**Gang Shi**
CTO, Module Business
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**Halil Demirdag**
Chairman
Smart SOLAR TECHNOLOGIES

**Roger Miao**
PV General Manager
TÜV NORD

**Moderated by**
**Sean Rai-Roche**
Section Editor
SOLAR MEDIA
EVENTS | PUBLISHING | RESEARCH
PVTECH

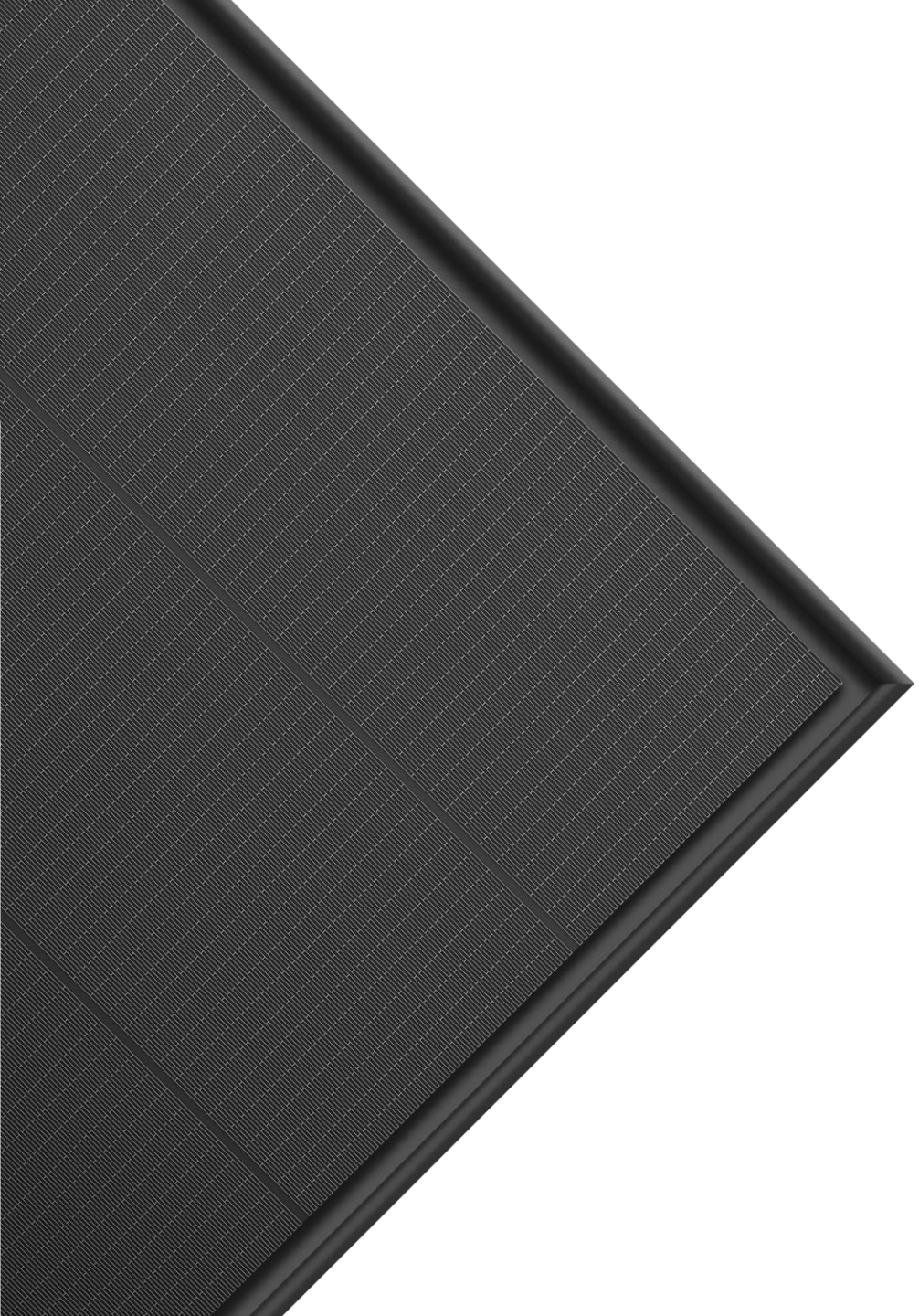
TW SOLAR

PVTECH TECHTalk

# WEBINAR

# How Tongwei Solar's shingled modules can boost power output and reliability

**18th October 2022**



# How Tongwei Solar’s shingled modules can boost power output and reliability

Speaker:Gang Shi

18th October 2022

PV CHANGES
THE WORLD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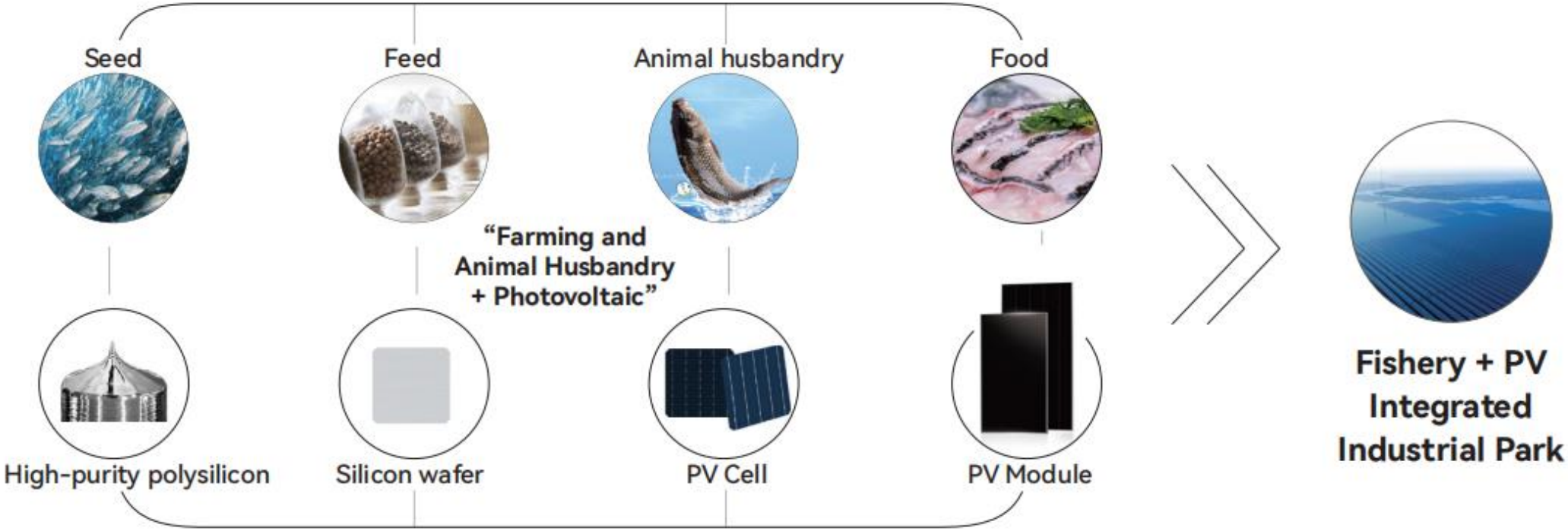
PV CHANGES
THE WORLD

# Tongwei's Fully-integrated Industrial Chains

Tongwei Group — a company with more than **300** branches and subsidiaries, with nearly **50,000** employees.

As a listed company, Tongwei (listed in 2004, stock code 600438) is a large-scale high-tech corporation with two core businesses — **Agriculture** and **Renewable energy**.



# Advantages of Fully-integrated PV Industrial Chain

In 2006, Tongwei entered the renewable energy market and has become a major player in PV in the upstream, midstream and downstream, with high-purity polysilicon, high-efficiency solar cell and module manufacturing, respectively, forming a complete PV industrial chain.

Yongxiang
High-purity Polysilicon

Upstream

Annual capacity : **230,000 tons**

Expected annual capacity by end of 2024-2026:

**800,000 - 1,000,000 tons**

**Production Capacity: No.1 in the world**

永祥股份 YONGXIANG CO.,LTD.

Tongwei
High-efficiency Cells

Midstream

Annual capacity: **54GW**

Expected annual capacity by end of 2024-2026:

**130 - 150 GW**

**Production Capacity: No.1 in the world**

通威太阳能 TW SOLAR

Tongwei
High-efficiency Modules

Downstream

Annual capacity : **15GW**

High efficiency shingled modules

Industry-leading automation

通威太阳能 TW SOLAR

Tongwei
“Fishery + PV” Power Plant

Projects

Organic integration of PV and modern fishery

Full investment process of PV project development, planning and design, intelligent operations and maintenance

通威新能源 TW NEW ENERGY


TW SOLAR

# CONTENT



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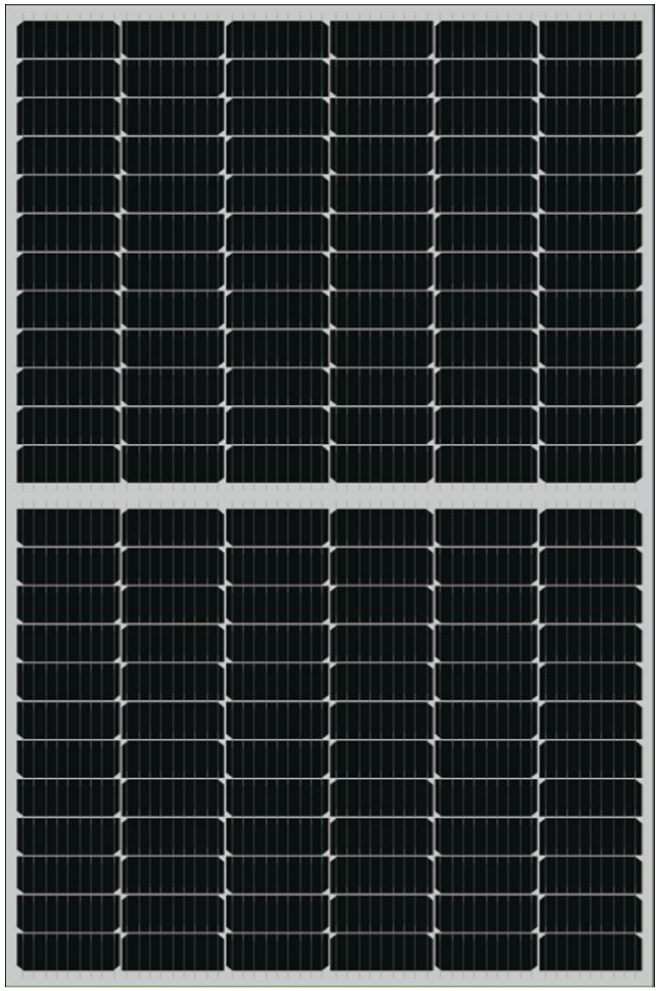
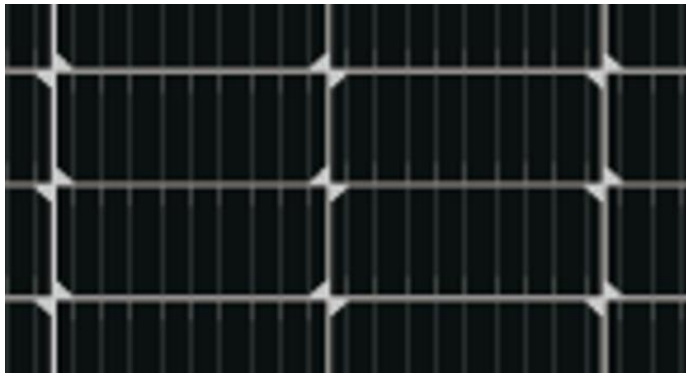
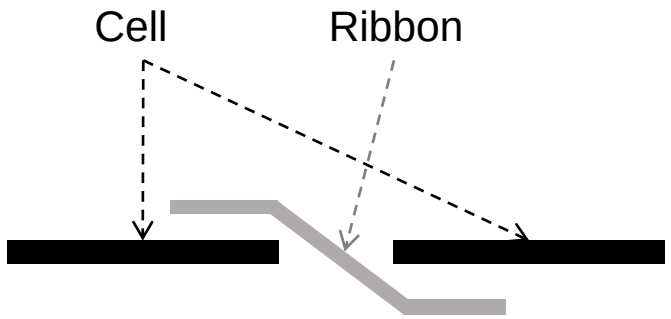
# Half-cut modules



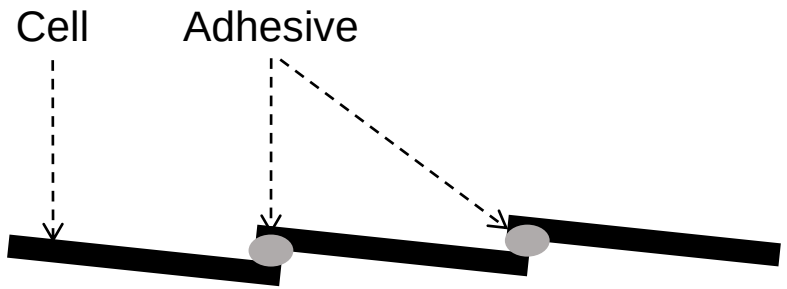


***Appearance***

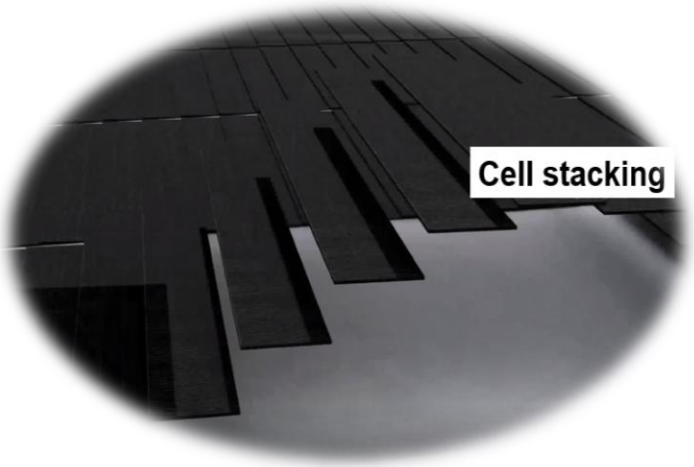



***Cell to cell connection***

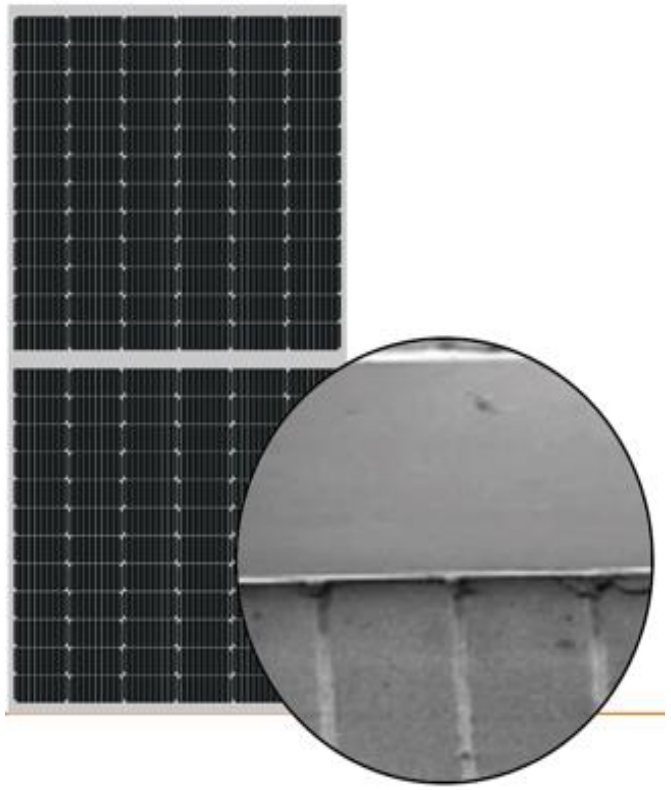
# Shingled module

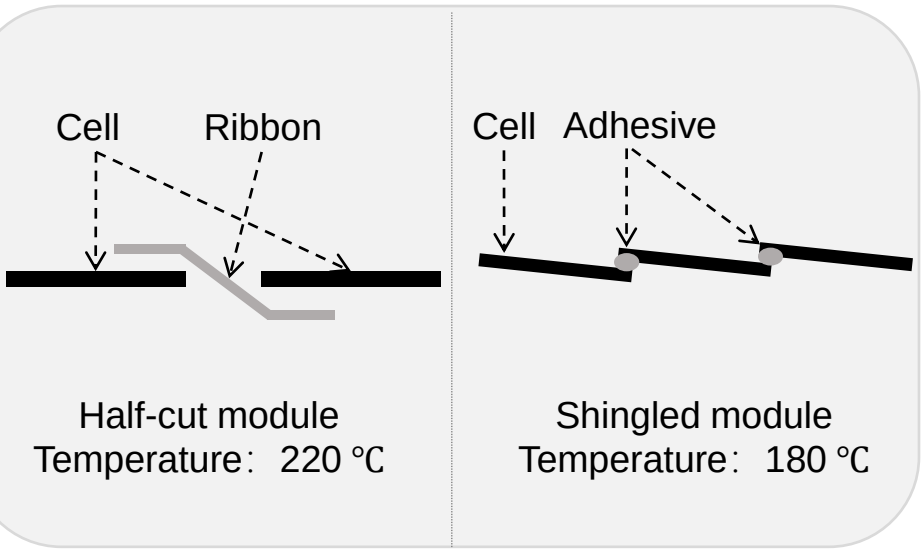



***Cell to cell connection***



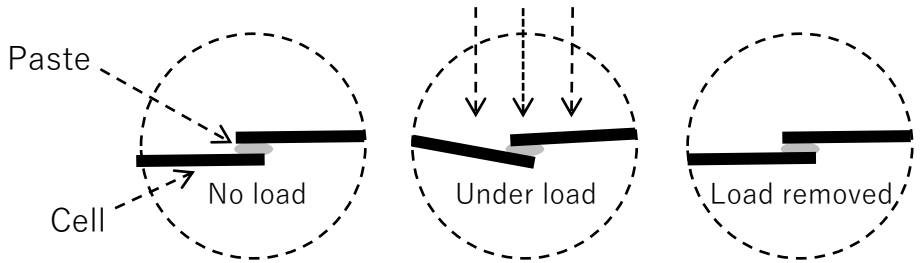

# Low temperature process



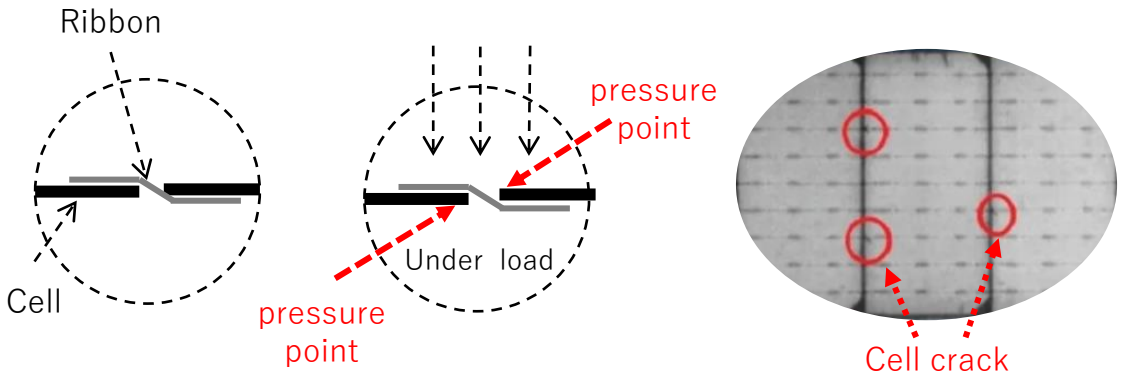



- The soldering temperature of half-cut module is 40 ℃ higher than shingling process of shingled modules.

