual operating temperature of the ultra-high-power modules in Trina Solar Vertex Series? Let us explore that from different perspectives, such as outdoor testing, heat transfer modelling, the empirical formula of module operating temperature calculations and finite element modelling analysis.

Outdoor testing results

An outdoor experiment was conducted in Trina test field, which located at the east side of the State Key Laboratory of Photovoltaic Science and Technology in Trina Solar, Changzhou. The samples were mounted on a fixed rack horizontally with a tilt angle of 25°, and 0.5m above ground. Temperature data was collected using the HIOKI temperature sensor, which attached to

the same position on the backplanes of different modules. Figure1 shows the setup of the experiment

Figure 1:The setup of experiment

The tests were conducted between September 3 and October 8 2020. Figure 2 demonstrates the weighted average operating temperatures of three different sizes modules(166*72, 182*72, 210*55):

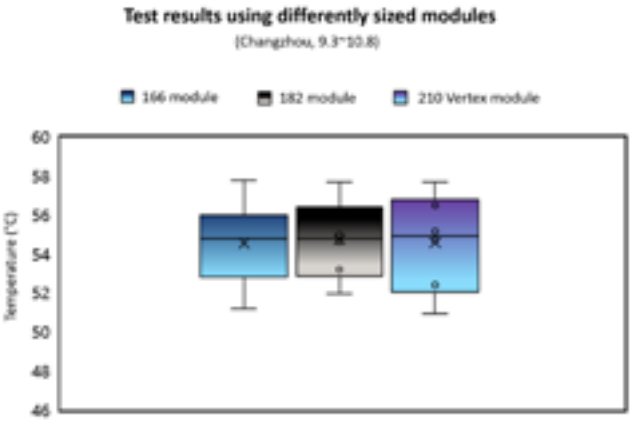


Figure 2:Test results using differently sized modules

The outdoor test results show that the difference in the average operating temperature of the three modules is insignificant.

Heat balance model

For photovoltaic modules, heat is transferred in three ways: conduction, convection, and radiation. Conduction is how heat transfers across components within the modules. For a monofacial module, the heat energy transfer of a monofacial module at steady state is demonstrated in Figure 3.

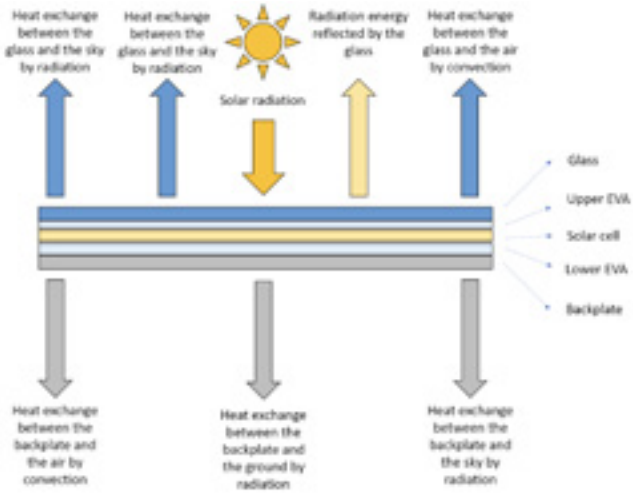


Figure 3:Demonstration of energy exchange in a monofacial modules at steady state

When the operating temperature at steady state, part of the solar energy is reflected into the atmosphere, where the rest is converted into electric energy and heat. Taking the monofacial modules as an example, according to the law of energy conservation, plus the energy exchange between the module and the surrounding, without considering the heat dissipation on the frame, the energy balancing can be described as the equation below:

Where,

$$I_{rec}=\frac{P}{A}+I_{rec}\rho_{PV}+h_{g,air}(T_{PV}-T_a)+\sigma F_{g,sky}(\varepsilon_g T_{PV}^4-\varepsilon_{sky}T_{sky}^4)+\sigma F_{g,gro}(\varepsilon_g T_{PV}^4-\varepsilon_{gro}T_{gro}^4)$$
$$+h_{b,air}(T_{PV}-T_a)+\sigma F_{b,sky}(\varepsilon_b T_{PV}^4-\varepsilon_{sky}T_{sky}^4)+\sigma F_{b,gro}(\varepsilon_b T_{PV}^4-\varepsilon_{gro}T_{gro}^4)$$

I_{rec} is the solar irradiance on a PV panel in the unit area (W/m2).

