WEBINAR

DATE: 23rd January 2024

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TÜVNORD PVTECH

Repower N: Key insights into the innovation and reliability of Tongwei's G12R Modules

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Repower N

Upgrade Your Power With TONGWEI Module

Jason Xia Tongwei's Director of Module R&D Department

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About Tongwei

About Tongwei

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≈ 50,000 Global employees

200+ Subsidiaries worldwide

476 2023 Fortune Global 500
World's First PV Company Listed

History 42 Years in business
Established in 1982

PV CHANGES THE WORLD

PV industry chain capacity roadmap

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Module

Continuous rise from 2022 to 2023 H1

Solar Cell

Ranked **No.1** for **6** consecutive years

2022 Module shipment ranking — InfoLink

Rank	Company
1	
2	
3	
4	
5	
6	
7	
8	
9	**Tongwei**

1H23 Module shipment ranking

Rank	Company
1	
2	
3	
5	
6	**Tongwei**
8	
9	
10	

InfoLink

1H23 Cell shipment ranking

Rank	Company
1	**Tongwei**
2	
3	
4	
5	

N-type Era, the Future Has Come

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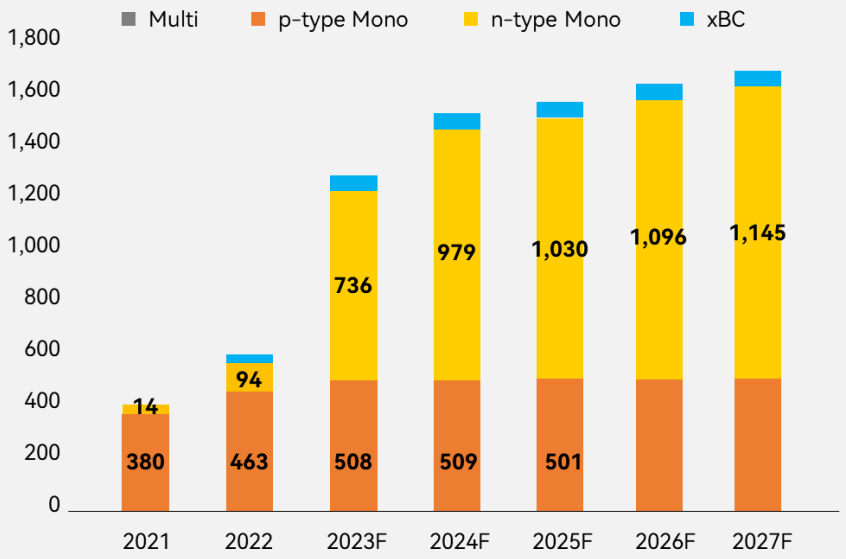
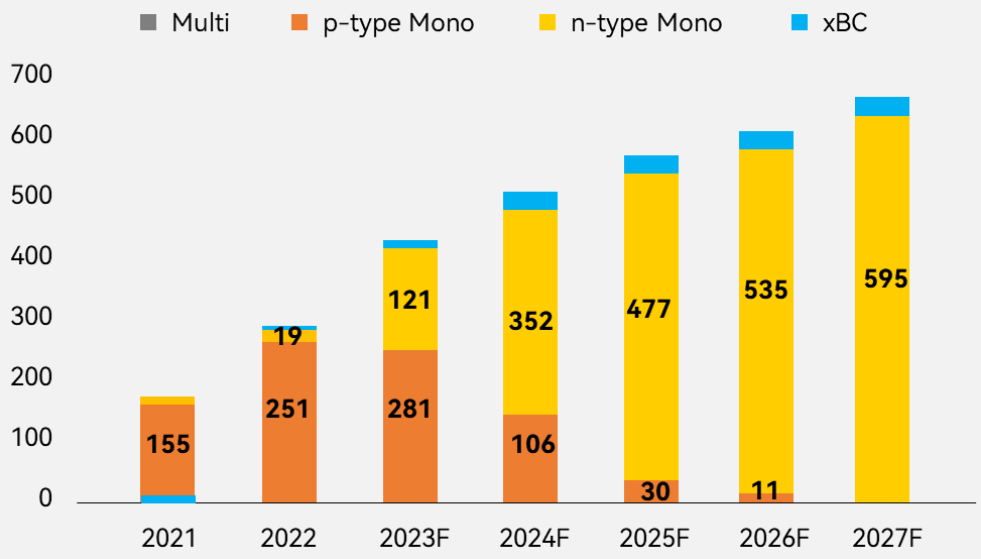
According to PV infolink's prediction, with the rapid growth of TOPCon capacity, TOPCon capacity will fully surpass PERC in the first half of 2024, and its market share will exceed 60%, making N-type products the absolute mainstream in the market.

Estimated Production Capacity Output of Mono/Polycrystalline and N-type Cells Unit: GW



Estimated Technology Production Capacity Output of High-efficiency Cell Unit: GW



Data Source: New Technolog Market Report_InfoLink _Aug-23

Tongwei-Excels in producing customer-centric products

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Lower BOS

Lower LCOE

Higher Customer Value

TONGWEI

Company Ⅰ

Company Ⅱ

Company III

Company IV

182*210
(G12R)

VS

182*19X
(G11L)

Company V

Company VI

Company VII

Company VIII

Company IX

2

Tongwei's New Generation N-Type Products

Tongwei's New Generation Flagship Product

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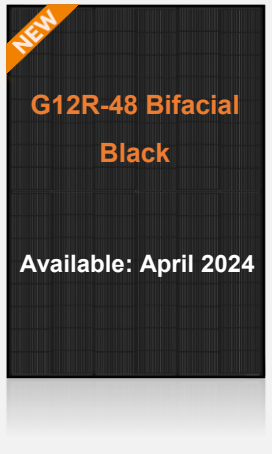
G12R

Residential Distributed

Commercial & Indusrtial
Utility Scale



Module Power Output	**440W**	**445W**	**610W**	**615W**
Module Efficiency	**22.0%**	**22.3%**	**22.8%**	**23.0%**
Product Model	TWMNH-48HC	TWMNH-48HD	TWMNH-66HD	TWMNH-66HS
Module Dimension	1762*1134*30	1762*1134*30	2382*1134*30	2382*1134*35

G12R - Tongwei Latest N-type TNC module

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615W

66 TNC Module

Advantages

- Maximum Power up to **615** W
- Ultra High Power Output
- Ultra-low LID
- Better Dimension Design

Power	Up to 615W
Efficiency	**Up to 23.0%**
Dimensions	**2382*1134*30mm (Bifacial)** **2382*1134*35mm (Monofacial)**
Weight	**33.2kg/29.0kg**

Note: module dimension has tolerances of ±4mm on the long side and ±2mm on the short side.

3

Advantages of the New Generation N-type Products

Domestic Tube-based PE-Tox & Poly TOPCon technology plays a key role in Tongwei's TNC cells

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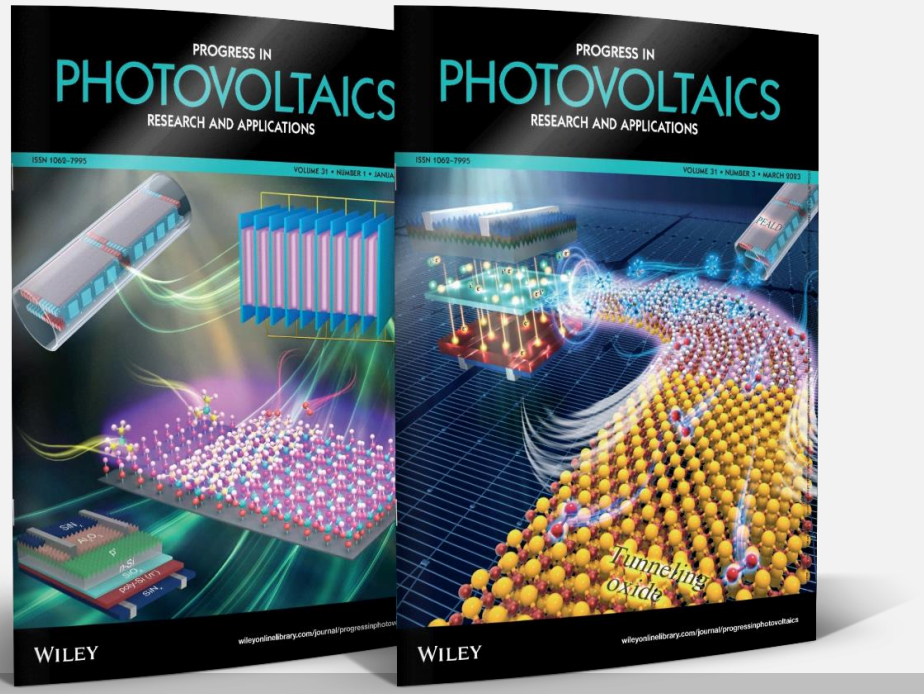
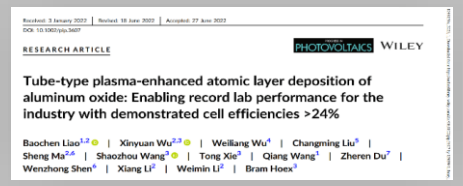
Cover of Jan. 2023 ▼ Cover of Mar. 2023 ▼

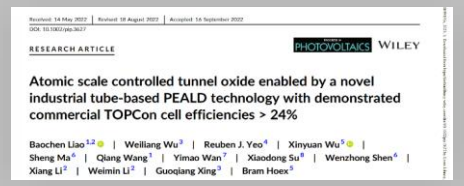


- Tube-based PECVD technology, developed by Nantong University/Leadmicro and Tongwei has been twice featured in the annual and monthly cover articles of *Progress in Photovoltaics* (PIP).

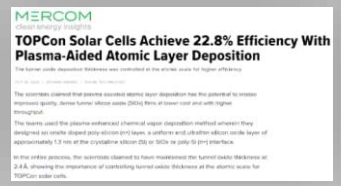
- China's achievements in Tube-based PE-Tox & Poly closed the industry gap.
- Cutting-edge development and industry-leading production process of TOPCon cells.


