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JA Solar

pv magazine webinars

N-type trends in 2024

25 January 2024

2:00 pm – 3:00 pm | GMT, London
3:00 pm – 4:00 pm | CET, Berlin
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Welcome!

pv magazine webinars

Do you have any questions? ❓ 🙋

Send them in via the Q&A tab. 👉 We aim to answer as many as we can today!

You can also let us know of any tech problems there.

We are recording this webinar today. 🎥

We'll let you know by email where to find it and the slide deck, so you can re-watch it at your convenience. 👀 💡

Never Stop Evolution

Empowering Tomorrow: Unveiling Advanced Solar Technology

Presenter: Lida Guo

Date: 25 January 2024

Contents

PV Technologies and Development Trend

Module Power Trend

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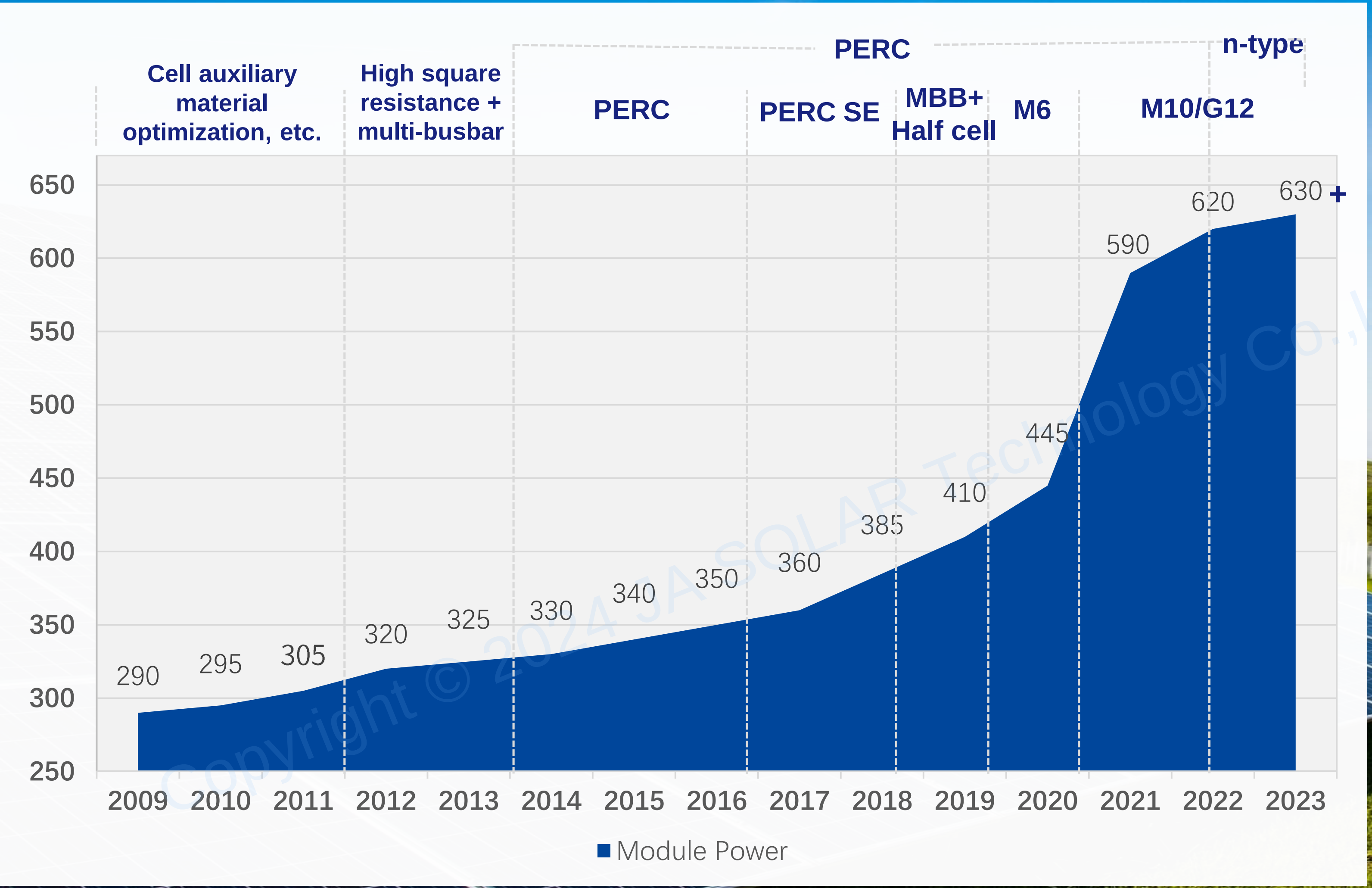

Cell Technology

PERC 2009-17% ➔ 2023-23.9%
SE + MBB + Bifacial
TOPCon and HJT >25%

Module Technology and Material Improvement

Double coating, glass with white glaze, highly reflective backsheet, high-transmission encapsulation film
Half cell+ MBB
Shingling, tiling ribbon, small spacing, gapless

Larger Wafer & Module

125➔156➔158.75 ➔ 166 ➔ 210 & 182 ➔182* (182+x)
Module area: $1m^2$→$1.5+m^2$ →$2.5+m^2$

Development of High-efficiency Cell Technologies

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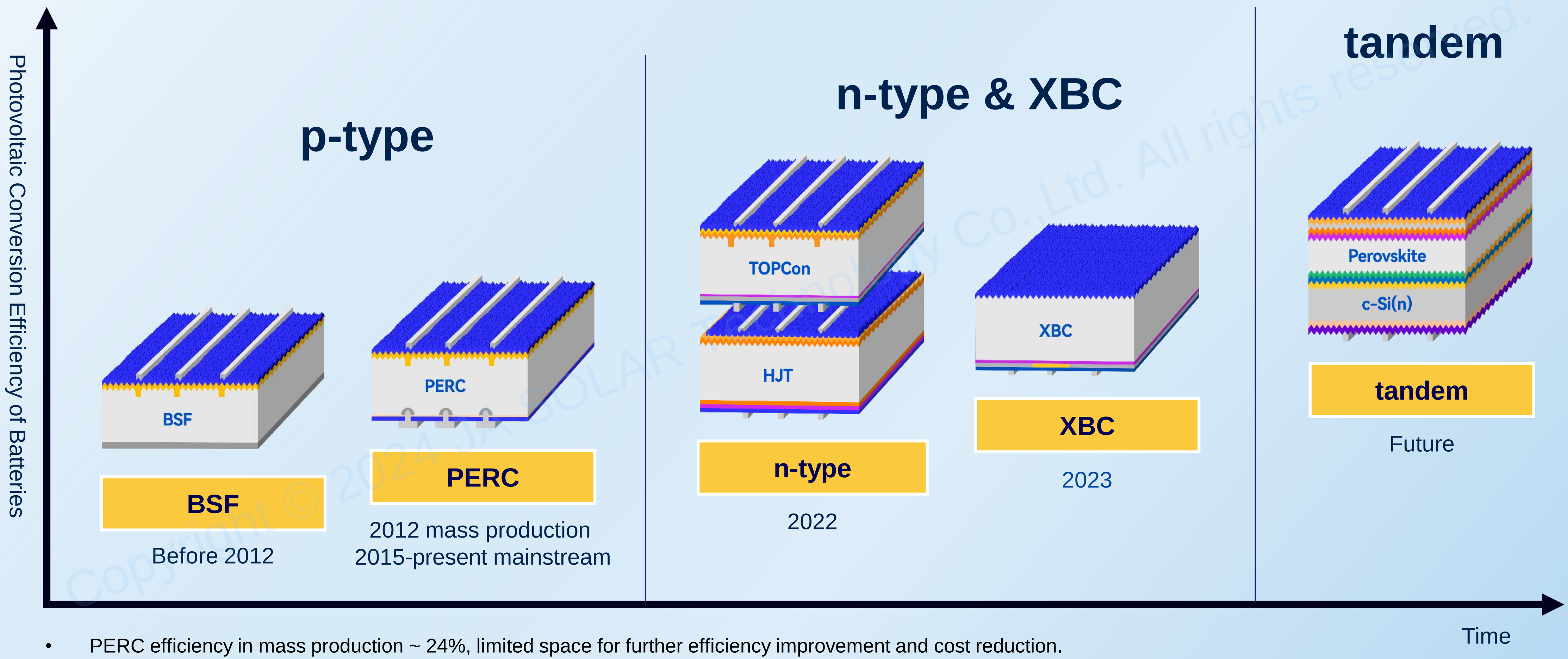
Development Roadmap of Solar Cell Technology



- PERC efficiency in mass production ~ 24%, limited space for further efficiency improvement and cost reduction.
- After PERC, the new technology still needs to have mass production characteristics, including high efficiency, low cost, good product yield and so on.
- TOPCon is this kind of technology, so it will gradually become the mainstream technology in the market.

High-density Encapsulation

Considering the power improvement, product yield, reliability and other factors, small spacing gradually become the mainstream of high-density encapsulation technology.

LCOE is the Core for Best Performance Modules

A **Module cost (price)**

The lower the module cost
the lower the initial cost

B **Module efficiency (power)**

High efficiency (power) modules can reduce system BOS (Balance of System) costs

C **Power generation performance of modules**

Modules with excellent power generation performance can increase electricity generation and reduce LCOE

D **Long-term reliability of modules**

High reliability ensures stable power generation throughout the entire life cycle

Optimal LCOE (core) + considering 4 aspects above = Optimal Solution

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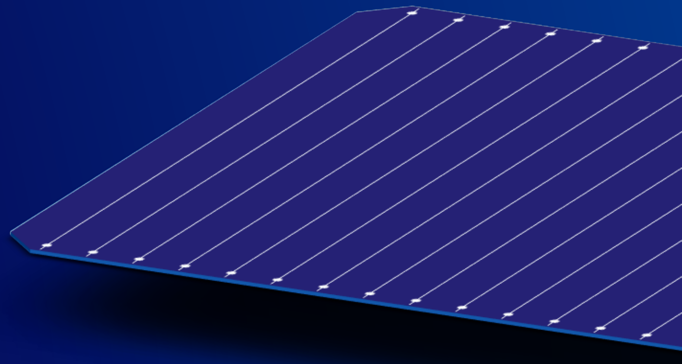
DEEP BLUE 4.0 Pro

New-generation N-type Products by JA Solar



DeepBlue 4.0 Pro

Design Concept of DeepBlue 4.0 Pro

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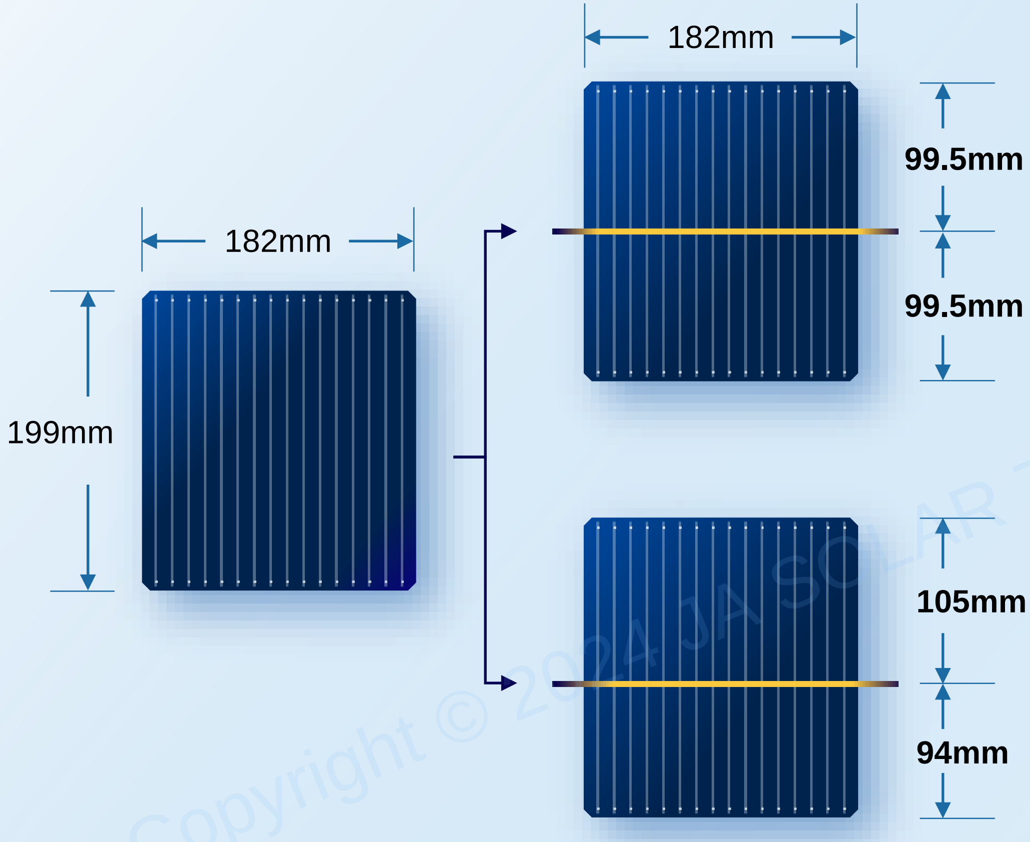
	54c		48c	66c	72c		78c
Module type	54c	54c	48c	66c	72c	72c	78c
Module length	1722	1762	1762	2382	2278	2333	2465
Wafer size (mm)	182*182 182*183.75 182*185.3	182*186.8	182*210	182*210 182*191.6	182*182 182*183.75 182*185.3	182*186.8	182*182 182*183.75 182*185.3

- The industry's mainstream 54/66/72/78c modules require at least three different sizes of silicon wafers
- JA Solar released a new generation of rectangular wafer size solution at SNEC 2023, solving the industry's difficulty in unifying wafer sizes.

