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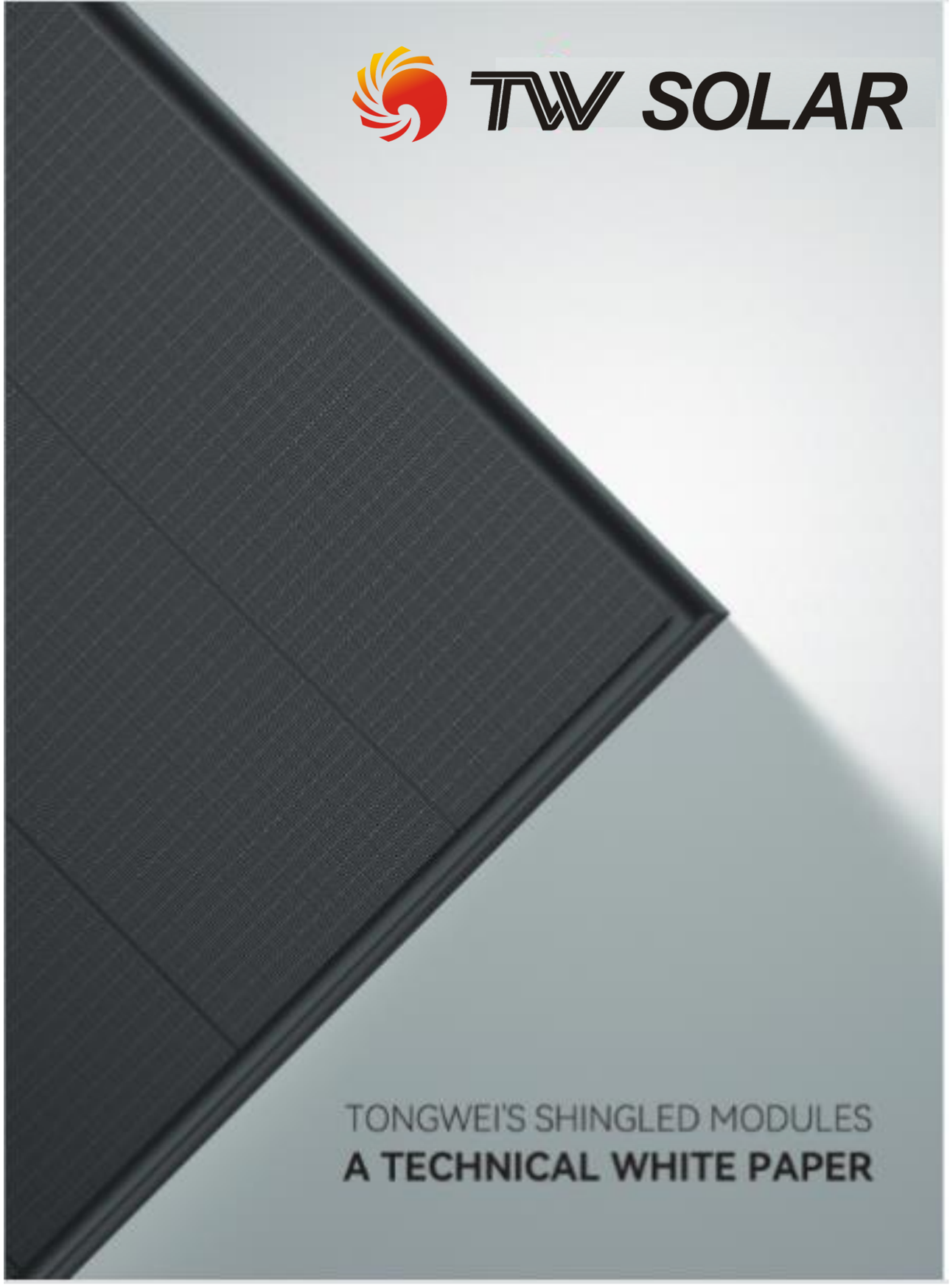


Contents

01 Background

1.1 History of TW Solar Group

300+

Tongwei Group has more than 300 branches and subsidiaries around the world, with nearly 50,000 employees. Listed in 2004 on the Shanghai Stock Exchange, stock code 600438), with a market Cap of over 300 billion RMB the company is s one of the top 500 in China and the world's largest solar cell manufacturer.

.

Chinese enterprise **TOP 500**

Most Contributing New Energy Enterprise in the World **Top 500**

Most Valuable Brands in China **Top 500**

Private Listed Companies in China **Top 500**

Tongwei brand value exceeded **250 billion$**

Established in 2006, TW Solar entered the renewable energy business becoming the largest vertically integrated solar company in the world with high-purity polysilicon production in the upstream, high-efficiency solar cell production, midstream, and module manufacturing in the downstream, as well as PV projects construction and operation, forming a complete solar energy industrial supply chain. Combined with independent intellectual property, TW Solar has become an important driving force in the development of the global PV energy industry.

