Webinar:

10th October 2023

Trinasolar

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PVTECH

How to navigate the N-type era with Trina Solar's Vertex PV modules

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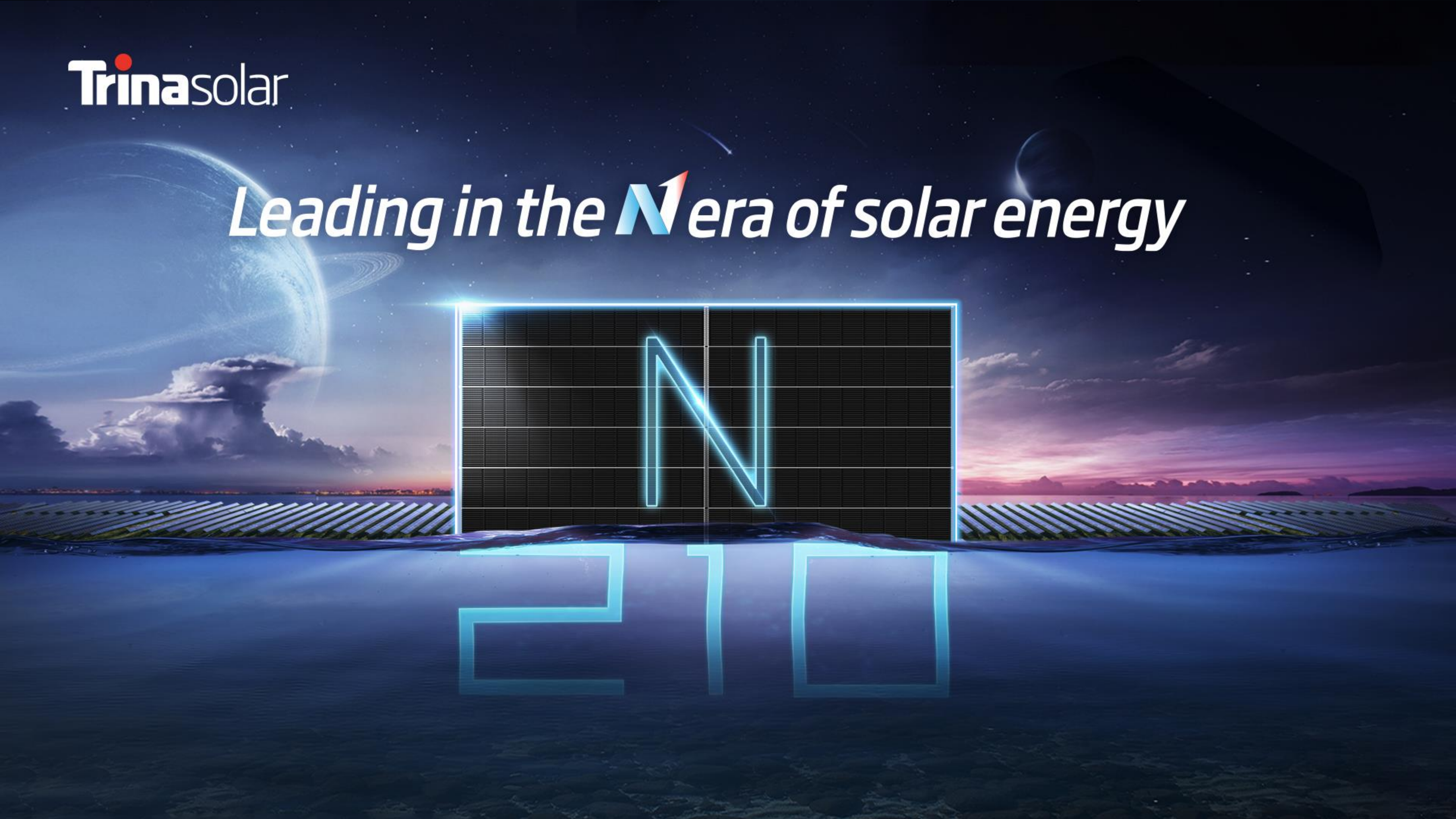
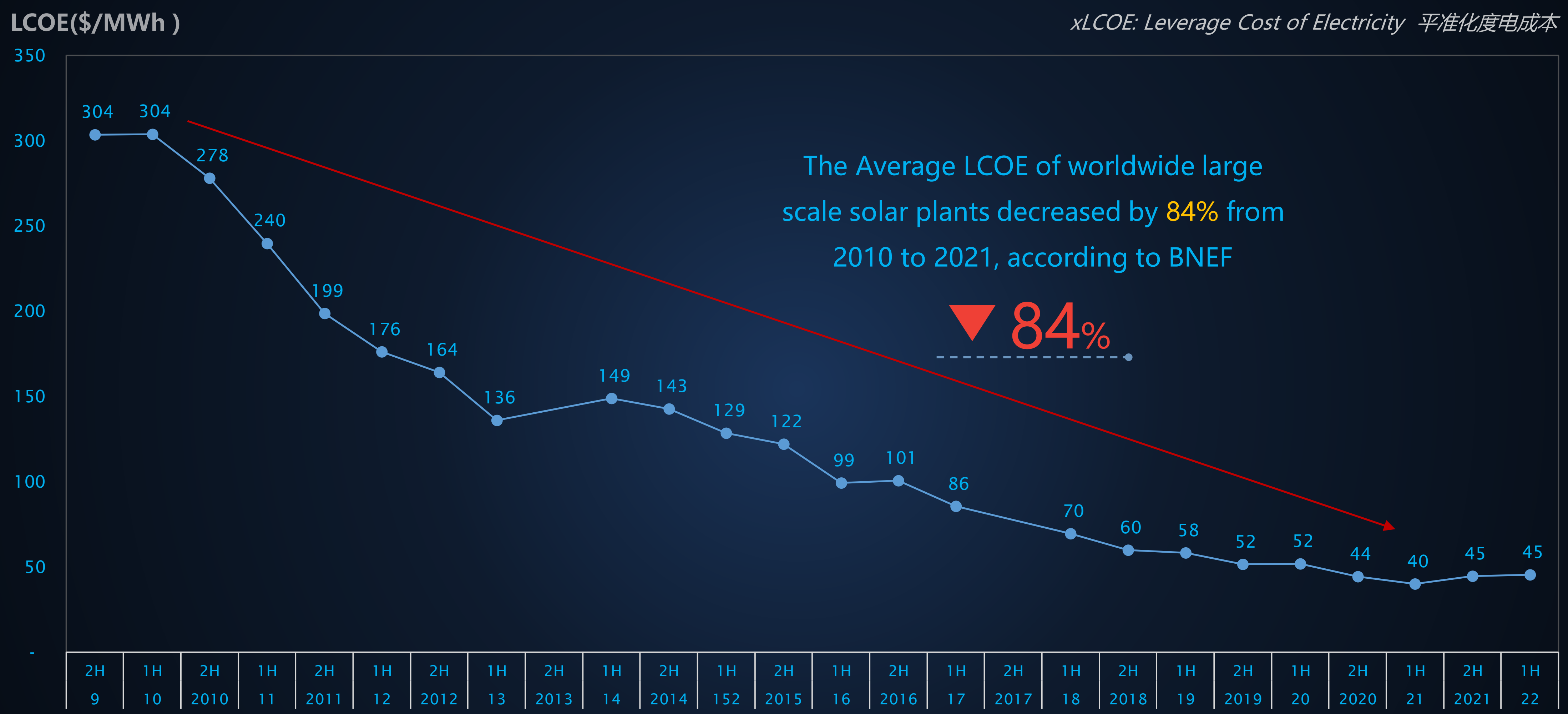