Design Concept of DeepBlue 4.0 Pro

JA SOLAR

The new-generation **182mm*199mm** rectangular wafers showing stronger industry chain and industry inclusiveness



182mm*199mm half cell

635w
72c / 2465 *1134

585w
66c / 2278 *1134

182mm*210mm half cell

615w
66c / 2382 *1134

182mm*188mm half cell

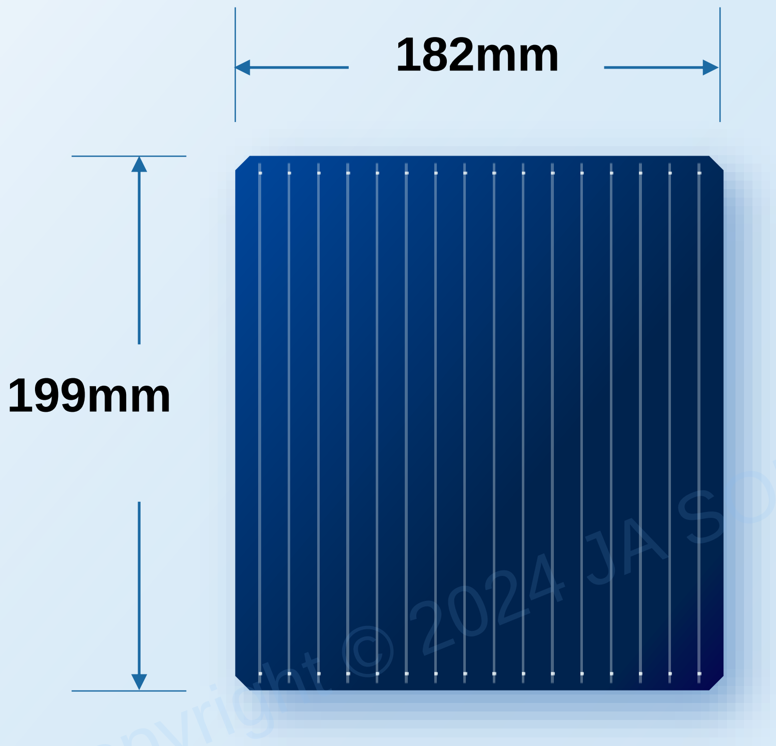
605w
72c / 2333 *1134

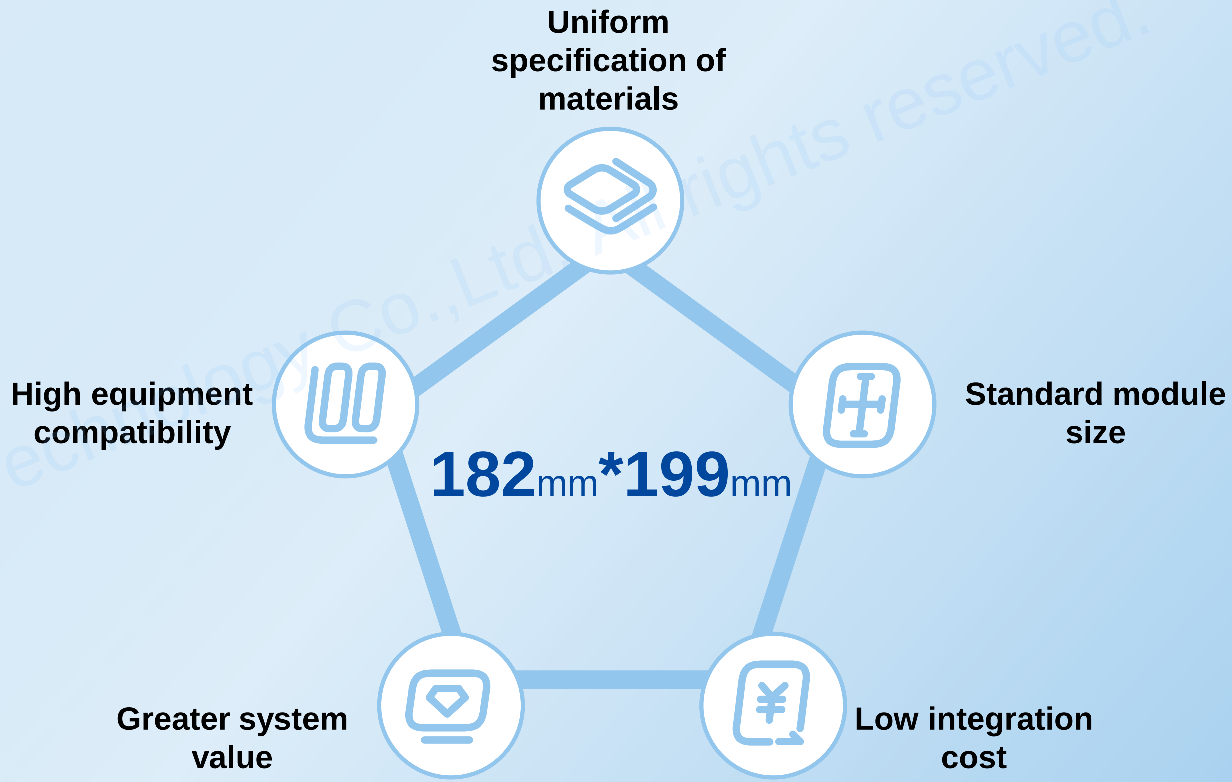
455w
54c / 1762 *1134

Design Concept of DeepBlue 4.0 Pro

JA SOLAR

The new-generation **182mm*199mm** rectangular wafers showing stronger industry chain and industry inclusiveness

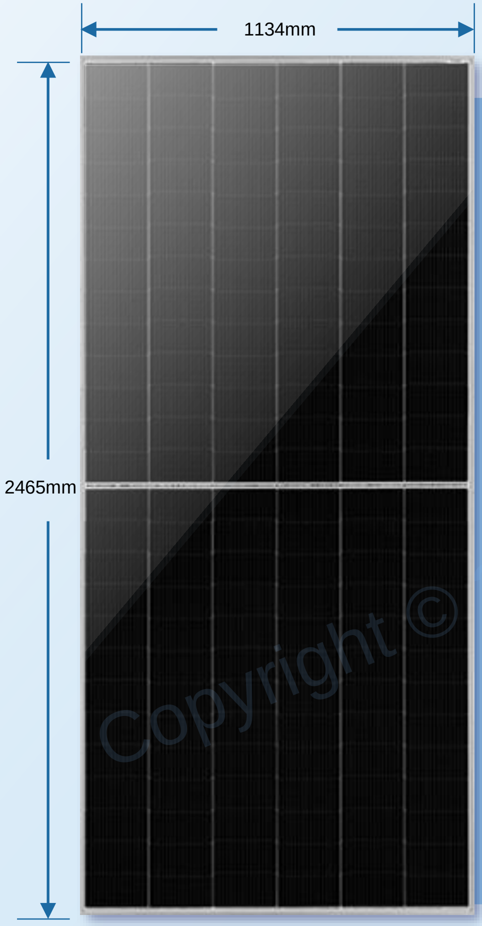




Design Concept of DeepBlue 4.0 Pro

Introduced in 2021, the **2465mm*1134mm** dimension has become an important product specification in the industry, widely applied and market-tested across various scenarios.

With higher power, better reliability and lower BOS cost, JA Solar's JAM72D42 module is currently the best module solution among all 182 series products.

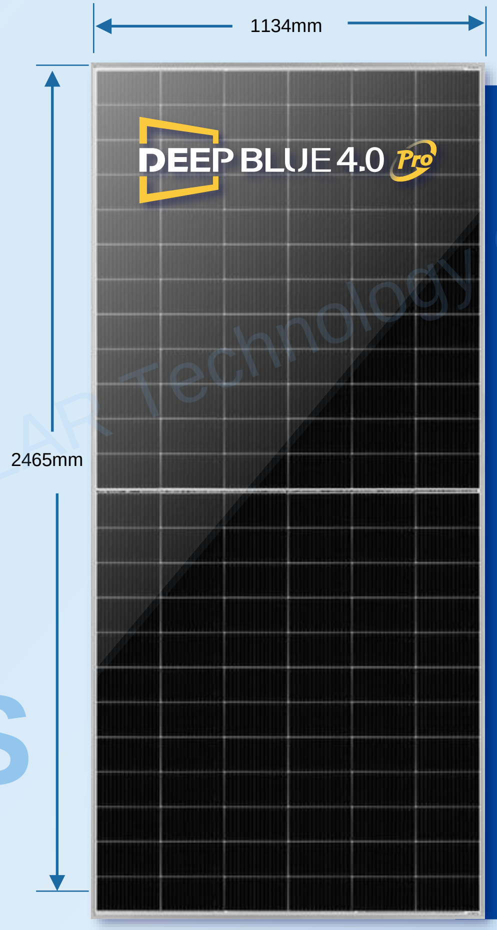


Industry mainstream 182-78 modules

78c

630W
22.6%

VS



JAM72D42

72c

635W
22.8%

Voc ↓ **7.69%**

Module:

Lower hot spot risk

System:

- The number of modules per string increases, lowering the BOS cost by about 0.5%.
- Good compatibility with 15A inverter.

Design Concept of DeepBlue 4.0 Pro — Offshore PV Solution

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DEEP BLUE 4.0 Pro

Fixed Pile-Based PV

SKYBLUE

Floating PV

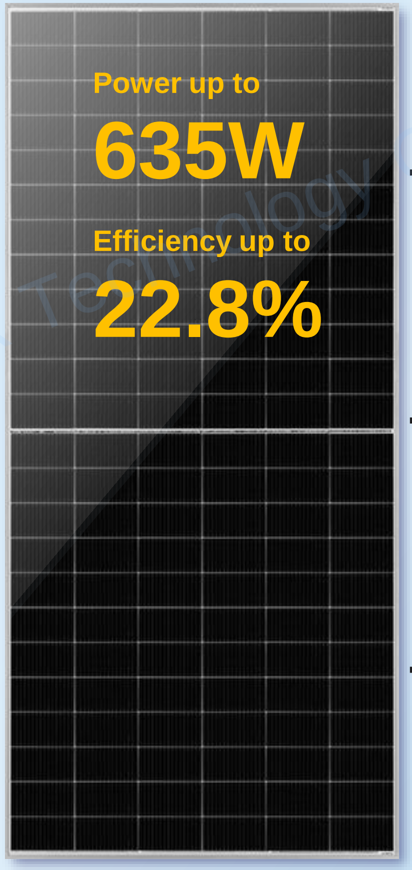
OCEANBLUE

Front Glass
Moisture resistance
Salt mist resistance

Encapsulation
EPE with optimized
POE layer

Connector
Connector protection

Frame
With thick oxide film
High corrosion resistance



Low Carbon

Light Weight

High Reliability

High-efficiency Bycium+ Cell Technology

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26%

Efficiency in Mass Production

733mV

Voc

Front surface SMBB + LECO

Laser-enhanced contact optimization (LECO)

Front surface passivation

FSP ($J_{0\ Front}$<8 fA/cm^2)

Selective emitter

N-type substrate

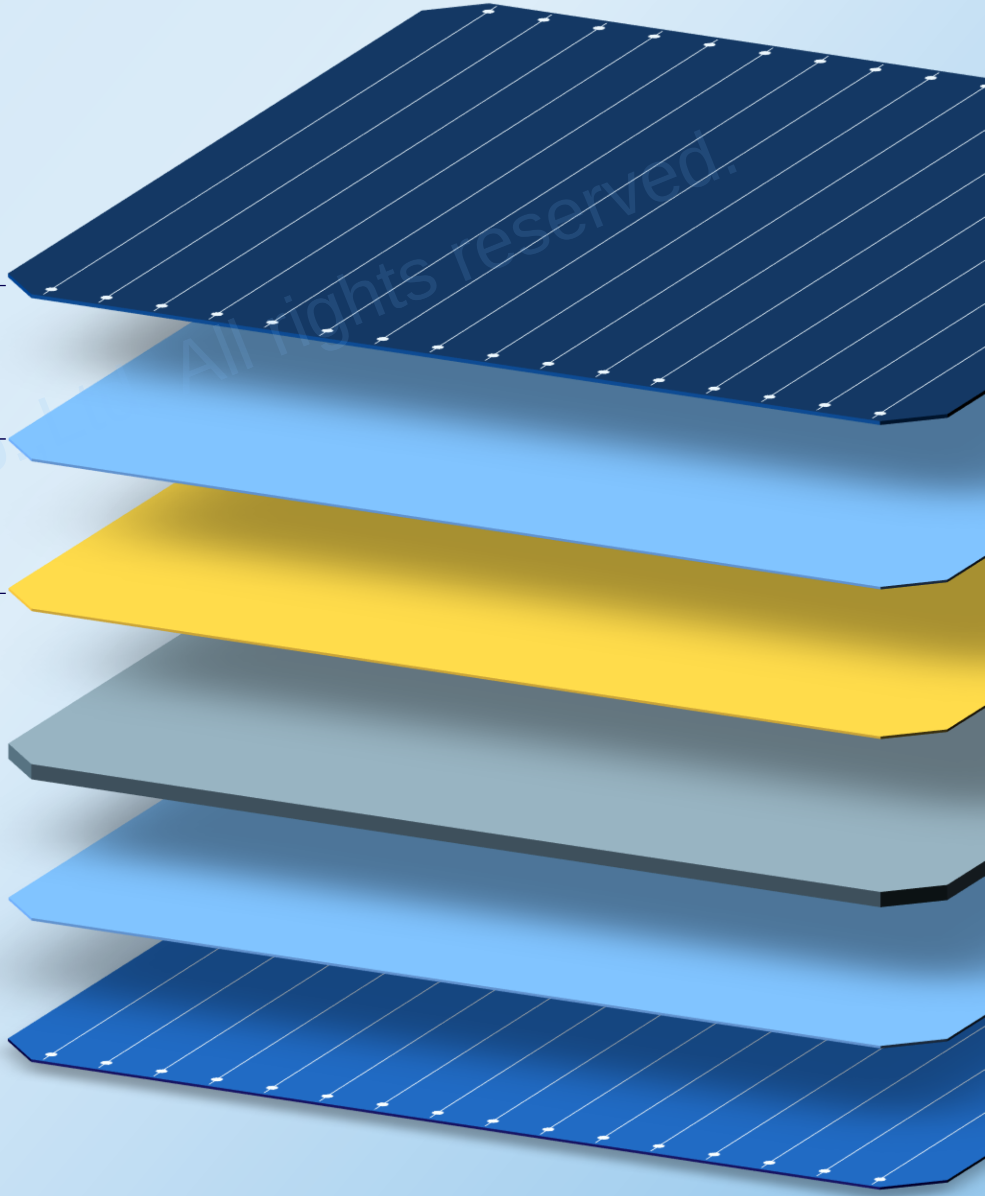
N-type low-oxygen silicon wafer (11 ppma)
Millisecond-class minority carrier lifetime