·Upstream·

Yongxiang High-purity Polysilicon

Ranked #1 by production capacity in the world
Annual capacity of high-purity crystalline silicon **230,000 tons**
:

·Midstream·

Tongwei High-efficiency Cells

Ranked #1 by production capacity in the world
Annual capacity of high-efficiency cells: **60GW**

TWSOLAR

Top 10 Tier I Manufacturer
Annual Capacity Modules: **30GW**

·Downstream·

Tongwei High-efficiency Modules

TW SOLAR

PV projects investment and development, design and construction, operation and maintenance

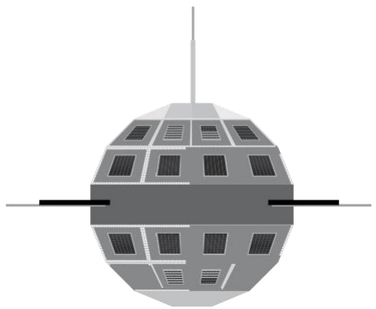
·Projects·

"Fishery + PV Power Station

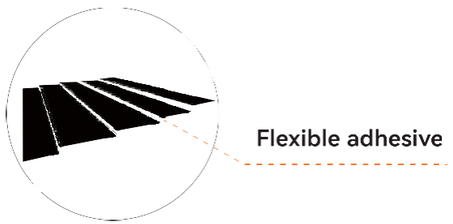
1.2 Development of Shingled Modules

In 1954, Bell Labs demonstrated the first practical silicon solar cells. In 1956, D.C. Dickson applied for a shingled PV module patent. In 1971, China successfully launched its satellite, "Shijian-1," with 14 shingled modules onboard demonstrating and proving the technology in space and on the ground

In 2016, TW Solar initiated its R&D program in shingled technology and committed to developing and promoting technology, with a multimillion-dollar investment program.

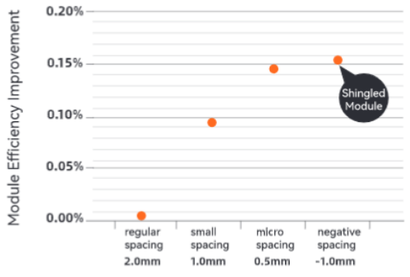


The Shingled modules onboard China's satellite, "Shijian-1"

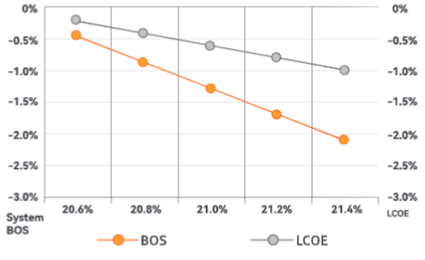


Shingled structure

Shingled modules employ solderless interconnection technology. The cells are stacked in a tiled manner and bonded with flexible adhesive, eliminating the spacing between solar cells, improving module efficiency, and reducing BOS and LCOE.

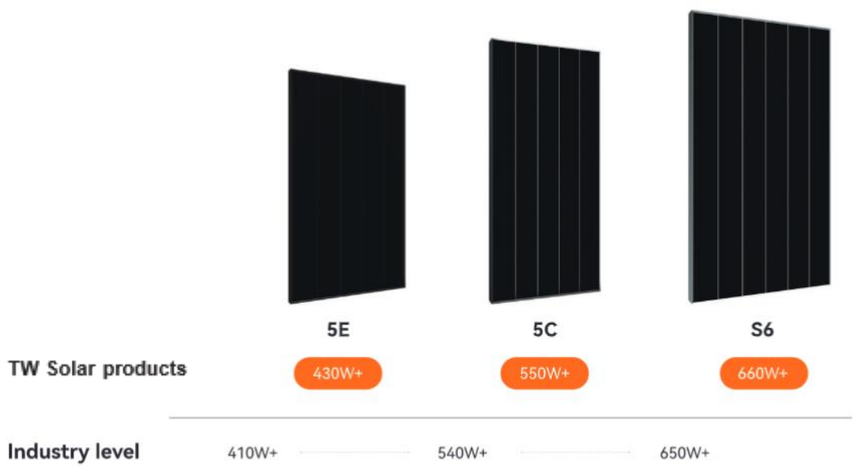


Correlation between cell spacing and module efficiency



Module efficiency correlates linearly with BOS and LCOE

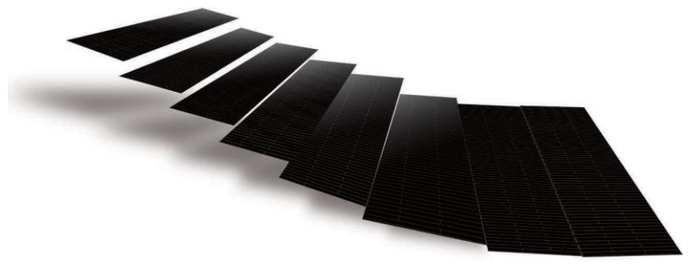
TW Solar shingled module family covers power output from 415W+ 430W+, 550W+, to 660W+, and are designed for residential, commercial and industrial, distributed, and large-scale ground-mount solar projects. The product has exceptional power output, efficiency, and reliability, which significantly improves the return on investment (ROI).



02 Technical Advantages

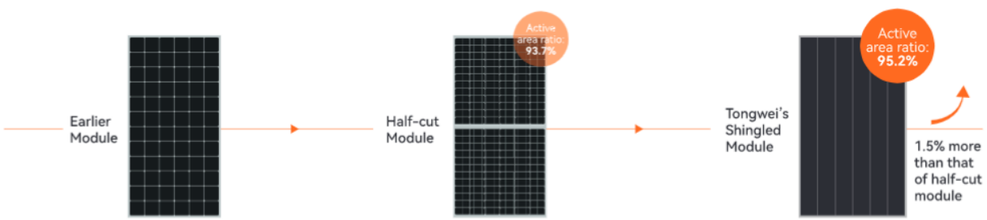
TW Solar's shingled module technology achieves high efficiencies, exceptional reliability, strong aesthetic appearance and are additionally environmentally friendly.

TW Solar's shingled module products conform with the latest industry standards and ethical production. The flexibility of shingled modules enables full compatibility with a wide range of system installations and solar schemes.