RESEARCH ARTICLE

Tube-type plasma-enhanced atomic layer deposition of aluminum oxide: Enabling record lab performance for the industry with demonstrated cell efficiencies >24%


RESEARCH ARTICLE

Atomic scale controlled tunnel oxide enabled by a novel industrial tube-based PEALD technology with demonstrated commercial TOPCon cell efficiencies > 24%


MERCOM

TOPCon Solar Cells Achieve 22.8% Efficiency With Plasma-Aided Atomic Layer Deposition


La cellule solaire TOPCon atteint une efficacité de 24,2 % grâce à la nouvelle technologie de dépôt de couche atomique assistée par plasma


pv magazine

TOPCon solar cell achieves 24.2% efficiency via new plasma-assisted atomic layer deposition tech


SOLAR NEWS

TOPCON SOLAR CELL ACHIEVES 24.2% EFFICIENCY VIA NEW PLASMA-ASSISTED ATOMIC LAYER DEPOSITION TECH

PCE of mass produced TNC cell＞26.1%, module power ＞585W

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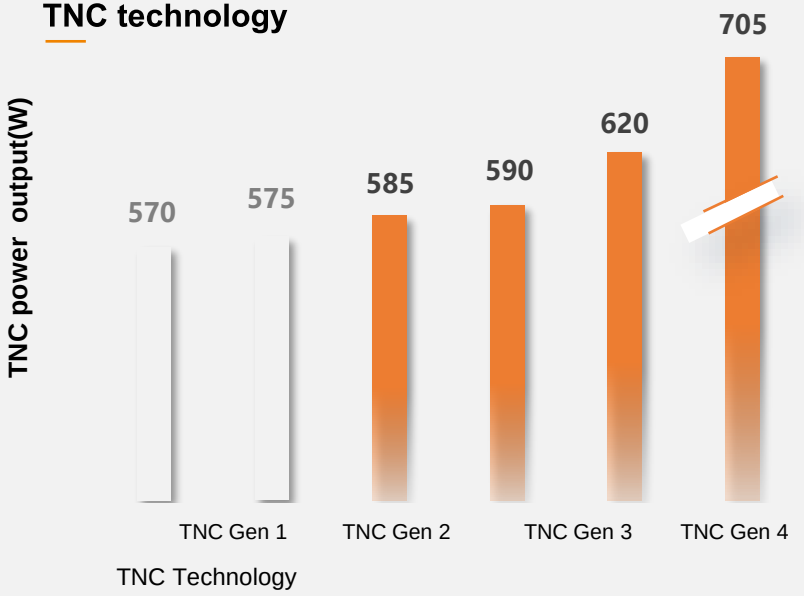
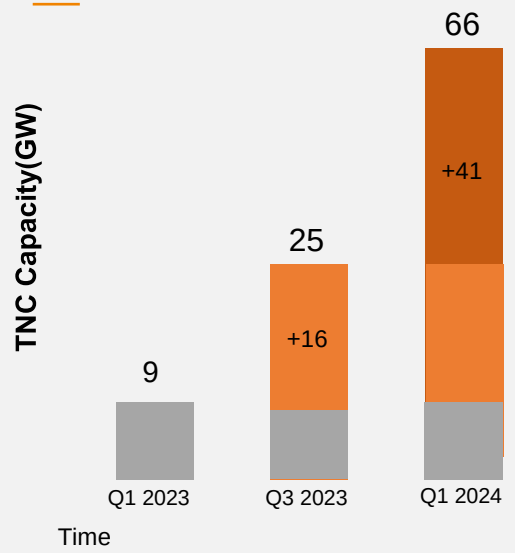
- In December 2021, Tongwei optimized the PECVD poly route for mass production.
- At the end of October 2023, a PCE of 26.1% was achieved from mass produced TNC cells.

Trend in PCE of mass produced TNC cell

TNC technology



Trend in TNC capacity



TNC Field test: 3.34% actual power generation gain than PERC

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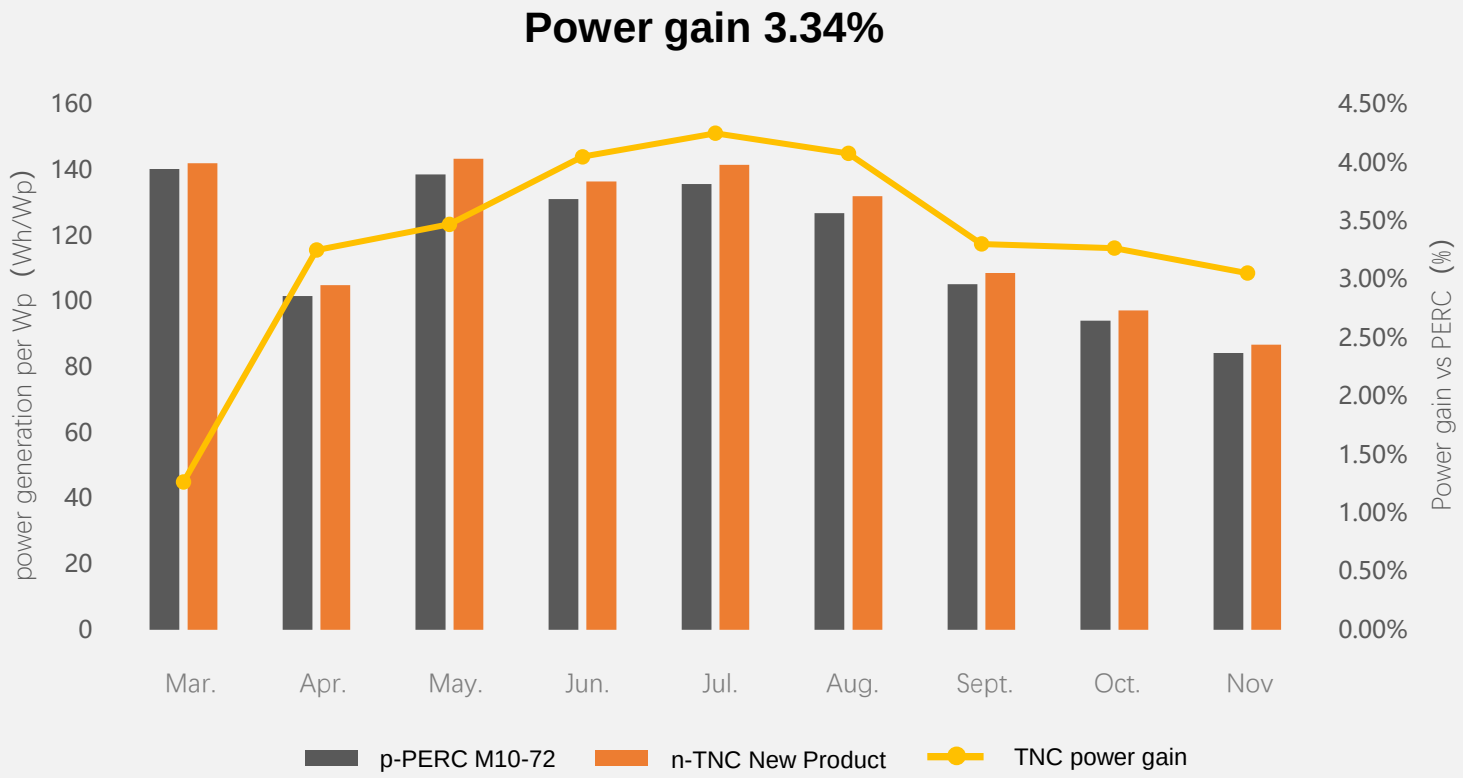

- **Monitoring period:**
  2/15/2023-19/11/2023
- **Field test location:**
  Sanya (18°31N;109°56E),
  Hainan province, China
- **Modules compared:**
  New TNC bifacial module
  M10-72 series PERC bifacial module
- **Climate type:**
  Tropical monsoon climate
- **Average temperature:** 25.7℃
- **Average daily irradiation:** 5.35 kWh/㎡

Transportation Advantage of G12R module

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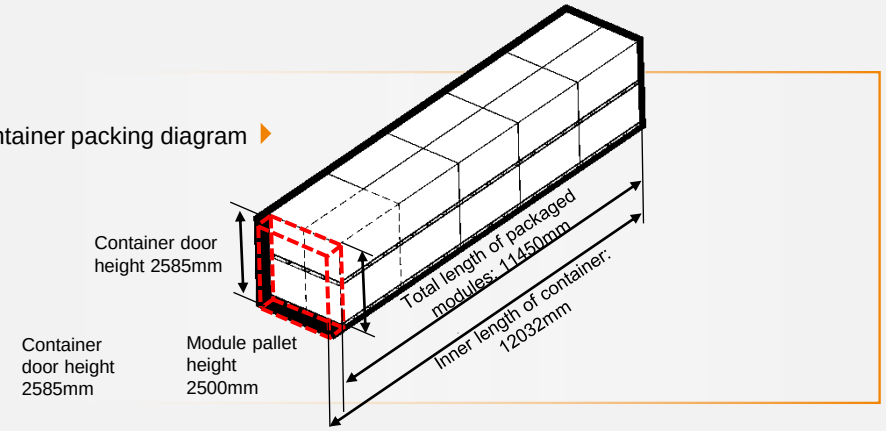
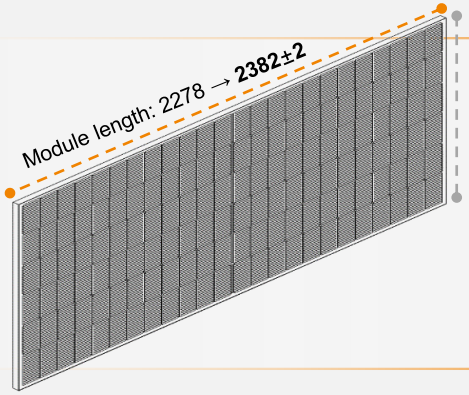
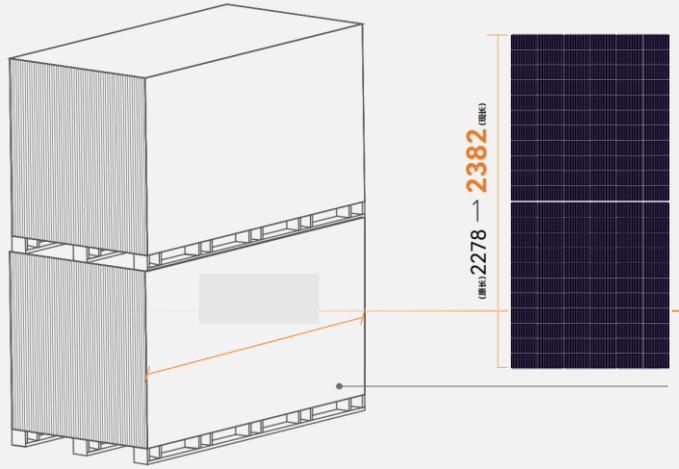
Design optimization to maximize packing efficiency and reduce transportation costs. By combining TNC technology with ultimate design, we bring higher product value.

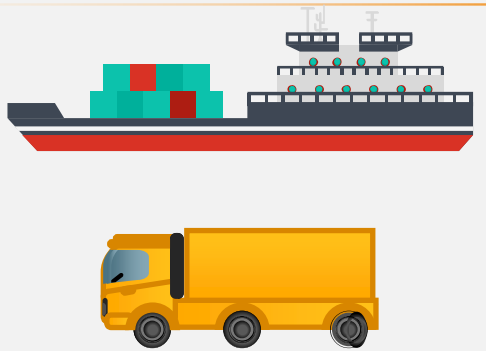
40H container packing diagram





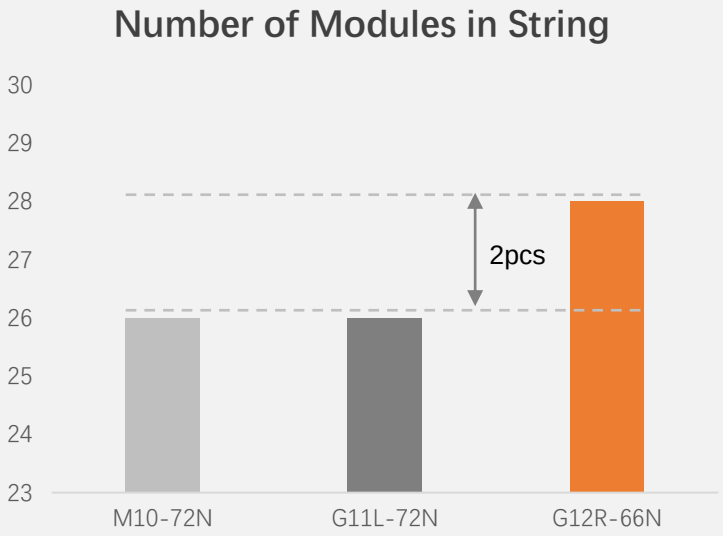
The module dimension is adapted to the container size, and the length can be further optimized to improve container utilization to 98.5%.