# Flexible interconnect



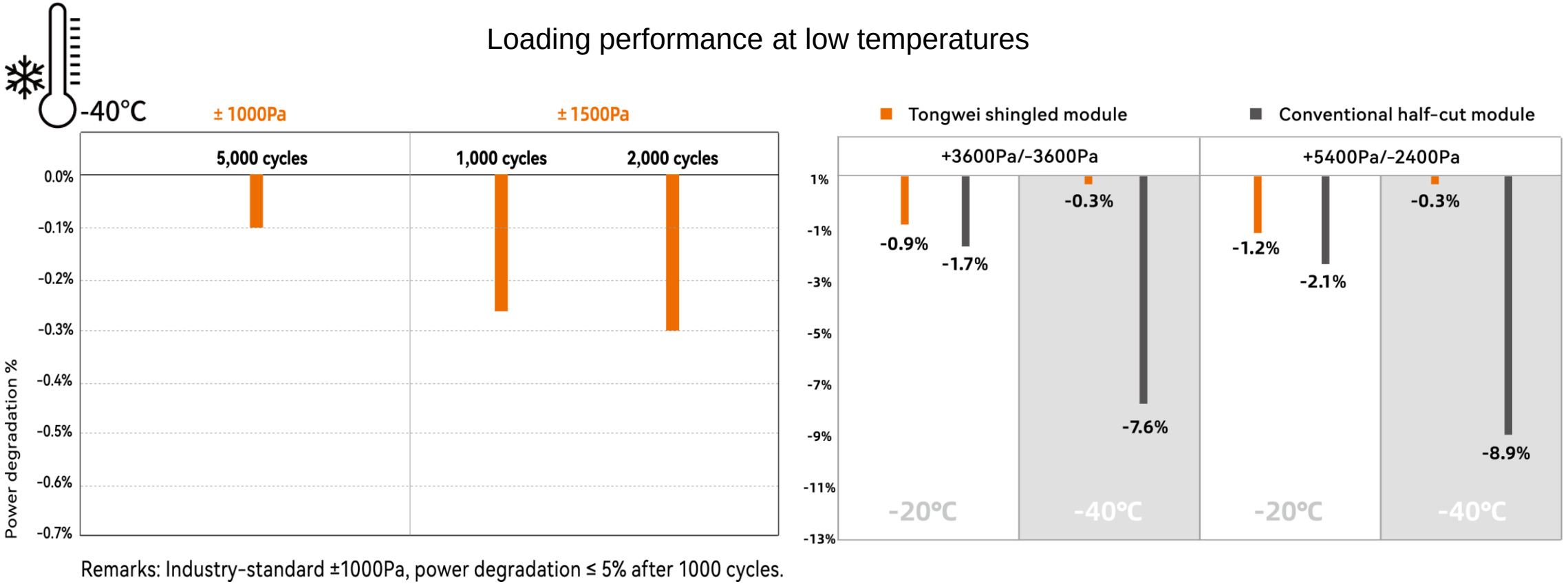

Shingled module flexible connecting trait




Half-cut module fragile part

- During construction and maintenance of PV power plants, PV modules are exposed to many risks such as mishandling and trampling, which could lead to cell cracks, affecting the reliability and power generation of the power plant.

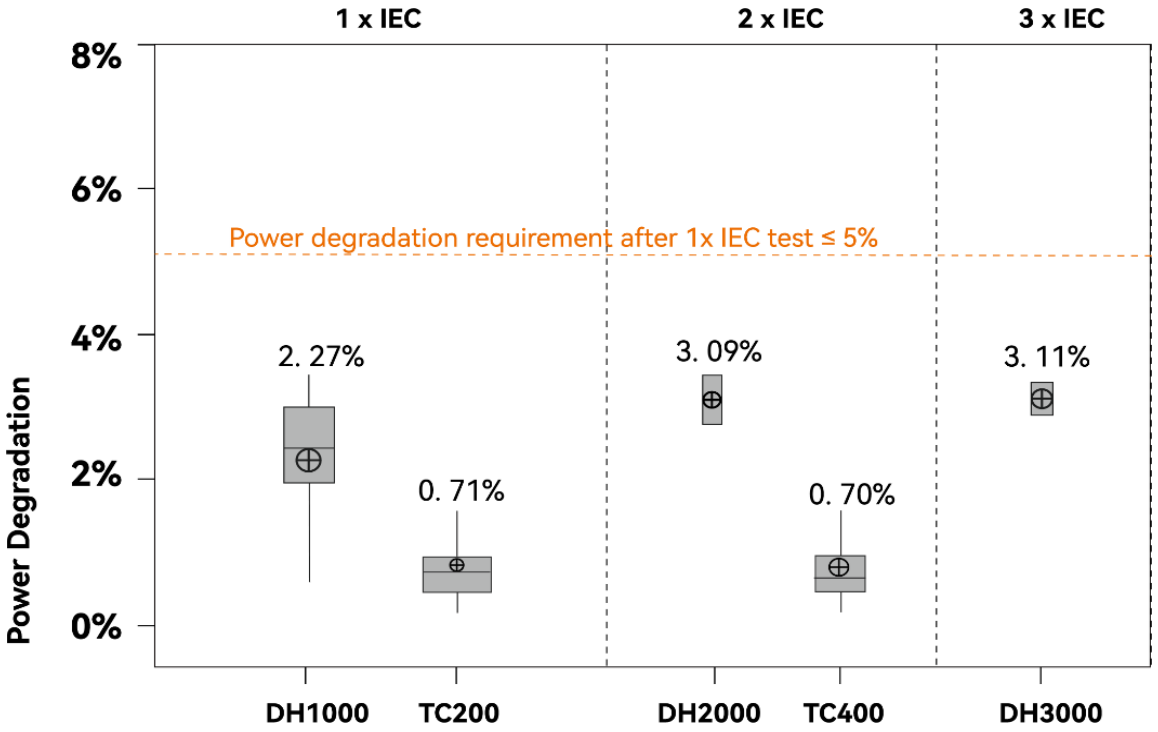
# Reliability



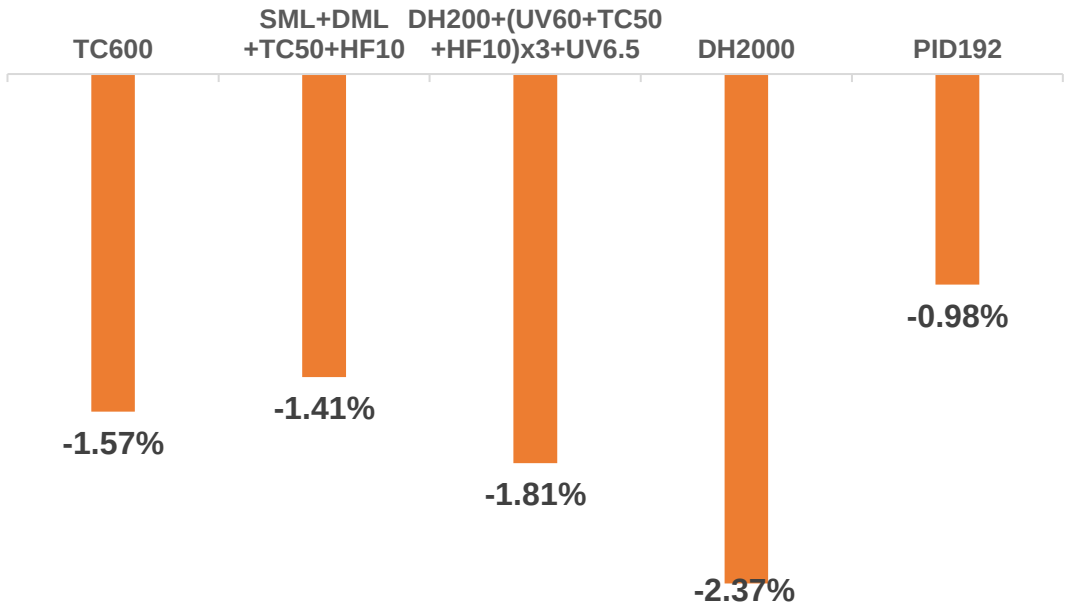

- Materials are subject to thermal expansion as temperature changes. Tongwei shingled module has better performance at low temperatures, which would be a better choice for customers from regions with challenging climates.

# Reliability

## ■ Multifold IEC Standard Test

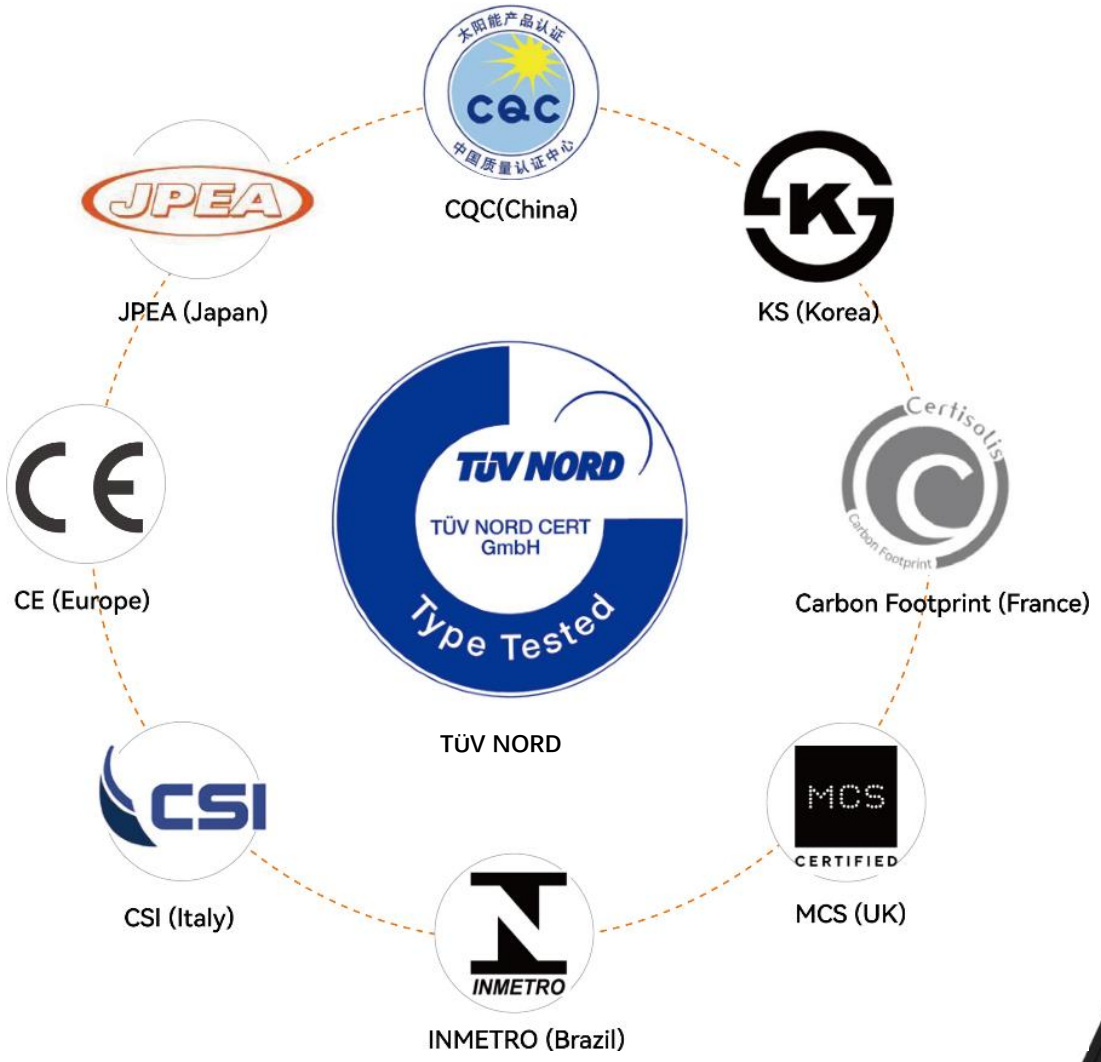


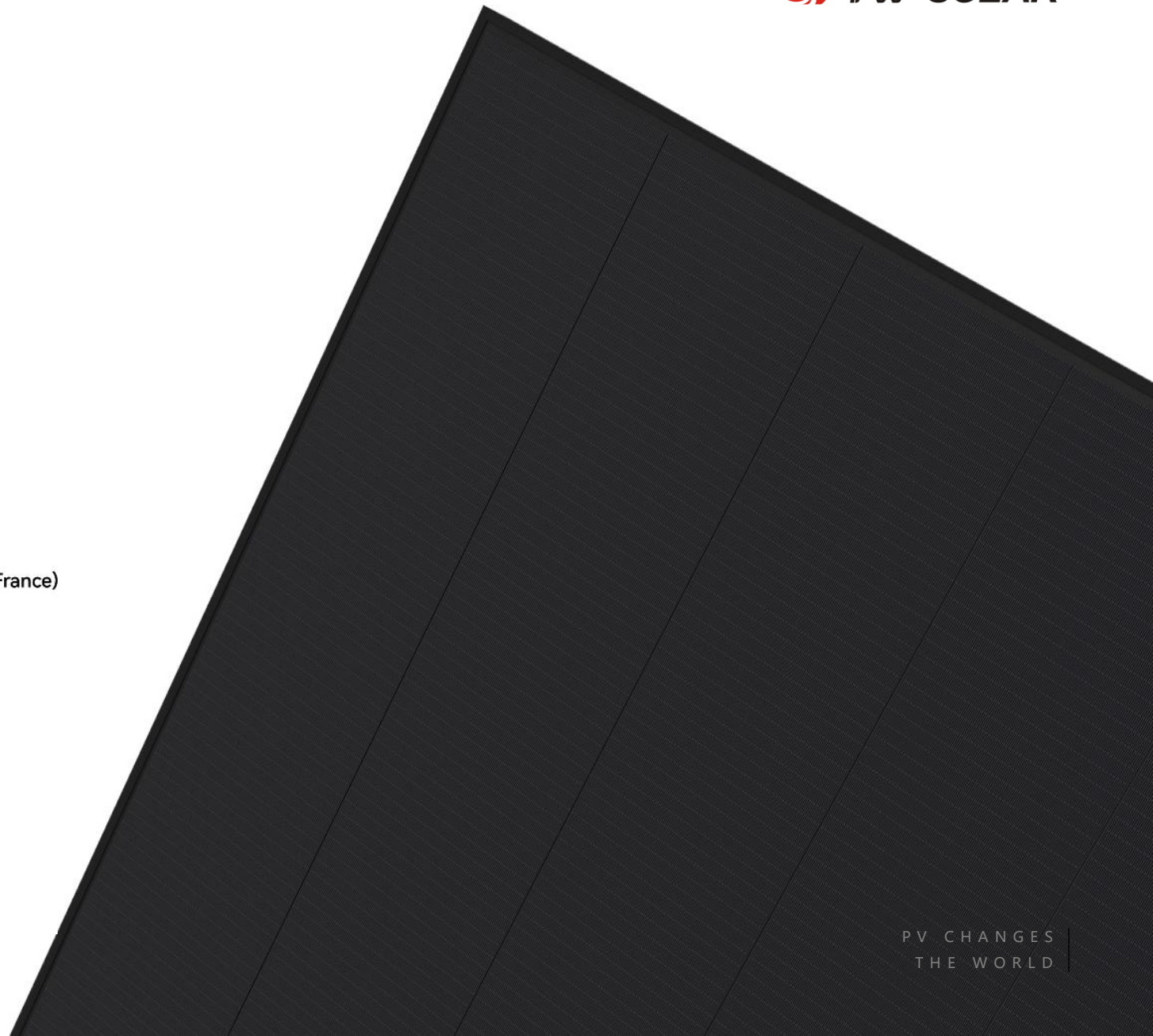

## ■ IEC63209 Test




- Tongwei shingled modules have passed multiple IEC environmental tests and work well in harsh environments - capable of withstanding extreme temperature and humidity, heavy snow and strong wind.

# Certification



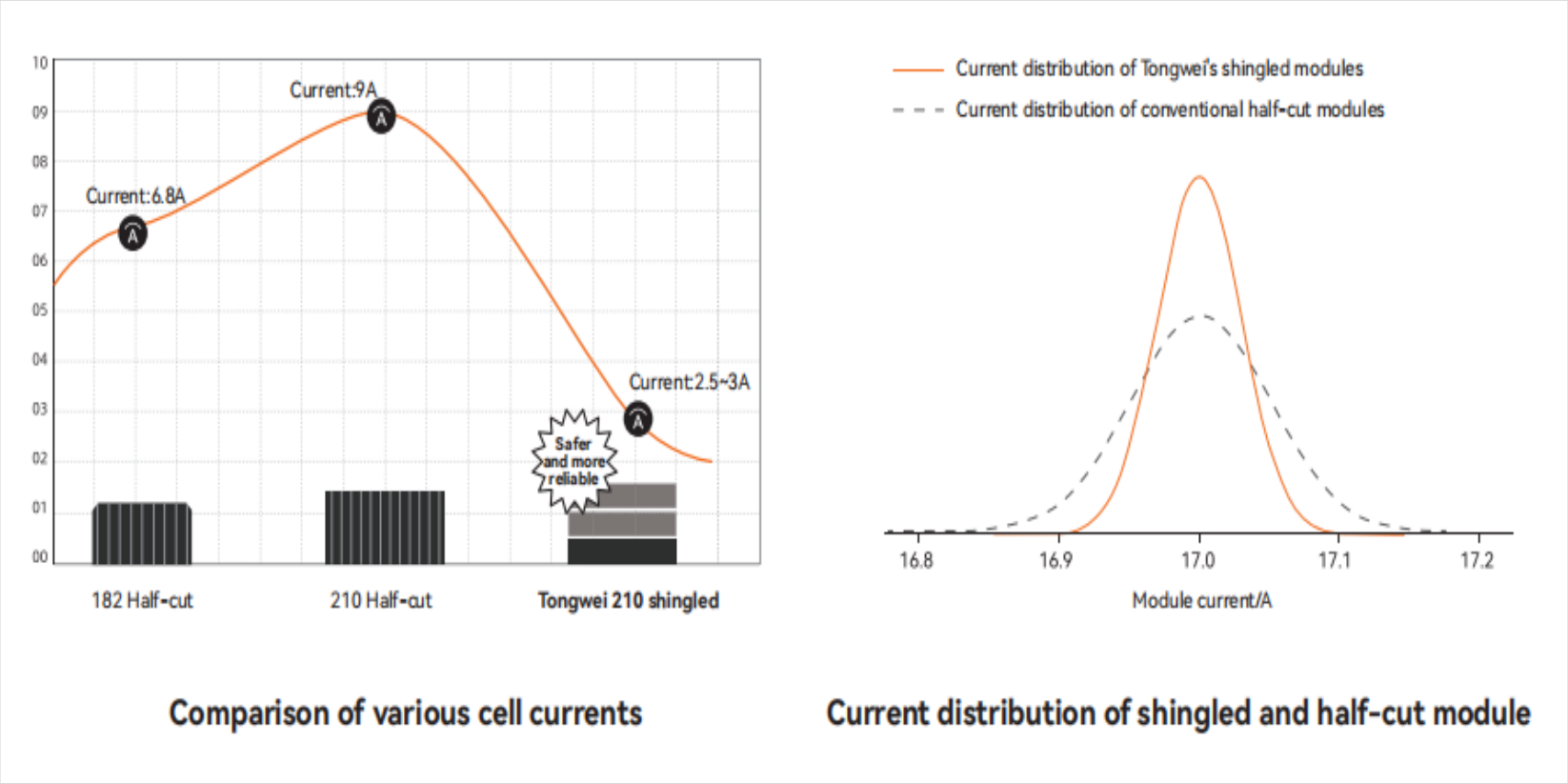



PV CHANGES
THE WORLD

# Hotspot risk

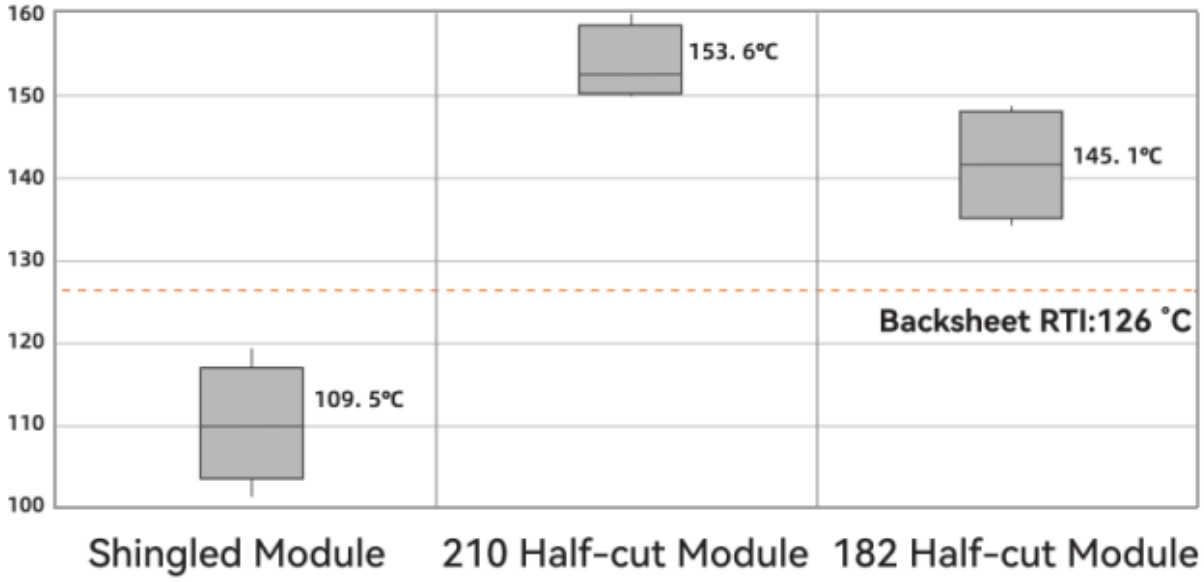

- Hotspot induced by uneven shading or local defects is a serious risk for PV projects.