RSP + passivated contact

Rear surface recombination ($J_{0\ Rear}$<2 fA/cm^2)

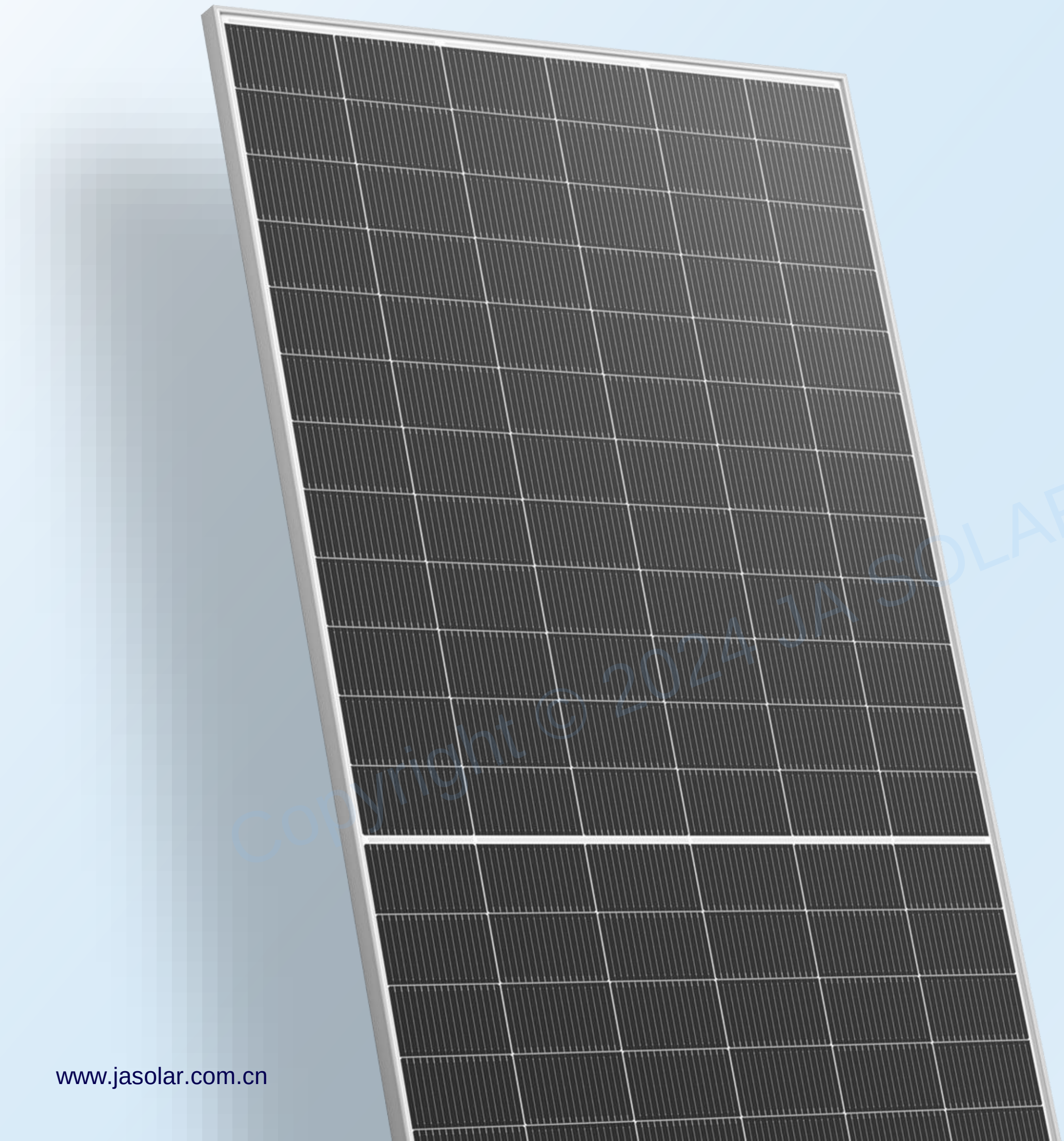
Rear surface SMBB

Double-side ARC + ultra-fine busbars



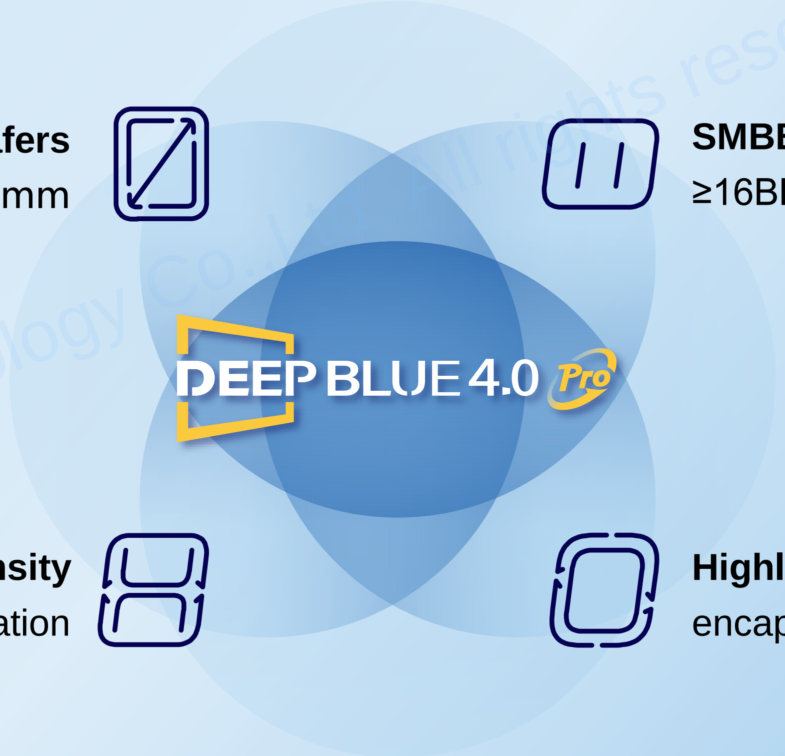
Advanced Module Technology

High-power and high-performance modules — rectangular wafers + SMBB + high-density encapsulation + highly reliable encapsulation materials



Rectangular wafers
182mm*199mm

SMBB
≥16BB

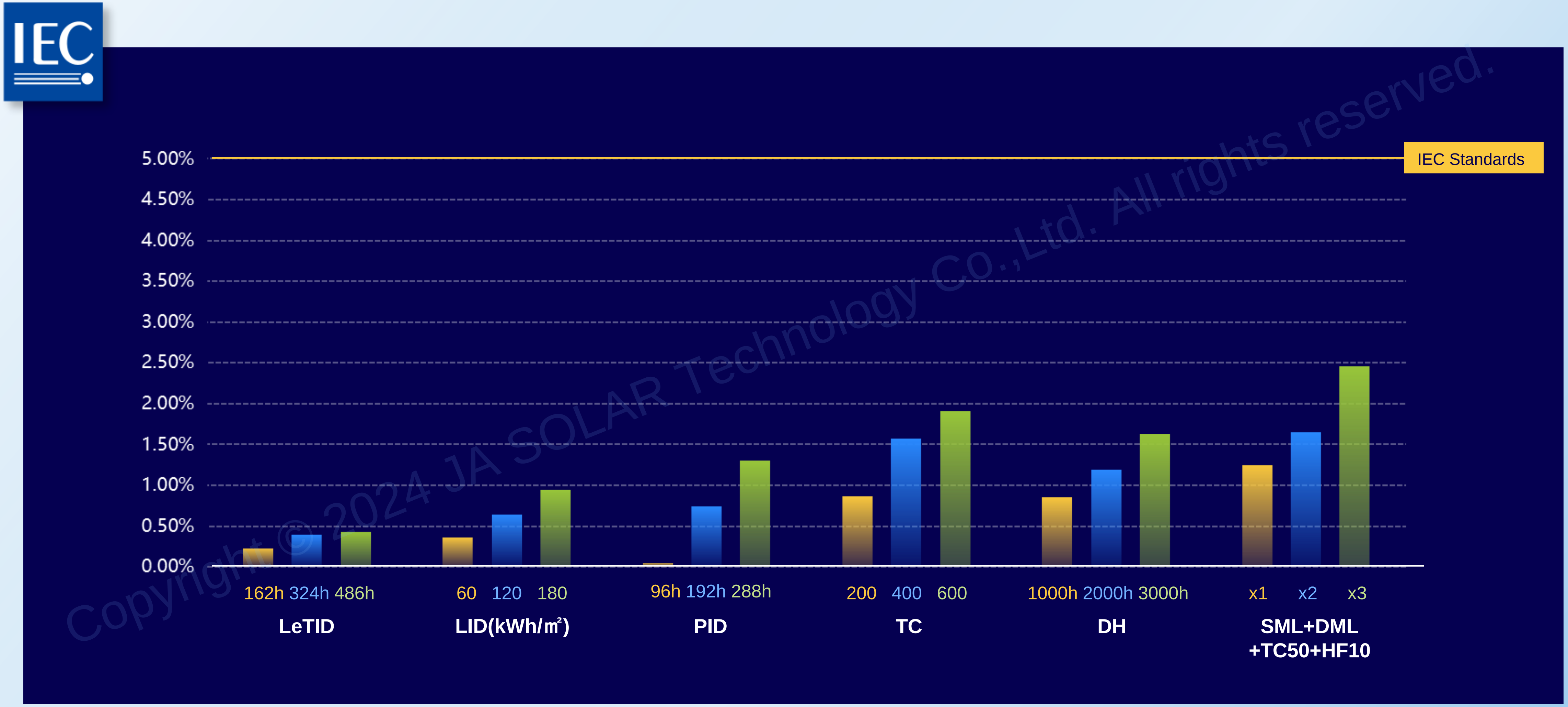


High-density
Encapsulation

Highly reliable
encapsulation materials

Excellent Reliability

Deep Blue 4.0 pro performs exceptionally well in various rigorous tests according to the IEC testing standards



Excellent Reliability

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Capable of withstanding repeated exposure to salty atmospheres, immersion in seawater and temperature changes caused by seawater splashing on modules in sunlight.

ASTM INTERNATIONAL

ASTM E1597 Standard Test

* Demonstrating the ability of PV modules to withstand repeated immersion or splash exposure by seawater as might be encountered when installed in a marine environment, such as a floating aid-to-navigation.

Saltwater Pressure Immersion and Temperature Testing

Only 0.322% power degradation

The test simulates immersion of modules in sealed containers at 45°C and 5°C, applying a pressure of 35 kPa, under specific seawater concentration (density 1.025 + 0.005 g/L) at 15°C. A total of 500 thermal cycles were conducted

4 modules
- MQT 01 Visual inspection
- MQT 19.1 Initial stabilization
- MQT 02 Maximum Power Determination
- Electroluminescence test
- MST 16 Insulation test
- MST 17 Wet leakage current test
- MST 13 Continuity test of equipotential bonding

3 PV modules → Saltwater Pressure Immersion and Temperature Testing (PIT 500)

1 control PV module →
- MST 16 Insulation test
- MST 17 Wet leakage current test
- Rinse the samples
- MQT 01 Visual inspection
- MQT 02 Maximum Power Determination
- Eleetrolumninescence test
- MST 13 Continuity test of equipotential bonding

DEEPBLUE 4.0 Pro

Performance Analysis of DeepBlue 4.0 Pro

Power Generation Performance

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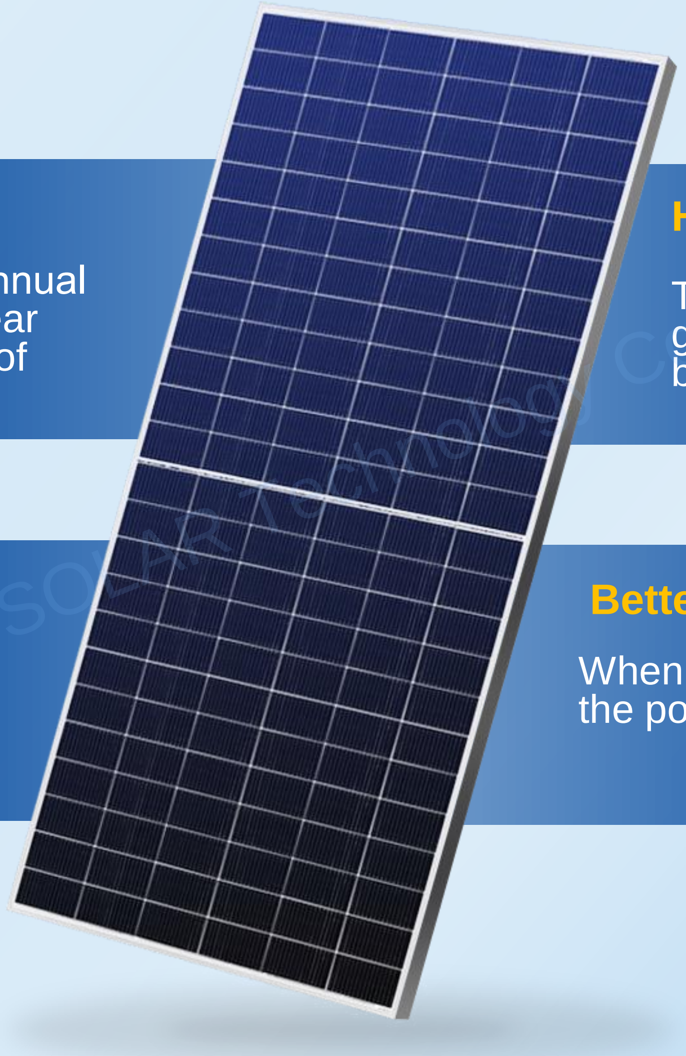
Lower power degradation