P/A is the power of the module per unit area;

$h_{g,air}$ is the convective heat transfer coefficient between the glass cover and the air;

$h_{b,air}$ is the convective heat transfer coefficient between air and backsheet (W/m2·K);

σ is Stefan-Boltzmann constant σ = 5.67×10^-8 W/m2·K4;

ε_g is emission rate of glass;

ε_{sky} is emission rate of the sky;

ε_b is emission rate of the backsheet;

ε_{gro} is emission rate of the ground;

$F_{g,sky}$ is view factor between the glass and the sky;

$F_{b,sky}$ is view factor between the backsheet and the sky;

T_{sky} is sky temperature

Assume that the two commercial 182mm and 210 mm PV modules were mounted on a fixed rack with a tilt angle of 25 degrees; the boundary conditions and calculated results are summarized in Table 1:

	182-535W module	210-545W module
Ambient temperature Ta(K)	298.15 (25° C)	
POA I_{rec} (W/m^2)	1000	
Average ground temperature T_{gro} (K)	302.55 (29.4° C)	
Sky temperature T_{sky} (K)	284.18 (11.03° C)	
Wind speed WS (m/s)	1.18	
Reflection index of module 'P_{PV}	0.10	
Installation angle (deg)	25	
Module size (m^2)	2.587	2.613
Result Tc (K)	323.32 (50.17° C)	323.26 (50.11° C)

Table 1:Boundary conditions and calculated results:

According to the steady-state heat balance PV model, our analysis shows that a typical 182mm, 535W module and a 210mm, 535W module have virtually the same operating temperature.

Furthermore, the outdoor measured data at a sunny weather condition on 5th September was selected. The comparison of real tested result and the steady-state heat balance model calculated results are shown in Figure 4 below:

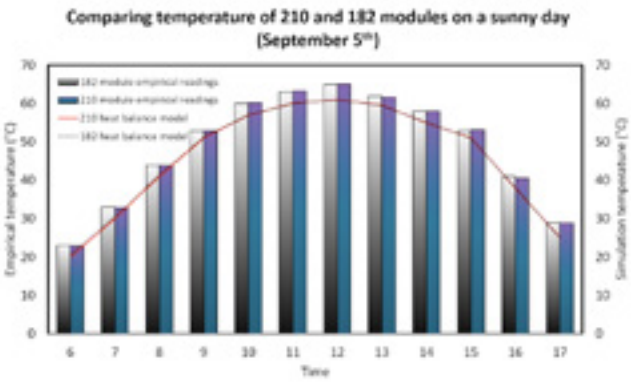


Figure 4:Comparing temperature of 210 and 182 modules on sunny day

The results shown in Figure 4 further proves there is no significant temperature increase for the low-voltage, high-current 210mm modules. During the morning and evening, with lower irradiance and lower temperature, the high-current 210mm PV module has a slightly lower operating temperature. A lower operating temperature can reduce power loss and thus enhance power generation performance.

Empirical formula

Many papers have proposed different operating temperature models. The most widely used models are Sandia, Faiman, PVsyst, Ross, and J. Kurnik models. The J. Kurnik model indicates the operating temperature of a photovoltaic module:$T_{PV} = T_{amb} + K*G$ (K is a coefficient determined by conversion efficiency, the tilt angle of installation and wind speed, etc.).

In other models such as Ross model, Nominal Operating Cell Temperature (NOCT) is also considered, where it measures the module temperature with an installation angle of 45° on an open tracker, the POA irradiation at 800W/m2 , the surrounding temperature of 20℃ and 1m/s of wind speed. As NOCT is only checked while the module is under open circuit condition, the measured and actual temperatures may differ. This paper takes the PVsyst cell model as the prototype, and the model described in the equation below:

$$T_c = T_a + POA\frac{\alpha(1-eta_m)}{U_0 + U_1 \times WS}$$

•Tc = Cell temperature (°C)

•Ta = Ambient temperature (°C)

•α = Module adoption coefficient

•POA = Solar irradiance on a PV panel in the Plane of Array (W/m2)

•Etam = Module efficiency

•U0 = Conduction coefficient (Wm2K)

•U1 = Convection coefficient (Wm2K)

•WS = Wind speed (m/s)

Assume the modules are installed on an open fixed rack with excellent air circulation. The POA irradiance is 1000 W/m2 , and the wind speed is 1m/s. Given U0=29, U1=0. The difference in efficiency between a 182mm, 535W model and a 210mm, 545W model is 0.18%. The boundary conditions and calculated results are listed as in Table 2 below:

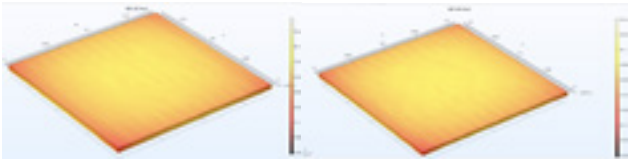
	182-535W module	210-545W module
Ta (° C)	25	
POA (W/m^2)	1000	
α	0.9	
eta_m	20.68%	20.86%
U_0 (Wm^2K)	29	
U_1 (Wm^2K)	0	
WS (m/s)	1	
Result Tc (° C)	49.617	49.560

Table 2: Boundary conditions and calculated results:

The results in Table 2 shows that the 210mm high-current module has virtually the same operating temperature as the 182mm module, giving it a slight edge.