# Shingled module advantages: low hotspot risk

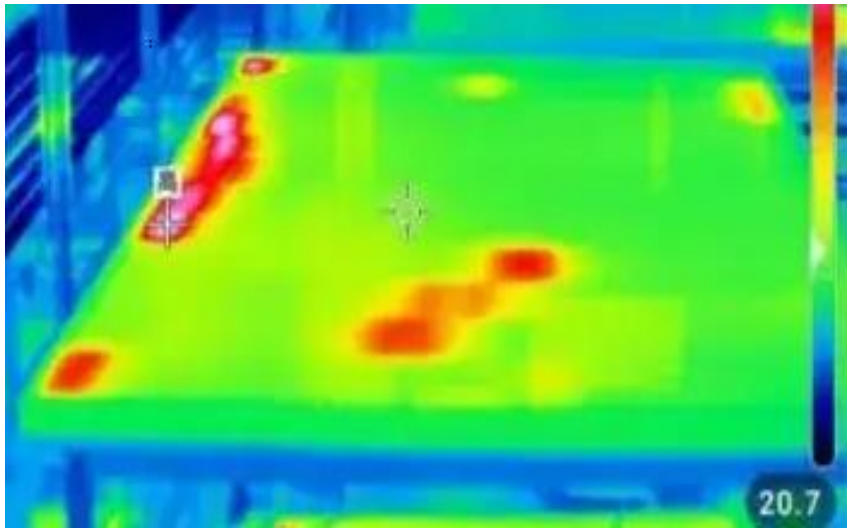



- In Tongwei's shingled module, the string current is 2.5-3.0 A, only **1/3** of that in half-cut modules.
- In addition, in shingled modules each cell is in direct contact with another. Thanks to silicon's higher heat conductivity the heat can be rapidly transmitted to the surrounding areas and hot spot temperatures can be rapidly reduced.

# Shingled module advantages: low hotspot risk




Data source: Fraunhofer ISE

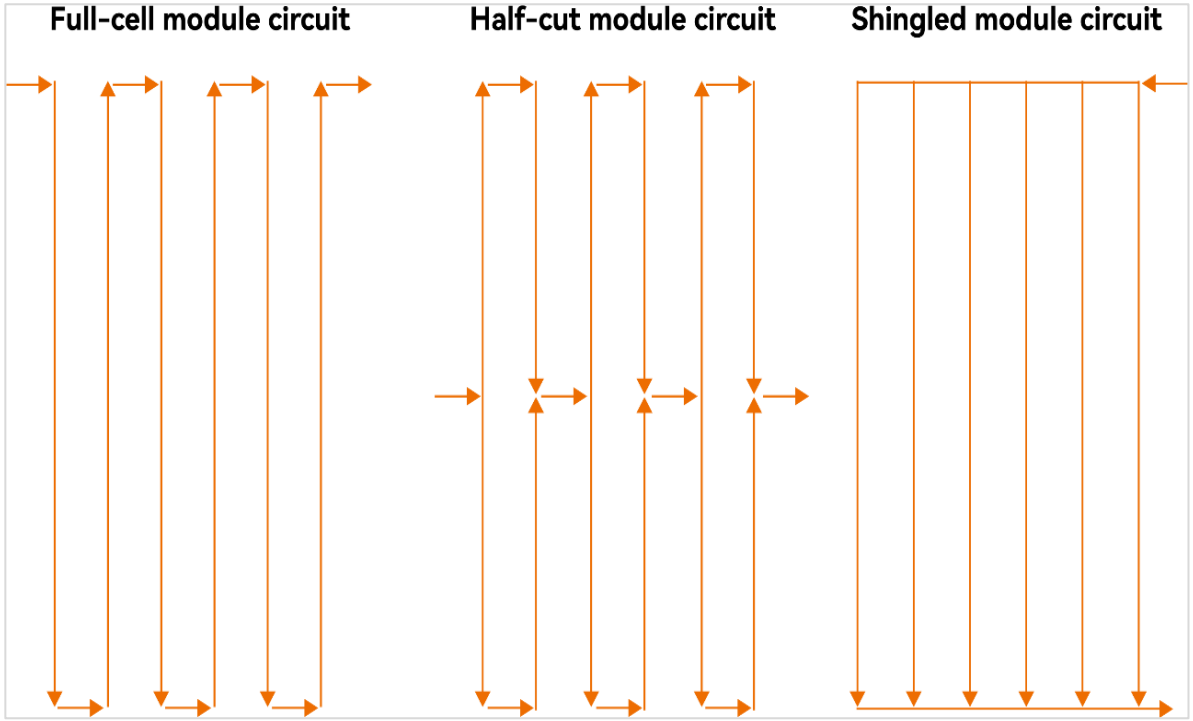



- Tongwei shingled modules have significant lower hotspot temperatures than that of 182 and 210 half-cut modules.

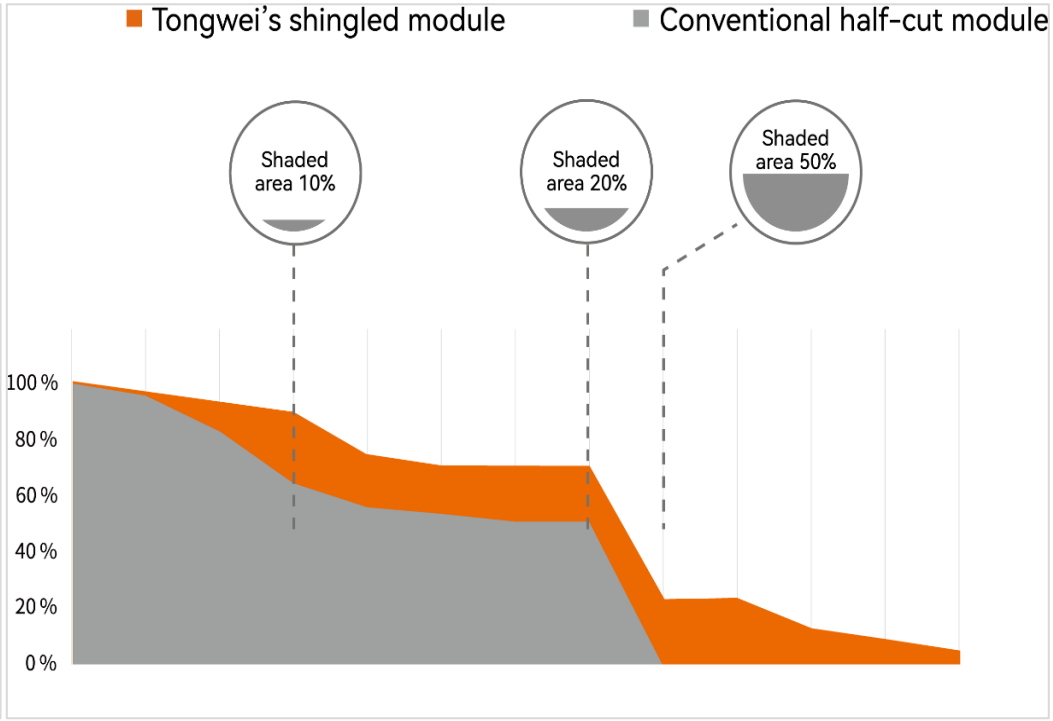
# Shading

- Under partial shading circumstances, Tongwei shingled modules perform better than half-cut modules.

# Shingled module advantages: anti-shading



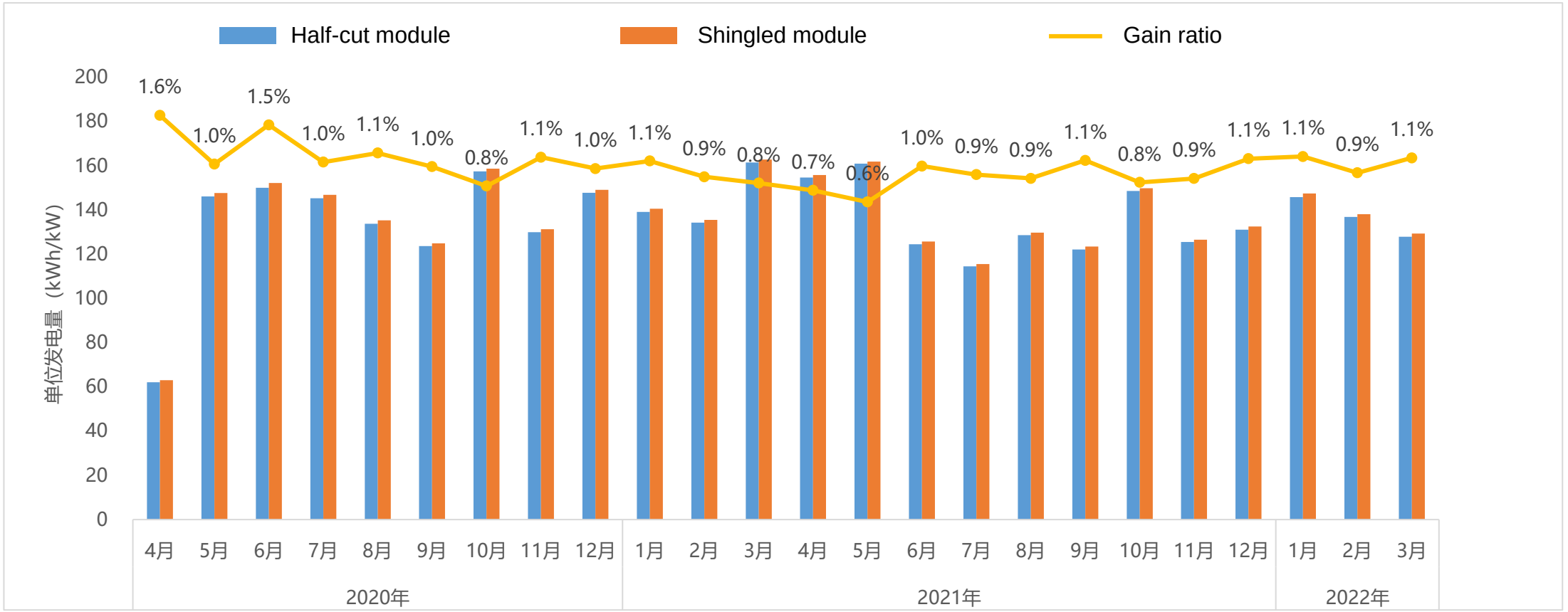

Note: The arrows represent the direction of the current.




Module's power retention under different occlusion ratios

- In a shingled module, all cell strings are connected in parallel, offering higher anti-shading capability.

# Long term power output monitoring



# BOS & LCOE

| Low-latitude Region (23° N) | | |
|---|---|---|
| Cost Type | Conventional half-cut module -545W | Tongwei 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%** |
| **LCOE** | Benchmark | **-1.5%** |

- Simulation results based on a low latitude application**, the system BOS cost is reduced by >3.6%, and the LCOE is reduced by >1.5%**

# BOS & LCOE

| Mid-latitude Region（47°N） | | |
|---|---|---|
| Type | Conventional half-cut module -545W | Tongwei shingled module-660W |
| Racking / 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%** |
| **LCOE** | Benchmark | **-2.1%** |

- In a mid-latitude application, the system **BOS** cost is further reduced by >**5.1%**, and the **LCOE** by >**2.1**%.

# Attractive appearance



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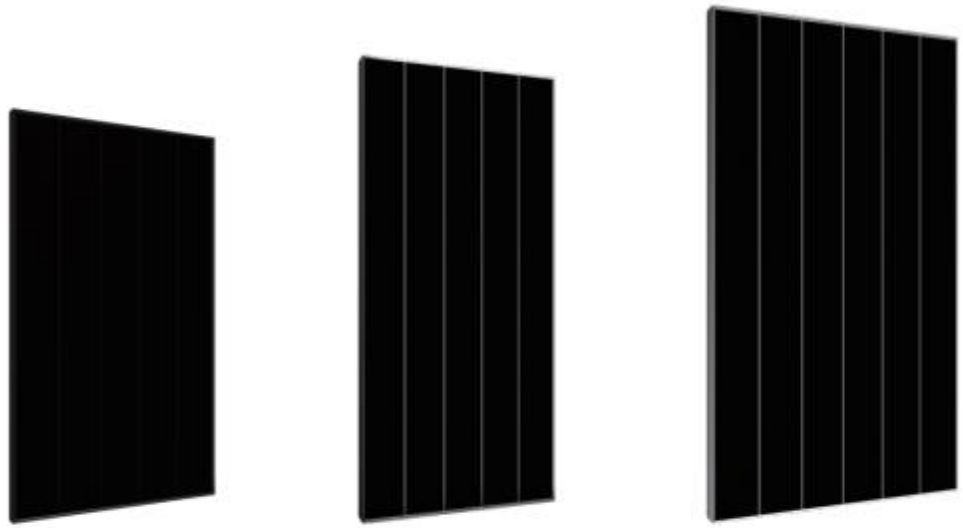
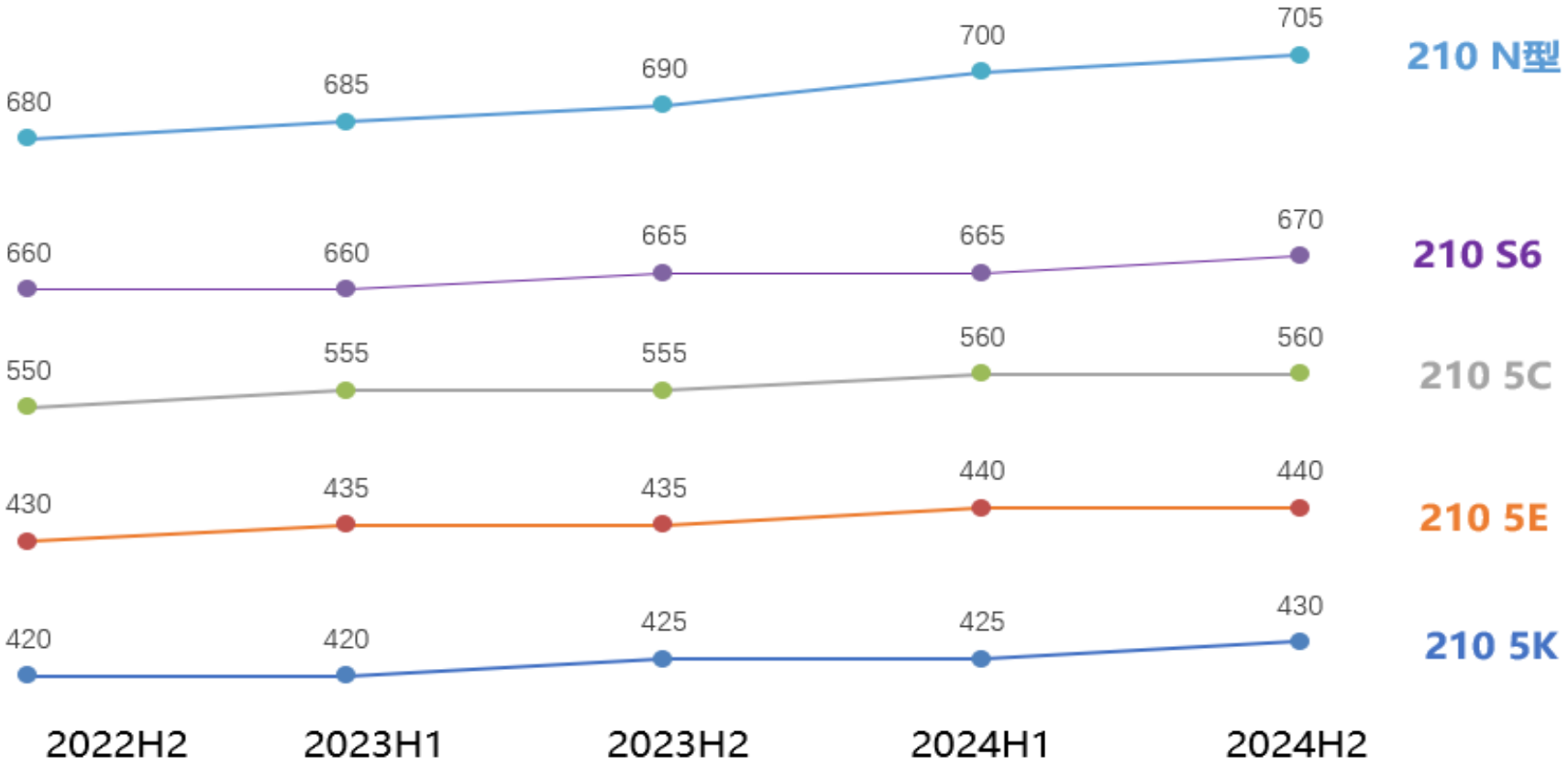
# Tongwei’s Shingled Modules Family

Tongwei shingled module family covers power output from 430W+, 550W+, to 660W+, suitable for residential, commercial and industrial (C&I) distributed, and large-scale ground-mount solar projects.

The product has exceptional power output, higher efficiency, and better reliability, which significantly improves the return on investment (ROI).



# Product Roadmap




Continuous technology investment to ensure our products meet customers' needs.

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# Project Examples

## Ground-mount Solar Projects




## Distributed Projects






# Global Markets


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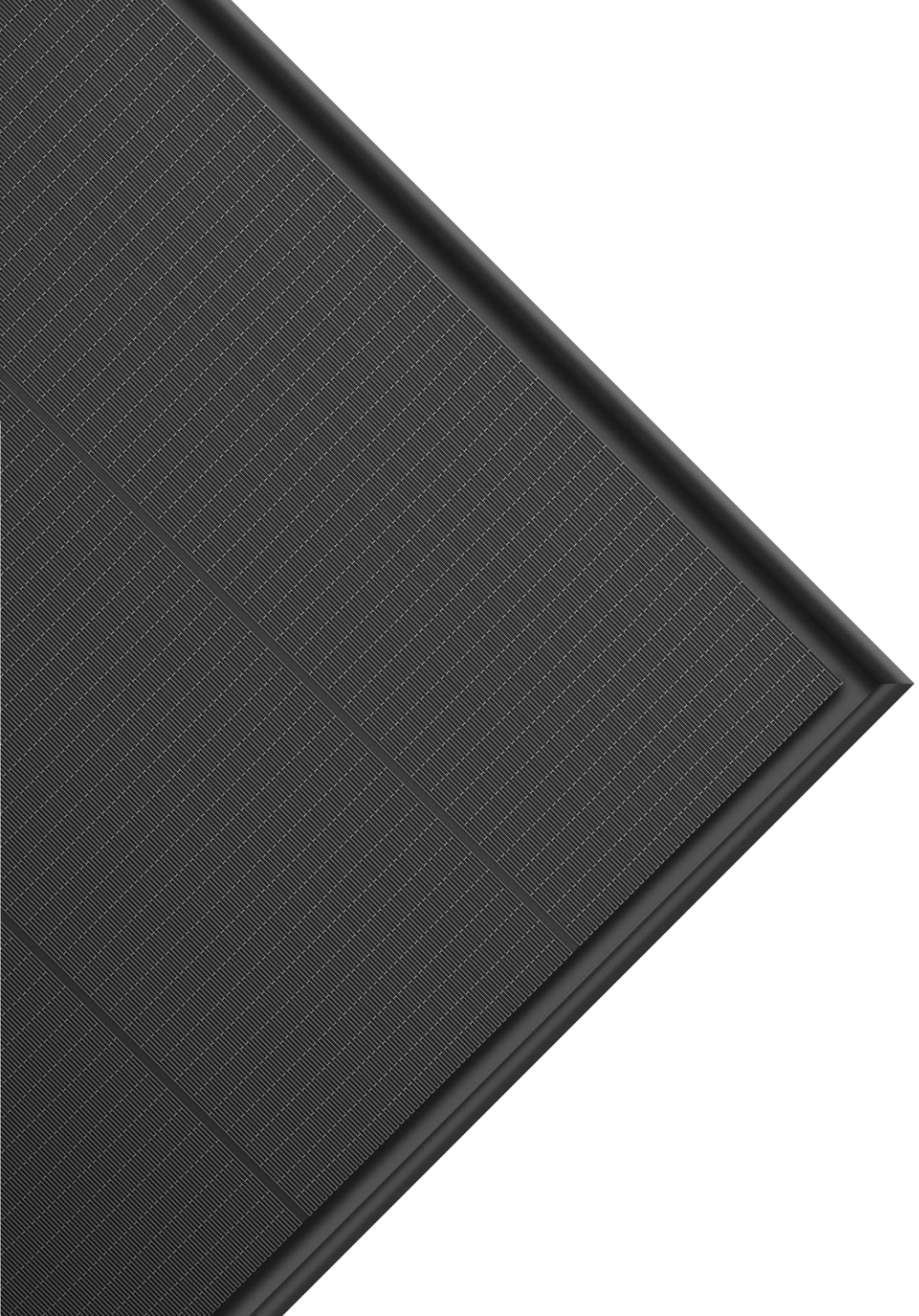

# Thank you!

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smartsolar.com.tr

# Smart SOLAR TECHNOLOGIES

18/10/2022

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# ABOUT US

As Smart Solar Technologies, one of the leading integrated solar companies in Europe in the field of turnkey installation services, solar power plant investments and PV module production, we offer a wide range of solar solutions to commercial and retail users.