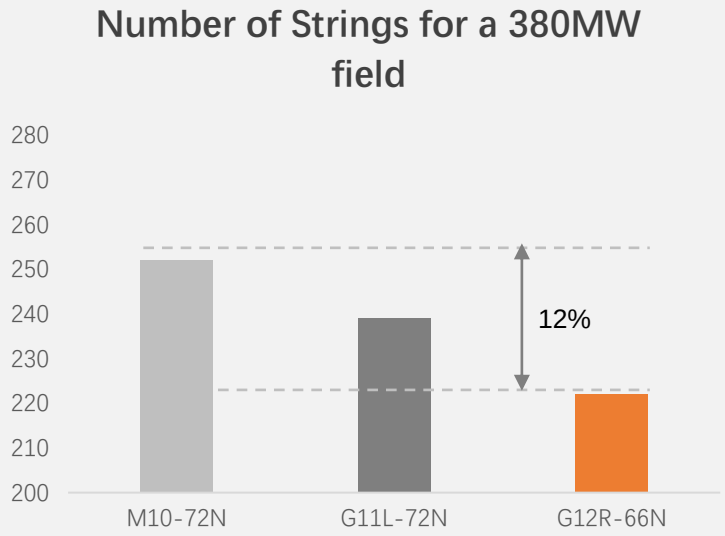


G12R-66 bifacial vs 182-72 bifacial
4% cost reduction for 40' HQ , 17.5m, 13m Flat

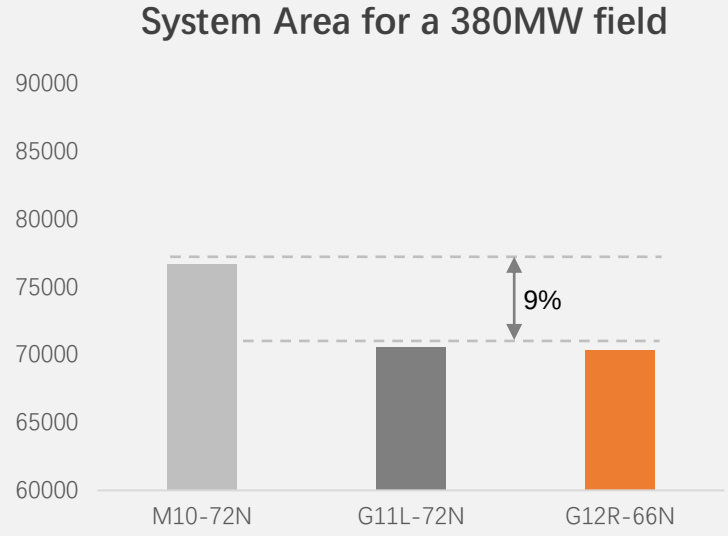
System Advantages of G12R module



More number of modules could be installed in a string, for 1500VDC it will be 2 pcs compared to M10-72N.



Number of inverters, cables and system components can be reduecd by 12% compared to M10-72N.



The power field area can be redcued by 9% compared to M10-72N.

*Using M10-72N Bifacial Module with 580W，G11L-72N with 610W and G12R-66N with 610W.

Application Value of G12R module

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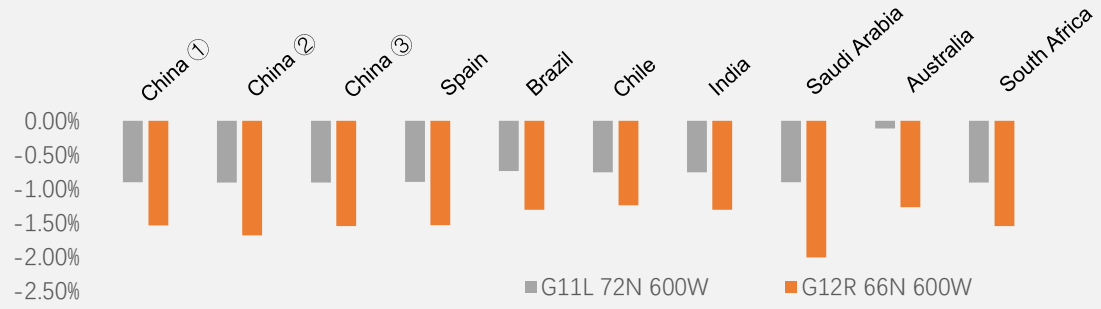
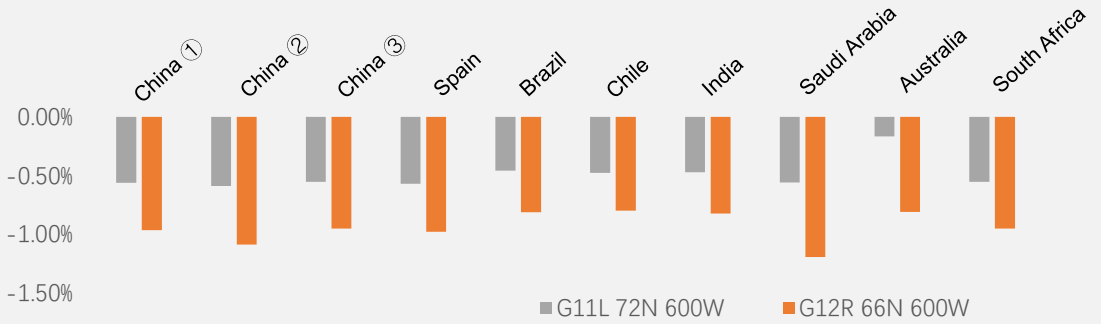
Based on calculations from 10 typical project locations, BOS and LCOE comparison shows that G12R brings higher system value.

BOS: G12R vs G11L，↓1.11%； G12R vs M10，↓2.01%.



LCOE：G12R vs G11L，↓0.63%； G12R vs M10，↓1.19%.



*Using TOPCon M10-72 Bifacial Module as BSL

G12R Module - Certification and Warranty

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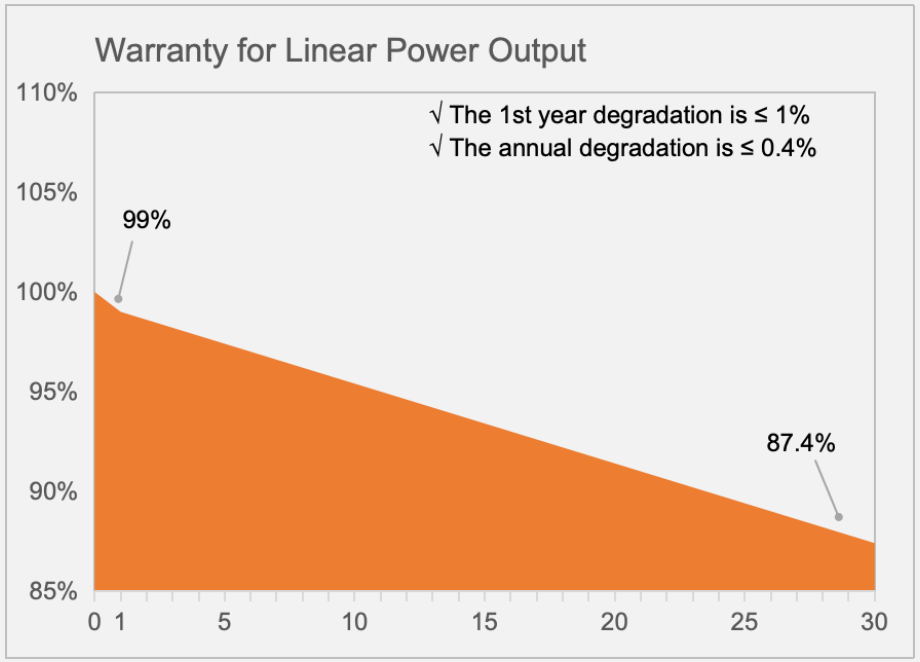
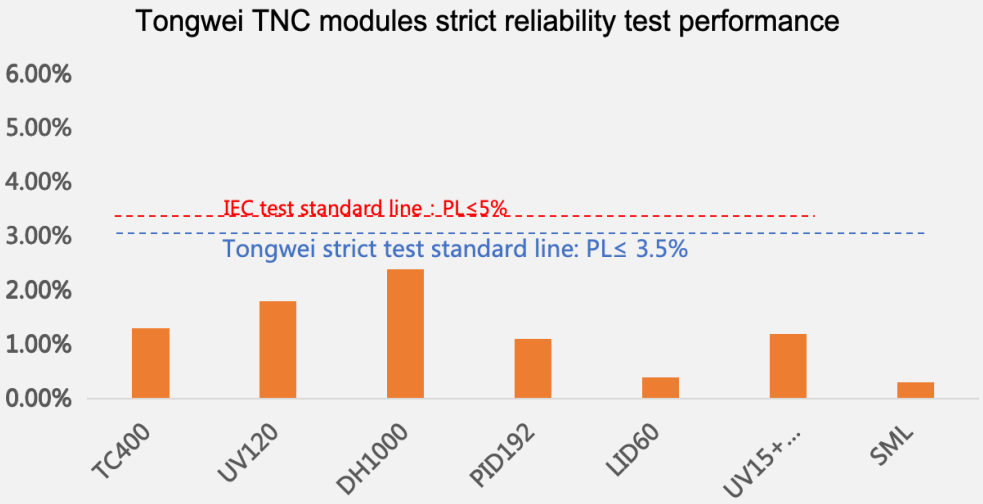
Warranty for Material: 15 years for G12R-48 modules, and 12 years for G12R-66 modules.

Warranty for Linear Power Output: 30 years





System Certification:

ISO9001
ISO14001
ISO45001
IEC62941

Product Certification:

ESG goals – To achieve operational carbon neutrality

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Tongwei set up 14 sustainable development goals for ESG, to achieve carbon neutrality by 2030.

1. 100% coverage of sustainable investigation and assessment for module suppliers
2. Company's water-saving target: 3.594 million tons
3. Plan to initiate 38 ESG and climate action projects
4. Female representation on the board of directors should be no less than 30%
5. Achieved a 19.5% reduction in carbon intensity compared to 2020
6. Annual renewable energy generation exceeds 9 billion kWh
7. Annual zero personal injury accidents
8. 100% product qualification rate annually
9. 100% annual supplier commitment rate for integrity
10. Annually, no fire, explosion, or poisoning incidents
11. Zero occurrence of quality and safety incidents annually
12. 100% customer complaint resolution rate annually
13. 100% annual internal anti-corruption audits and key position employee training
14. Achieved operational carbon neutrality

ESG honors

- Silver Medal (EcoVadis Silver 2023)
- "A" Grade — STαR ESG
- "AA" Grade — CSI ESG Rating
- "A" Grade — Wind ESG
- "A-"Grade — IIGF ESG
- Fortune China ESG Influential Listing
- China Top 100 ESG Listed Companies
- State-level Green Factory