First year power degradation ≤ 1%, annual power degradation rate ≤ 0.4%, 30-year life cycle, and power generation gain of about 1.8%

Higher bifacial benefits

The bifaciality rate is about 80%; the power generation gain brought by a 10% bifaciality increase is around 0.8% -1.2%



Better temperature coefficient

The power temperature coefficient of the module is -0.30%/℃; in high temperature environments, the power generation gain is about 1.5% -2%

Better low light performance

When the irradiance is below 600W/ m^2, the power generation gain is about 0.2%

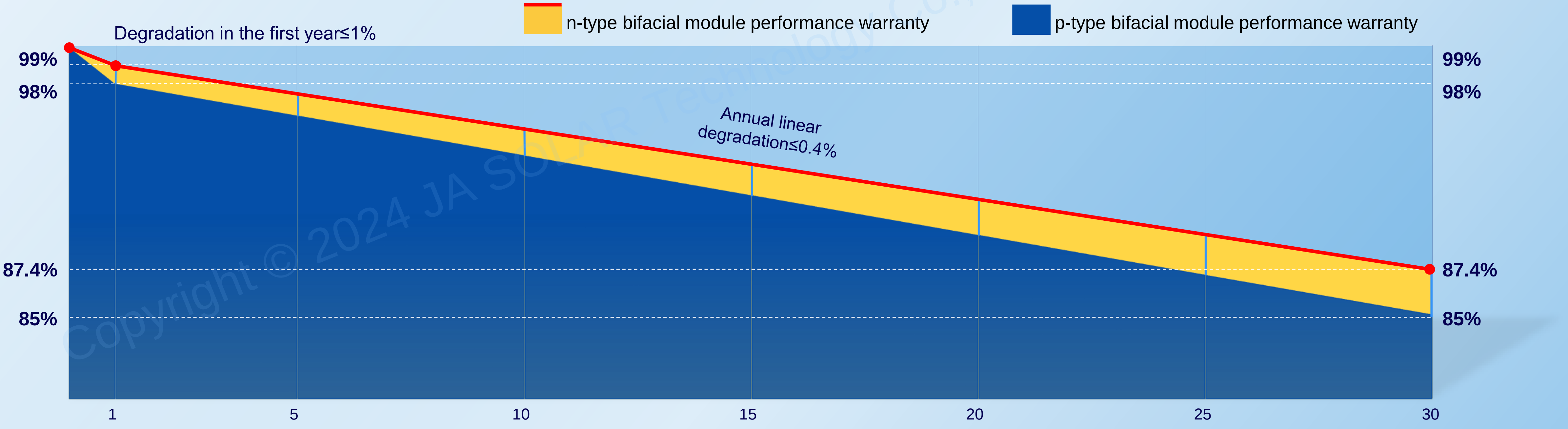
Power Generation Performance — Lower Degradation

≤1%

1st year Degradation

≤0.4%

Annual degradation over 30 years



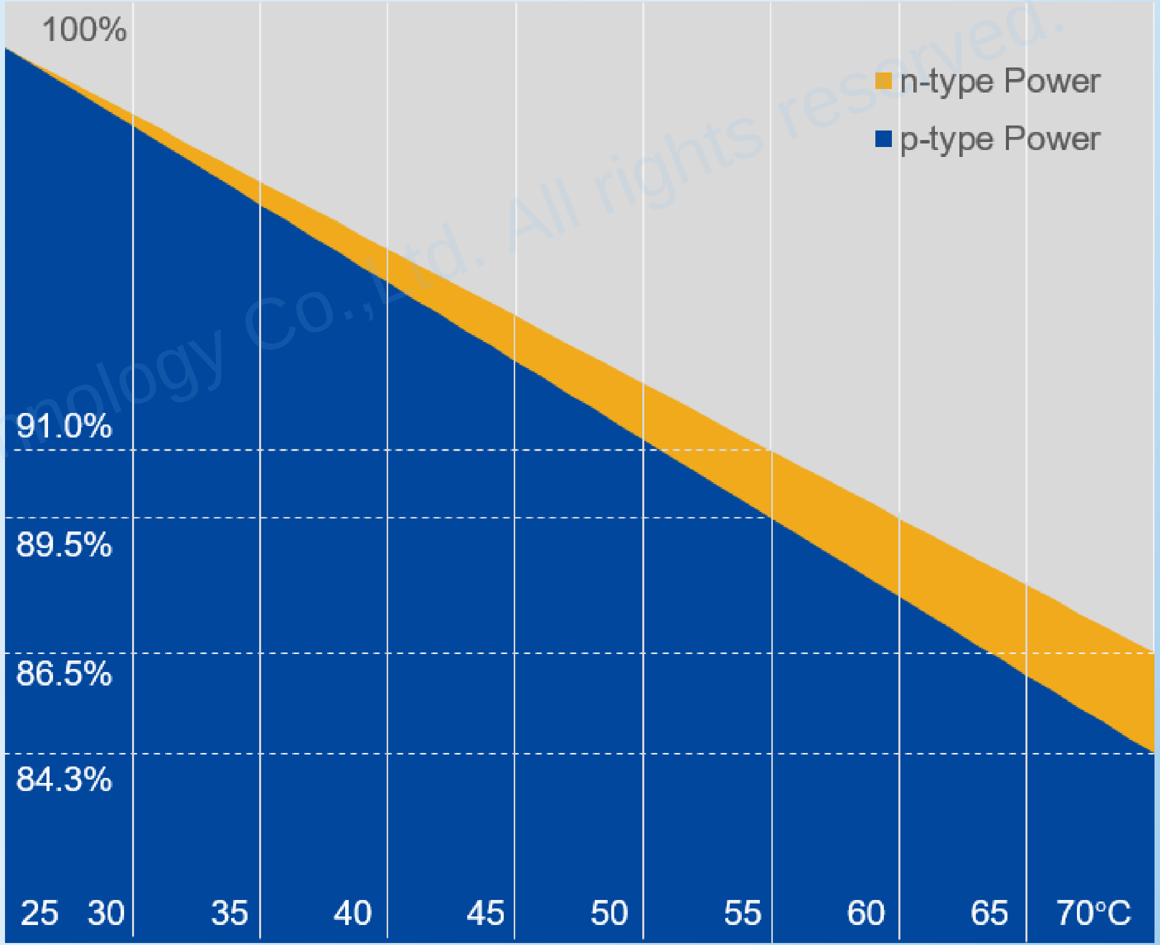
Power Generation Performance — Better Temperature Coefficient

The temperature coefficient for Pmax is as low as

-0.30%/℃

Power generation benefits in high temperature environments

1.5-2%



Power comparison of n-type and p-type PERC modules

Power Generation Performance — Higher Bifacial Power Gain

Bifacial ratio

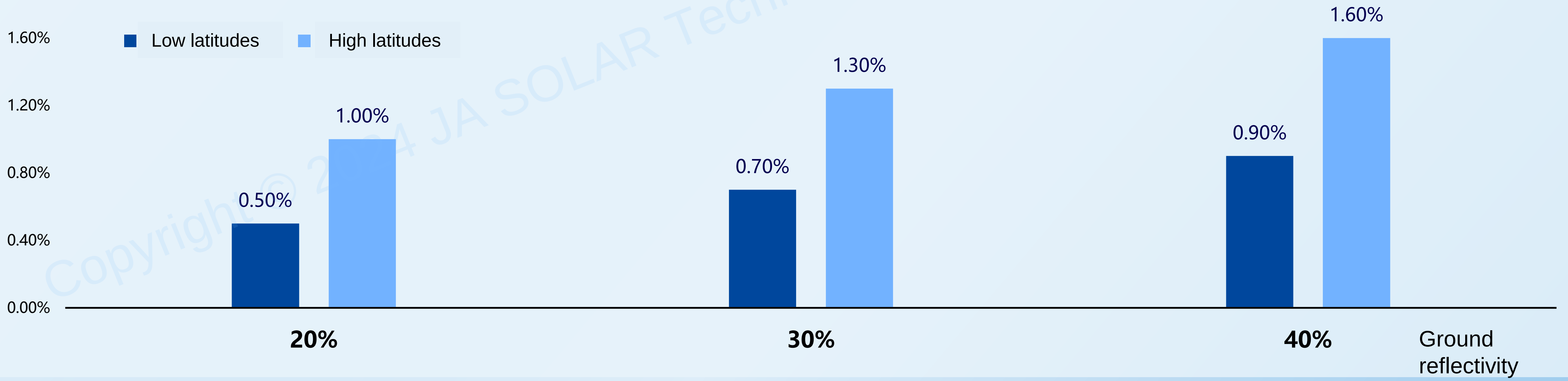
80% p-type **70%**

Power generation benefits

0.8~1.2%

10% difference in bifacial ratio

Power generation benefits at various latitudes and ground reflectance



Power Generation Performance — Excellent Low Light Performance

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Bycium+ cells have better low irradiance performance due to its longer minority carrier lifetime, better passivation and reduced recombination. During early mornings or late evenings with around 400W/m^2 irradiance, DeepBlue 4.0 Pro showcases an energy yield gain of approx. **0.2%.**

At an irradiance level below 600 W/m^2

the benefit is approx. 0.2%

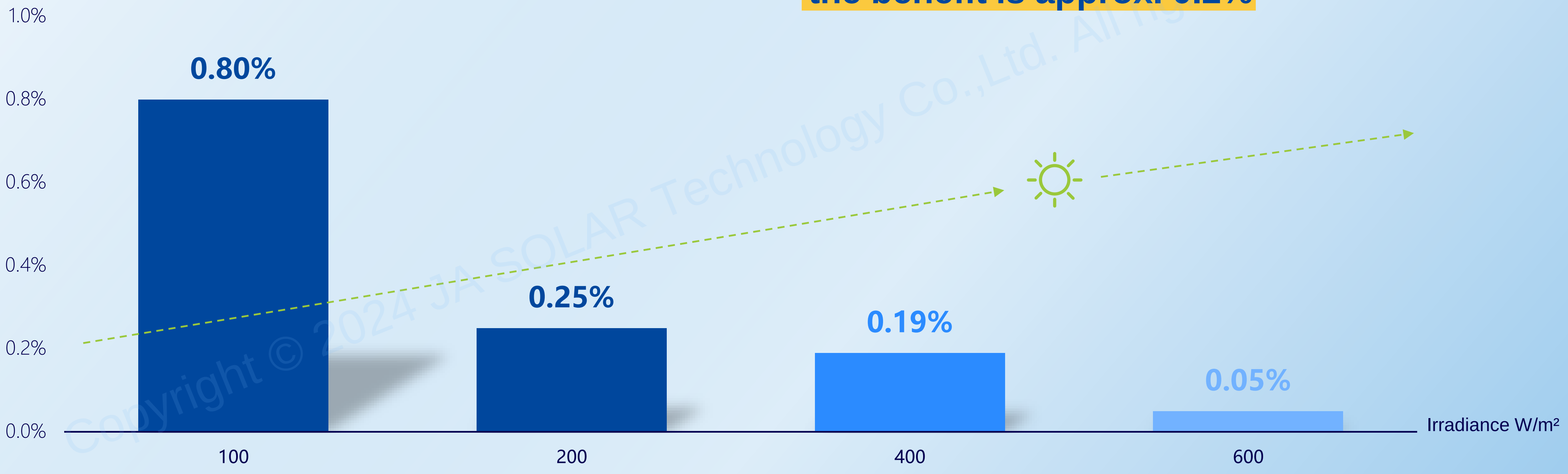

Fig. DeepBlue 4.0 Pro module low irradiance power generation gain

DeepBlue 4.0 Pro — Customer Value Analysis

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DeepBlue 4.0 Pro modules offer lower BOS & LCOE, delivering greater customer value

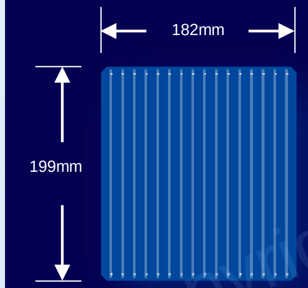
DeepBlue 4.0 Pro VS p-type module		DeepBlue 4.0 Pro VS Original n-type module	
↓ 2%-4.5% Lower BOS	↓ 2.5%-6% Lower LCOE	↓ 1.4%-2.8% Lower BOS	↓ 0.7%-1.6% Lower LCOE