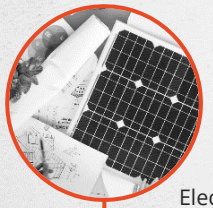
Our company was established in 2009, based in Istanbul. Smart Solar Technologies continues its activities with offices located in Turkey, Romania, Greece, Bulgaria, Germany, Switzerland, Ukraine and production facility located in Gebze.

Smart Solar Technologies, listed on Borsa İstanbul with the ceremony held on March 24, 2022.

The shares offered to potential investors began to be traded on BIST STARS with the ticker code "SMRTG".

# ABOUT US





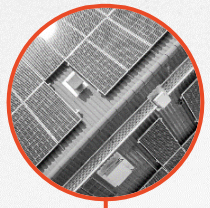
**2009**
Smart Energy was founded in Bulgaria.

**2010**
2010 PV projects were developed in Bulgaria.

**2011**
Electricity production started in Rakovskovo with a 1 MW PV power plant.

**2012**
The 12 PV power plant, with a total capacity of 30 MW, was connected to the grid in Bulgaria.

Greece and Romania offices opened.



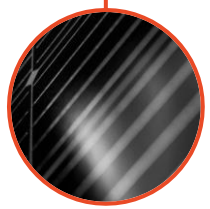
**2013**
PV power plants were established in Greece and Romania and connected to the grid.

**2014**
The first PV power plant installation was completed in Turkey.

The first roof project was realized in Romania.

**2015**
A total of 15 MW capacity project approval was received in Turkey.

The first CIS GLASS-GLASS panel project installation was completed.



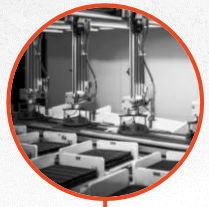
**2016**
Smart Solar Technologies started the factory construction process in an area of 23.500 m² in Gebze.

The 300 solar power plant projects completed were approved by TEDAŞ.


**2017**
The solar panel factory established in Gebze, started production with a capacity of 420 MW.

The installation of the world's second largest GLASS-GLASS panel solar power plant project has been completed.

**2018**
PV panel production capacity was increased to 800 MW.



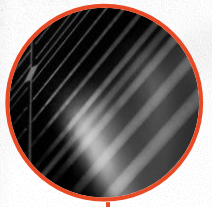
**2019**
Germany and Ukraine offices were opened.

The holding structure was started.

Mass production of Bifacial and Half-Cut panels started.

**2020**
PV panel production capacity was increased to 1200 MW.

**2021**
Smart Güneş Teknolojileri Pazarlama A.Ş. and Smart Güneş Enerjisi Teknolojileri ARGE Üretim San ve Tic. A.Ş. were merged and all the engineering capabilities were transfered to Smart Güneş Enerjisi Teknolojileri ARGE Üretim San ve Tic. A.Ş.



**2022**
A new solar module production factory has been commissioned with 600 MW capacity.

The foundations of 1200 MW solar cell factory and another 600 MW of solar module factory has been laid.

And another land for 3600MW ingot, wafer, cell and modules factory have been bought in same industrial zone.

Smart GÜNEŞ TEKNOLOJİLERİ

# ABOUT US

## CELL PRODUCTION
Production Capacity 2000 MW
(to be realized 2023)

+

## PV PRODUCTION
Production Capacity
1500 MW

## EPC
Provided EPC services 500+ MW installed

## INVESTMENT
In operation 100+ MW

## EXPANDING VERTICAL INTEGRATION

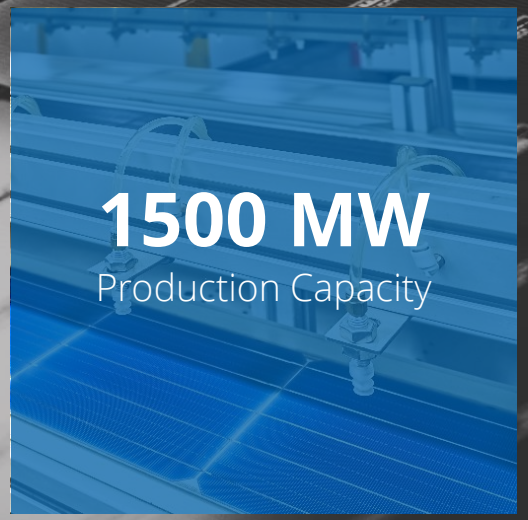
Smart Solar Technologies is active in large parts of the PV Value Chain.
We believe the future of the solar energy and we are expanding vertical integration with cell production facility which will be realized next year.

Smart SOLAR TECHNOLOGIES

# ABOUT US

## PV MANUFACTURING

**600+**
Employees
(%49 Women employment June2022)



**1500 MW**
Production Capacity

**%95**
Automation

**31.500 m²**
Facility Area

Smart SOLAR TECHNOLOGIES

# Big Star Award

Smart SOLAR TECHNOLOGIES

## Deloitte. recently annouced fastest growing technology companies in Turkey

Smart Solar Technologies won the "**BIG STARS**" award in **Deloitte.** Technology **Fast 50** awards

50

Technology **Fast 50**
**2020** TURKEY **WINNER**

15 years of innovation

**Deloitte.**


## Smart Solar Technologies
## is Among 100 Fastest Growing Companies in Turkey

We are pleased and honored to be awarded for being among 100 fastest growing companies in Turkey by The Union of Chambers and Commodity Exchanges of Turkey (TOBB)

In the face of innumerable challenges arising from the pandemic, the best and brightest were able to pivot, reinvent and transform and grow. We celebrate our award-winning organization and especially the talented employees driving our success.

TOBB TÜRKİYE 100

Smart SOLAR TECHNOLOGIES

# PV Module References

*Some of our pv modüle references.

**UCK**

Turkey

**71.300,00 kWp**

**Doğan Enerji**

Turkey

**24.690,00 kWp**

**Spor Yapı**

Turkey

**7.200,00 kWp**

**Sungen**

Turkey

**10.480,00 kWp**

**Akfen**

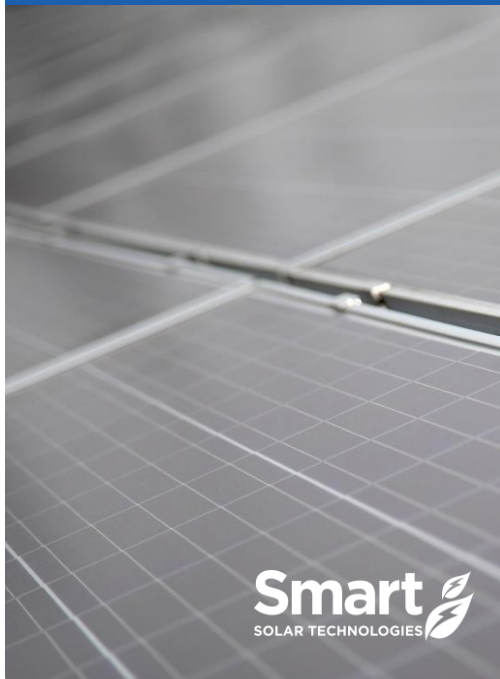
Turkey

**24.201,00 kWp**

**Birleşim Grup Edikli**

Turkey

**15.237,12 kWp**



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# Shingled Solar Module Technology

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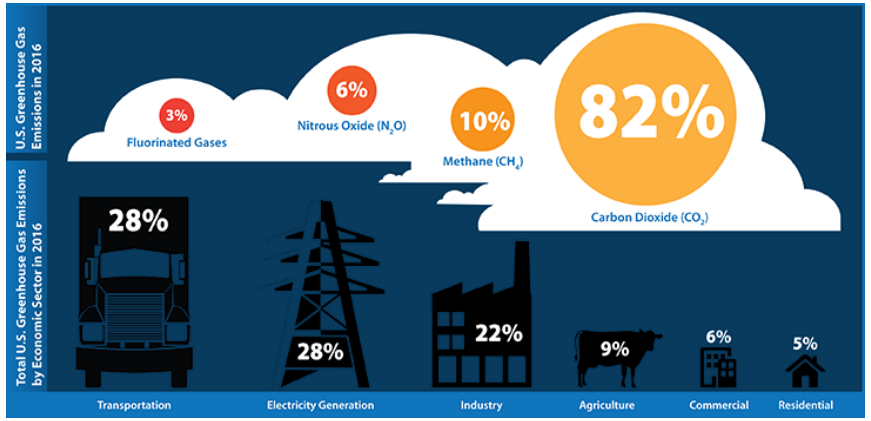
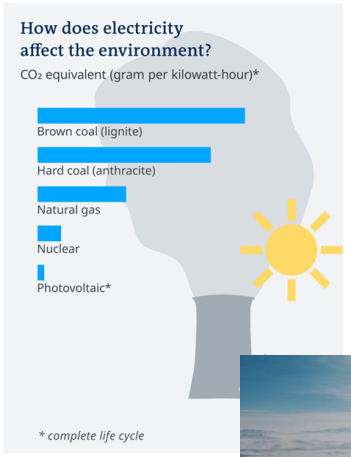
# Solar Energy & Carbon Footprint



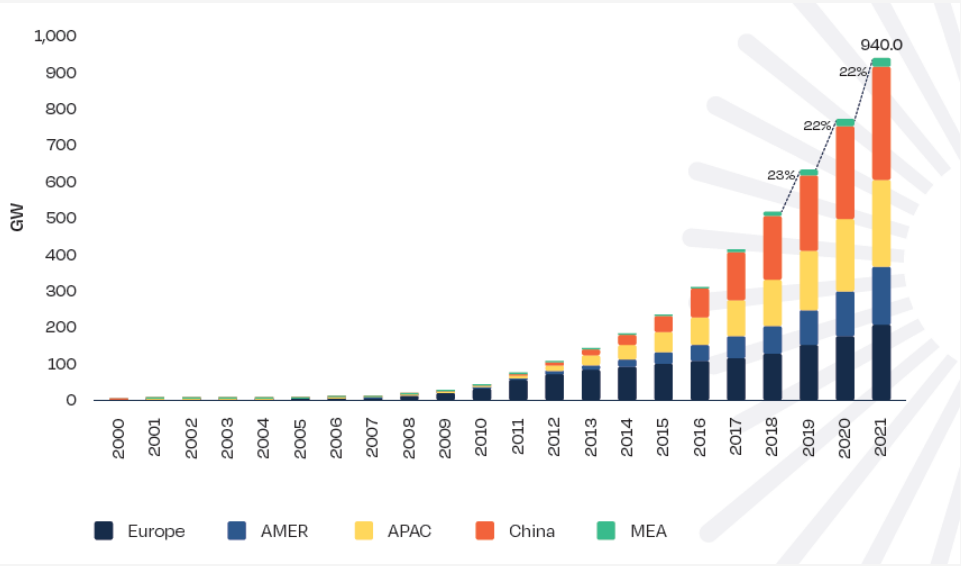

**PV solar - CO2 emissions during electricity generation: 0 g-CO2 kWh**



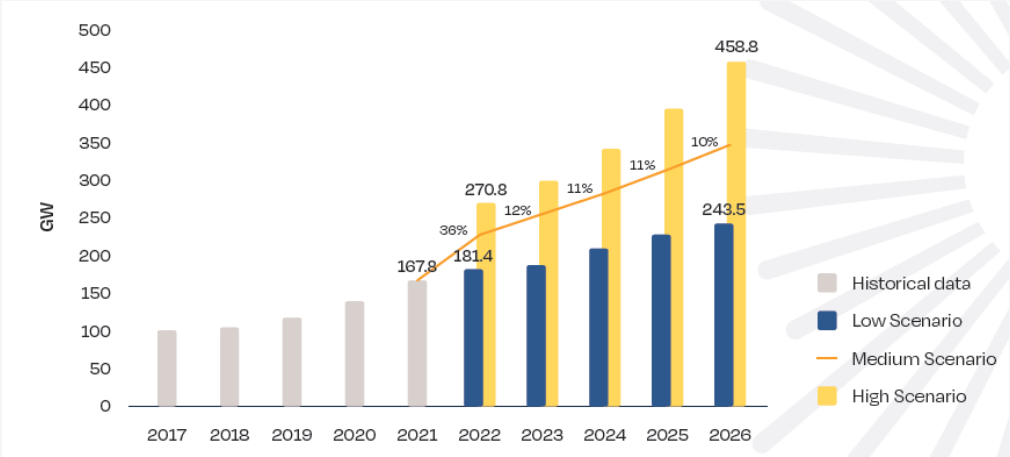



**Planting 1 tree can absorb approx 21kg of CO2 per year.**

## Total Solar PV Installed Capacity 2000-2021




## World Annual Solar PV Market Scenarios 2022-2026





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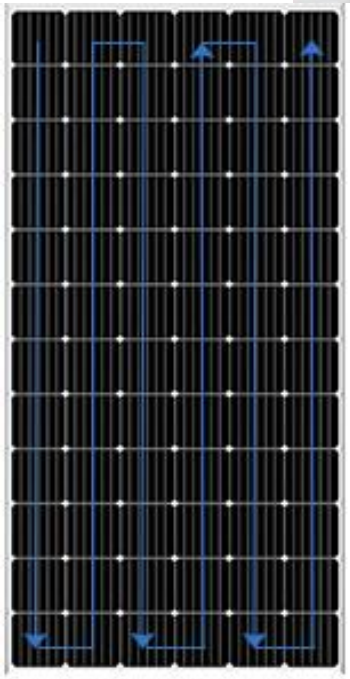
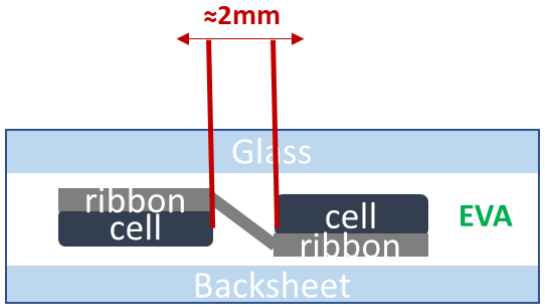
Europe, S. (2020). Global market outlook for solar power/2020–2024. *Solar Power Europe: Brussels, Belgium*.
solarem.com.au/benefits-of-solar-panels/

# No Gap Technologies: Shingled Module

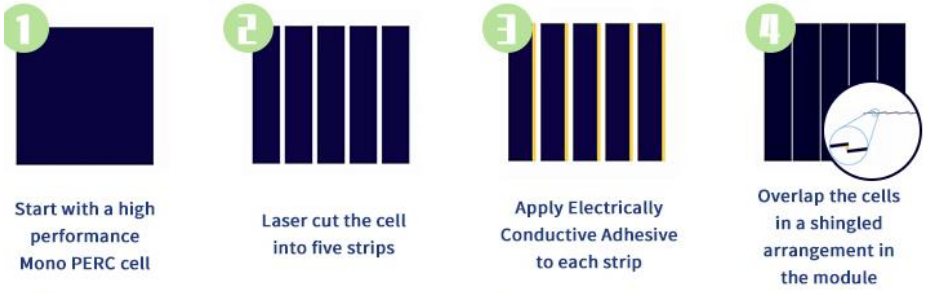


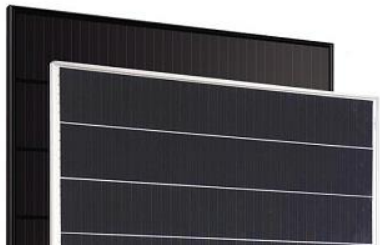
## Conventional Module

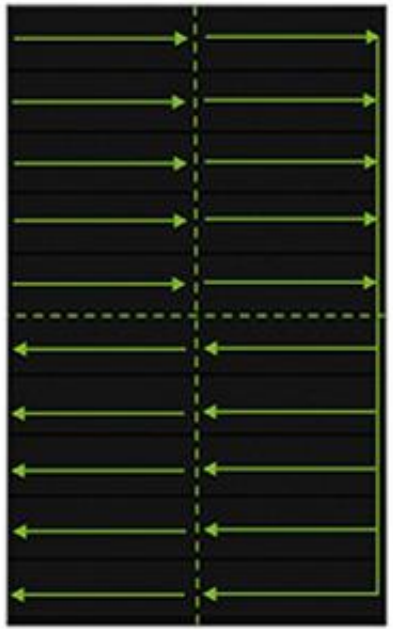


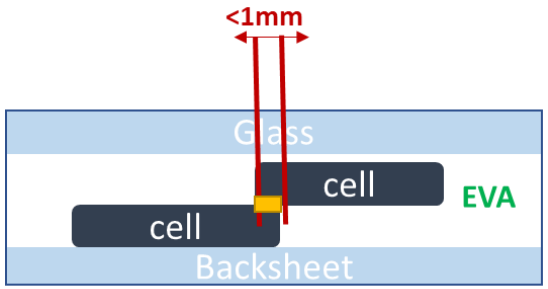



## Shingled Module





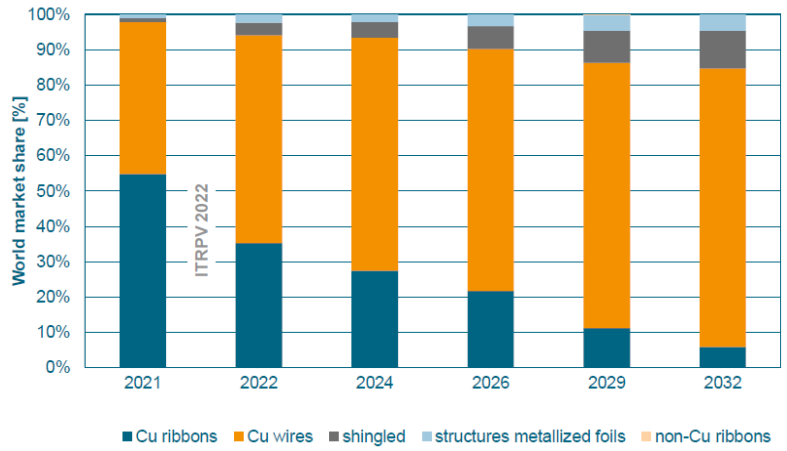

ESG-Shingled-All-Black-Mono-Solar
maysunsolar.eu/
anerngroup.com

Smart SOLAR TECHNOLOGIES

# No Gap Technologies: Shingled Module

PVTECH TECHTalk

**Different cell interconnection materials**




**ITRPV, generally, is underestimate the advances achieved by the new technologies**

Tongwei Solar shingled modules offer high efficiencies and reliable, clean power generation at competitive costs