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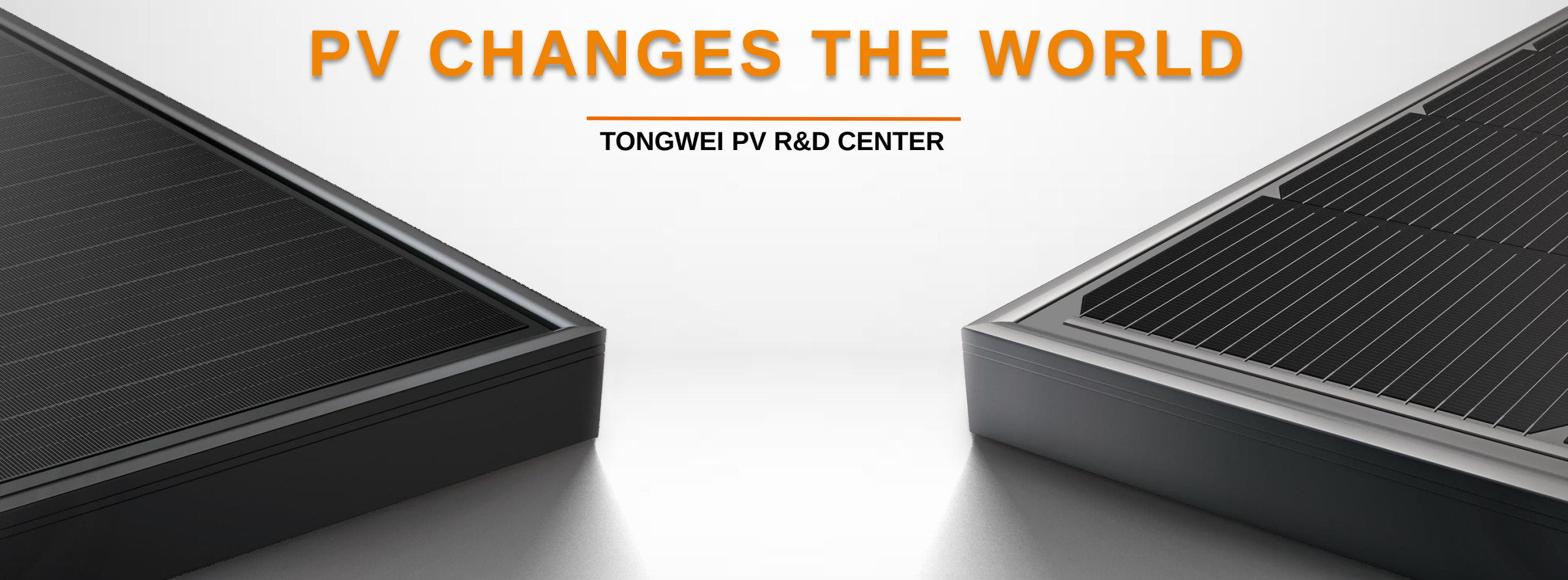
TONGWEI PV R&D CENTER



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Performance & reliability evaluation

of n-type high-efficiency PV modules

Shimeng Wei | BF Renewables | 23.01.2024

Topics

Performance & reliability evaluation of n-type high-efficiency PV modules

- 01 Background
- 02 Performance evaluation
- 03 Characterization
- 04 Reliability evaluation
- 05 Conclusion

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Topics

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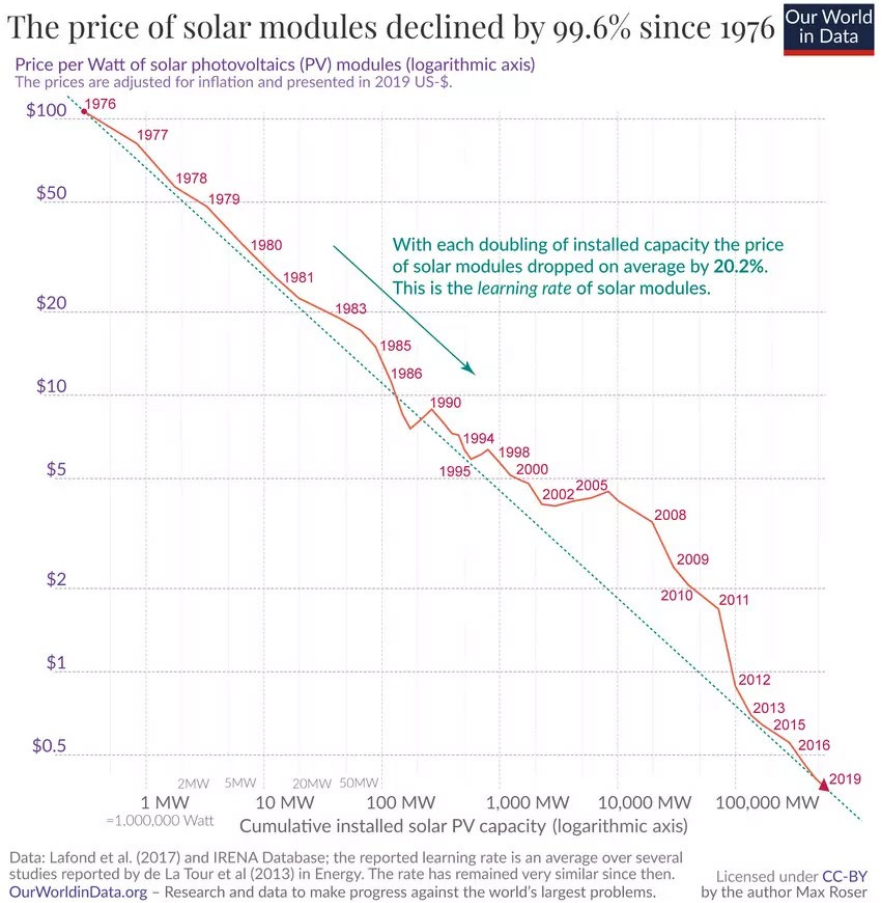
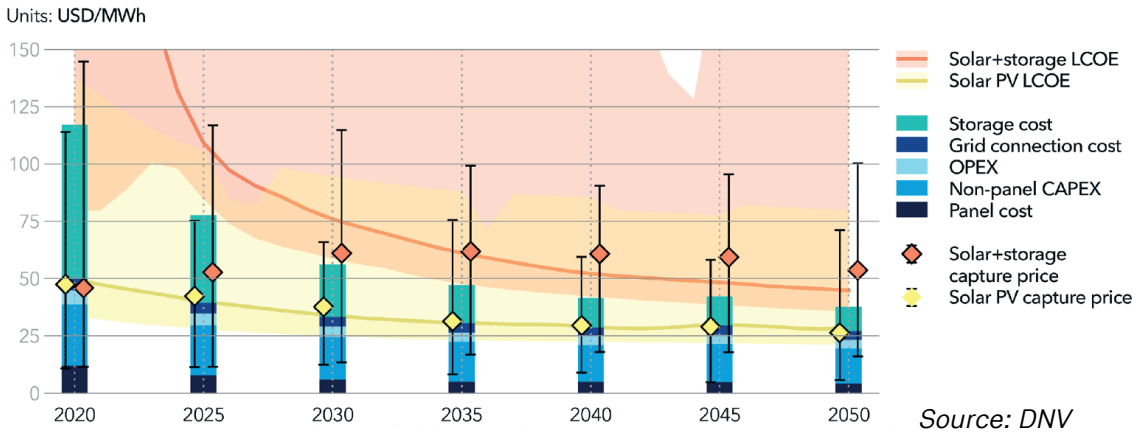
Global solar LCOE and capture price





Source: DNV

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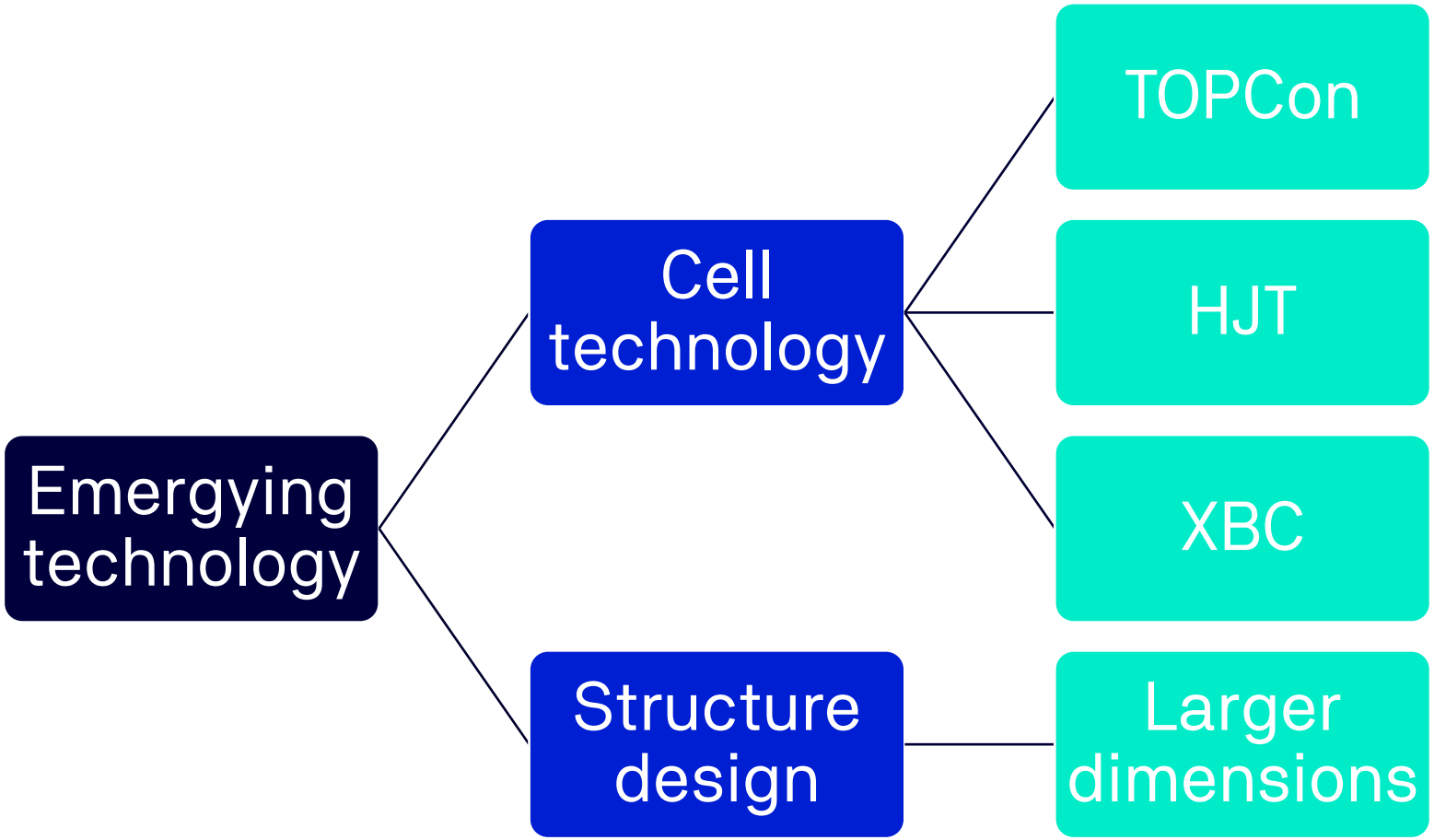
Emerging technology



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Topics

Performance & reliability evaluation of n-type high-efficiency PV modules

- 01 Background
- 02 Performance evaluation
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Outdoor 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