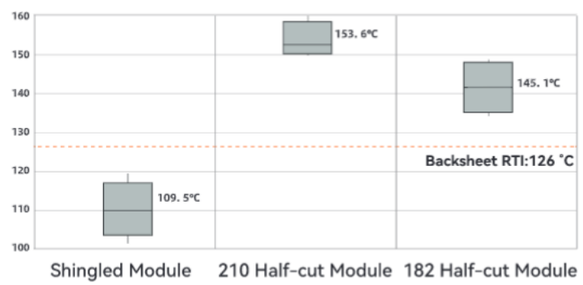


2.1 High-density Packaging

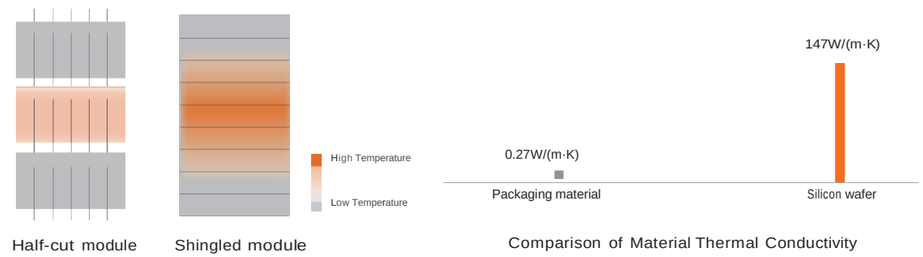
In the development of photovoltaics, cells have transitioned from multicrystalline to monocrystalline, the size of modules has expanded, and the manufacturing efficiencies have improved to reduce the all-important cost per watt. In the continuous pursuit of higher efficiency TW has adopted high-density packing technology as a primary approach to improving module efficiency (the area of a module act. TW Solar's high-density packaging has an "active area ratio" of 95.2%, the highest in the industry, achieving a conversion efficiency of 21.25%.



The thermal conduction efficiency is related to the contact area and thermal conductivity. The cell shingles are closely packed to form the physical contact between the cells. The contact area of the overlapping cells is more than 140 times that of the cross-sectional area of the half-cut module's soldering ribbons. The thermal conductivity of the silicon material is 540 times that of the packaging film. Therefore, the thermal conduction efficiency of the shingled module is much higher than that of the half-cut module. Tested by Fraunhofer ISE, TW Solar's shingled modules have a lower hotspot temperature by about 40°C than that of the half-cut modules, demonstrating excellent hotspot resistance.



Data source: Fraunhofer ISE

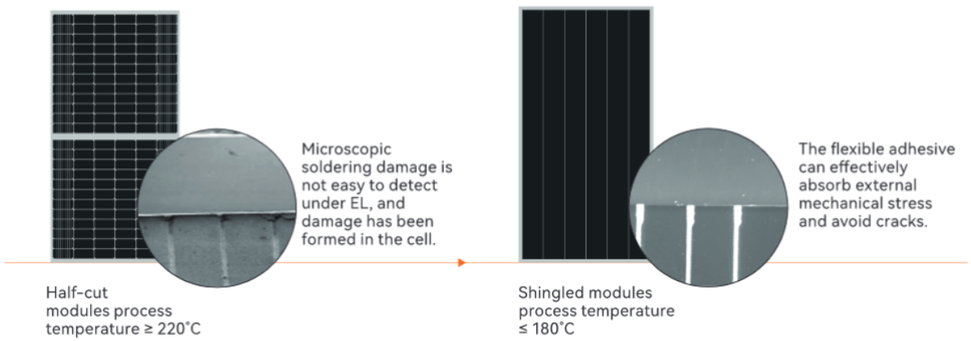


Half-cut module Shingled module Comparison of Material Thermal Conductivity

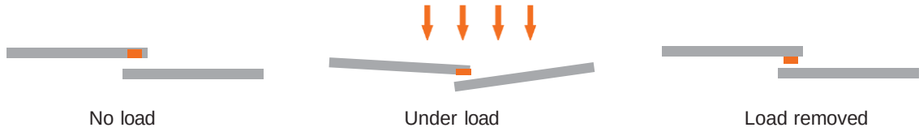
The hotspot temperature of TW Solar shingled module is significantly lower than the RTI (relative thermal index) of the backsheet material, ensuring that the packaging material is always within the safe operating temperature range.

2.2 Flexible Interconnects

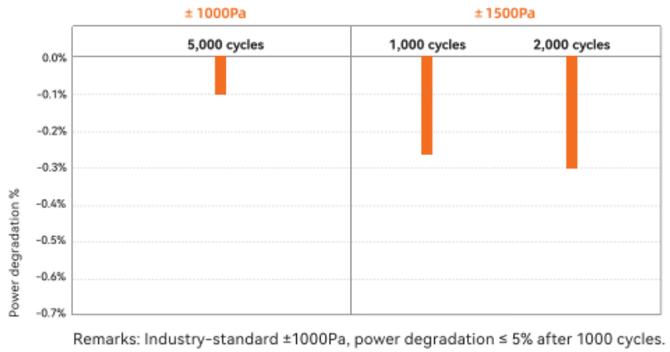
The soldering temperature in the tabbing process of conventional half-cut modules exceeds 220°C . Due to the difference in thermal expansion coefficients of different materials, thermal stress is generated, causing micro-cracks. In addition, the tabbing ribbon is a rigid material. The edge of the cell is in contact with the bending structure of the tabbing ribbon, which can easily cause stress concentration on the edge of the cell and induce cracking or damage to the cell edge.



TW Solar's shingled module adopts solderless, flexible interconnection technology, and the process temperature is lower than 180°C, which reduces the thermal stress generated as in conventional half-cut modules. The flexible interconnects also effectively absorb the stress under load to ensure the safe and durable operation of the modules.