Finite element analysis

A finite element modelling was carried out, the models includes glass, EVA on upper and lower layers, cell, ribbons and backsheet. As there is no difference on the frame, the heat dissipation has been neglected to simplify the model. The boundary conditions for the simulations are set as follows: ambient temperature at 20℃ , irradiance at 800W/ m2, wind speed at 1m/s. Figure 5 shows the result: the temperatures of the 210mm and the 182mm modules are basically the same.



Conclusion

Trina Solar's Vertex series ultra-high power modules are designed in lower voltage and high current characteristics, which increases the length of single strings. It helps lower the BOS cost and LCOE while driving grid parity. Research and simulations in the National Laboratory have proven the reliability of Vertex series modules with their ideal operating temperature, which can ultimately drive down the energy cost of photovoltaic modules.

About the Vertex Series 600W+/550W+

Trina Solar's superior multi-busbar technology, along with its

unique low-voltage, high-current design, combined with non-destructive cutting and high-density cell interconnect technology, help enhance anti-cracking and lower hot-spot temperature properties. Low voltage, meanwhile, can effectively increase the length of single string and boost power, which can ultimately reduce costs of the system and per-watt electricity.

The high-current junction box **fully meets the needs of high-power 210mm modules**

As mass production of 166mm, 182mm, and 210mm modules advances, the industry continues to discuss the advantages and disadvantages of silicon wafer size changes. These discussions focus on modules' electrical parameters and dimensions, transportation, material supply, etc. Some extend to junction box reliability and material selection. As a material supplier engaged in the research, development and manufacturing of junction boxes for a long time, we will analyze the relationship between junction boxes and large size silicon wafers as well as high power modules from the perspective of materials.

How the junction box works

The junction box is mainly used to transmit the electricity generated by the PV module to the external circuit. It is composed of housing, diode, connector, cables and other modules, in which the diode is the core device. When the module is working normally, the diode in the junction box stays in the state of reverse cut-off. The bypass diode protects the entire PV module by conducting when the module cell is blocked or damaged or in case of hot spot effect.

Table 1 Electrical performance parameters of modules and selection of junction boxes

The above table shows the electrical performance parameters and rated current selection of junction boxes for typical 166mm, 182mm and 210mm modules produced by PV module factories. The parameters of the modules show the phenomenon of low current + high voltage and high current + low voltage,

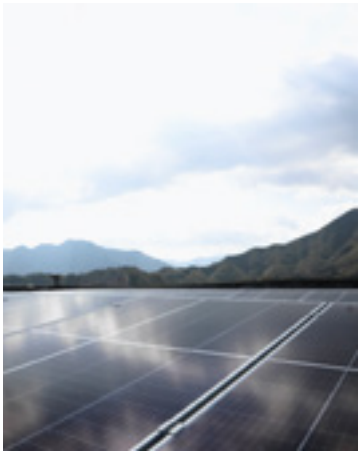
Module Type	Module Power/W	Module Isc/A	Module String Voc/V	Junction Box Rated Current/A
166mm	450W	11.5A	16.5V	16,18 or 20
182mm	530W	13.9A	16.5V	20,22 or 25
	590W	13.9A	17.9V	
210mm	540W	18.6A	15.1V	25 or 30
	600W	18.6A	13.9V	

respectively.

Junction box and diode

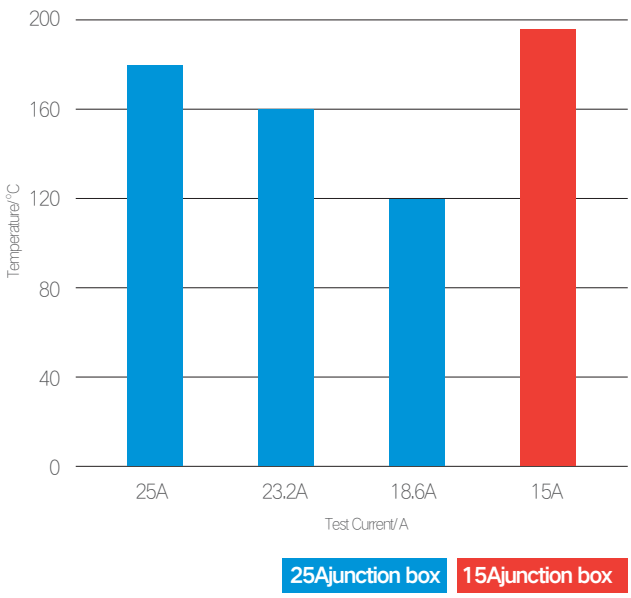
The key indicators of the junction box include the rated current of the junction box, the rated current of the diode and the reverse voltage resistance, etc. These parameters depend on the structural design of the junction box and the specification of the diode.