By PV Tech

September 8, 2022

Modules

Central & East Asia

Facebook Twitter LinkedIn Reddit Email

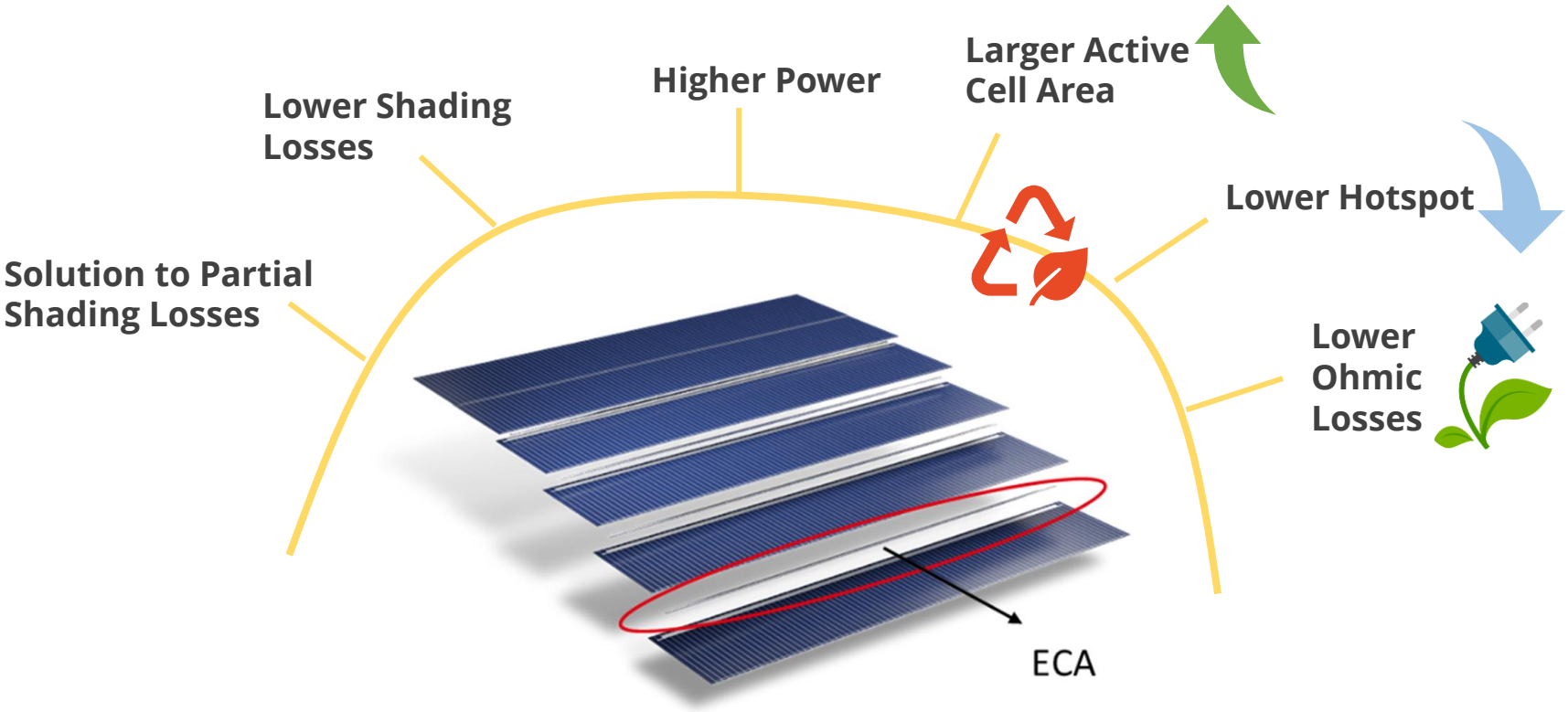

*Tongwei's Solar shingled modules can now reach 670W and its efficiency has been enhanced to 21.6%. Image: Tongwei.*

**China's First 5MW PV Power Plant with Shingled-cell Modules**

Smart SOLAR TECHNOLOGIES

# No Gap Technologies: Shingled Module





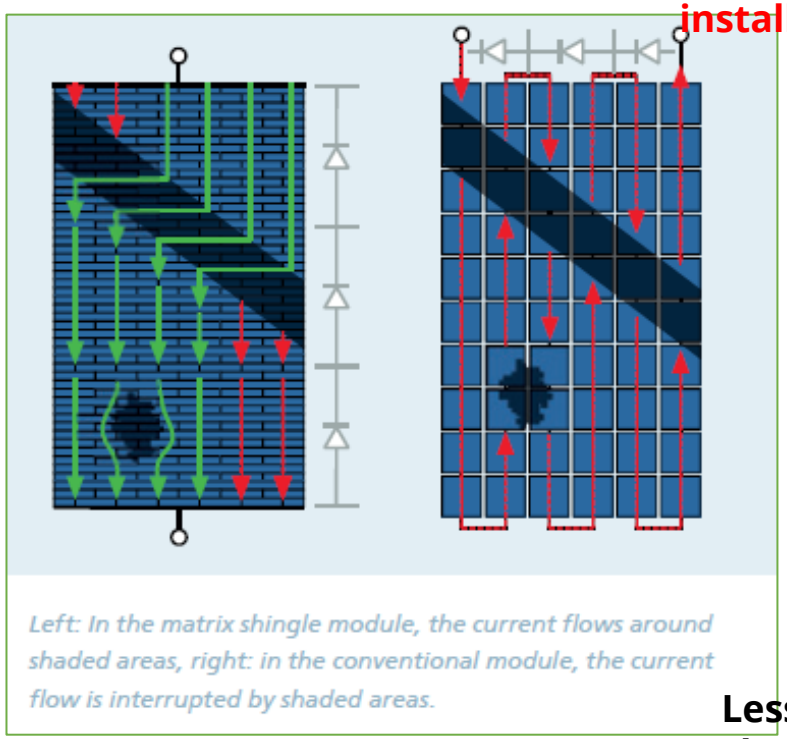

***" CTM power gain more than 100% can be achieved with the proper choice and mix of complementing materials that result in higher optical gains than combined optical and electrical losses"***

***" TaiyangNews Solar Module Innovations"***

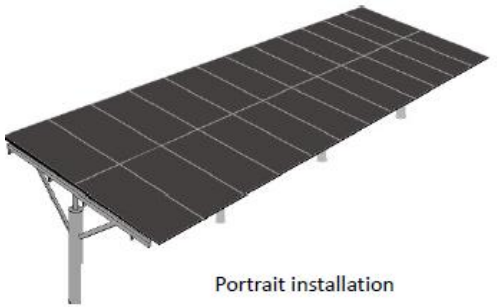
21_en_ISE_Matrixschindel
Tonini, D., Cellere, G., Bertazzo, M., Fecchio, A., Cerasti, L., & Galiazzo, M. (2018). Shingling technology for cell interconnection: Technological aspects and process integration. *Energy Procedia*, *150*, 36-43.
Clement, C. E., Singh, J. P., Khoo, Y. S., Halm, A., Tune, D., & Birgersson, E. (2022). Design of shading-and hotspot-resistant shingled modules. Progress in Photovoltaics: Research and Applications, 30(5), 464-480.
Klasen, N., Weisser, D., Rößler, T., Neuhaus, D. H., & Kraft, A. (2022). Performance of shingled solar modules under partial shading. Progress in Photovoltaics: Research and Applications, 30(4), 325-338.
Theunissen, L., Willems, B., Burke, J., Tonini, D., Galiazzo, M., & Henckens, A. (2018, August). Electrically conductive adhesives as cell interconnection material in shingled module technology. In AIP Conference Proceedings (Vol. 1999, No. 1, p. 080003). AIP Publishing LLC.

# Advantages: Solar Power Plant Installations

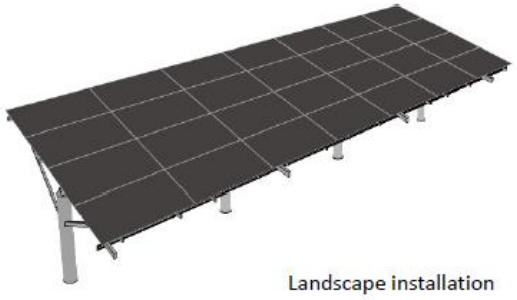
**The circuit design allows high power generation even shaded by shadow,**
**Best solution for small area installations**



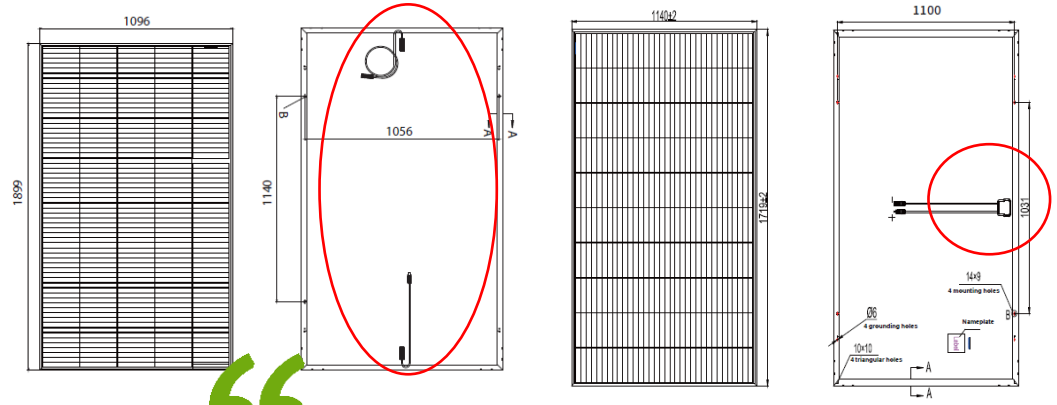
*Left: In the matrix shingle module, the current flows around shaded areas, right: in the conventional module, the current flow is interrupted by shaded areas.*



Portrait installation



Landscape installation



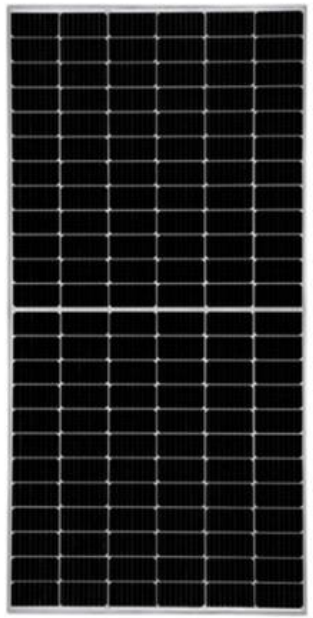

**Less Current Losses due to shading, Less Hot Spot, Higher Energy Yield**

**Different string configurations of the module allows more flexible installation.**


21_en_ISE_Matrixschindel
Tonini, D., Cellere, G., Bertazzo, M., Fecchio, A., Cerasti, L., & Galiazzo, M. (2018). Shingling technology for cell interconnection: Technological aspects and process integration. *Energy Procedia*, *150*, 36-43.
Clement, C. E., Singh, J. P., Khoo, Y. S., Halm, A., Tune, D., & Birgersson, E. (2022). Design of shading-and hotspot-resistant shingled modules. Progress in Photovoltaics: Research and Applications, 30(5), 464-480.
Devoto, M. I., Timofte, T., Halm, A., & Tune, D. (2021, June). Contact resistivity of ECA bonded joints. In AIP Conference Proceedings (Vol. 2367, No. 1, p. 020011). AIP Publishing LLC.
Chowdhury, S., Cho, E. C., Cho, Y., Kim, Y., & Yi, J. (2020). Analysis of cell to module loss factor for shingled PV module. New & Renewable Energy, 16(3), 1-12.
Park, J., Oh, W., Park, H., Jeong, C., Choi, B., & Lee, J. (2019). Analysis of solar cells interconnected by electrically conductive adhesives for high-density photovoltaic modules. Applied Surface Science, 484, 732-739.

# Advantages: Solar Power Plant Installations



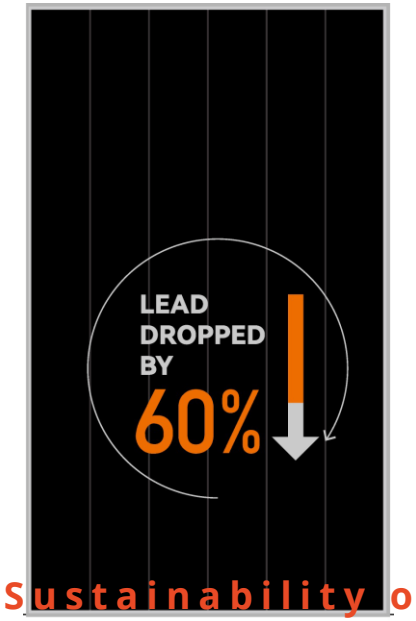


The System BOS cost is reduced >3.6%

LCOE is reduced >1.5%

Increased cell area, Increased efficiency

Increased efficiency, less area requirement




Sustainability of the investment increases

Better aesthetics for rooftop applications

Smart SOLAR TECHNOLOGIES

http://www.tw-solar.com/en/

# Advantages of Smart Solar Technologies:

## Solar Power Plant Installations

Gün Güneş Arısu - 55,6 MWp

Çeltikaltı – 8,2MWp

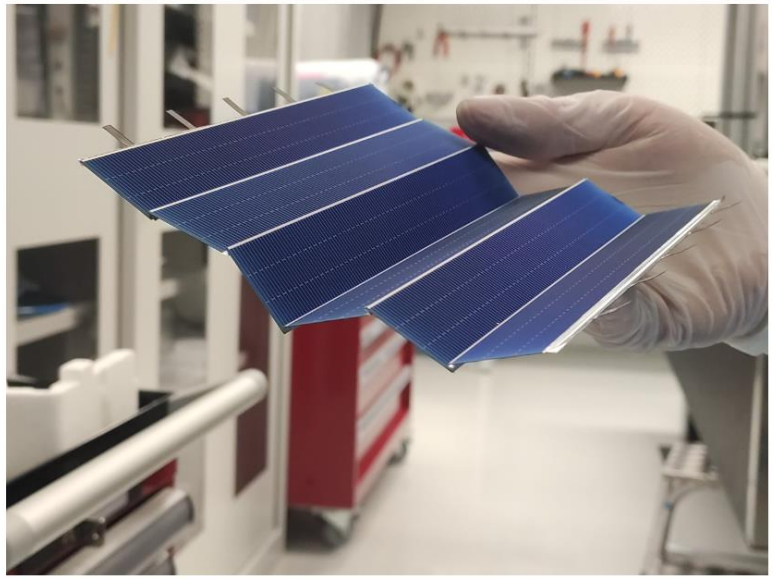
High quality material usage
Optimum design
- Cabing loss <0,5% at DC side
- Cabing loss <0,5% at AC side
- Preventing shading factors
- Optimization of the placement of inverters, transformer etc.
- Increasing bi-faciality effect

>2110 kWh/kWp/year specific yield

# Technological Development : Sustainability Increasing



## Foilmet PV



The Fraunhofer ISE is in the process of patenting its FoilMet Interconnect.

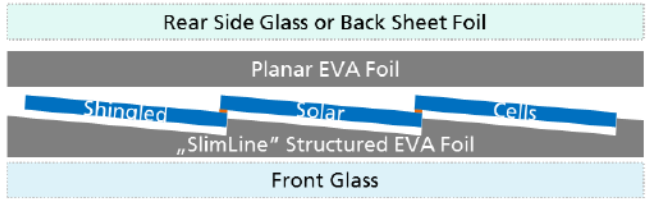
**FoilMet®-Interconnect:**

**Busbar free, electrically conductive adhesive-free, and solder-free aluminum interconnection for modules with shingled solar cells**

Paschen, J., Baliozian, P., John, O., Lohmüller, E., Rößler, T., & Nekarda, J. (2022). FoilMet®-Interconnect: Busbarless, electrically conductive adhesive-free, and solder-free aluminum interconnection for modules with shingled solar cells. Progress in Photovoltaics: Research and Applications, 30(8), 889-898.

## Shingled Bifacial PV

**Before lamination: positioned on a pre-shaped "SlimLine" EVA**




***"Fraunhofer Institute for Solar Energy Systems (ISE)"***

Mondon, A., Klasen, N., Fokuhl, E., Mittag, M., Heinrich, M., & Wirth, H. (2018). Comparison of layouts for shingled bifacial PV modules in terms of power output, cell-to-module ratio and bifaciality. In *35th European Photovoltaic Solar Energy Conference and Exhibition (EU PVSEC)* (pp. 1333-1336).