DeepBlue 4.0 Pro Series — Integration and Win-win

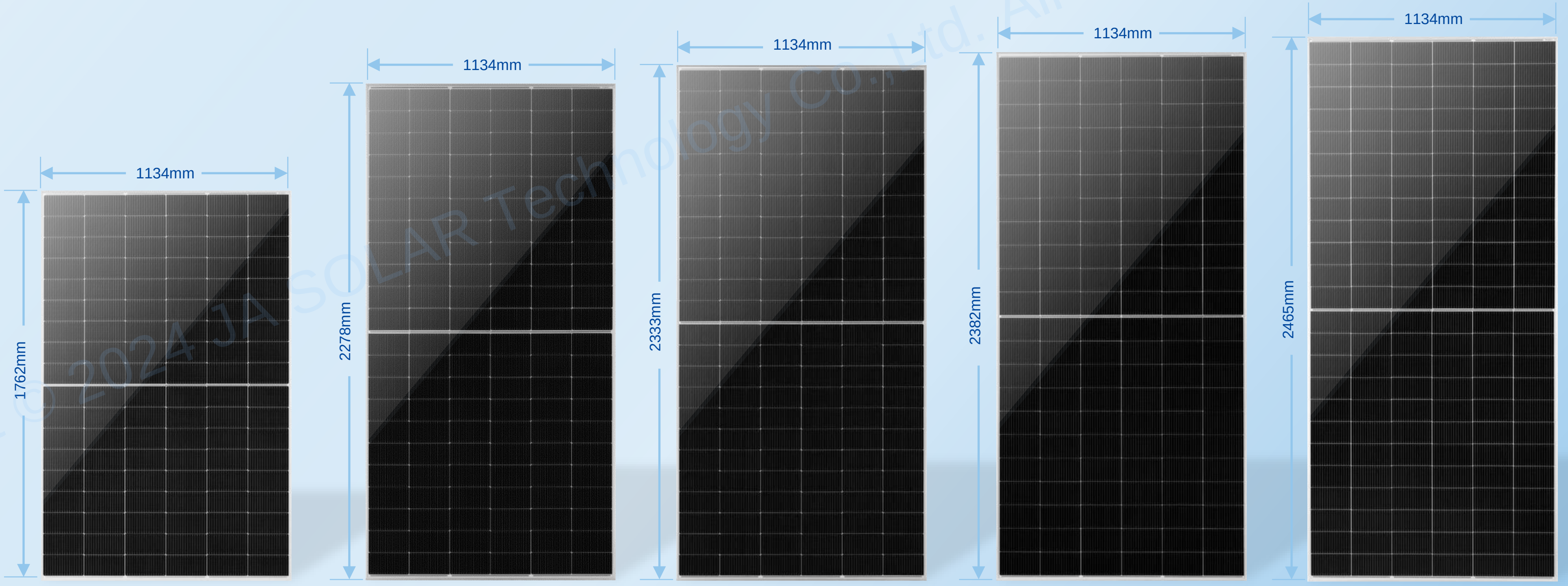
4 types of high-efficiency and high-power modules and **1** type of conventional modules can satisfied customers' needs in various scenarios.

182mm*199mm

1 wafer size
5 types of module



Residential	Commercial & Industrial, Utility-Scale			
455W	**585W**	**605W**	**615W**	**635W**
22.8%	22.7%	22.8%	22.8%	22.8%
22kg	31.8kg	32.5kg	33.1kg	34.6kg



JAM54D40/LB	JAM66D42/MB	JAM72D40/LB	JAM66D45/LB	JAM72D42/LB

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Harvest the Sunshine

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Performance & reliability evaluation

of n-type high-efficiency PV modules

Yixiao Zhang | TÜV NORD China REN | 25.01.2024

Topics

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

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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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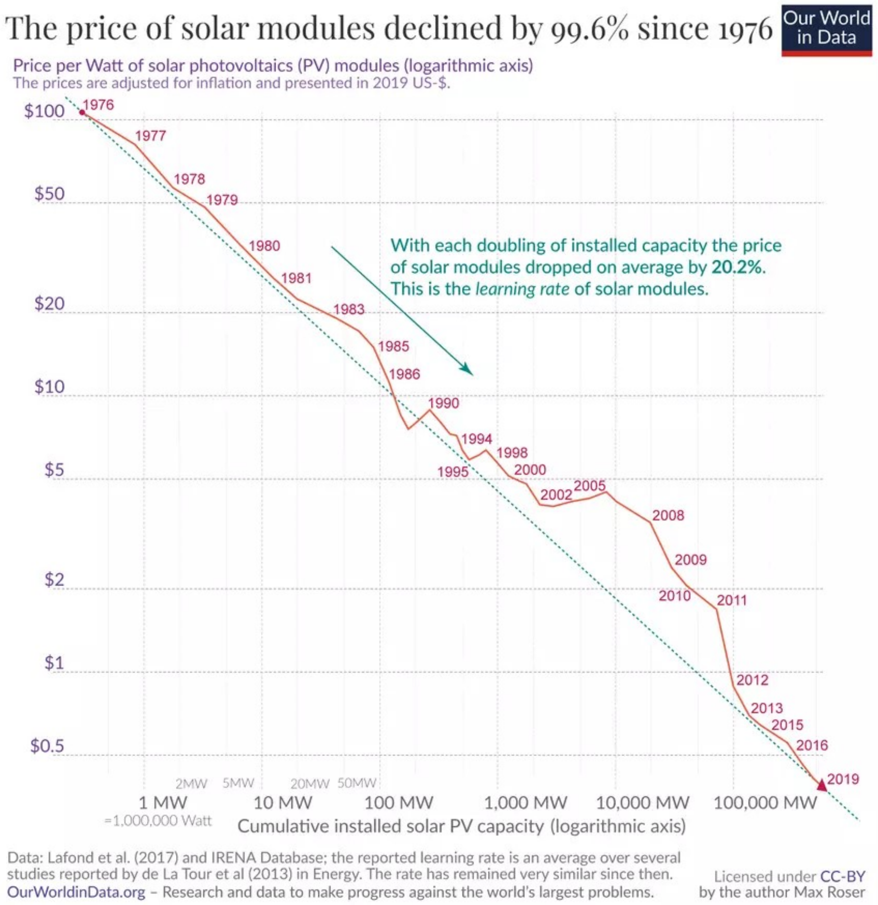
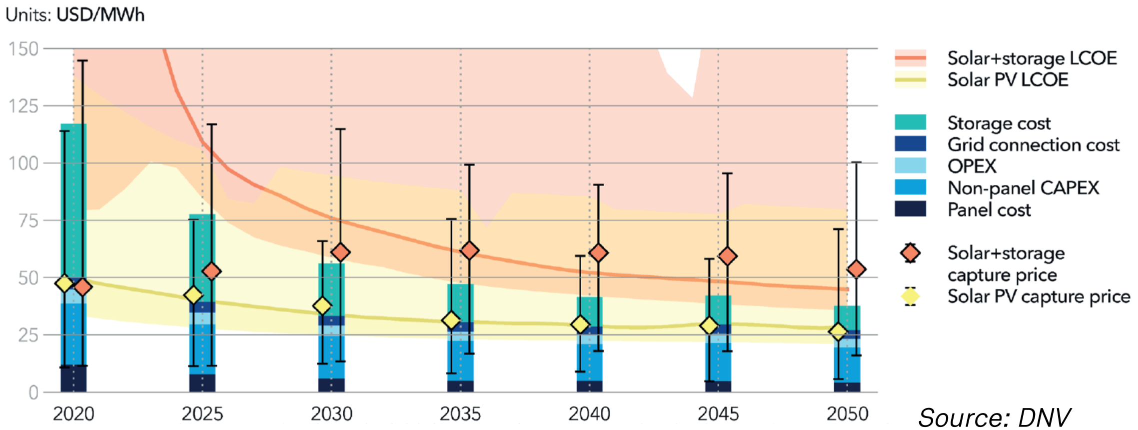
Global solar LCOE and capture price





Source: DNV

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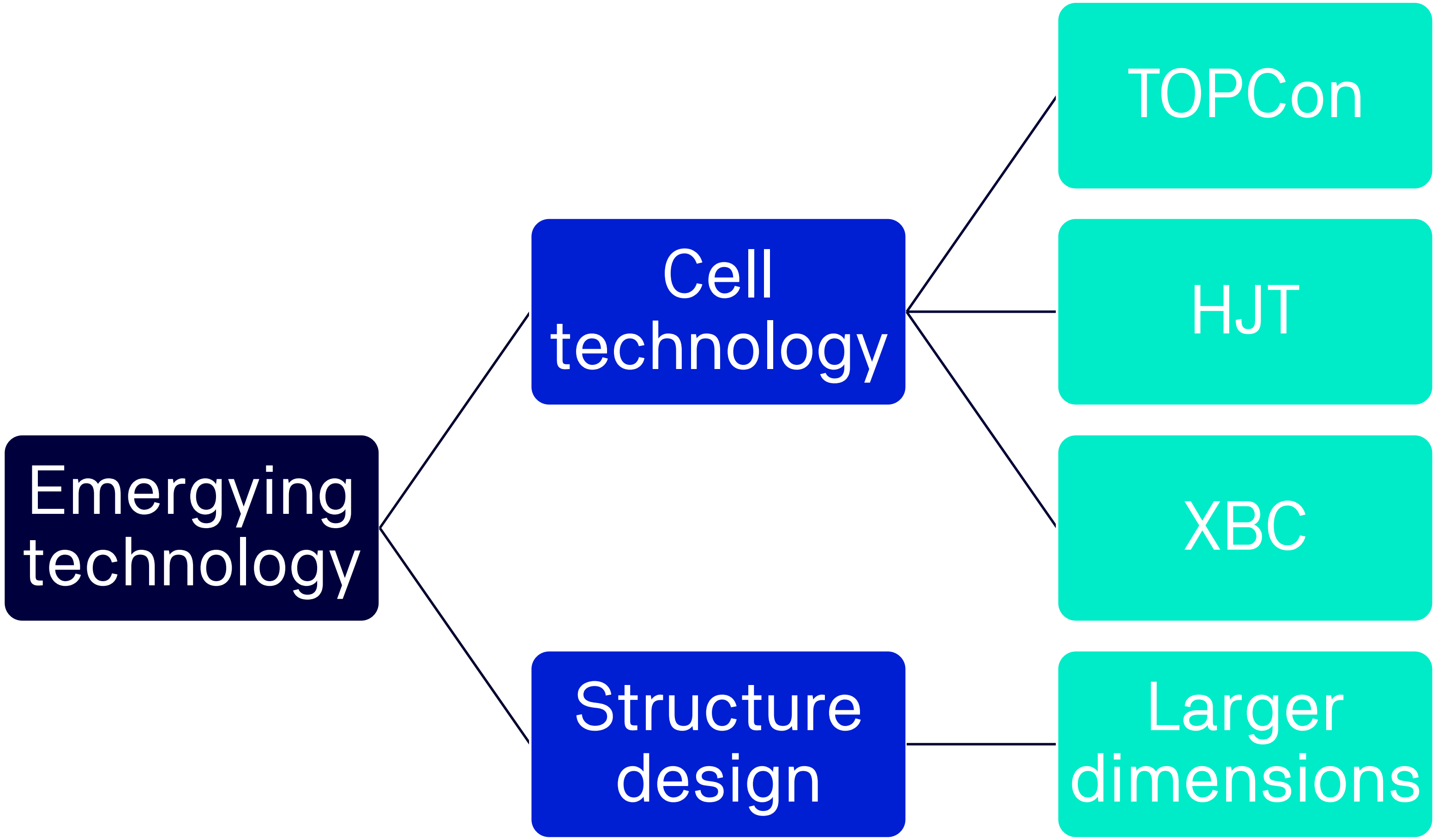
Emerging technology



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Topics

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

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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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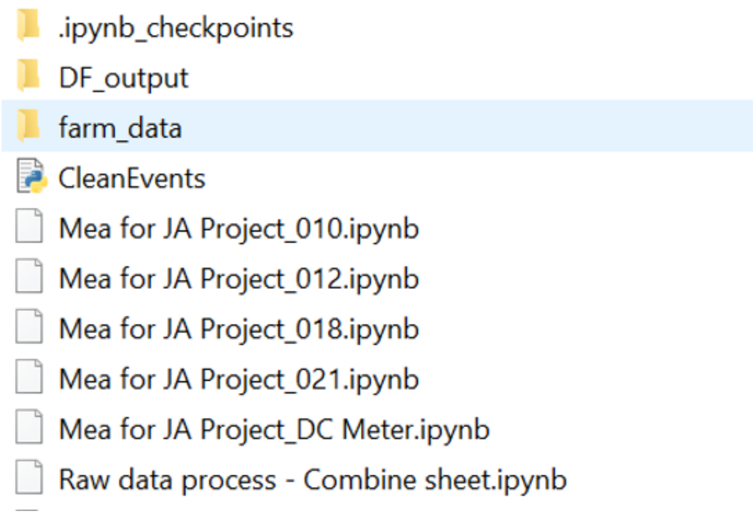
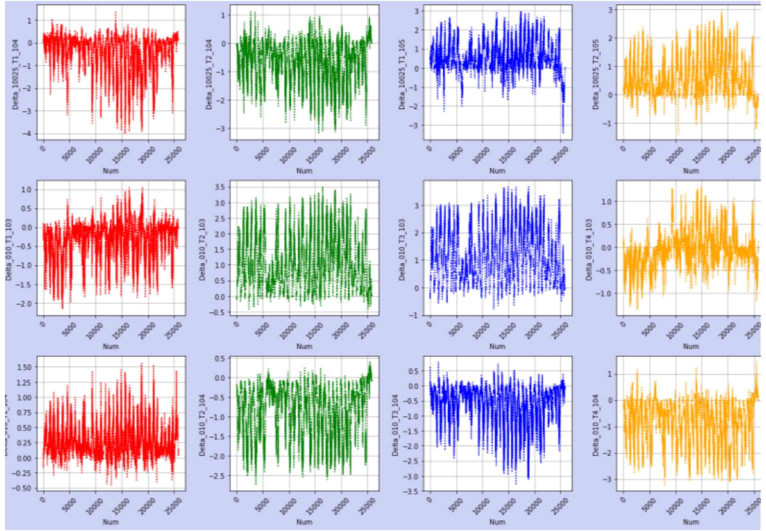
Outdoor performance test