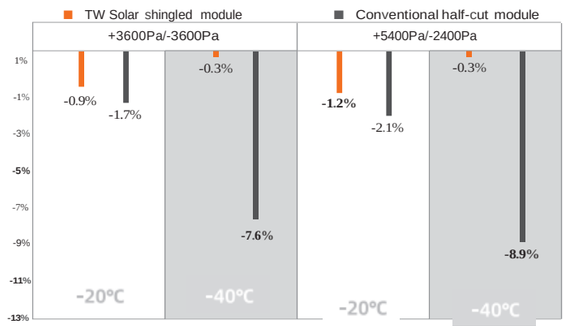
After dynamic mechanical load test, the power degradation of TW Solar shingled module is 0.3%.



Remarks: Industry-standard ±1000Pa, power degradation ≤ 5% after 1000 cycles.

The thermal stress in conventional half-cut modules further increases at low temperatures. The power degradation under the static load test could be as high as 9%. The flexible adhesive of TW Solar's shingled module remains elastic at -40°C , and the power degradation is less than 1.5%, as tested by TUV NORD.

- **TW Solar products have significant advantages under load at low temperatures.**



2.3 Eco-friendly

According to International Energy Agency PVPS's report, the global PV module recycling will reach 8 million tons in 2030. On October 14, 2021, PVPS officially released the latest guideline, "PV Module Design for Recycling Guidelines." Article 3 of the guideline recommends that PV modules should minimize the use of harmful materials and achieve efficient recycling; the Articles 2 and 3 of "Crystalline silicon-specific guidelines" emphasize that the module backsheet materials and metal materials (Ag, Ni, Pb) have a significant impact on the module recycling process and recycling cost.

TW Solar's shingled modules, adhering to the DfR (Design for Recycling) concept from the R&D stage. Using no tabbing ribbon, the lead content of the entire modules is reduced by 60%. TW Solar's shingled modules plans to further achieve 100% lead-free and fluorine-free with strategic BOM selection. Aspired to be eco-friendly, TW Solar's shingled modules help to reduce the environmental impact and simplify the recycling process.

Half-cut Module Shingled Module

Module Type	$W_{Pb-ribbon}/W_{Module}$ (%)	$W_{Pb-busbar}/W_{Module}$ (%)	wt.%
Half-cut Module	0.033%	0.006%	0.039%
TW Solar shingles			
Tongwei shingles	0	0.016%	0.016%

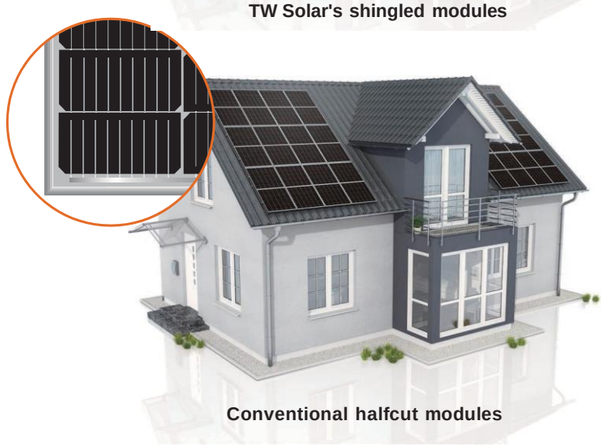
60%↓

$W_{Pb-ribbon}$ represents the weight of the lead element in the ribbon, $W_{Pb-busbar}$ represents the weight of the lead element of the bus bar, and W_{Module} represents the total weight of the module.

2.4 Aesthetic Appearance

The cells of the shingled module are densely packed, free of tabbing ribbons, and have a uniform appearance, which greatly improve the integration between the PV system and the building.

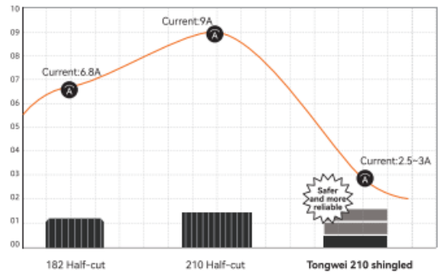
TW Solar's shingled modules



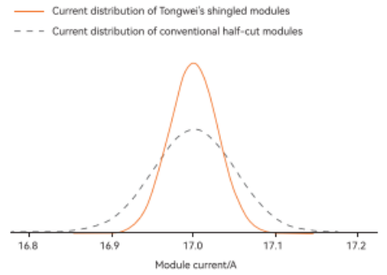
Conventional halfcut modules

2.5 Segmented Cells Laser Cutting

TW Solar’s shingled module uses segmented cell technology. The string current is 2.5-3.0A, 1/3 of the string current of half-cut modules; the module current mismatch is also reduced, resulting in higher module reliability.