In general, certification testing of modules and junction boxes



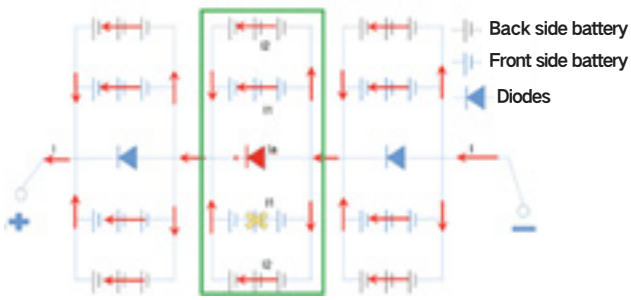
should be carried out in accordance with the principle that junction box's rated current is equal or greater than 1.25 times of the Isc, and that headroom should be allowed. Under normal operation, the junction box diode is in reverse cut-off state, that it will not conduct or heat up for 166mm, 182mm, or 210mm modules. The junction box diodes for 182mm and 166mm modules should bear slightly higher reversed bias voltage than the 210mm modules.

When hot spots occur in the PV module, the diode will go through forward conduction and be heated. For example, when the output current Isc is at 18.6A (actually, the module is operating, the Imp ≈ 17.5A), the junction temperature is about 120℃ . Even in partially illuminated conditions, the junction temperature of the junction box is about 160 °C at 1.25 times of the Isc (23.2A). In other words, the junction temperature in both cases is far below the upper limit of 200℃ stipulated by the IEC62790 standard. With a slightly lower Isc for the 182mm and 166mm modules, the junction boxes of the same configuration are less calorific so that the junction boxes are in safe operation and do not pose the reliability risk.



The above is the working condition of the junction box when hot spots appear in the modules. And if the hot spot of the photovoltaic module caused by the shielding of birds or leaves disappears quickly, thermal escape occurs in the diode, that is, the module string brings instantaneous reversed bias voltage and leakage current to the diode, making higher series voltage more challenging to the junction box and the diode. From the point of view of junction box design, reasonable box structure design, diode connection facilitating heat dissipation and better performance of chip can solve these problems.

Each unit of the dual-glass module and half-cut module adopts the parallel structure, as shown in the figure below. Therefore, when local hot spot effect or thermal escape occurs, the parallel part of the junction box can retain greater headroom of safety through shunting. According to calculation, it is almost impossible that the two parallel sides and the front and back of the dual-glass half-cut module are covered at the same time. This could happen to only one module out of a capacity of approximately 10GW. Therefore, it is almost impossible for the junction box to work at full load in practical operation, so reliability can be guaranteed.



Connectors and cables

As one of the power transmission components, the connector is responsible for the connections within a power station. At present, the rated current of the mainstream connectors commonly used in the market is all higher than 30A, up to 55A, which is sufficient to meet the power transmission requirements of the existing high power modules.

The rated current of an EN or IEC compliant cable (4mm2 cable, the rated current is 44A when the surface is adjacent to each other) is much higher than the rated current of a junction box, so the reliability is ensured.

Manufacturing process and market overview of junction box

With the steady improvement of the manufacturing level and quality control of the junction box vendors, the performance and reliability of the junction box have been highly guaranteed, which can meet the requirements of large-size silicon wafers and high-power modules.

In addition to the self-improvement of junction box vendors, module manufacturers and third-party institutions are also constantly improving the testing, evaluation and quality control of junction boxes and modules, which further promotes the quality control and research and development capabilities of junction box vendors.

Since the first half of 2020, a number of junction box vendors have obtained 25A and 30A junction box certifications issued by certification bodies such as TUV. After seeing batches of high-current junction boxes pass the tests of third-party certification bodies, the confidence of junction box vendors and PV module vendors is greatly boosted. With the release of capacity of large-size 182mm and 210mm wafer modules, supporting capacity for large current junction boxes will be gradually established and expanded.

To sum up, the high-current junction boxes and their components have matured in terms of performance, reliability and manufacturing capacity to the extent that they can fully meet the requirements of different types of large-size silicon wafers and high power modules.

Trinasolar

Promote Standardization from Upstream to Downstream
of the Industry Chain Through Intra-Industry Collaboration