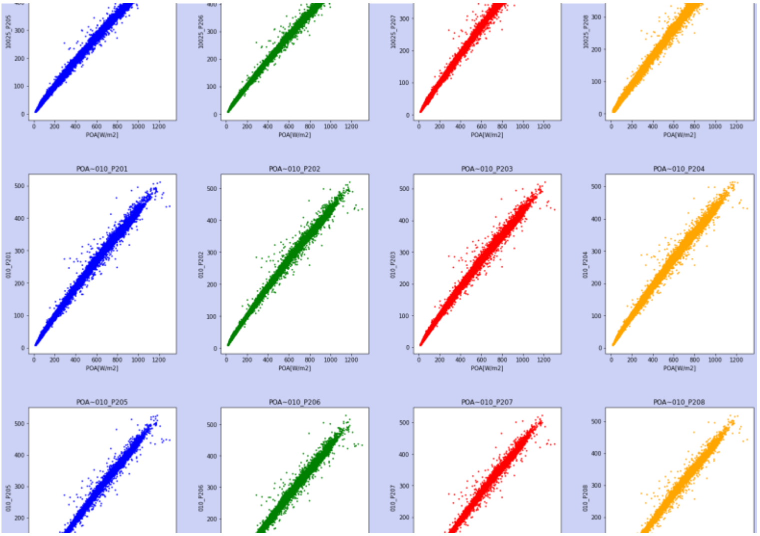
Python data analysis tool



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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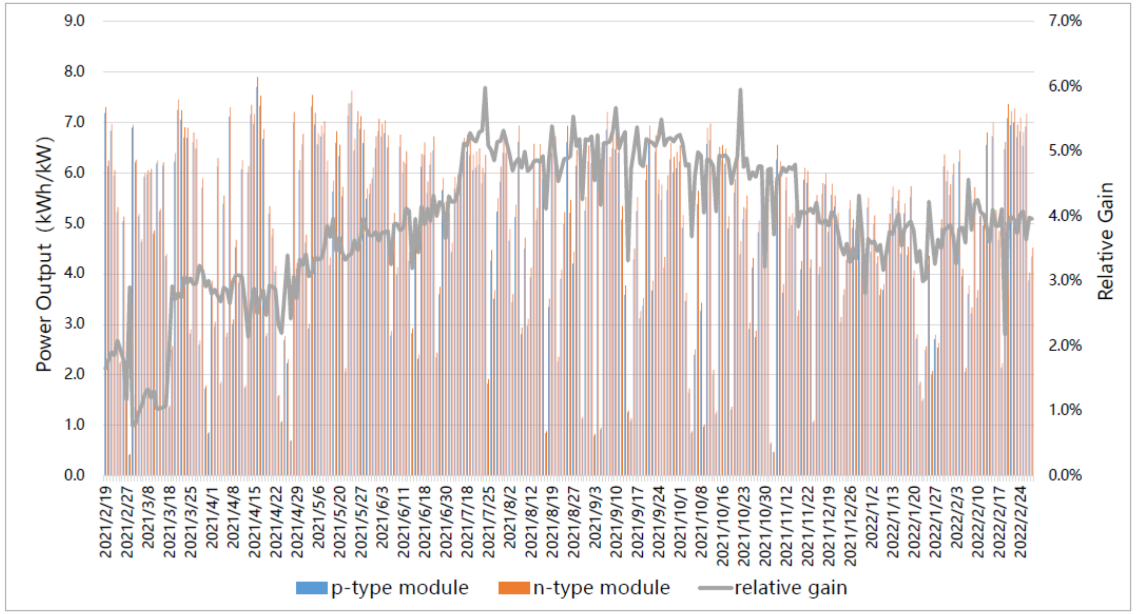
Outdoor performance test

Power generation

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



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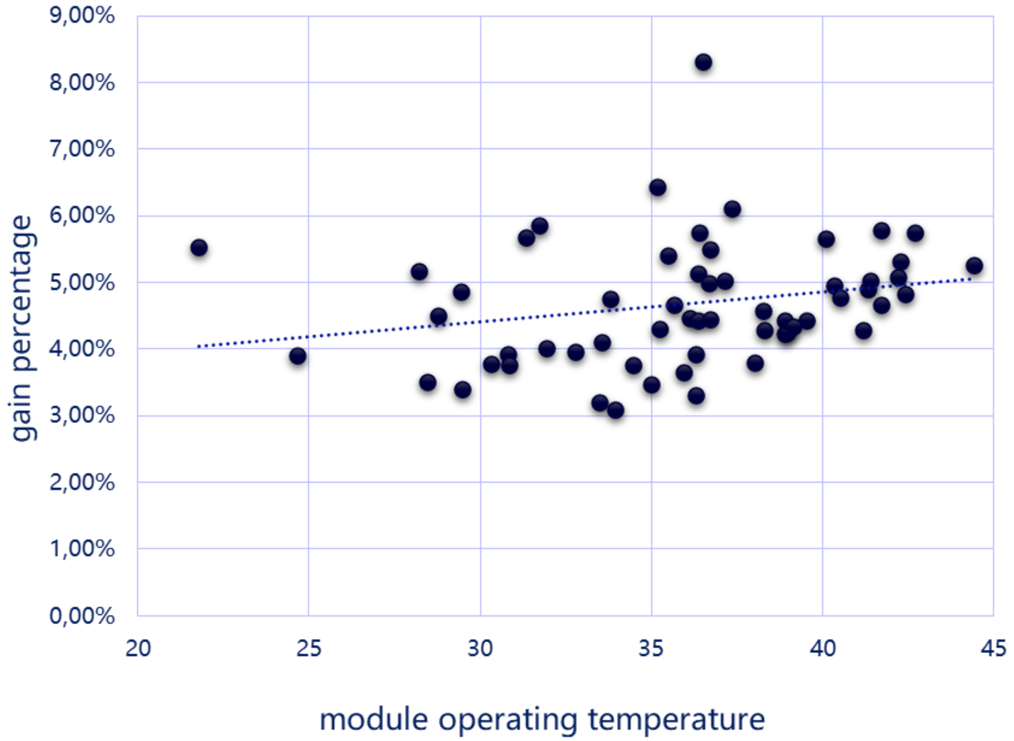
Outdoor performance test

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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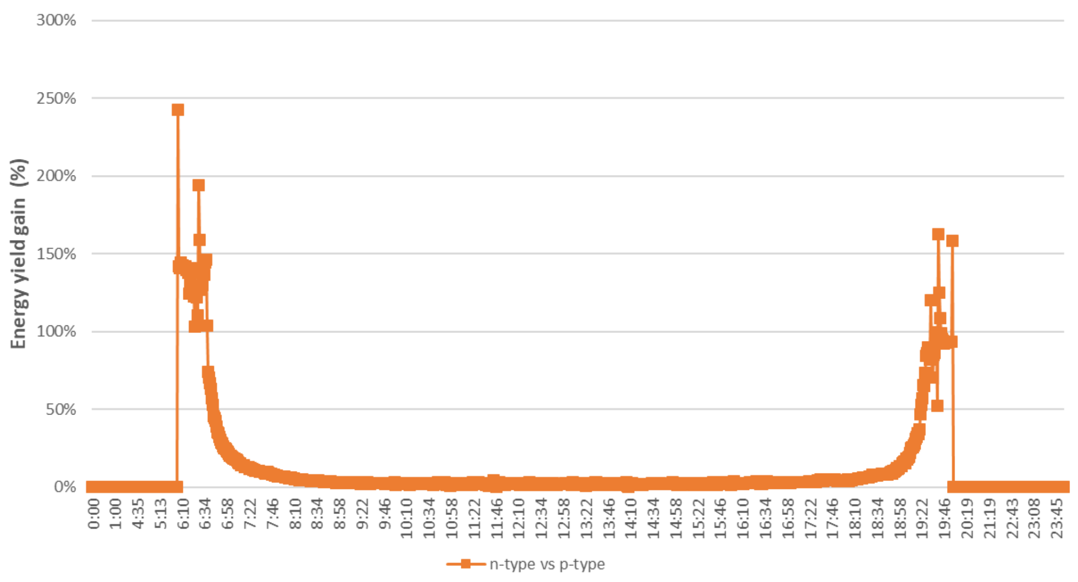
Outdoor performance test

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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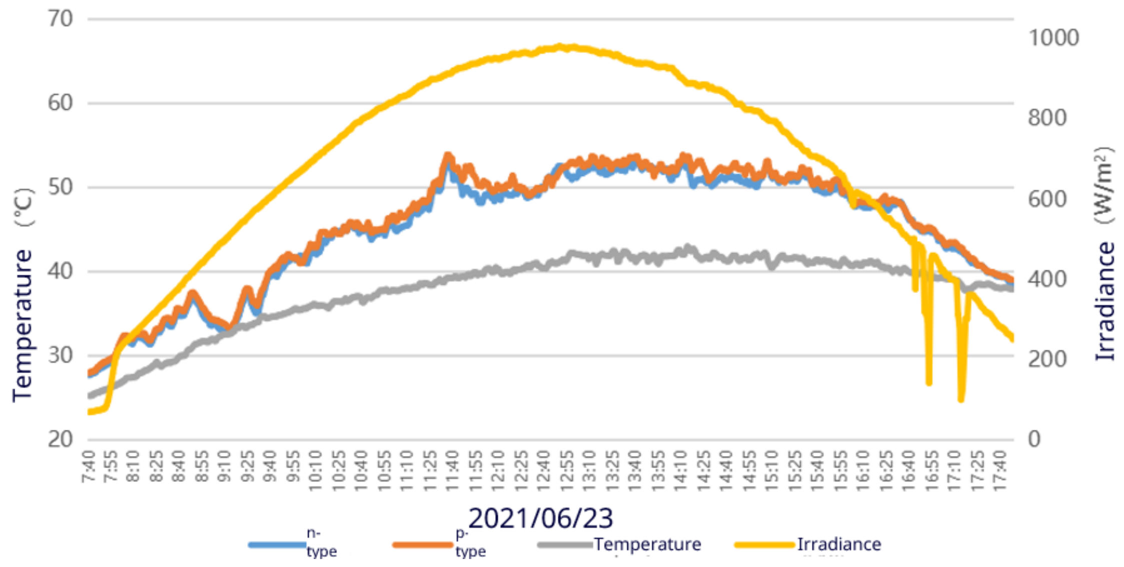
Outdoor performance test

Operation temperature

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



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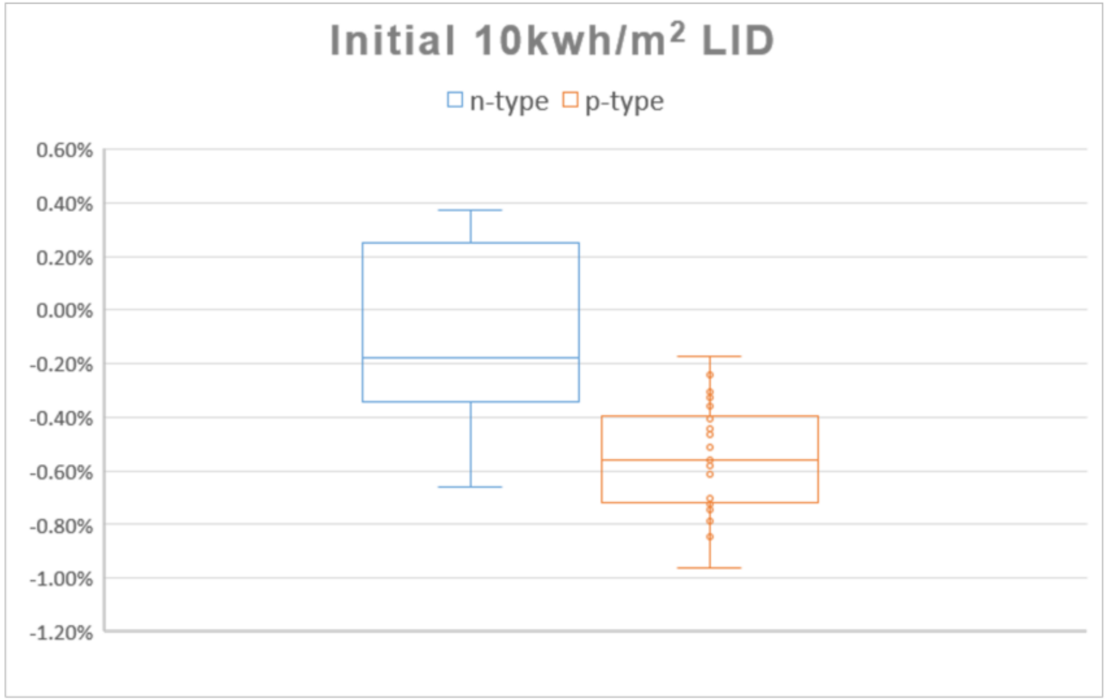
Lab performance test