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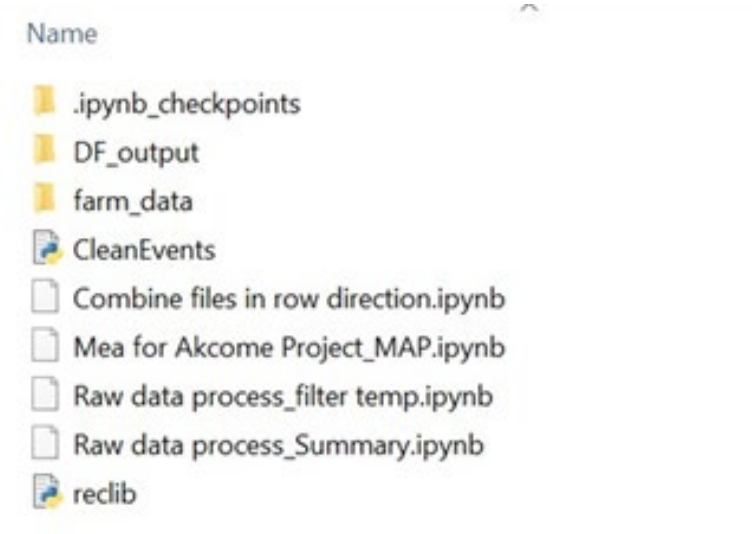
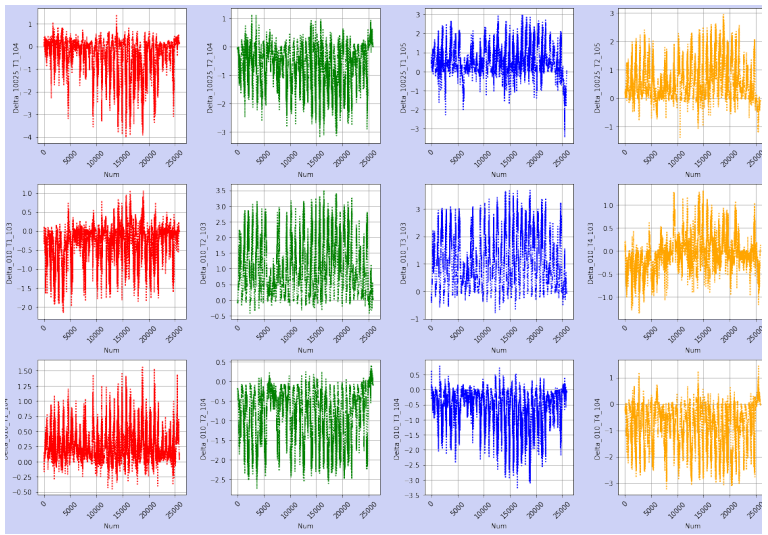
Outdoor performance test

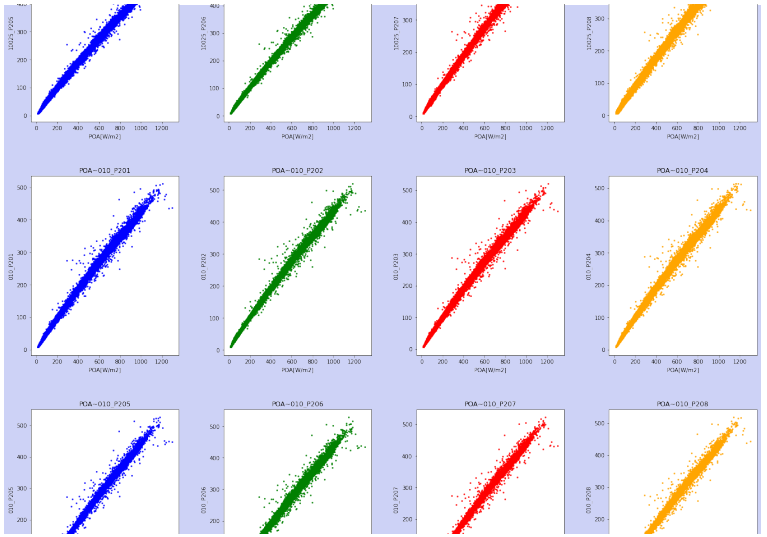
Python data analysis tool



Based on Python data analysis tool, efficiently perform raw data processing, data quality inspection, problem location analysis, and result output



Distribution of module output power with irradiation



Distribution of differences between module operating temperature and average temperature

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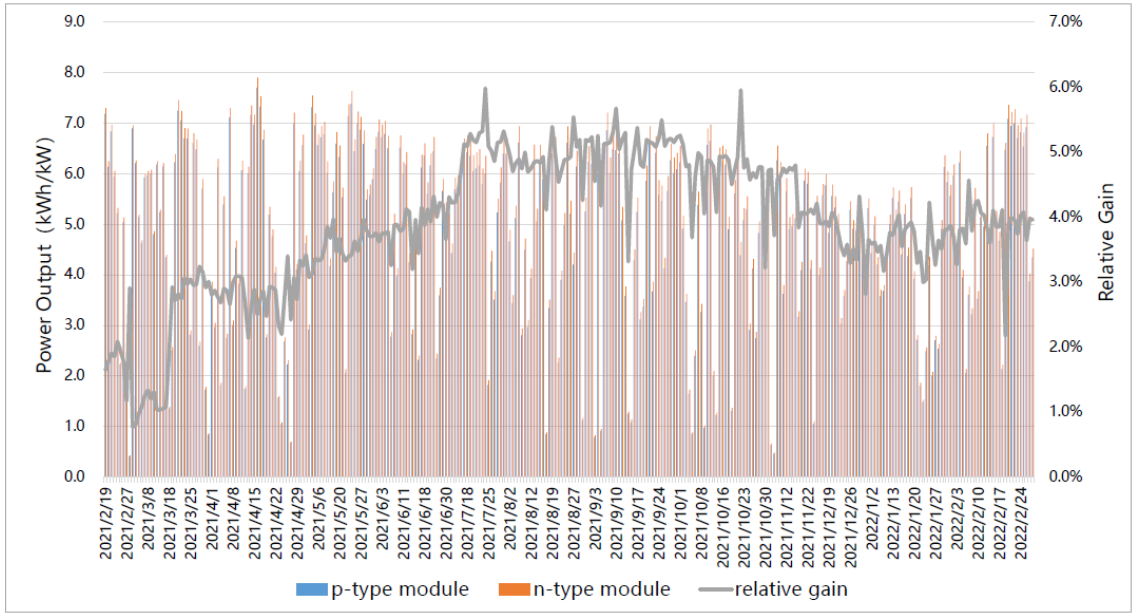
Outdoor performance test

Power generation

Compared with PERC modules, n-type TOPCon modules cumulative kWh/kW power generation difference is +3.93%.



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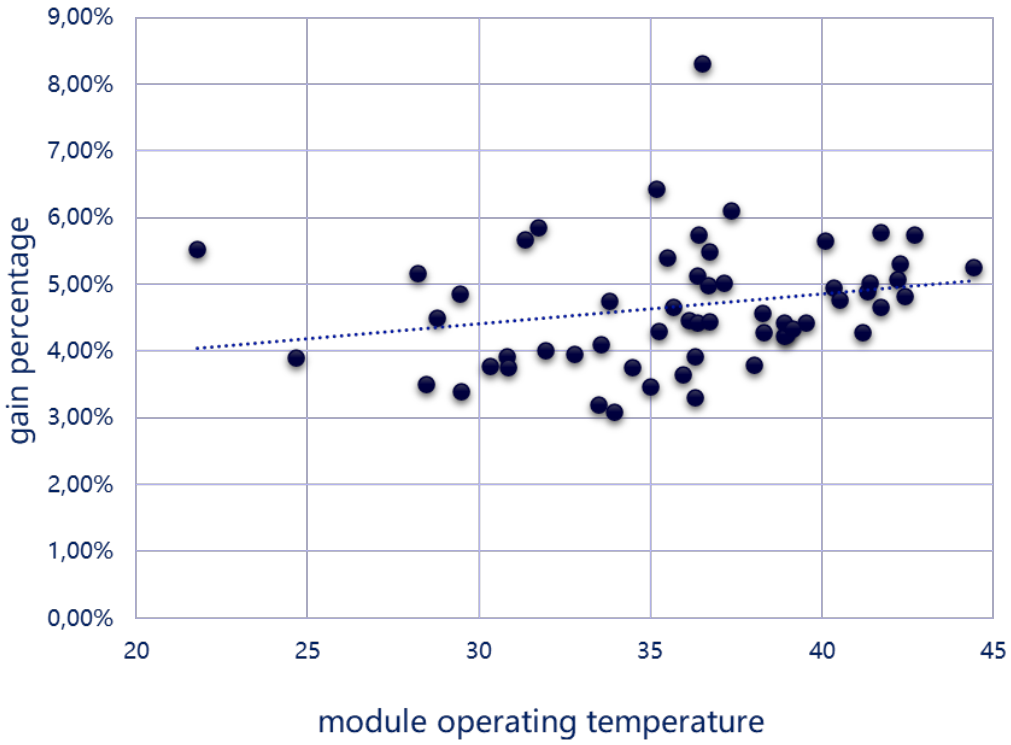
Outdoor performance test

Temperature coefficienct

Compared with PERC modules, the kWh/kW power generation gain of n-type TOPCon modules also shows an increasing trend when the module temperature increases, which can reflect the temperature coefficient advantage of n-type TOPCon modules.



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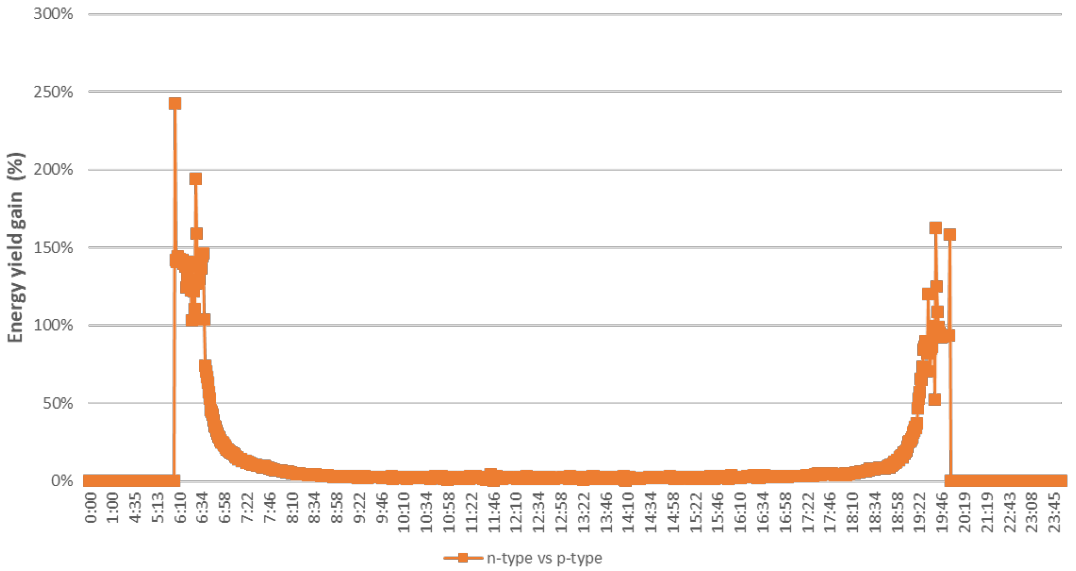
Outdoor performance test

Low-irradiance behaviour

Compared with PERC modules, n-type TOPCon modules have more obvious power generation in the early morning and nightfall.



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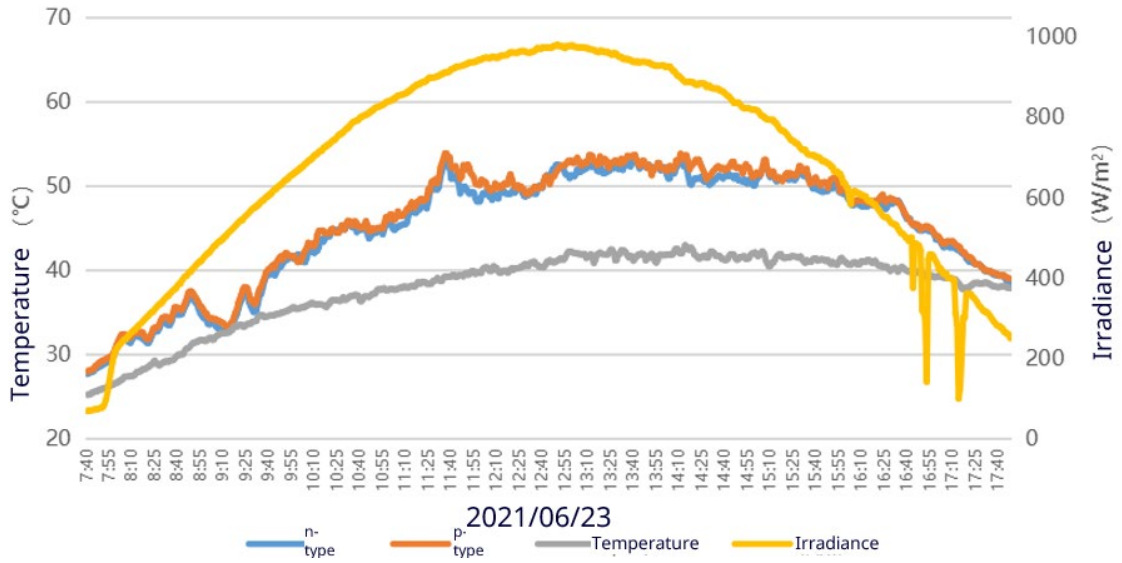
Outdoor performance test

Operation temperature

Compared with PERC modules, the average operating temperature of n-type TOPCon modules is about 1°C lower.