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GLOBAL VIEW

Smart SOLAR TECHNOLOGIES

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T: + 40758110110

PVTECH TECHTalk

# Smart
## GÜNEŞ TEKNOLOJİLERİ

www.smartsolar.com.tr / smartgunesteknolojileri

# Reliability Evaluation of n-type High-efficiency PV Modules

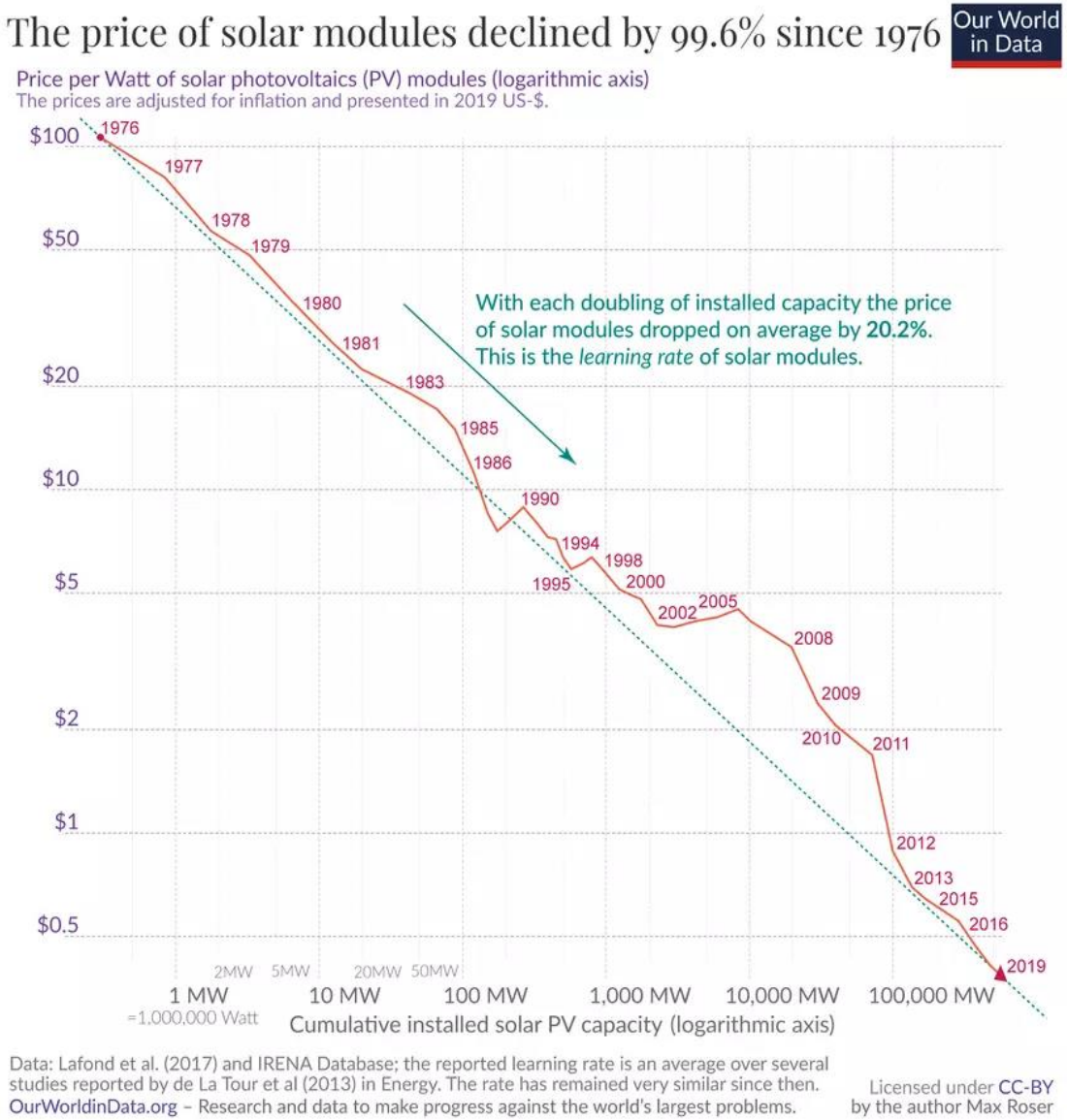
**TÜV NORD China —— PV Business**

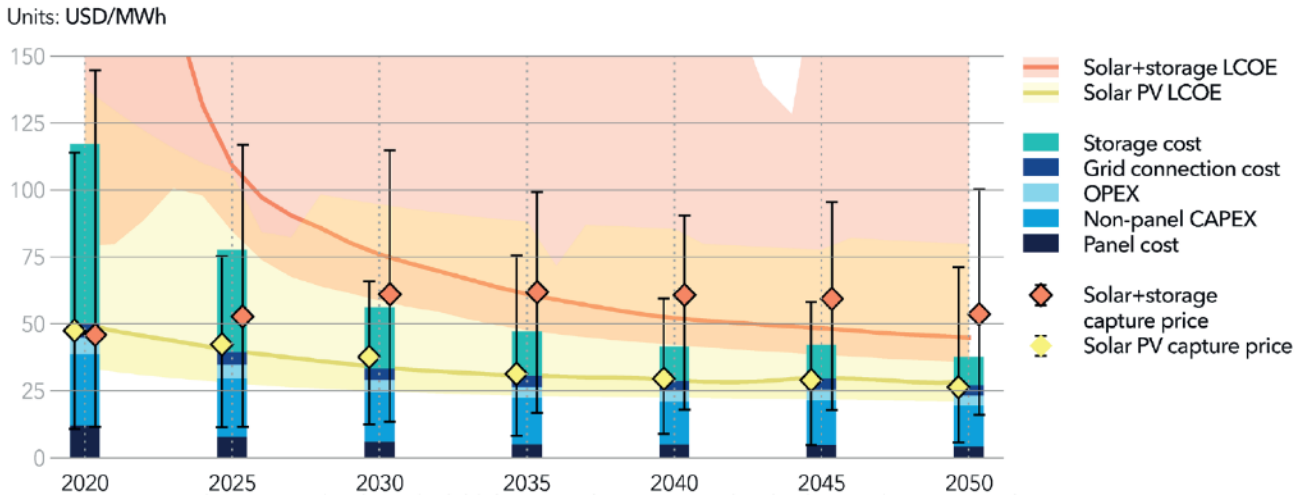
**We Focus on the Quality Assurance!**

**We Commit to Offer You the Service More Than a Certificate!**

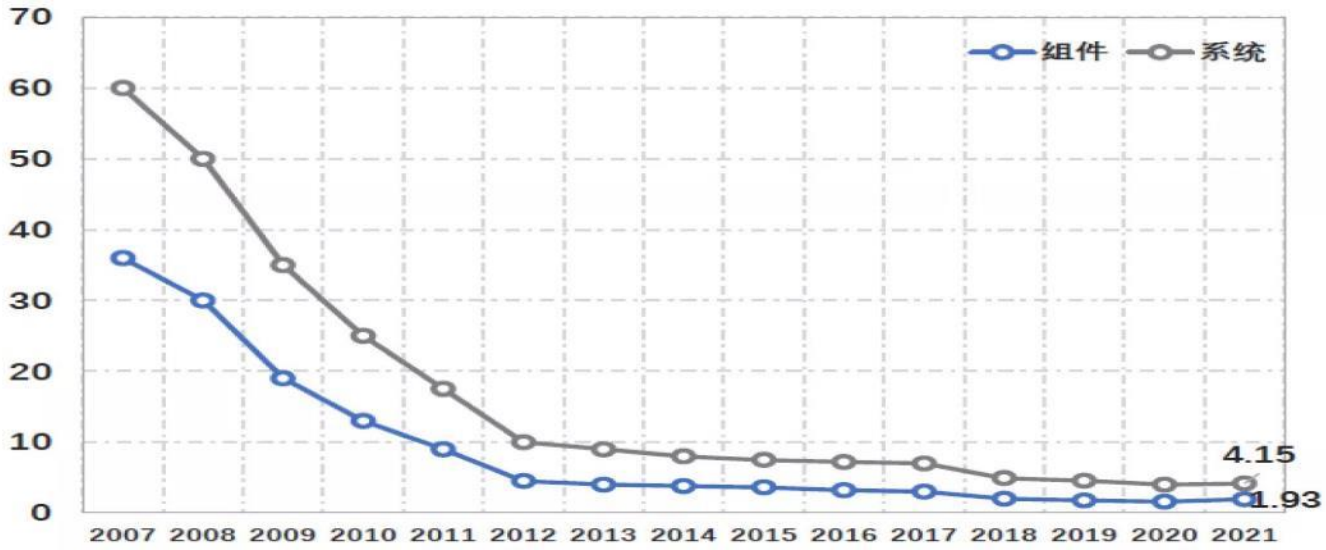
# CONTENT

# GLOBAL SOLAR LCOE AND CAPTURE PRICE




*Source: DNV*




*Source: CPIA*

# LEVELIZED COST OF ENERGY（LCOE）

$$\mathrm{LCOE} = \frac{C + \sum_{t=1}^{n} \frac{(L_t + M_t + T_t)}{(1+r)^t} - \frac{R}{(1+r)^n} + \sum_{t=1}^{n} I_t}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

**C**： Total investment capital

**n**： **Life-cycle (years)**

Lt： No.t year’s land fee

Mt： No.t year’s OM fee

Tt： No.t year’s tax

R： PV plant’s residual value

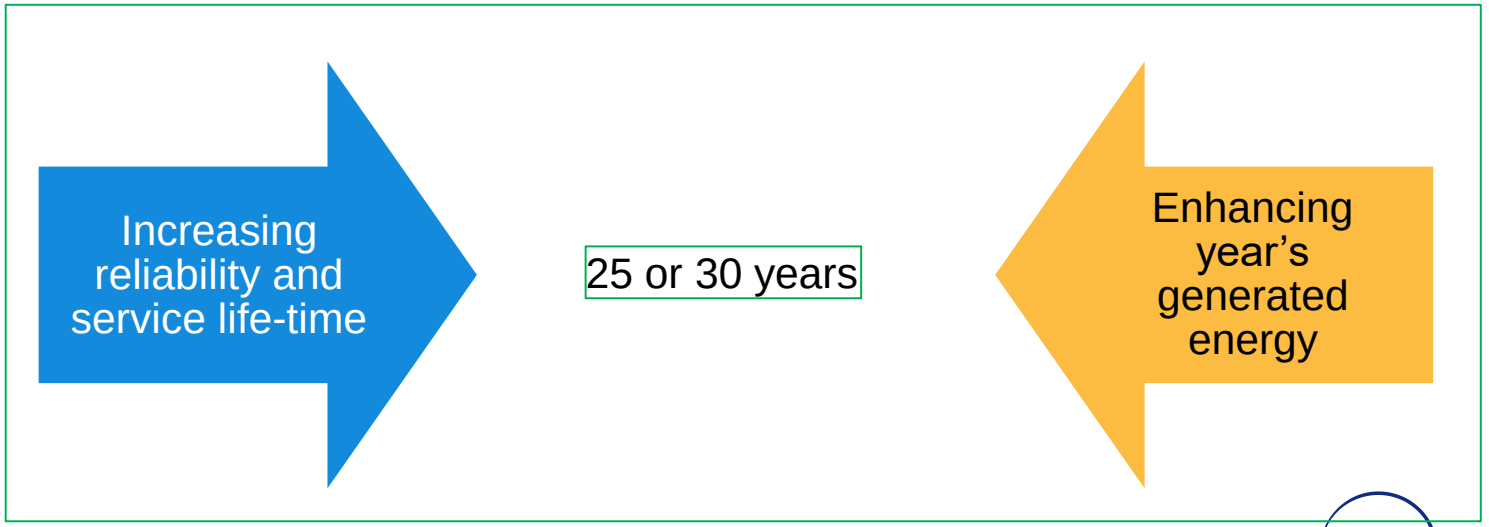
It： No.t year’s loan interest

**Et： No.t year’s generated energy**

r： Discount rate

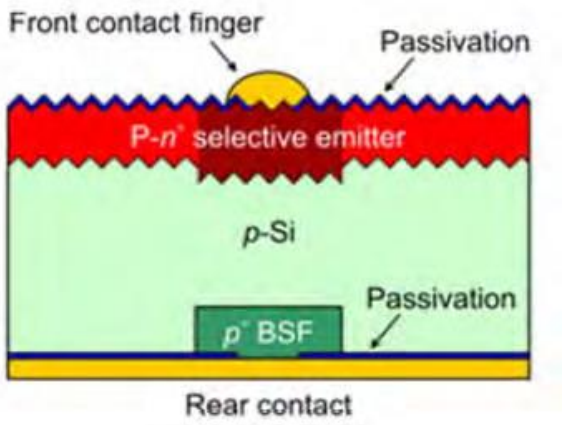
Increasing life-cycle generation may be an effective way to lower the cost of kilowatt-hours

LCOE can be significantly reduced by improving the efficiency of PV modules, optimizing the temperature and low-irradiance performance, and extending the life cycle of PV system.

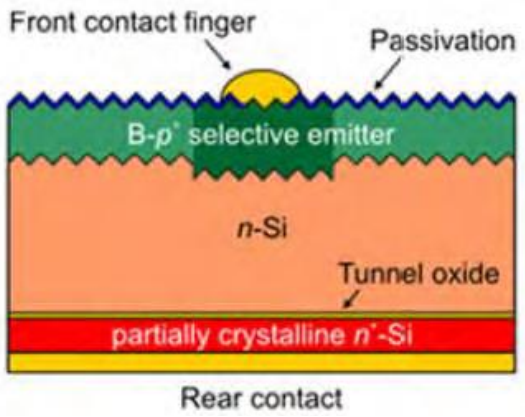


# CONTENT

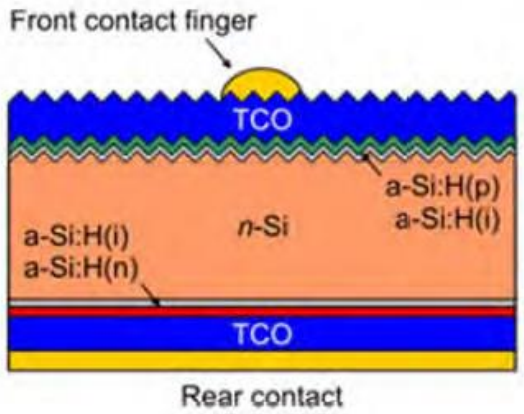
# EMERGING TECHNOLOGIES FOR PV - N TYPE




PERC
Production efficiency
22.5%-23.1%
Theoretical efficiency
~24.5%



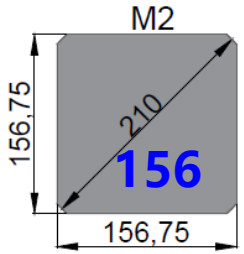
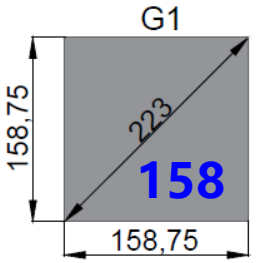
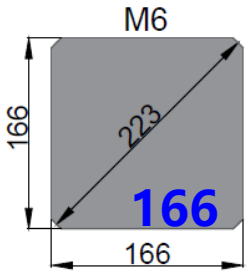
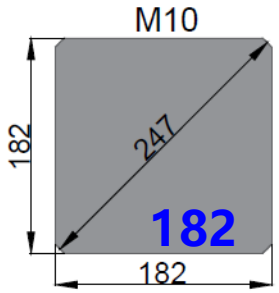
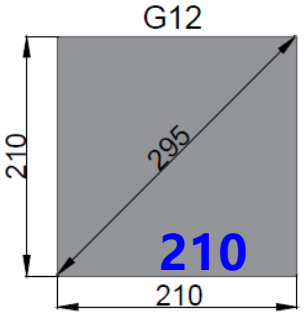

TOPCon
Production efficiency
23.5%-24.5%
Theoretical efficiency
28.2%-28.7%




HJT
Production efficiency
23.9%-24.6%
Theoretical efficiency
27.5%~28.5%

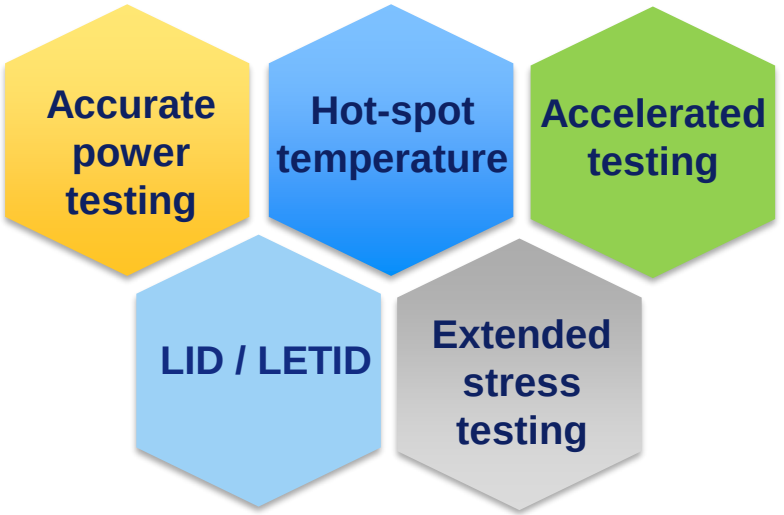
- ✓ Higher efficiency
- ✓ Bifacial output
- ✓ Lower Temp. Coe.
- ✓ Lower LID
- ✓ thinner wafer

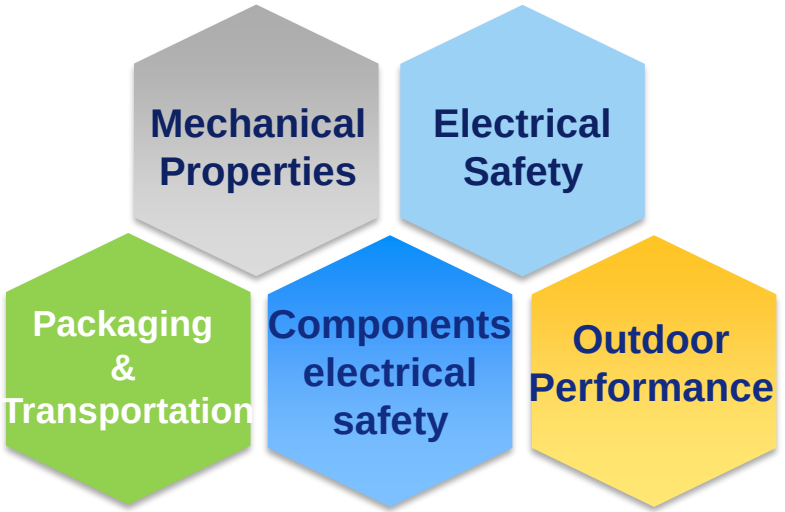
# EMERGING TECHNOLOGIES FOR PV - N TYPE WITH LARGER SIZE

| | | | | | |
|---|---|---|---|---|---|
| **Solar cell** |  |  |  |  |  |
| | Area: 24432mm² (**base line**) | Area: 25199mm² (**3.14%** ↑) | Area: 27416mm² (**12.21%** ↑) | Area: 33011mm² (**35.11%** ↑) | Area: 44096mm² (**80.48%** ↑) |
| **PV module** | 156.75 (144 half-cut) | 158.75 (144 half-cut) | 166 (144 half-cut) | **182 (156 half-cut)** | **210 (132 half-cut)** |
| **Size (mm)** | 2007x992 | 2031x1008 | 2117x1052 | **2471x1134** | **2384x1303** |
| **Pmax (W)** | 390 | 420 | 455 | 600 | 700 |
| **Isc (A)** | 9.79 | 10.70 | 11.46 | 14.04 | 17.26 |
| **Voc (V)** | 49.28 | 48.74 | 49.75 | 54.11 | 50.00 |

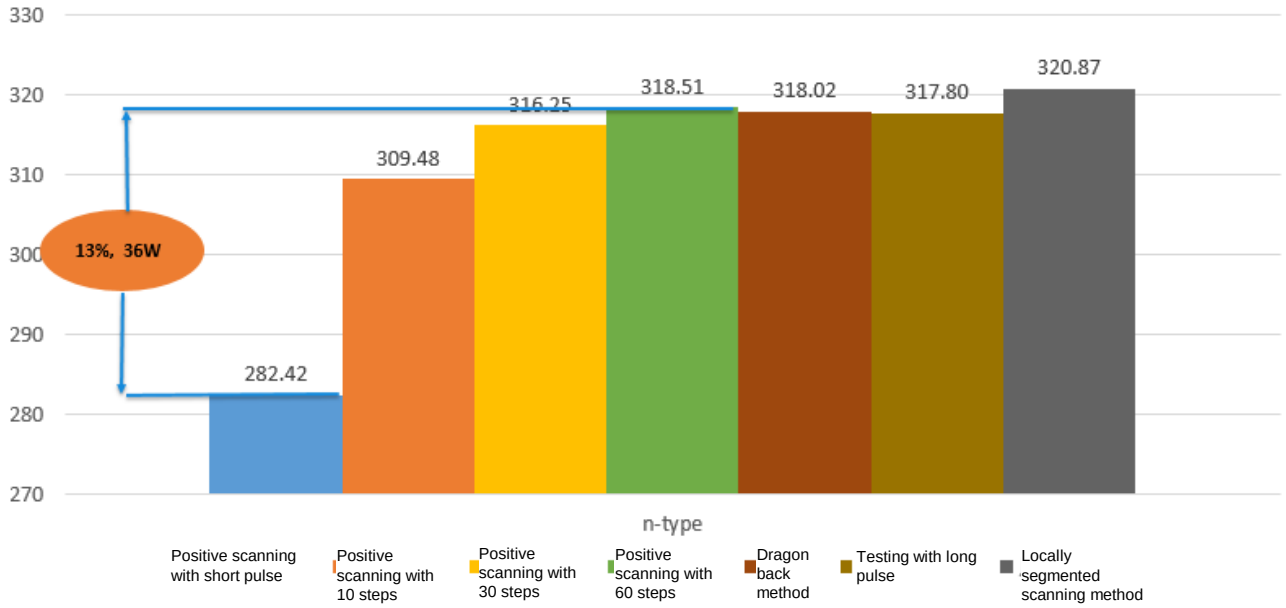
# CONTENT

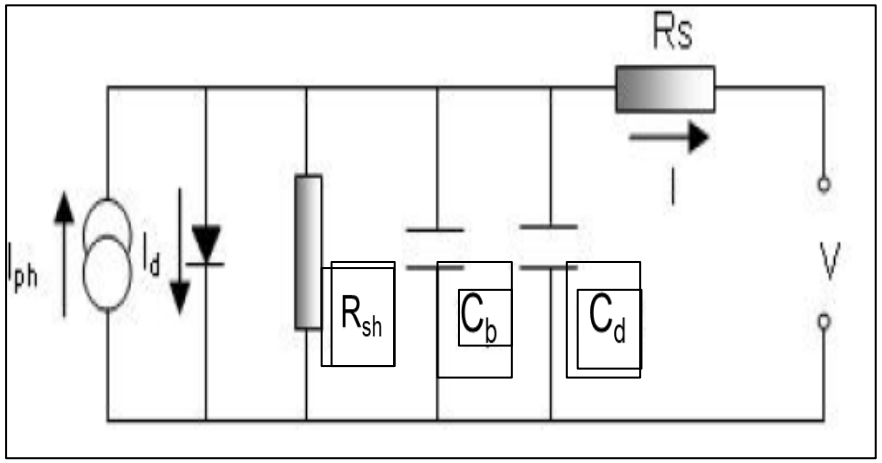
# RELIABILITY EVALUATION - HIGH-EFFICIENCY PV MODULES

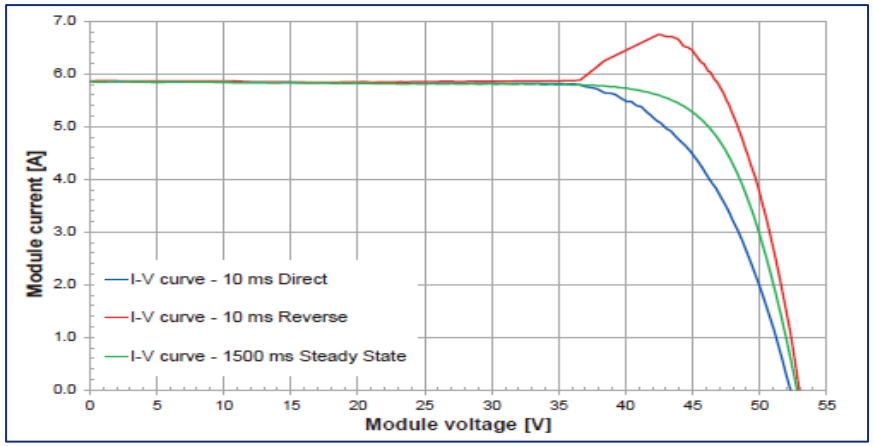



# ACCURATE TESTING FOR HIGH-EFFICIENCY MODULES



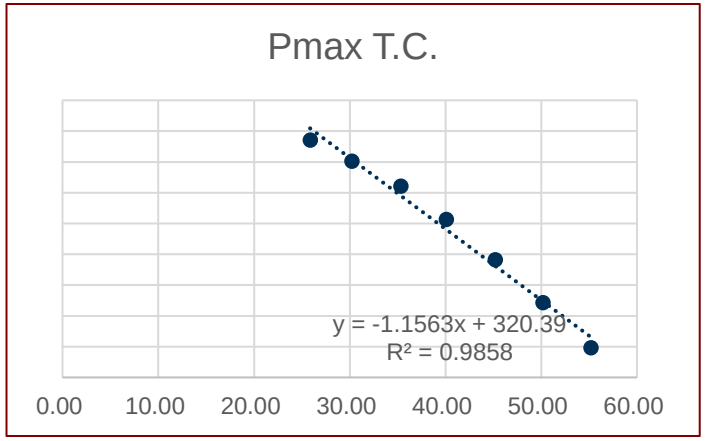

- The internal capacitance lead to a strong hysteresis effect in I–V measurements. This hysteresis introduces a significant error in measurement results.
- The test results of the multi-flash and DB methods are basically consistent with those of the long pulse simulator。
- Short pulse simulators are not able to measure power accurately and not suitable for high-efficiency module.