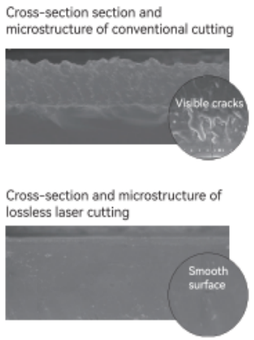


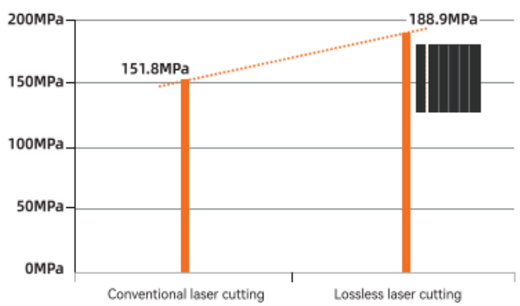
Comparison of various cell currents



Current distribution of shingled and half-cut module

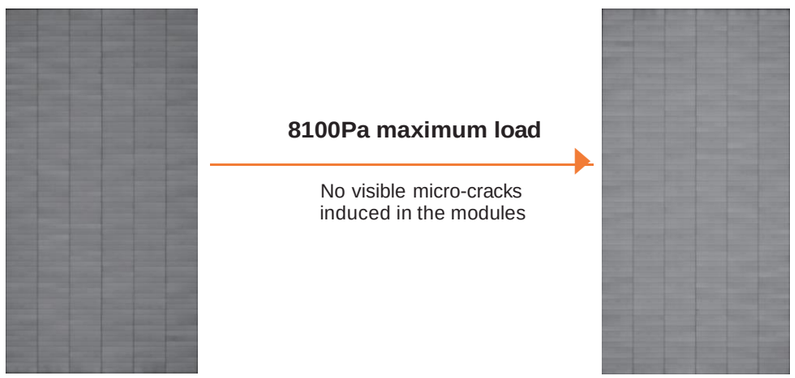
TW Solar's shingled modules use low-temperature lossless laser cutting technology to split the cells to reduce thermal damage and improve the mechanical strength of the cells.





Mechanical strength of conventional laser cutting VS lossless laser cutting

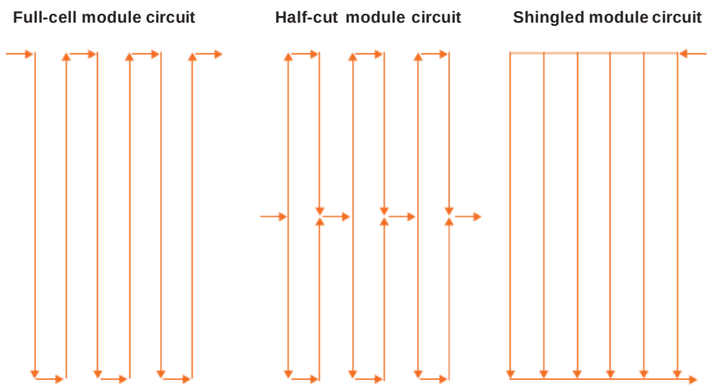
TW Solar's shingled modules passed the 8100Pa maximum load test, with no micro-cracks induced and with a power degradation of less than 0.5%.



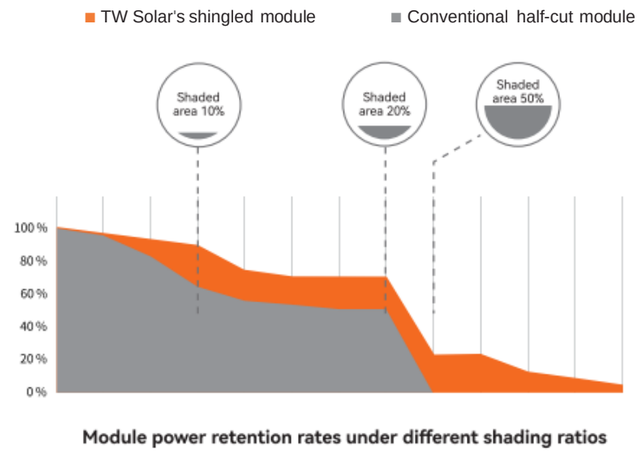
Remarks: In IEC standard test, the load is 5400Pa and the power degradation criteria is 0.5%

2.6 Full-Parallel Circuit Design

Compared with a full-cell module, a half-cut module is designed with a 2- string parallel circuit to improve the anti-shading capability of the module. TW Solar's shingled module adopts a 6-string parallel connection design, increasing the number of current paths. It is the only module design in the industry that realize a multi-channel parallel circuit, further improving the anti-shading capability.



Note: The arrows represent the directions of the current.

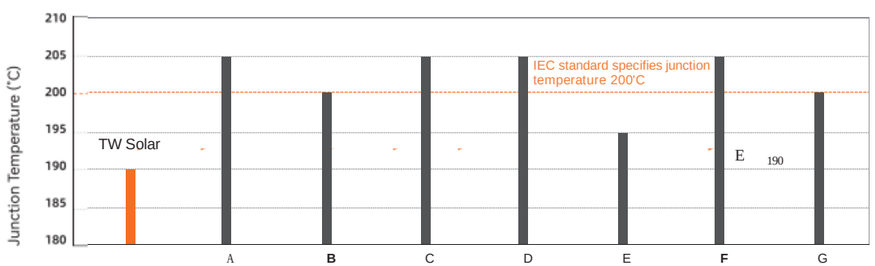


Module power retention rates under different shading ratios

03 Product reliability

3.1 Junction Box Reliability

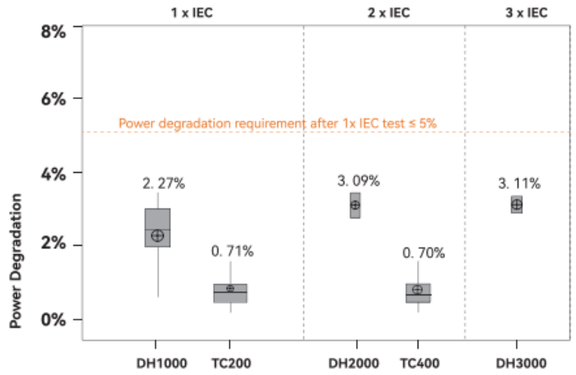
IEC62790 requires that the rated current of the junction box is greater than or equal to 1.25 Isc. UL1730 requires that the rated current of the junction box is greater than or equal to 1.5 Isc. In addition, according to the draft of the new IEC standard, in bifacial modules, Isc=Isc'x(1+0.3xΦ), where Isc' is the front short-circuit current and Φ is the bifaciality. The rated current of TW Solar's shingled module junction box is 1.56 Isc, and the 660W+ product is equipped with a junction box with a rated current of 30A, exceeding the requirements set forth by the IEC standards.