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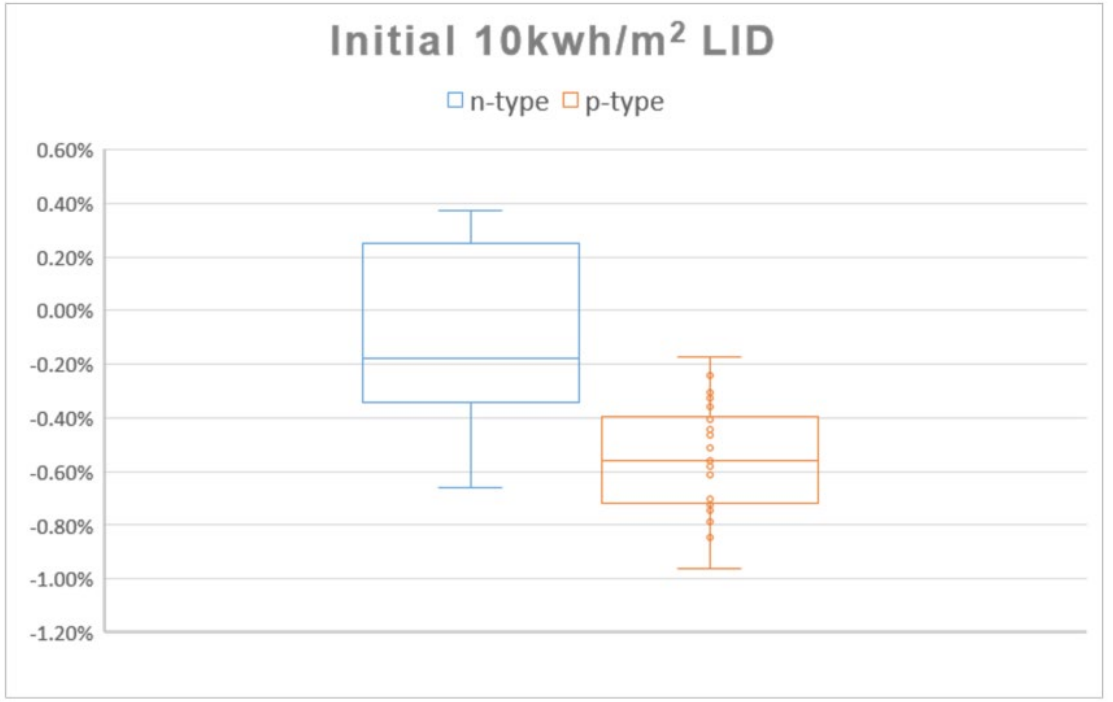
Outdoor performance test

LID

LID (10kWh/m²)	Min	Max	Ave
n-type Topcon	+0.37%	-0.66%	-0.08%
PERC	-0.17%	-0.96%	-0.55%



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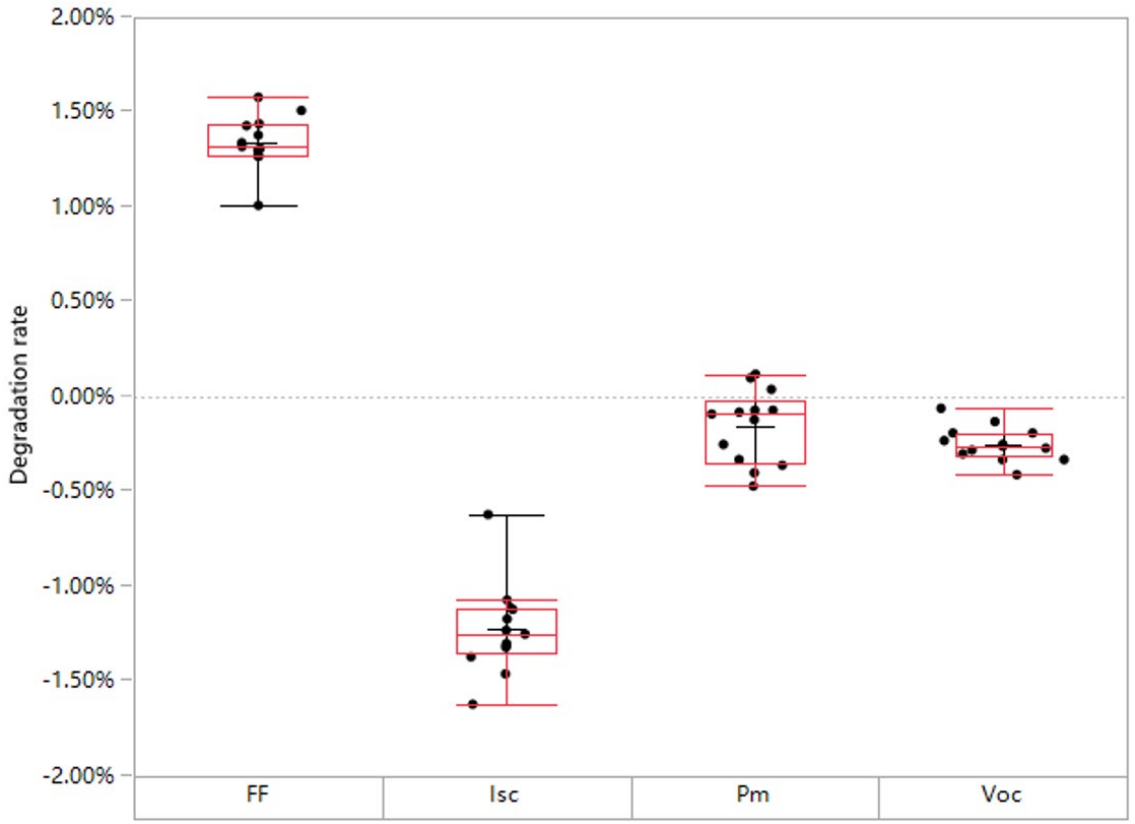
Outdoor performance test

LID

After more than one year of outdoor grid-connected power generation, for n-type TOPCon modules, the average attenuation of all modules in the entire string is 0.15%.



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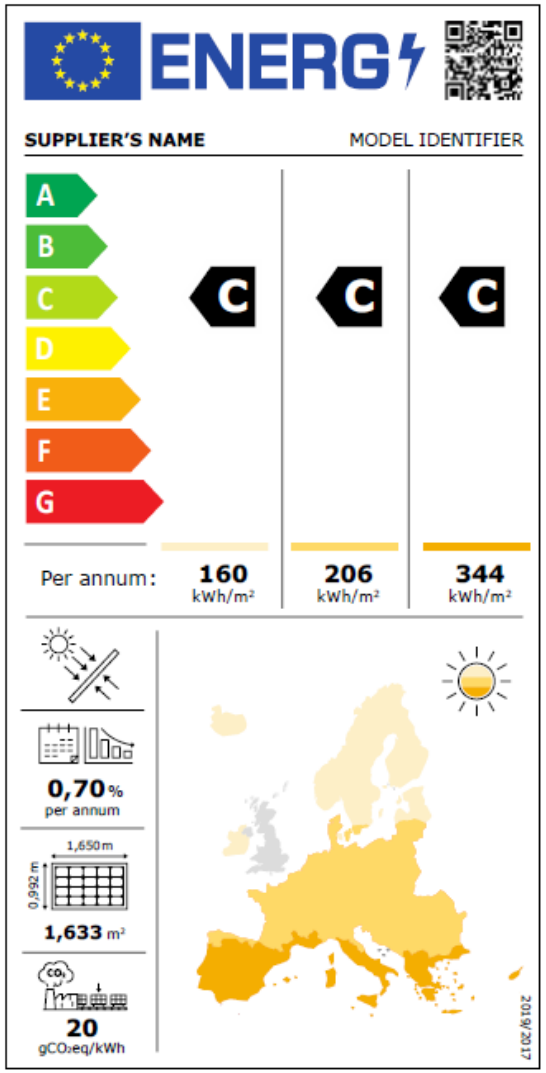
Eco design & energy label



	Energy Efficiency Index (EEI_M), kWh/m²		
Energy Efficiency Class	Subtropical arid	Temperate coastal	Temperate continental
A	$EEI_M > 566$	$EEI_M > 257$	$EEI_M > 330$
B	$496 < EEI_M \leq 566$	$226 < EEI_M \leq 257$	$291 < EEI_M \leq 330$
C	$426 < EEI_M \leq 496$	$195 < EEI_M \leq 226$	$252 < EEI_M \leq 291$
D	$356 < EEI_M \leq 426$	$164 < EEI_M \leq 195$	$213 < EEI_M \leq 252$
E	$310 < EEI_M \leq 356$	$140 < EEI_M \leq 164$	$182 < EEI_M \leq 213$
F	$265 < EEI_M \leq 310$	$117 < EEI_M \leq 140$	$151 < EEI_M \leq 182$
G	$EEI_M \leq 265$	$EEI_M \leq 117$	$EEI_M \leq 151$

PERC

Input parameters	
a_r	0.07491
β	20

Input module efficiency - from laboratory measurements

Irradiance	Module temperature 15	25	50	75
100	20.90	20.16	18.31	16.42
200	21.42	20.70	18.90	17.07
400	21.79	21.09	19.35	17.57
600	21.88	21.20	19.49	17.74
800	21.87	21.20	19.50	17.78
1000	21.79	21.13	19.45	17.74
1100	21.74	21.08	19.41	17.71

Input the test module Uc	
Uc	33

Climate Type	Subtropical arid
Module type	182 p_type
Emod,year (kWh)	1167.7
Pmax,STC (W)	545
Hp (kWh/m²)	2295.5
CSER	92.3%
EEI_M	451.2
Energy Efficiency Class	C

TOPCon

Define same a_r and β

Input module efficiency - from laboratory measurements

Irradiance	Module temperature 15	25	50	75
100	21.89	21.18	19.35	17.47
200	22.46	21.76	19.98	18.15
400	22.83	22.14	20.42	18.64
600	22.91	22.25	20.54	18.79
800	22.87	22.21	20.53	18.80
1000	22.77	22.11	20.45	18.74
1100	22.70	22.05	20.39	18.69

TOPCon have better conversion efficiency

Input the test module Uc	
Uc	35

TOPCon have better operating temperature

Climate Type	Subtropical arid
Module type	182 n_type
Emod,year (kWh)	1286.6
Pmax,STC (W)	570
Hp (kWh/m²)	2295.5
CSER	98.3%
EEI_M	498.1
Energy Efficiency Class	B