# ACCURATE TESTING FOR HIGH-EFFICIENCY MODULES

## Temperature coefficient of n-type modules

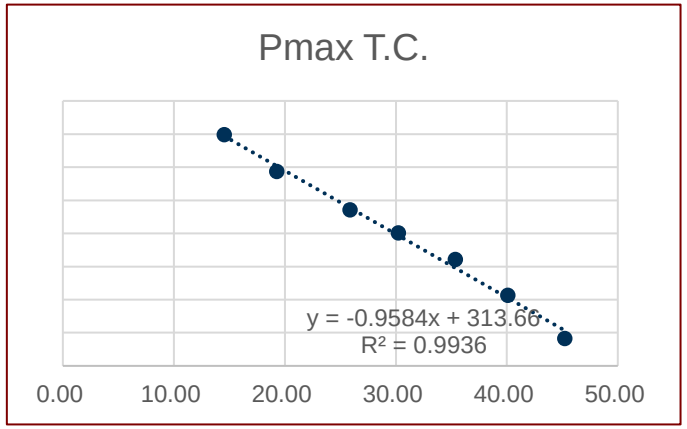
Regular natural cooling + 10ms pulse single flash

55℃ - 25 ℃ : **-0.364%**



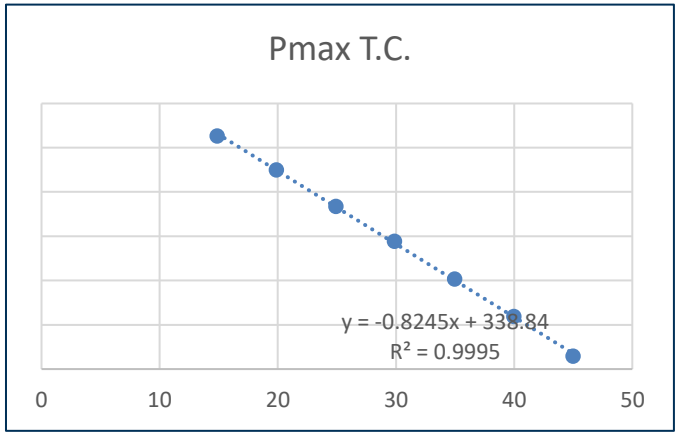

Low temperature area + 10ms pulse single flash

15℃ - 45 ℃ : **-0.302%**

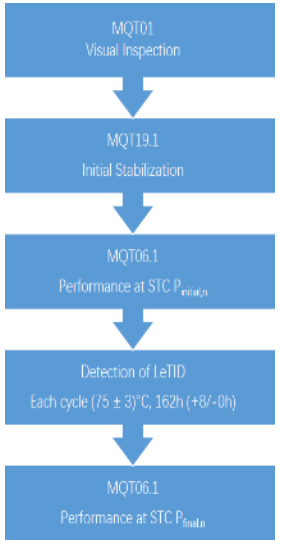


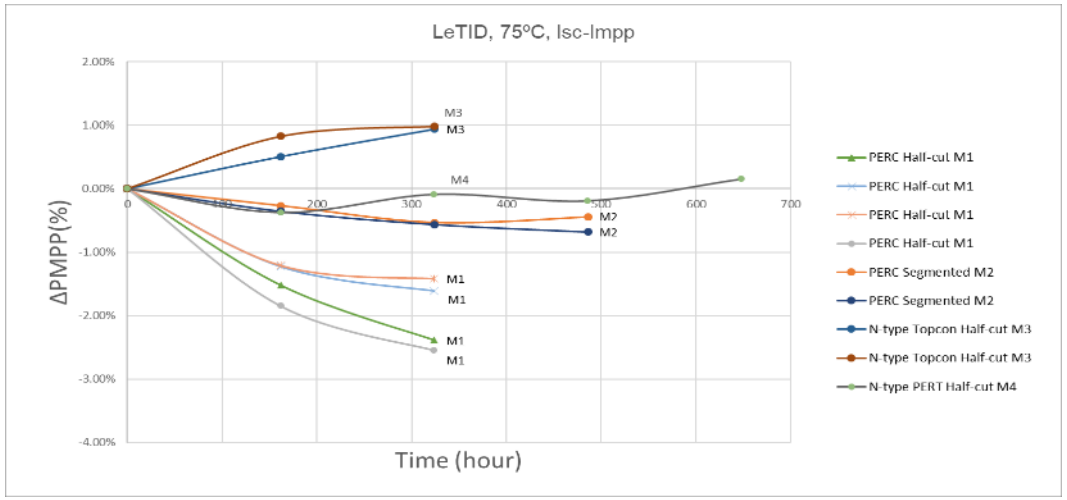

**Temperature control box + accurate test**

45℃ - 15 ℃ : **-0.259%**



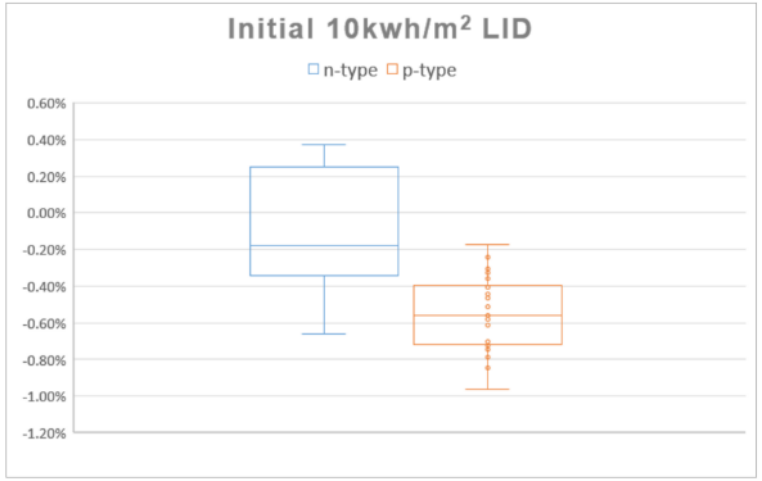
# LIGHT AND ELEVATED TEMPERATURE INDUCED DEGRADATION (LETID)
# LIGHT INCLUDING DEGRADATION (LID) - N TYPE



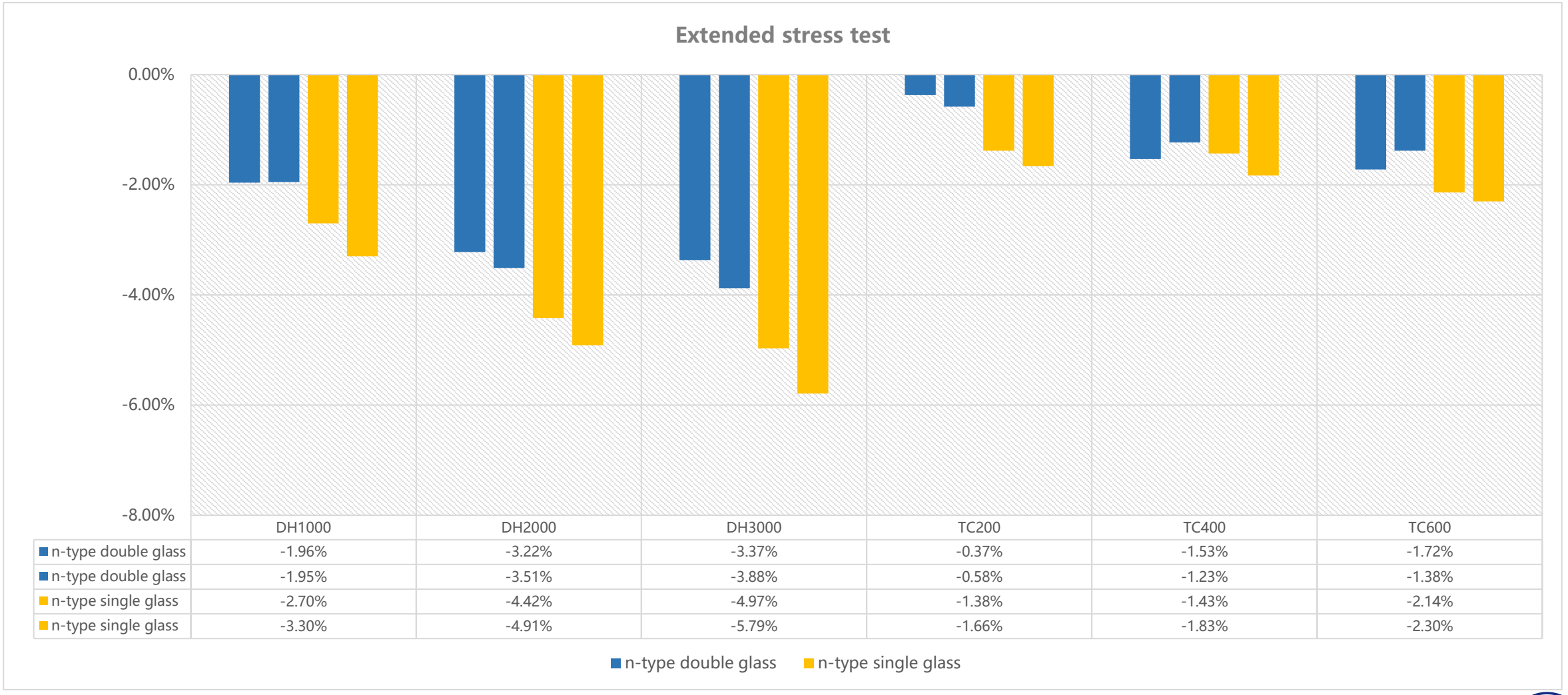

- ✓ Several n-type modules show nearly 0 degradation after multiple rounds of testing

| LID | Min PL | Max PL | Ave PL |
|---|---|---|---|
| **n-type** | **+0.37%** | **-0.66%** | **-0.08%** |
| p-type | -0.17% | -0.96% | -0.55% |



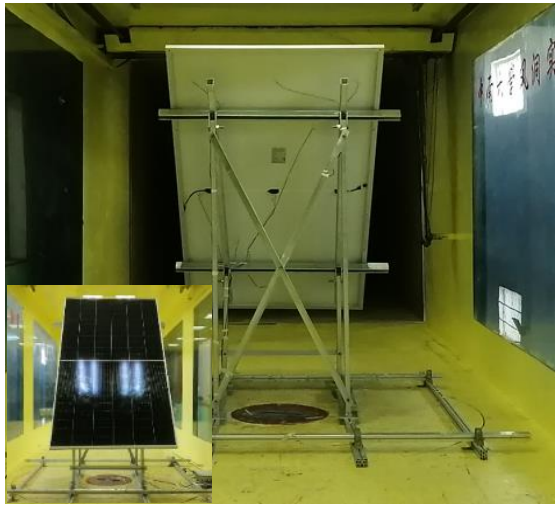

- ✓ Module exposure with irradiance dose at 10kWh/m²

# ACCELERATED TESTING - N TYPE




| | DH1000 | DH2000 | DH3000 | TC200 | TC400 | TC600 |
|---|---|---|---|---|---|---|
| n-type double glass | -1.96% | -3.22% | -3.37% | -0.37% | -1.53% | -1.72% |
| n-type double glass | -1.95% | -3.51% | -3.88% | -0.58% | -1.23% | -1.38% |
| n-type single glass | -2.70% | -4.42% | -4.97% | -1.38% | -1.43% | -2.14% |
| n-type single glass | -3.30% | -4.91% | -5.79% | -1.66% | -1.83% | -2.30% |

# MECHANICAL PROPERTIES - LARGER SIZE



- Risk increases with the greater size

**Static & dynamic Mechanical Load**

- The bottom frame suffers greater non-uniform snow load as the modules become wider.

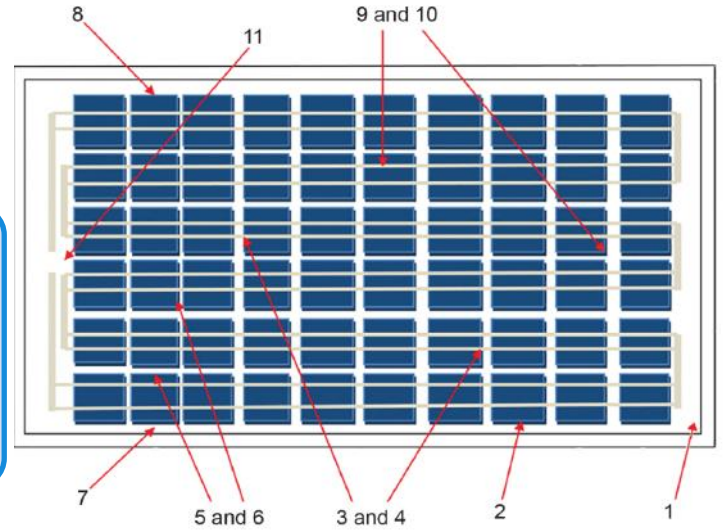
**Non-uniform Snow Load**

**Wind tunnel test**

- Dynamic changes of strong wind pressure may cause the failure of components and installation systems

**Hail impact test**

- Large size modules are with wider sides, requiring higher toughened quality control on the edges of the glass



# PACKAGING & TRANSPORTATION - LARGER SIZE

The weight and size of the whole package of larger-size modules are greatly increased, raising up the risk in transportation.

| |
|---|
| Random vibration testing |
| Inclined impact test |
| Rotational edge drop test |
| Vertical shock test |
| Horizontal impact test |
| Dynamic mechanical load |
| Thermal cycles |
| Humidity freeze |
| Mechanical load |

IEC 62759-1

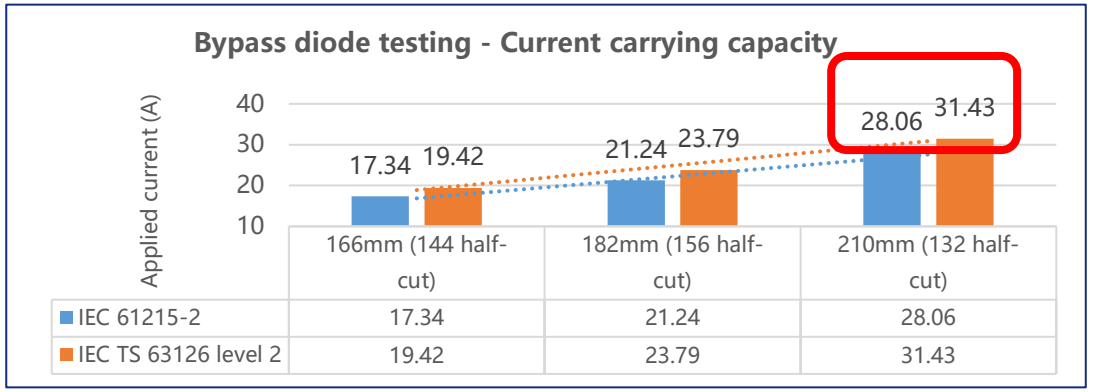
For larger-size modules, the pallet and packaging methods is highly recommended to be strengthened.

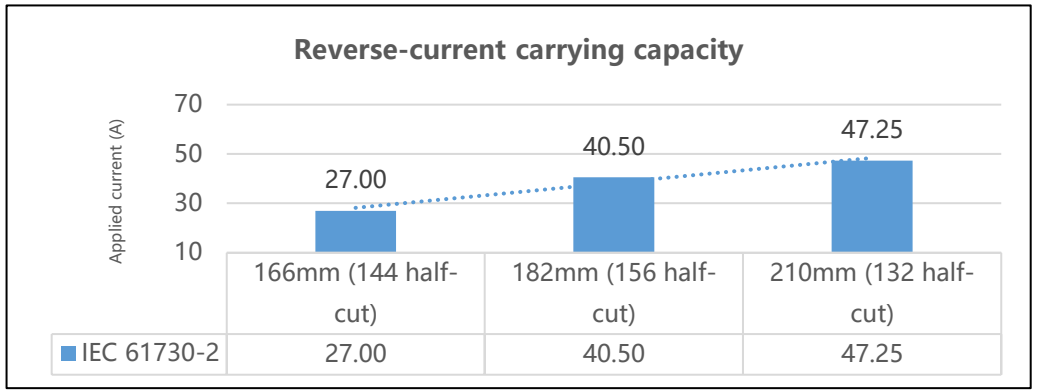
# ELECTRICAL SAFETY - HIGHER CURRENT LEVEL

| | M6 | M10 | G12 |
|---|---|---|---|
| **Modules** | **166mm (144 half-cut)** | **182mm (156 half-cut)** | **210 (132 half-cut)** |
| **Size (mm)** | 2117x1052 | 2471x1134 | **2384x1303** |
| **Pmax (W)** | 475W | 600W | 700W |
| **Isc (A)** | **11.06** | ***14.04*** | ***17.26*** |
| **Voc (V)** | 54.25 | 54.11 | 50.00 |
| **Imp (A)** | 10.35 | 13.27 | 16.28 |
| **Vmp (A)** | 45.90 | 45.21 | 43.00 |
| **Fuse rating (A)** | **20** | ***30*** | ***35*** |
| **Bifaciality coefficient** | | *70%* | |
| **BSI (W/m²)** | | *300* | |

# CURRENT-RELATED TESTS FOR BIFACIAL PV MODULES

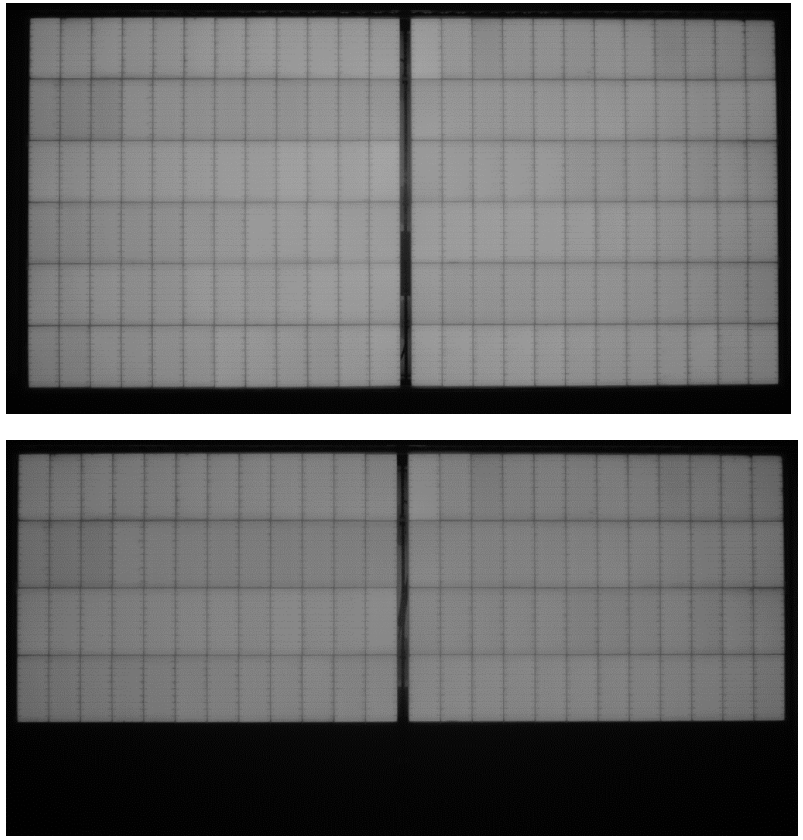
| | 166mm (144 half-cut) | 182mm (156 half-cut) M10 | 210mm (132 half-cut) G12 |
|---|---|---|---|
| **Isc-BSI (A)** | **13.87** | **16.99** | **22.45** |
| **Imp-BSI (A)** | **13.26** | **16.06** | **21.09** |
| **MQT 18 Bypass diode testing: 1.4*Isc-BSI at 75℃ 1hour, according to IEC TS 63126 level 2** | | | |
| **Applied current (A)** | **19.42** | **23.79** | **31.43** |
| **MST 26 Reverse current overload test: 1.35*fuse rating 2hours, according to IEC 61730-2** | | | |
| **Applied current (A)** | **27.00** | **40.50** | **47.25** |
| **MQT 11 Thermal cycling test: Imp-BSI, according to IEC 61215-2** | | | |
| **Applied current (A)** | **17.34** | **21.24** | **28.06** |




When the temperature of installation environment is high enough (e.g. dessert climate), the installation method is difficult for heat dissipation (e.g. double-skin curtain wall BIPV), higher current carrying capacity is required for bypass-diode in larger-size modules.