Junction box junction temperature test data

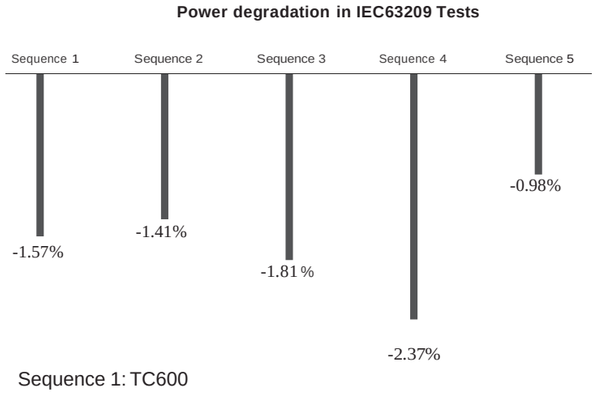
3.2 Multifold IEC Standard Tests

TW Solar shingled modules have been tested beyond the IEC standard requirement, demonstrating their exceptional reliability.



3.3 IEC63209 Tests

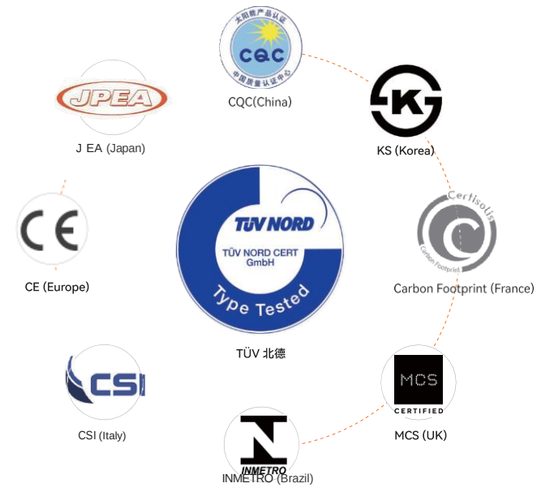
TW Solar's shingled modules passed IEC63209: Extended-stress testing of photovoltaic modules for risk analysis, with excellent performance. The tests were carried out and verified by VDE.



Sequence 1: TC600
Sequence 2: SML+DML+TC50+HF10
Sequence 3: DH200+(UV60+TC50+HF10)x3+UV6.5
Sequence 4: DH2000
Sequence 5: PID192

3.4 Certifications

TW Solar's shingled modules have obtained the IEC61215 and IEC61730 certificates issued by TUV NORD and have been further obtained international certificates including CQC, KS, MCS, CE, JPEA, CSI, etc.

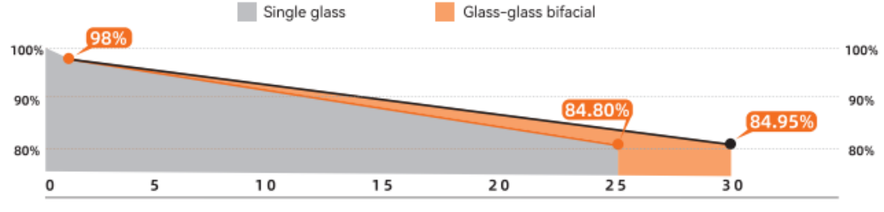


TW Solar is committed to providing customers with high-quality, high-performance, and high-reliability module products to meet the growing global demand for clean energy.

3.5 Warranty

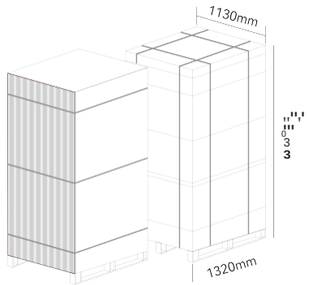
TW Solar's shingled single-glass modules offer a 25-year warranty of linear power output. The first year's degradation is less than 2%, and the annual degradation is less than 0.55% from the second year. At the end of the 25 years warranty period, the power is no less than 84.8%. TW Solar's shingled glass-glass bifacial modules offer a 30-year linear power output warranty. The degradation is less than 2% in the first year, the annual degradation is less than 0.45% from the second year. At the end of the 30 years warranty period, the power is no less than 84.95%.

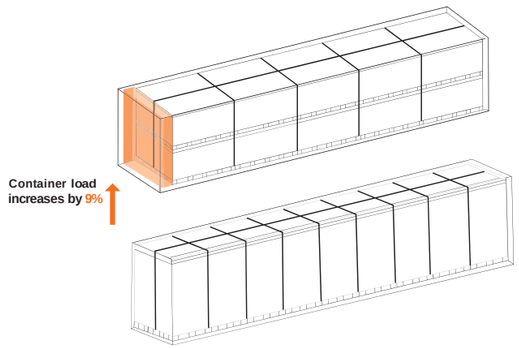
Linear Power Warranty of TW Solar's Single Module



04 Transportation

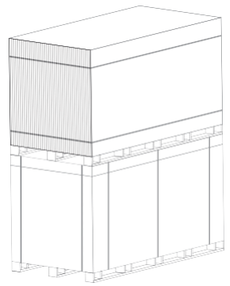
TW Solar adopts vertical packaging for large-sized modules and increases the container utilization rate by 9%. After maritime and land transportation verification, the module transportation process is proven to be safe and reliable.