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Topics

Performance & reliability evaluation of n-type high-efficiency PV modules

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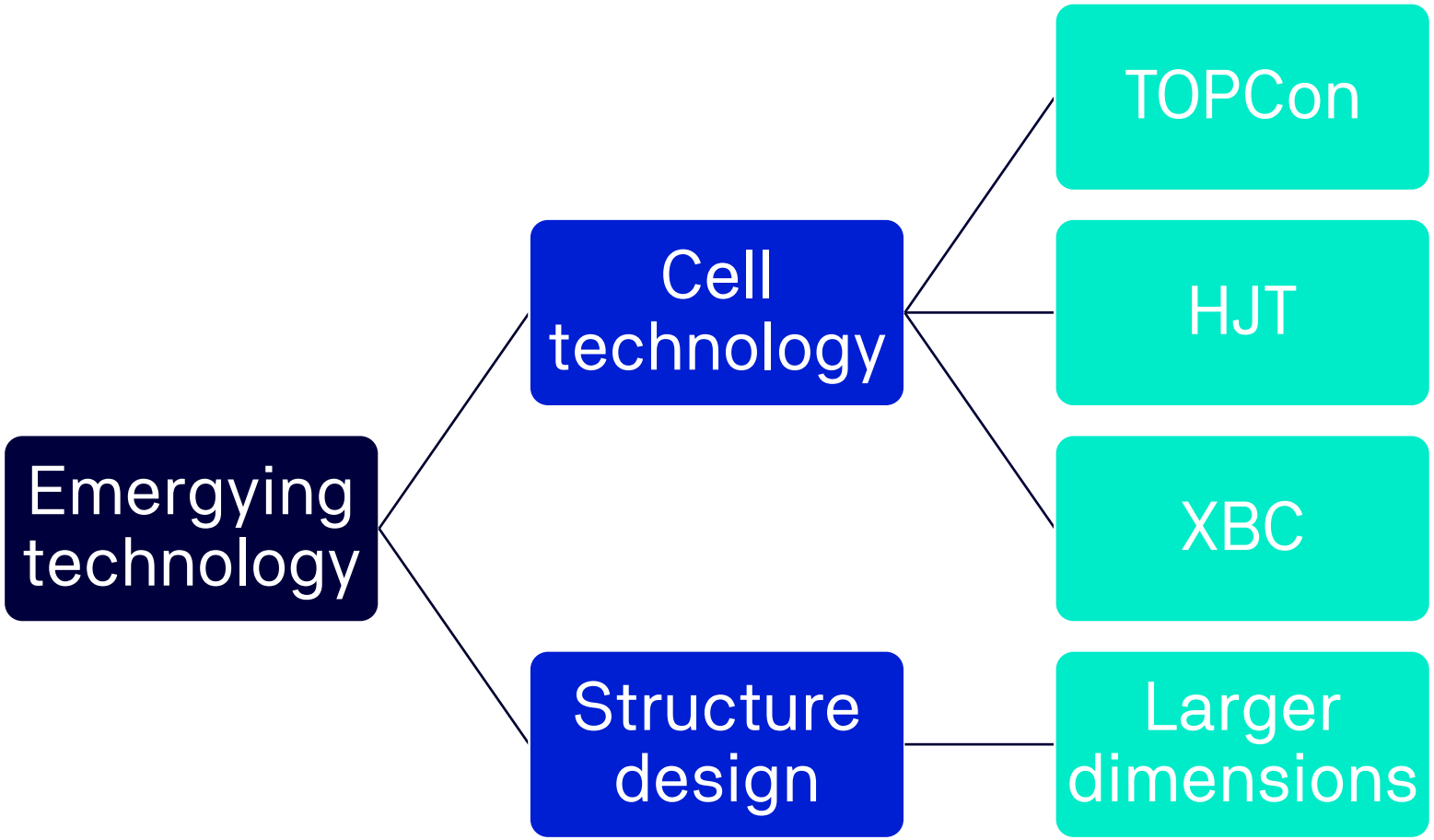
Emerging technology



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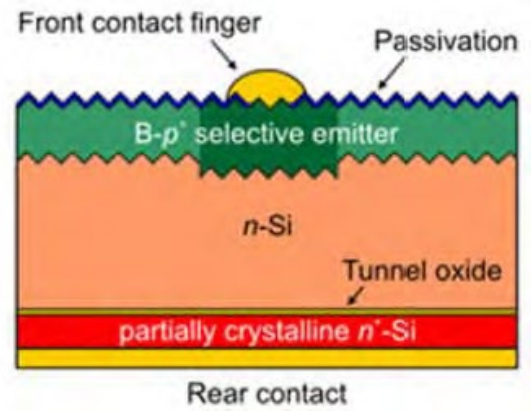
Characterizations of n-type modules with new cell technology

- Accurate power testing
- Moisture
- UV
- Temperature coefficient
- LID



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

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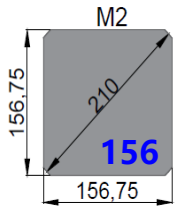
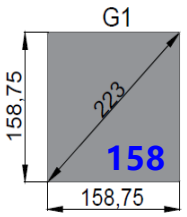
Characterizations of n-type modules with larger dimensions

- Installation
- Packaging & transportation
- Mechanical properties
- Electrical safety

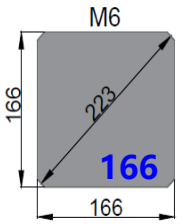
Larger dimensions



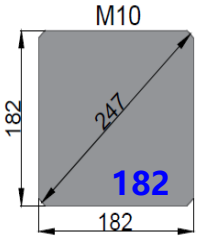
Area: 24432mm² (**base line**)



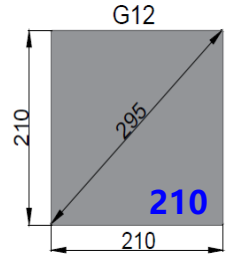
Area: 25199mm² (**3.14% ↑**)



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	2465x1134	**2384x1303**
Pmax (W)	390	420	475	620	**720**
Isc (A)	9.79	10.70	11.46	14.30	**17.74**
Voc (V)	49.28	48.74	51.25	55.34	**49.20**

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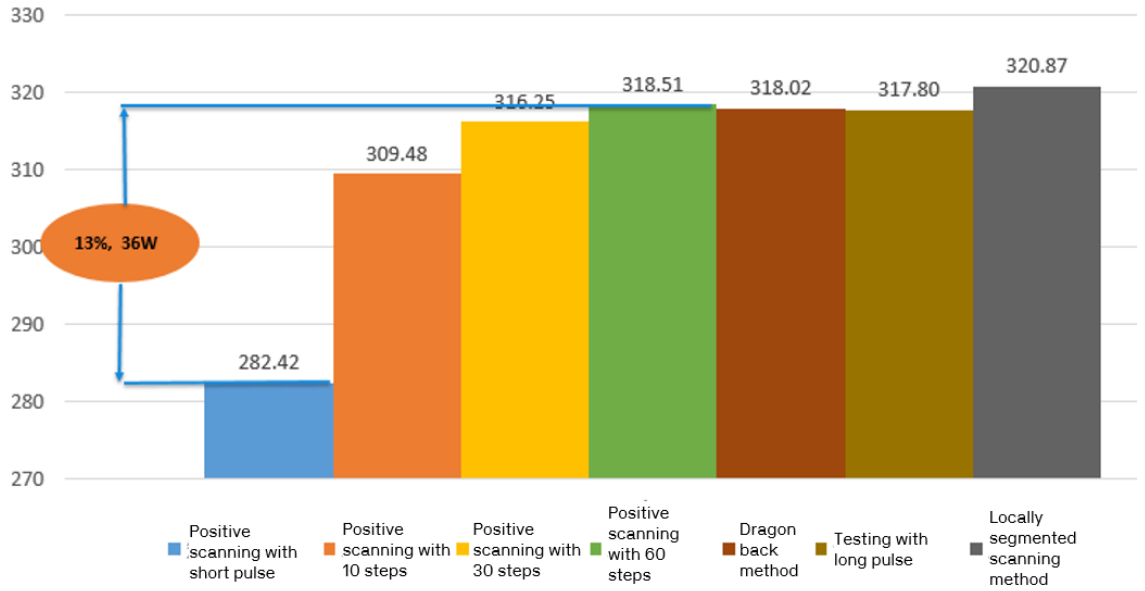
Accurate power testing

The internal capacitance leads 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.



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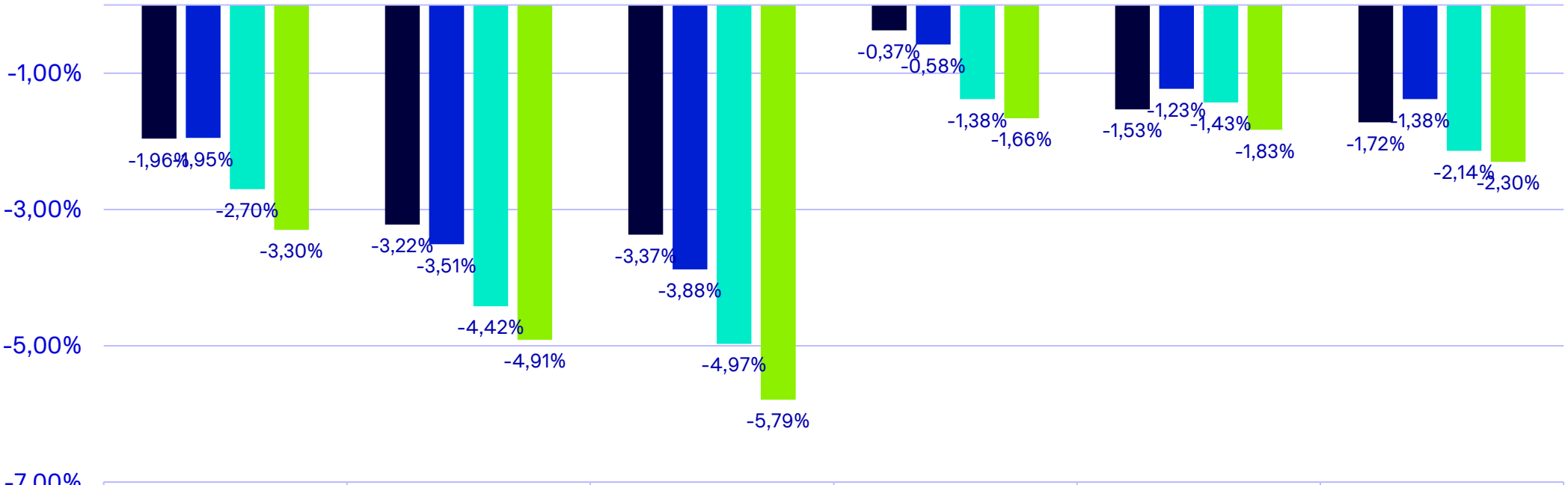
Moisture

Damp-heat test simulation



	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%

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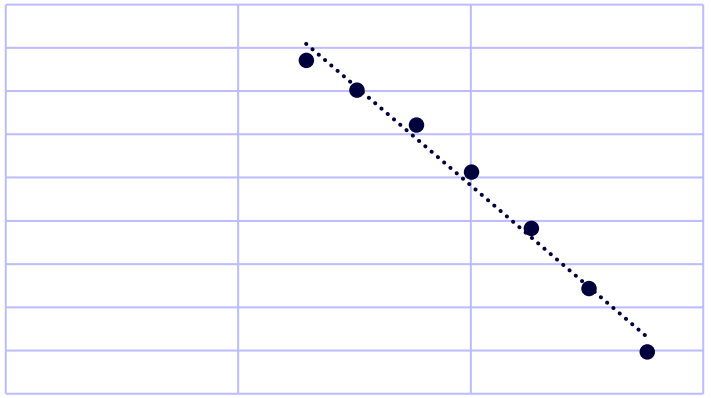
Accurate power testing

Temperature co-efficient

55°C - 25°C
α = -0.352%

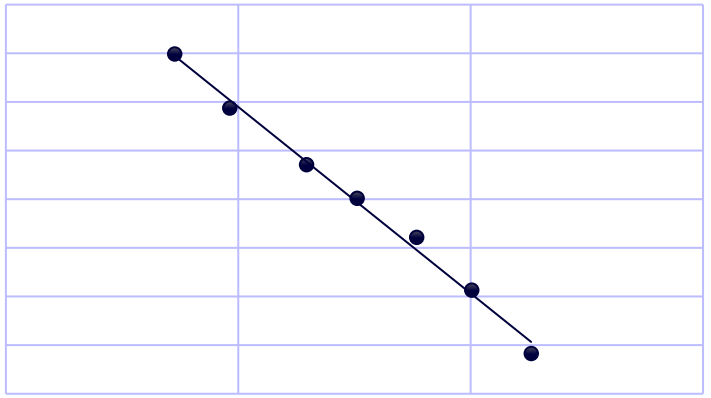
Pmax T.C.