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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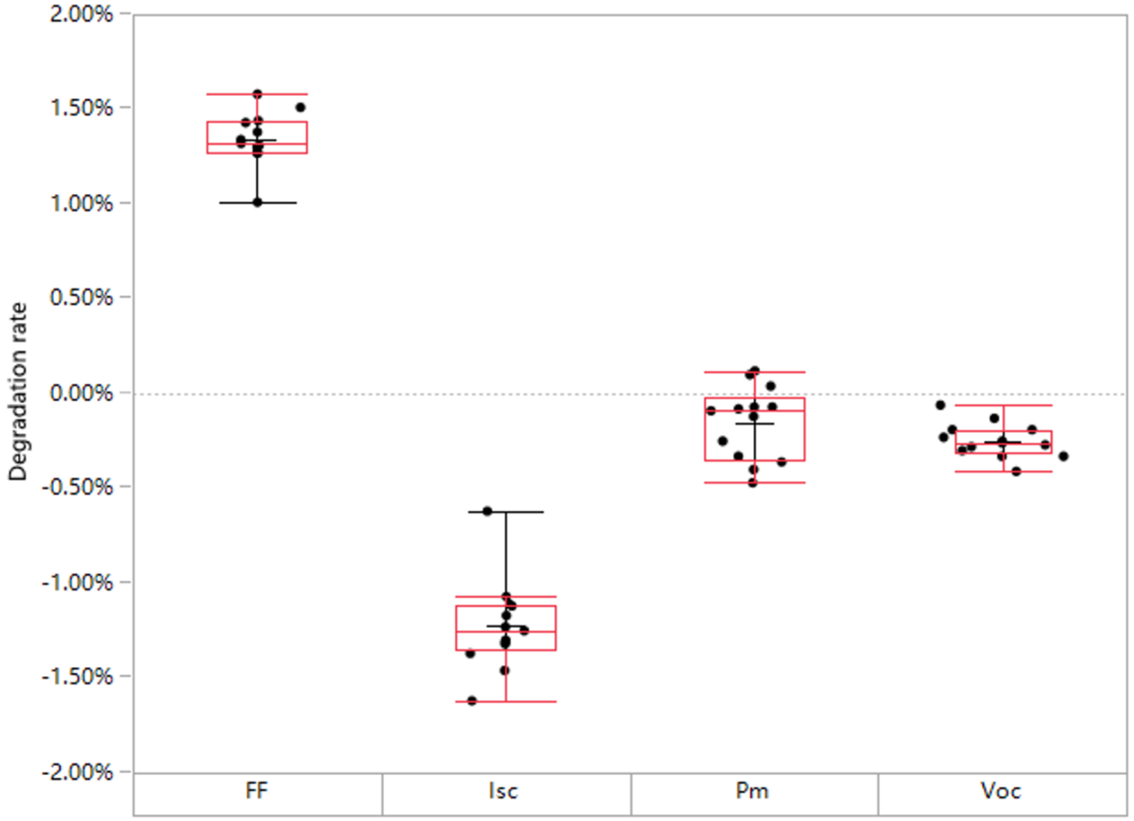
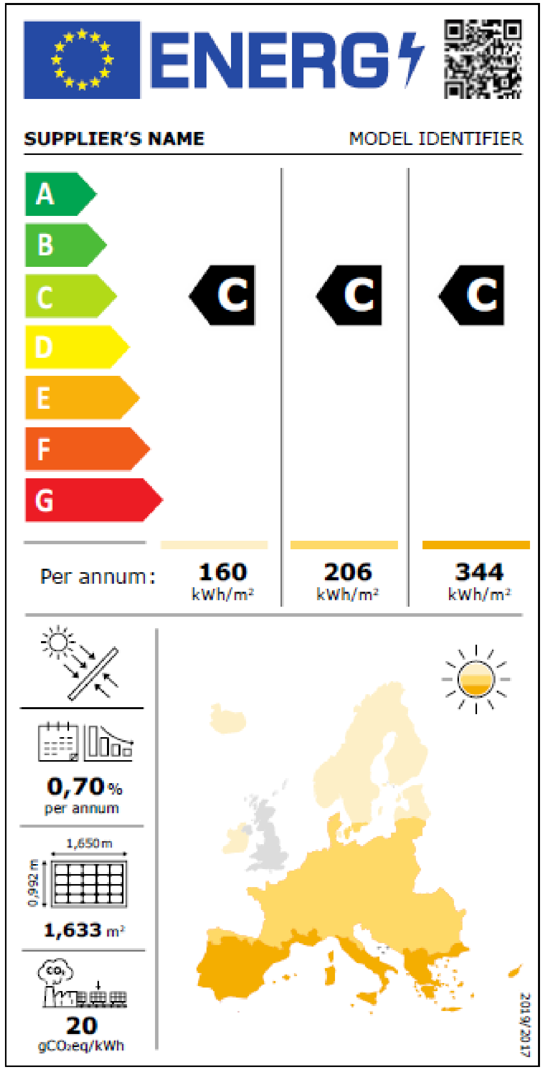
Outdoor performance test

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%.



Eco design & energy label



	Energy Efficiency Index (EEI_M), kWh/m^2		
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 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/m^2)	2295.5
CSER	93.3%
EEI_M	451.2
Energy Efficiency Class	C

Input parameters	
a_r	0.07491
β	20

Define same ar and β

TOPCon

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

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/m^2)	2295.5
CSER	98.3%
EEI_M	498.1
Energy Efficiency Class	B

TOPCon have better conversion efficiency

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Topics

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

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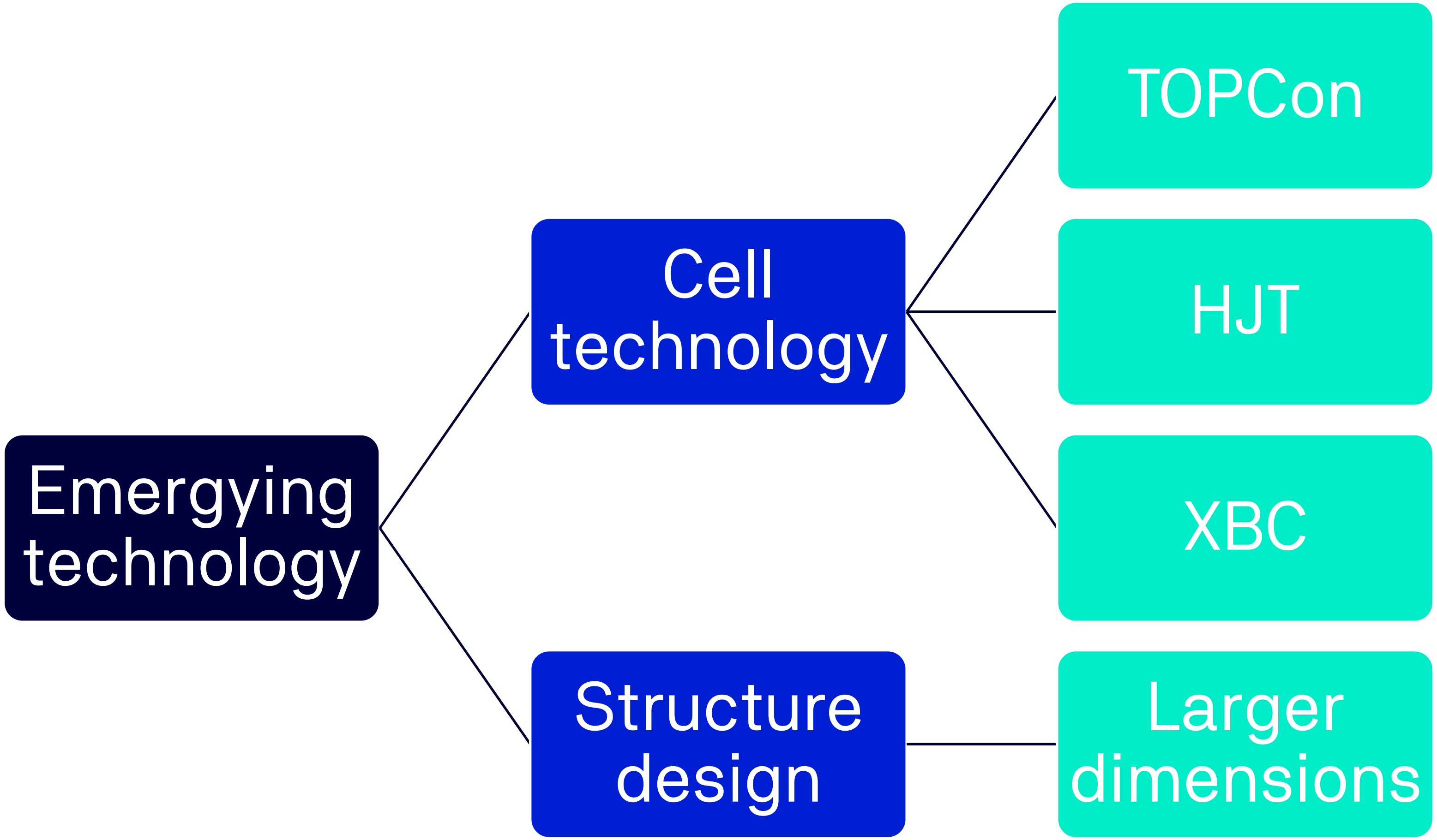
Emerging technology



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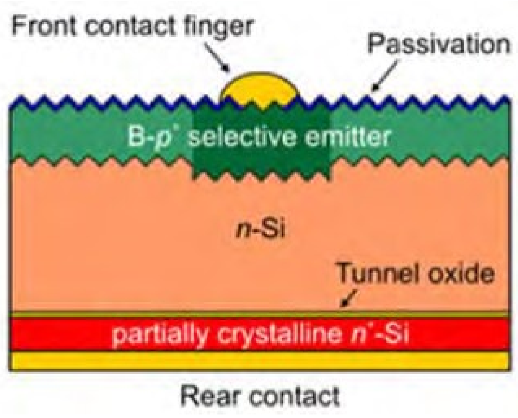
Characterizations of n-type modules with new cell technology

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



Production efficiency
25.0%-26.0%
Theoretical efficiency
28.2%~28.7%

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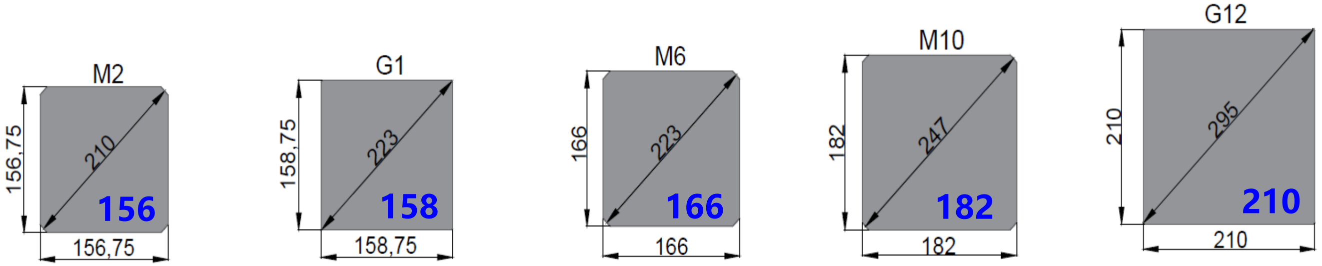
Characterizations of n-type modules with larger dimensions

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

Larger dimensions



	M2	G1	M6	M10	G12
	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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Topics

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

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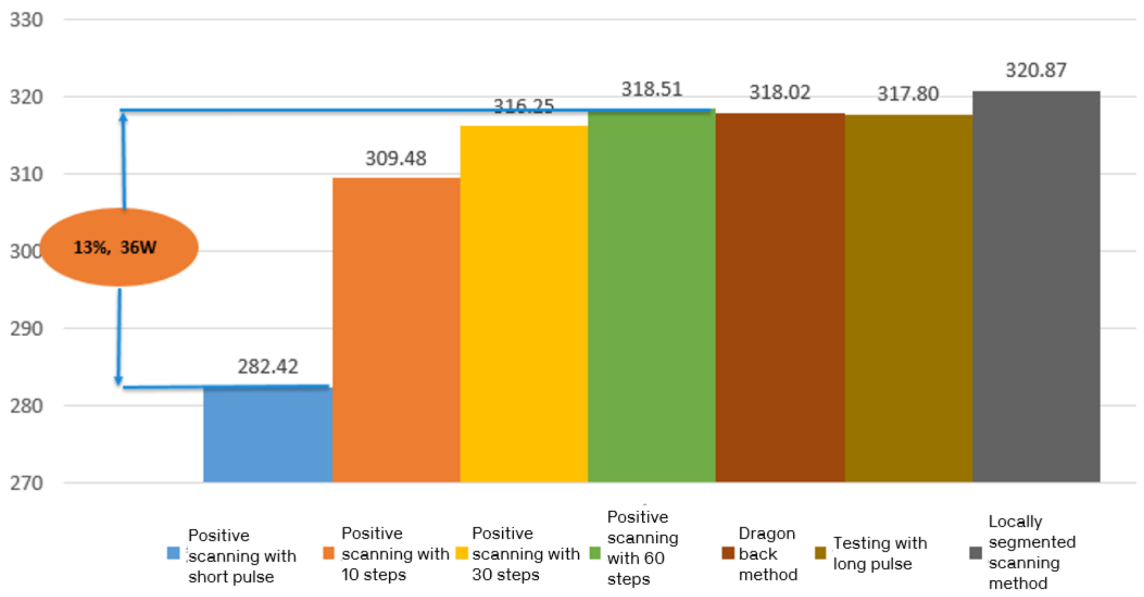
Accurate power testing

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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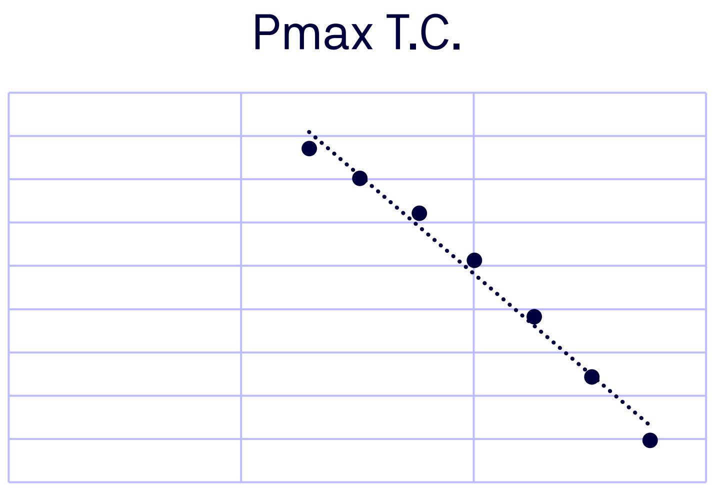
Accurate power testing