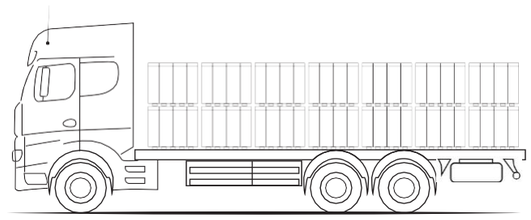




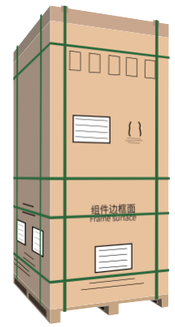
Type	Module Power	Number of modules/ pallets	Number of pallets/ container	Total module power/ container
competitor modules	545W	31pcs	20 pallets	0.33MW
TW Solar S6 series	660W	31pcs	18 pallets	0.36MW

TW Solar's shingled modules also provide horizontal packaging solutions to meet customers' needs in different transportation and installation scenarios.

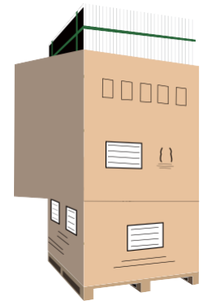




Unpacking Steps of TW Solar's Vertical Packaging



TW Solar's shingled module vertical package



Remove the carton

Position the unpacking stand

Tilt the modules, and remove the modules in sequence

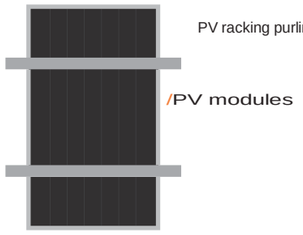
05 System Compatibility

5.1 Mounting Compatibility

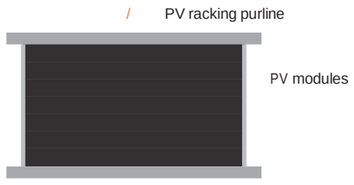
The external dimensions of TW Solar's modules are consistent with industry standards and are compatible with various types of PV mounting systems.

5.1.1 Fixed Racks

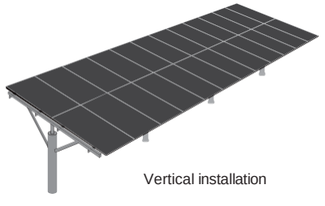
TW Solar's shingled modules are compatible with various fixed racks to achieve horizontal and vertical installation.



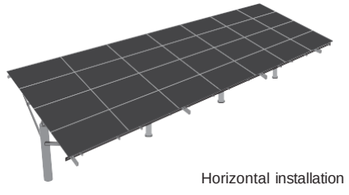
Long side of purline vertical module
(+5400Pa, -2400Pa)



Long side of purline parallel module
(+3600Pa, -2400Pa)



Vertical installation



Horizontal installation

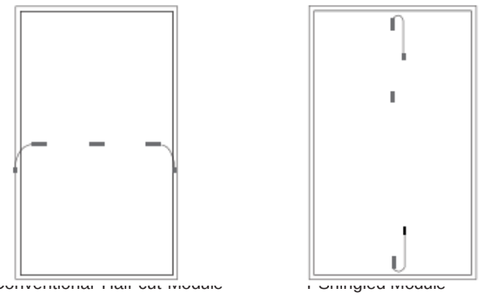
5.1.2 Tracking System

TW Solar's shingled modules match the length, width, string arrangement, and motor driving force of the tracking systems.

1P Tracking rack

2P Tacking rack

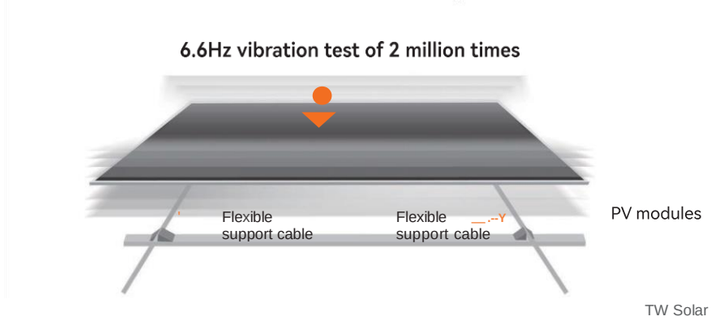
The junction box of TW Solar's shingled modules is asymmetrically designed to avoid stress concentration points. TW Solar conducted a compatibility test with Arctech Solar and Nextracker, the leading companies in tracking systems. The mechanical load capability reaches ±2500Pa (±2400Pa for conventional half-cut modules of the same size).



Conventional Half-cut Module | Shingled Module

5.1.3 Flexible Mounting

The flexible mounting system adopts a wide-span steel cable structure, and the degree of vibration with strong wind is higher than that of the fixed racking. The flexible interconnects of TW Solar's shingled modules can better withstand the vibration and reduce cracking risks.

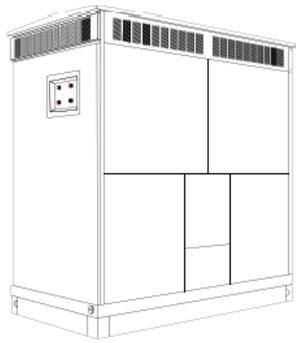


Simulating the installation method of flexible mounting, TW Solar's shingled modules have undergone 2 million vibration tests, and there is no micro-crack or frame deformation.

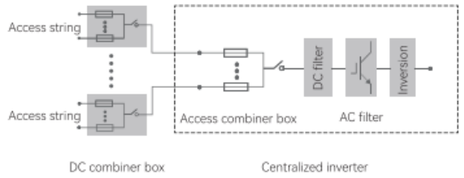
5.2 Inverters

5.2.1 Centralized Inverter

By selecting a suitable combiner box, TW Solar shingled modules are fully compatible with various centralized inverters.



Centralized inverter



Schematic diagram of centralized inverter system

5.2.2 String Inverter

The MPPT current of the string inverter used in the ground-mount solar projects needs to match the PV modules. The MPPT current of standard string inverters is compatible with TW Solar shingled modules. The upcoming models from mainstream inverter manufacturers will better match the application of TW Solar shingled modules.