Regular natural cooling + 10ms pulse single flash

40°C - 10°C
α = -0.312%

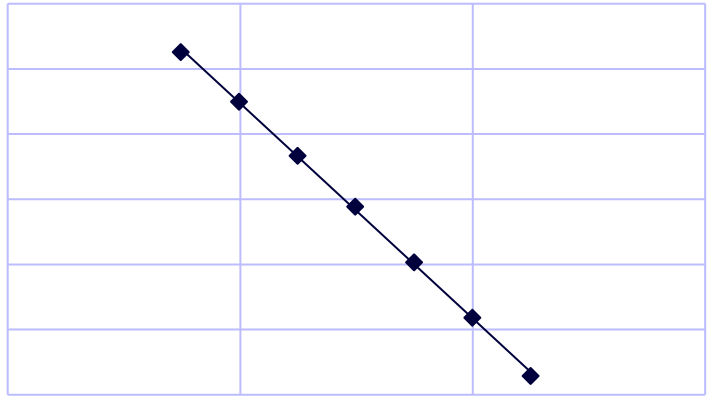
Pmax T.C.



Low temperature area + 10ms pulse single flash

45°C - 15°C
α = -0.285%

Pmax T.C.



Temperature control box + accurate test

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Installation

Installation method

- The position of mounting holes
- The amount of mounting holes
- Tracker or Fixed bracket

Extreme climate

- Rainy, snowy, hailing, windy weather

Packaging & transportation

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

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

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

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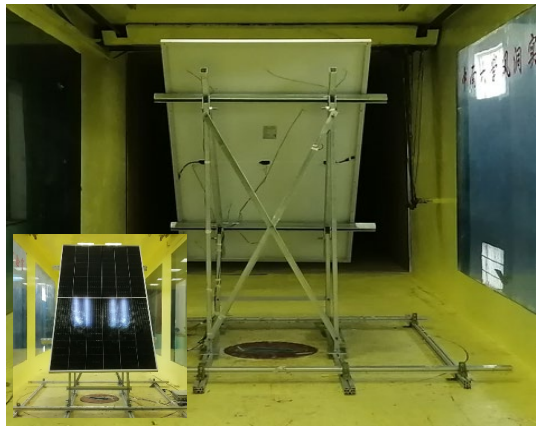
Mechanical properties



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

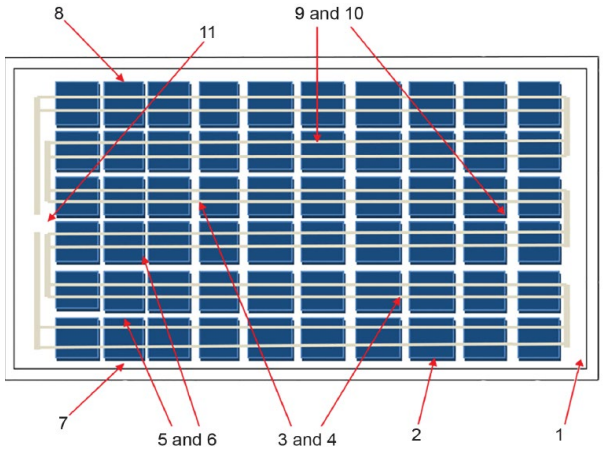
Static & dynamic Mechanical Load

Non-uniform Snow Load

Wind tunnel test

Hail impact test

- Dynamic changes of strong wind pressure may cause the failure of components and installation systems
- Large size modules are with wider sides, requiring higher toughened quality control on the edges of the glass



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Electrical safety

Current-related tests for bifacial PV modules

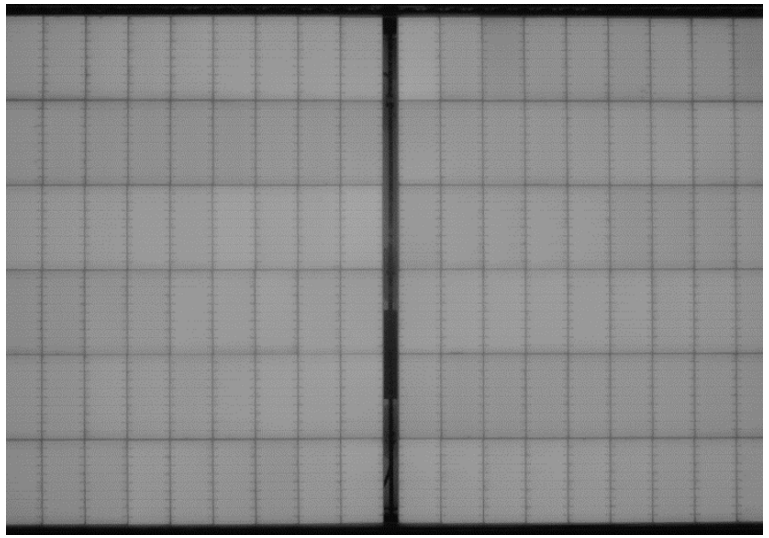
When the temperature of installation environment is high enough (e.g. dessert climate), the installation method is difficult for heat dissipation (e.g. double-skin curtain wall BIPV), higher current carrying capacity is required for bypass-diode in larger-size modules.

	166mm (144 half-cut)	182mm (156 half-cut)	210mm (132 half-cut)
Isc-BSI (A)	13.87	17.30	21.47
Imp-BSI (A)	12.52	16.24	20.57
MQT 18 Bypass diode testing: 1.4*Isc-BSI at 75℃ 1hour, according to IEC TS 63126 level 2			
Applied current (A)	27.19	33.91	42.08
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)	12.52	16.24	20.57

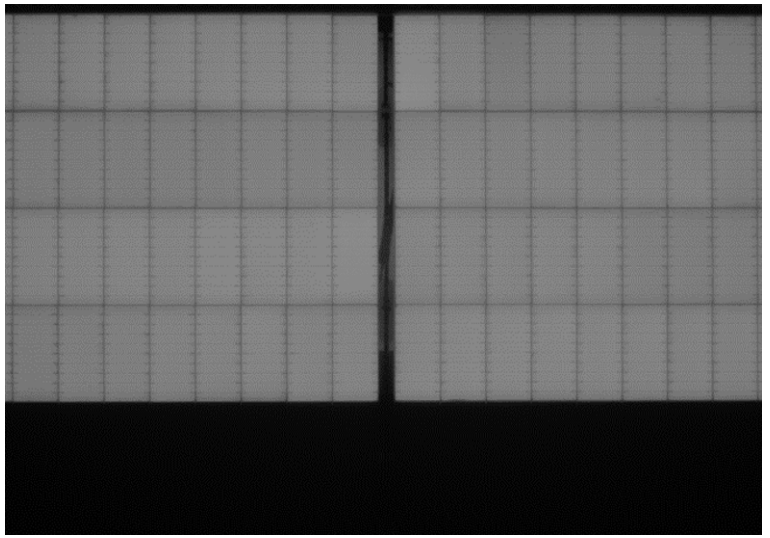
Electrical safety

Thermal cycling test

Normal operation



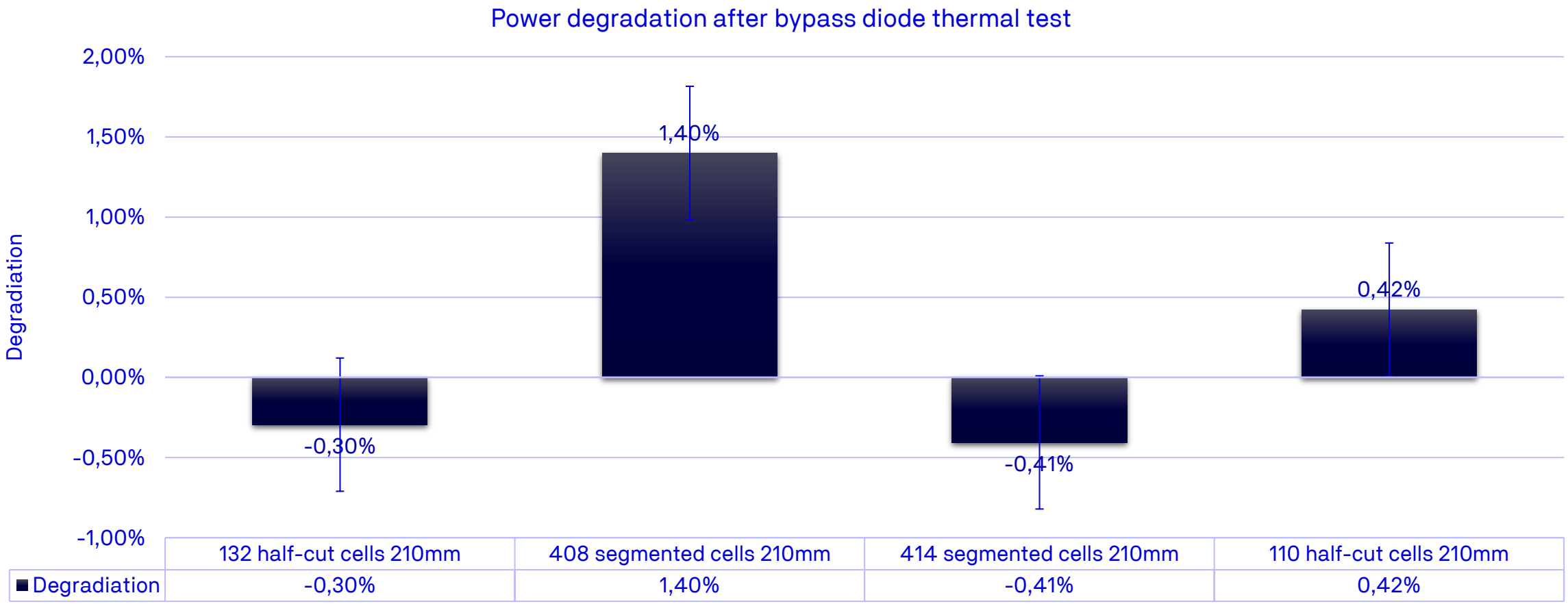
Bypass diode fails



Junction box melt after thermal cycling

Electrical safety

Bypass diode thermal test



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Conclusion

- LCOE continues to decrease, which is becoming the most important factor of global PV projects.
- n-type PV modules with larger dimensions is an emerging technology.
- Outdoor performance test shows the power generation advantages of n-type PV modules.
- Risks come along with the benefits of high-efficiency PV modules with larger dimensions and larger current, solutions are already available and therefore additional care need to be taken.

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Do you have questions?

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