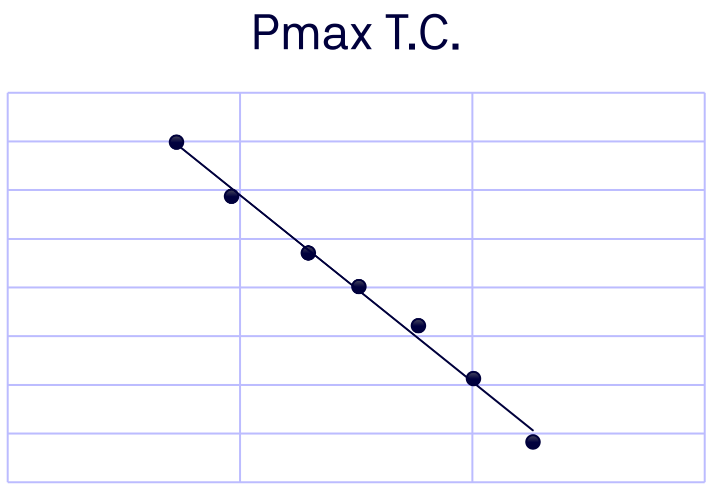
Temperature co-efficient

55°C - 25°C
γ = -0.352%



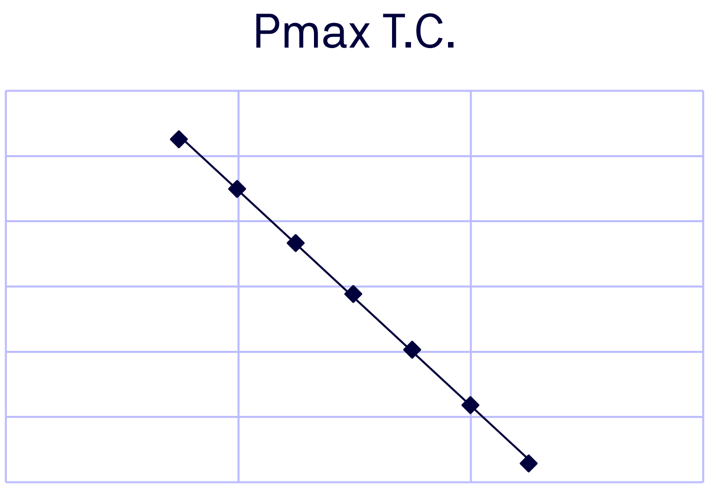
Regular natural cooling + 10ms pulse single flash

10°C - 25°C & 40°C - 25°C
γ = -0.312%



Low temperature area + 10ms pulse single flash

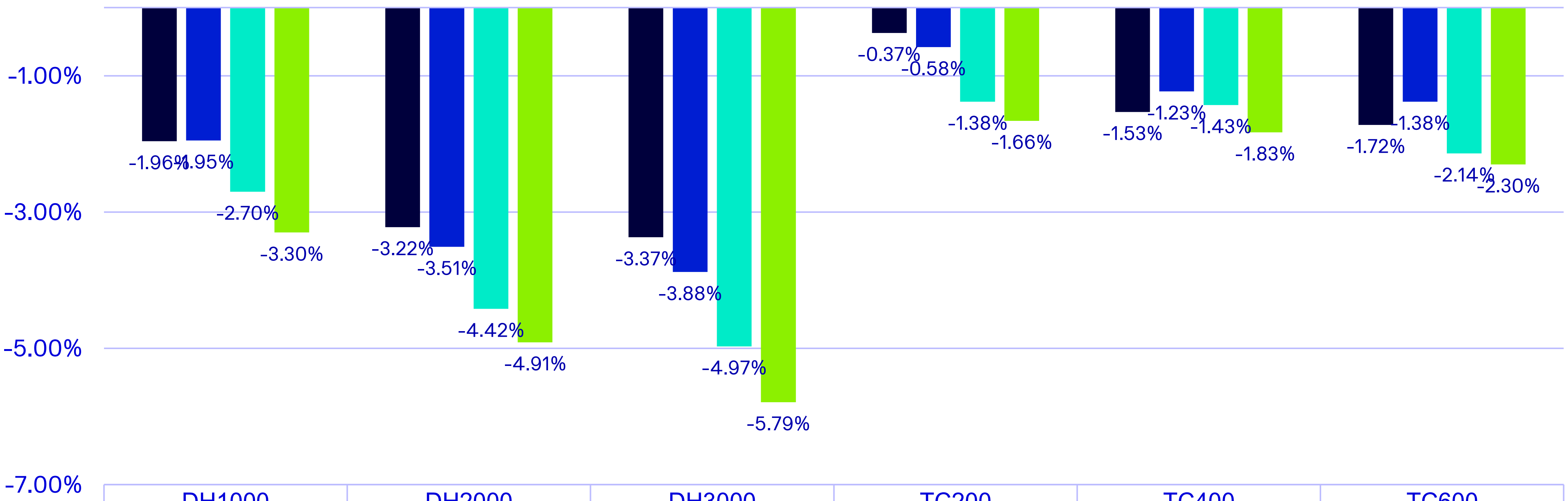
45°C - 15°C
γ = -0.285%



Temperature control box + accurate test

Moisture

Damp-heat and thermal cycle 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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Installation

Installation method

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

Extreme climate

- Rainy, snowy, hailing, windy weather

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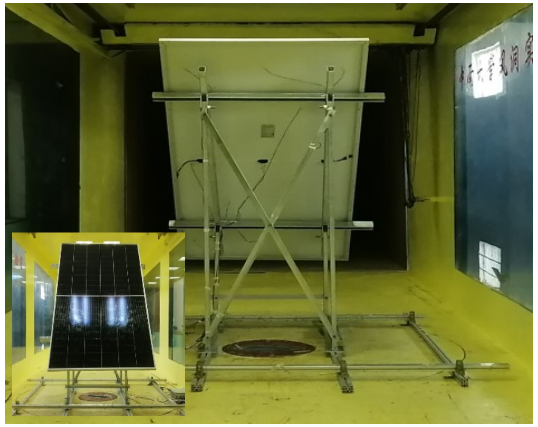
Packaging & transportation

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	

Mechanical properties



- Risk increases with the greater size

Static & dynamic Mechanical Load

Non-uniform Snow Load

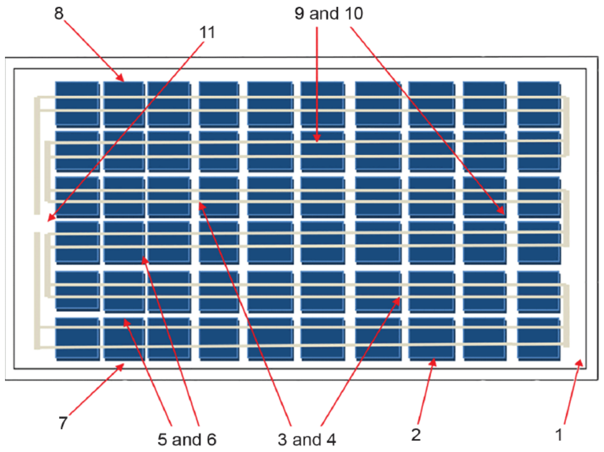
- The bottom frame suffers greater non-uniform snow load as the modules become wider.

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

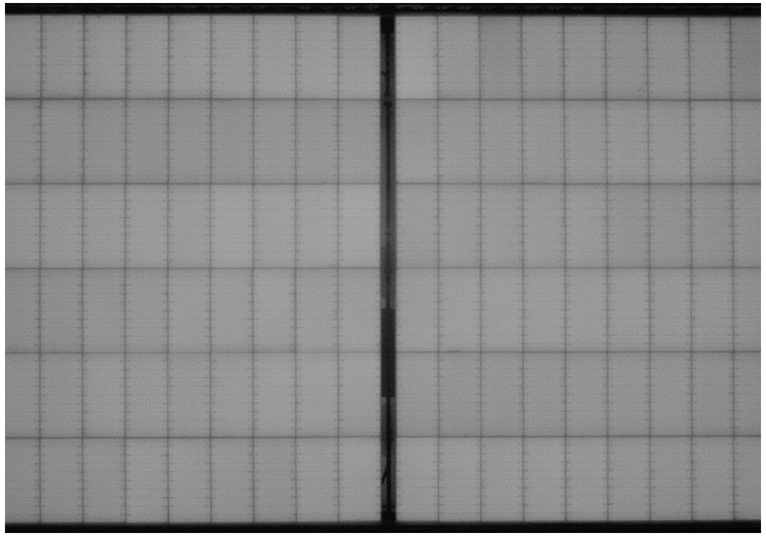
When the temperature of installation environment is high enough (e.g. dessert climate), the installation method is difficult for heat dissipation (e.g. double-skin curtain wall BIPV), higher current carrying capacity is required for bypass-diode in larger-size modules.

	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

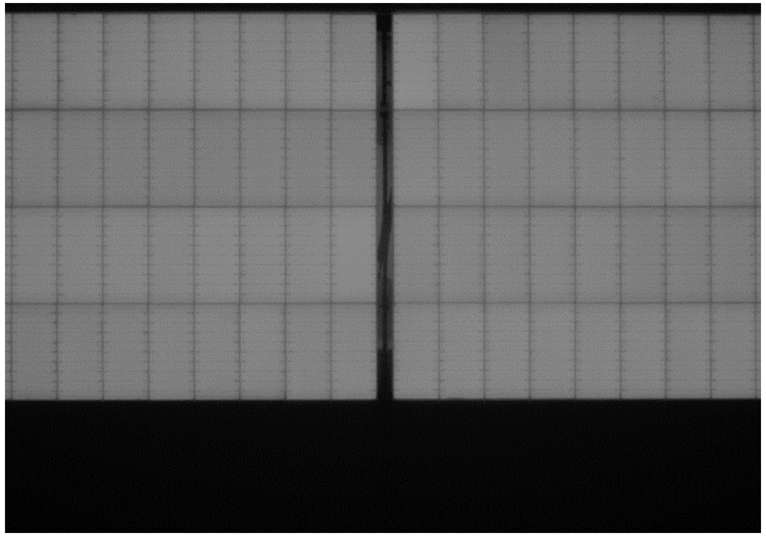
Electrical safety

Thermal cycling test

Normal operation



Bypass diode fails



Junction box melt after thermal cycling

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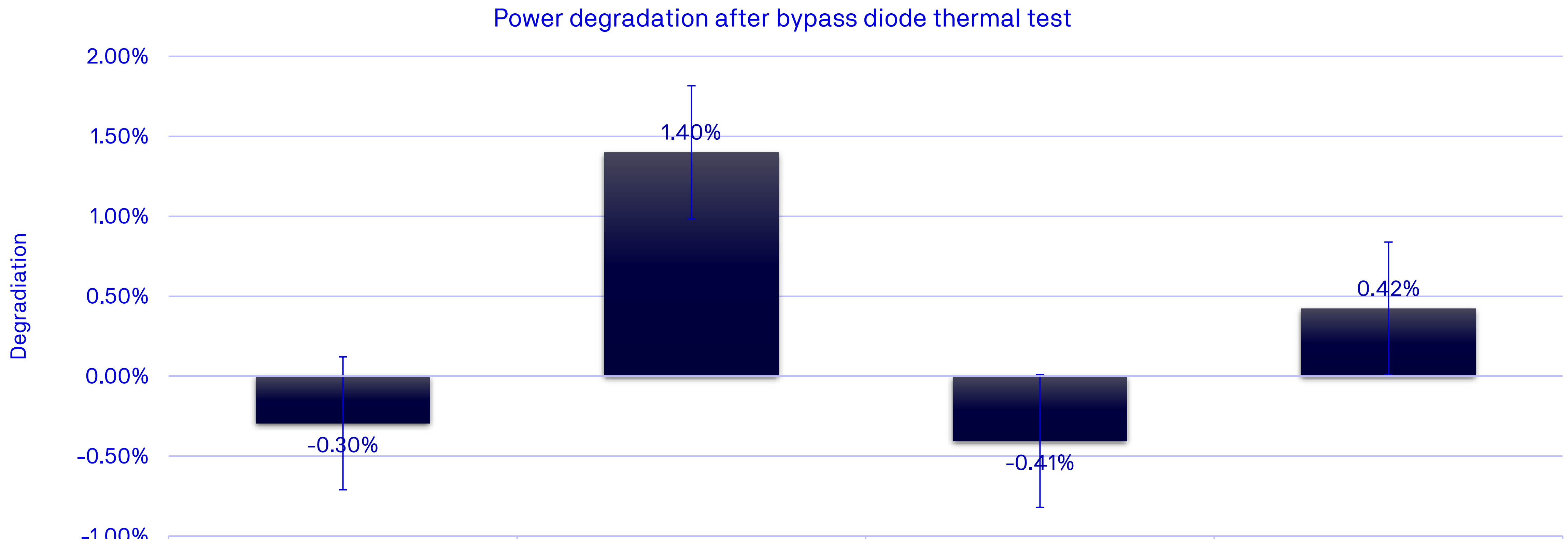
Electrical safety

Bypass diode thermal test



	132 half-cut cells 210mm	408 segmented cells 210mm	414 segmented cells 210mm	110 half-cut cells 210mm
■ Degradiation	-0.30%	1.40%	-0.41%	0.42%

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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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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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N-type trends in 2024

Q&A

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