# FAILURE CASES

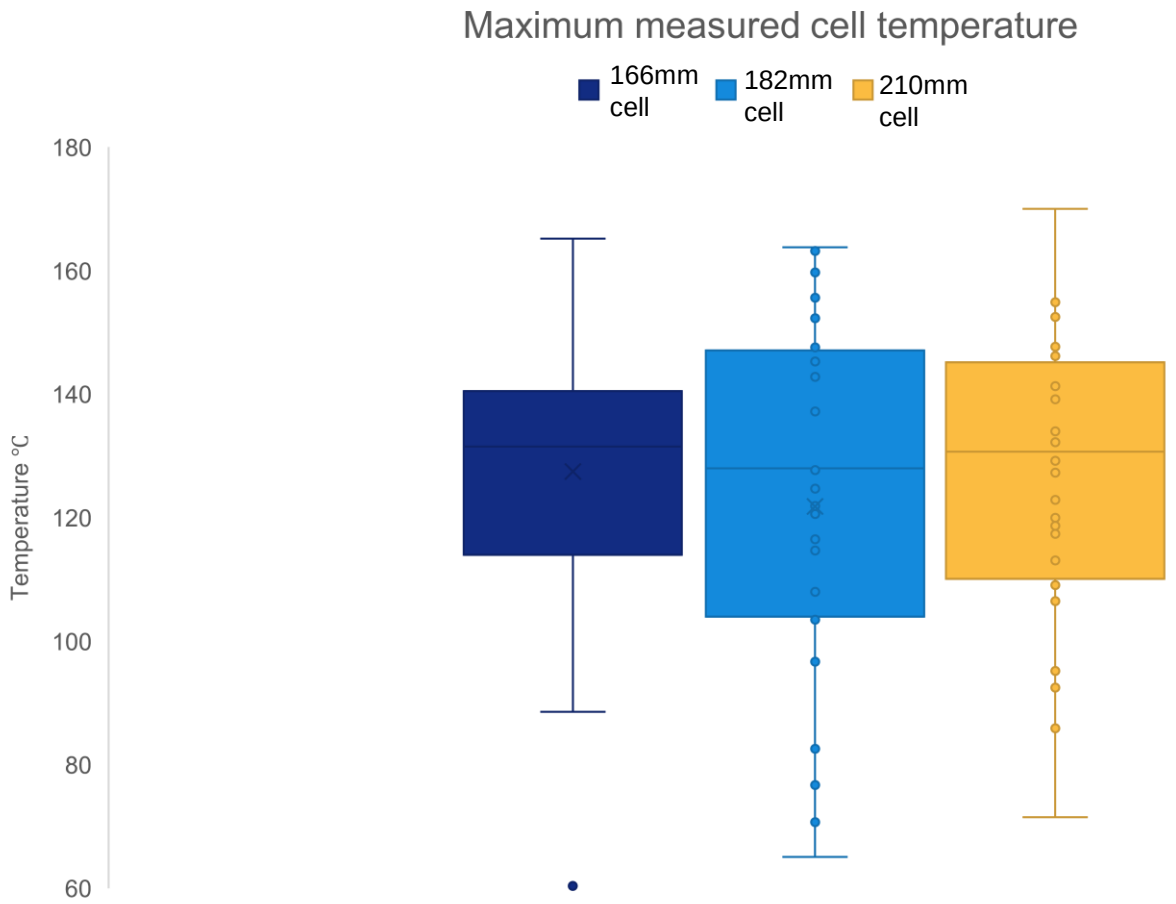


Bypass diode fails after BDT testing

Junction box melted after RC testing

Connectors melted after TC200 and RC testing

# HOT-SPOT TEMPERATURE - LARGER SIZE




From the laboratory data, hot-spot temperature of PV modules with same-size solar cells varies from a large range, due to the different cell technology in different manufacturer.

From this point, in addition to the solar cell size, the cell technology and slicing technology also plays an important role in hot-spot performance.

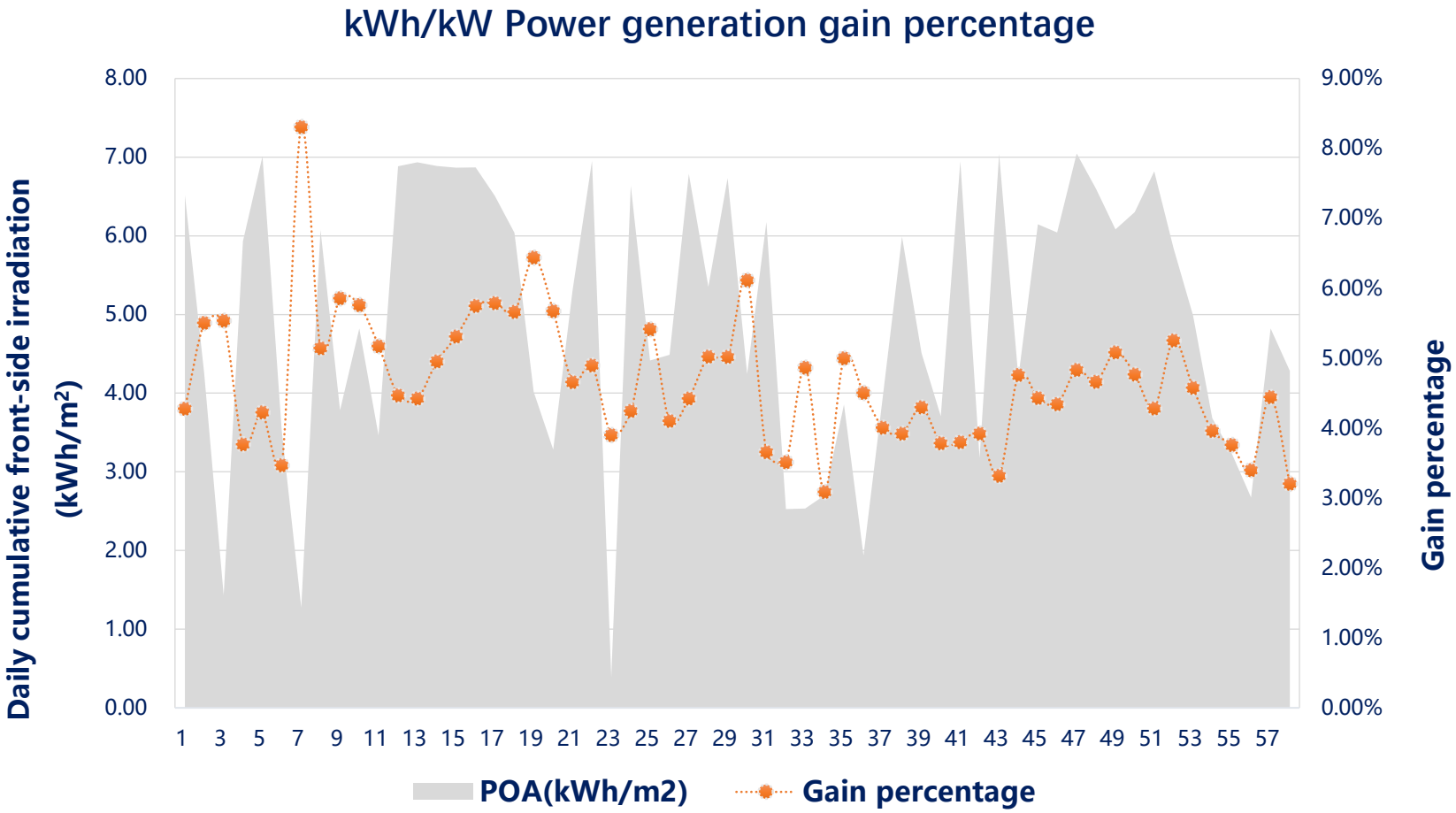
# OUTDOOR YEILD PERFORMANCE TEST

Location: Yinchuan, China

N 38°27′ 55.38″; E 106°6′ 7.90″

- Abundant sunlight for more than 3200h / year
- Typical xerothermic climate at average altitude of 1100m
- Solar spectrum is highly consistent with AM1.5 spectrum
- Equipped condition for PV monitoring and testing

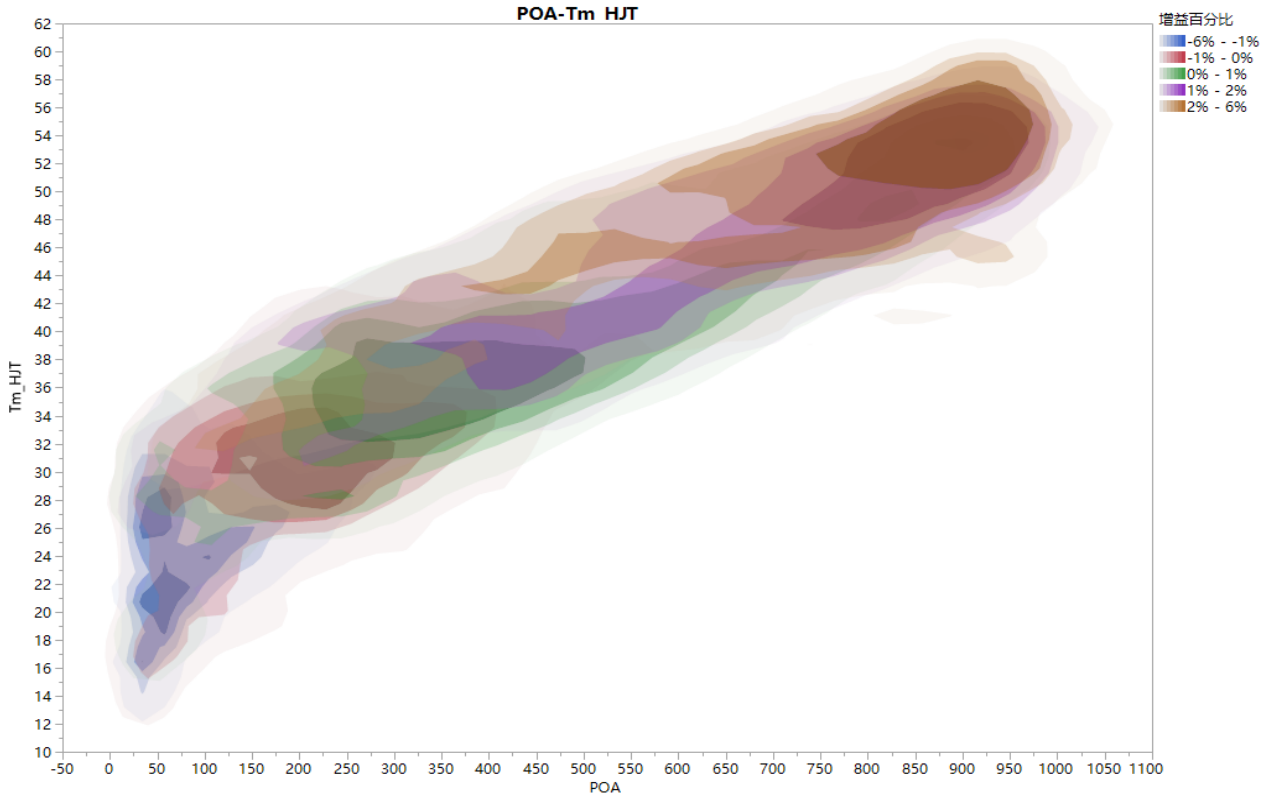
# OUTDOOR PERFORMANCE TEST

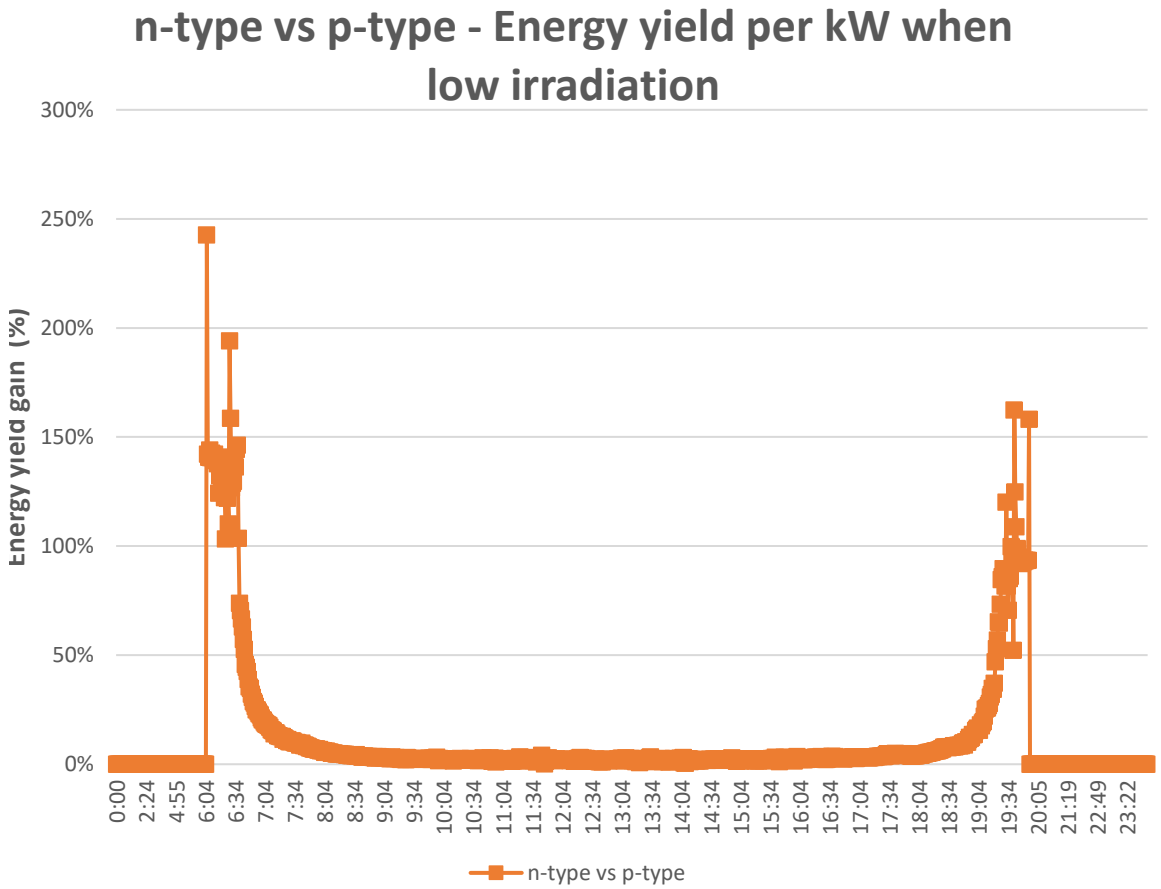



- PV modules of n-type and PERC performance comparison in outdoor performance base in Yinchuan, China

  Cumulative kWh/kW power generation increases **+4.65%**, the highest kWh/kW power generation increases **+7.57%**

# OUTDOOR PERFORMANCE TEST




- Benefiting from temperature coefficient advantage, kWh/kW power generation of n-type increases with higher temperature, compared with PERC modules
- Benefiting from low-irradiance performance advantage, kWh/kW power generation of n-type increases with lower light intensity, compared with PERC modules.

# CONTENT

# CONCLUSIONS

- LCOE continues to decrease, which is becoming the most important factor of global PV projects
- From the perspective of market trends, n-type PV modules with larger size is more promising to be an emerging technology
- Risks come along with the benefits of high-efficiency PV modules with larger size and larger current
- It is a challenge for manufacturers and third-party certification body to fully evaluate the product characteristics and reliability of n-type high-efficiency modules
- The outdoor yield performance shows the power generation advantages of n-type PV modules, as well as risks existing in outdoor installation regarding to the larger size

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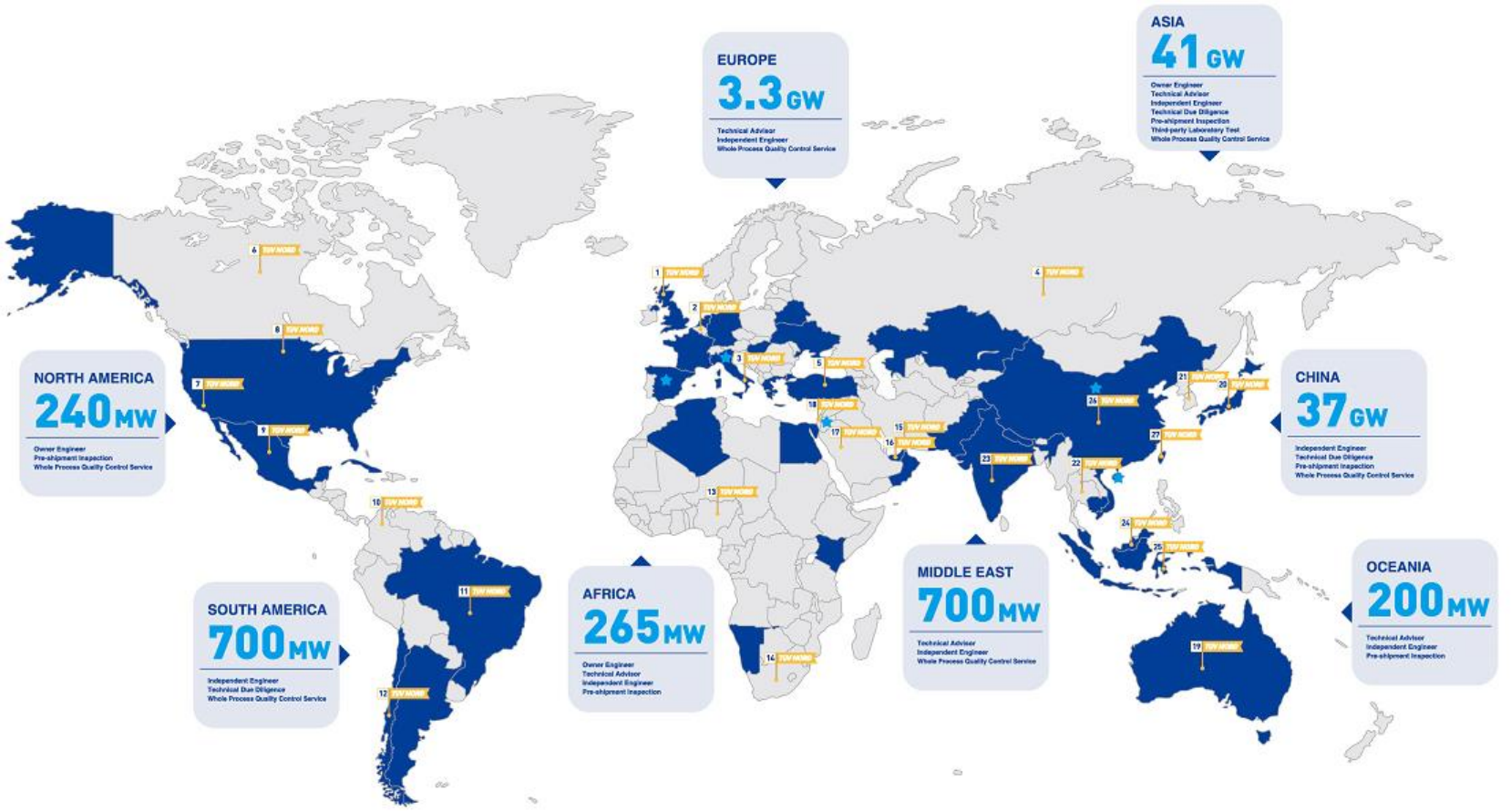
(*All figures as of 2020)

# PV BUSINESS

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