Application scenarios	Maximum power point current of the module	Current of string inverter	Mainstream inverter brands
Ground-mount solar projects	17A	2: 20A	HUAWEI, SUNliROW, 上能电气 SINENG, KELONG 科华技术, 固德威 GOODWE, 锦浪科技, CHNTi::E, 中国中车 CRRC, KSTAfIII1:Iii

Distributed generation (DG) and residential applications of TW Solar shingled module have a maximum power point current of 12A; Commercial and industrial (C&I) applications of TW Solar shingled module have a maximum power point current of 14A. Currently 80% of the existing inverters are fully compatible.

Application scenarios	Maximum power point current of the module	Current of string inverter	Mainstream inverter brands
Residential	12A	2:12.5A	Compatible
Commercial and industrial (C&I)	14A	2: 15A	Iml!!liil: GOOCII.IE, SUNliROW, 锦浪科技, GROWATT 古瑞瓦特, !ii!lil.U Eti'=\. SINENG, Afore 艾伏, SMA, SOFAR SOLAR, Fronius

06 System Cost Advantages

6.1 BOS Analysis

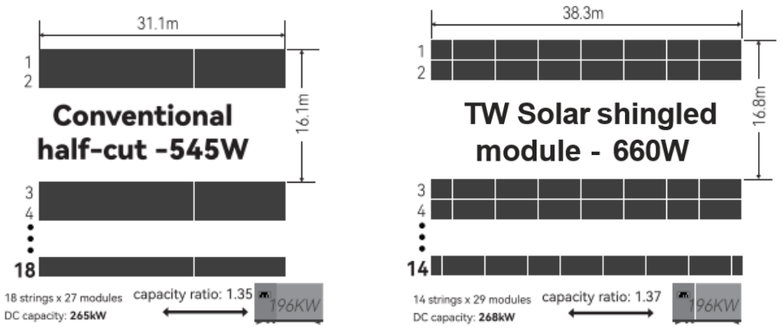
TW Solar shingled module features low voltage and high string power, which improves utilization rate of racks, pipe piles, and cables, resulting in reduced engineering and construction cost per watt for the solar project.

Type	Binyang,Guangxi		Suihua,Heilongjiang	
	Quantity per string (Modules)	Power per string **(kW)**	Quantity per string (Modules)	Power per string **(kW)**
Conventional half-cut module -545W	29	15.8	27	14.7
TW Solar shingled module -660W	30	19.8	29	19.1

Using a low latitude (Binyang, Guangxi, 23° N) 10° inclination fixed rack project as an example, the BOS cost is reduced by 3.6% with of TW Solar's shingled modules.

Cost Type	Conventional half-cut module -545W	TW Solar shingled module -660W
Racking / pile foundation	Benchmark	-7.4%
Electrical material/ equipment	Benchmark	-2.2%
Installation work	Benchmark	-15.1%
Construction work	Benchmark	-0.4%
System BOS cost	Benchmark	-3.6%

For a mid-latitude region (Suihua, Heilongjiang, 47° N) project, increased installation inclination and spacing between the rows lead to changes in the number of racks, pipe piles, cables, etc. The difference in BOS costs between the conventional half-cut module and TW Solar's shingled modules further widens. The BOS cost is reduced by 5.1% with TW Solar's shingled modules.



Cost Type	Conventional half-cut module -545W	TW Solar shingled module -660W
Racking material / pile foundation	Benchmark	-10.3%
Electrical material / equipment	Benchmark	-6.2%
Installation work	Benchmark	-14.1%
Construction work	Benchmark	-2.3%
System BOS cost	Benchmark	-5.1%

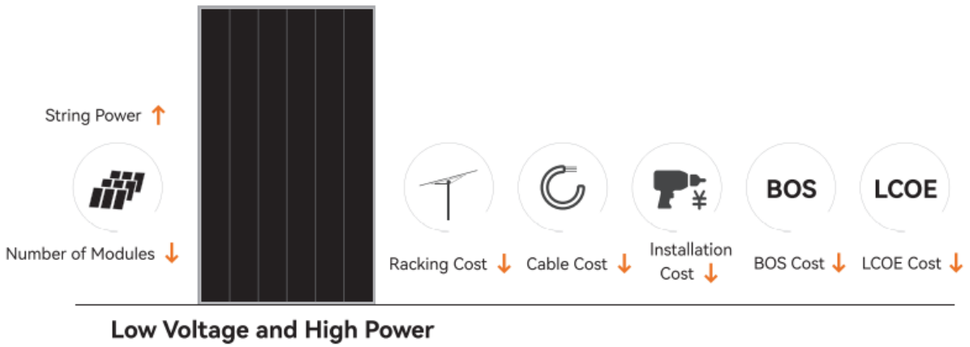
6.2 LCOE Analysis

Levelized Cost of Energy (LCOE) is the cost of power generation calculated based on the cost and power generation during the project life cycle.

$$LCOE = \frac{I_0 - \frac{V_R}{(1+i)^n} + \sum_{n=1}^{25} \frac{A_n + D_n + P_n}{(1+i)^n}}{\sum_{n=1}^{25} \frac{Y_n}{(1+i)^n}}$$

1.: Project initial investment. Ai Operating cost in yearn. Yi Electricity generation in yearn. V.: Residual value of fixed assets.
Dn: **Depreciation in yearn.** **i: Depreciation rate.** **P,,: Interest in yearn**

TW Solar shingled modules with low voltage and high power reduce LCOE by more than 1.4% compared with conventional half-cut modules.



07 Products and Project Examples

7.1 Product Roadmap