Trinasolar
Leading in the N era of solar energy
N
210

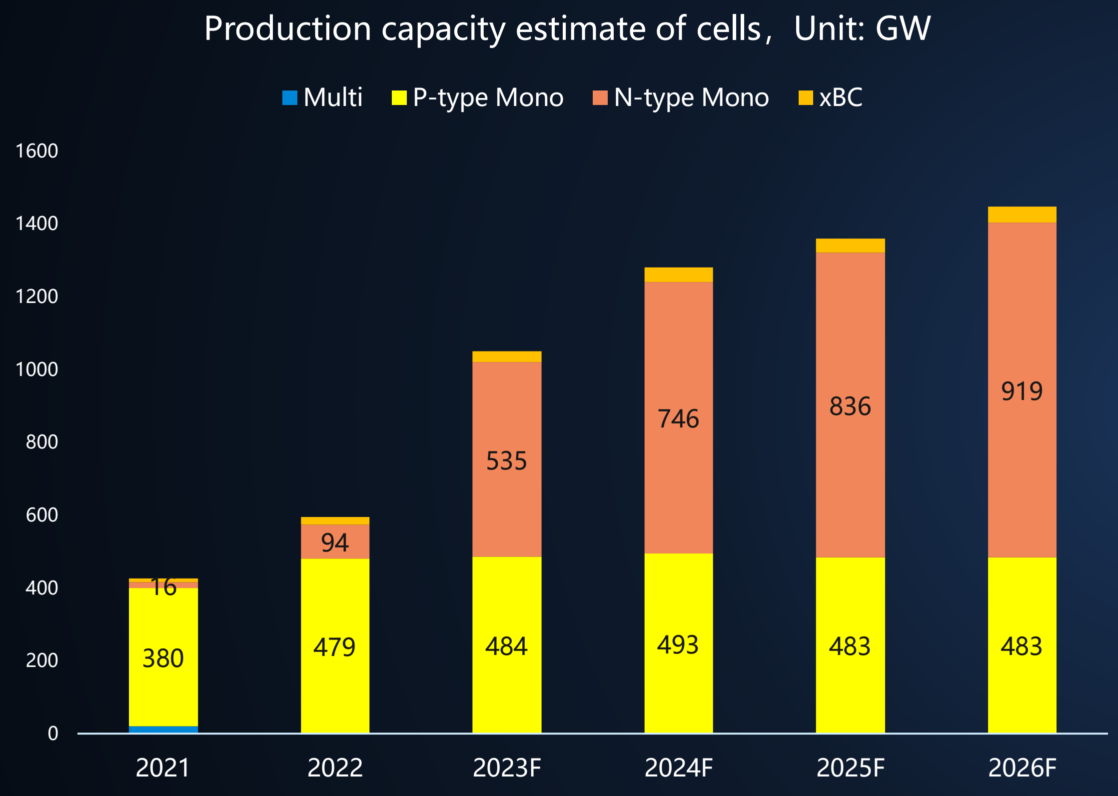
LCOE Declining Trend of PV from 2009 to 2022

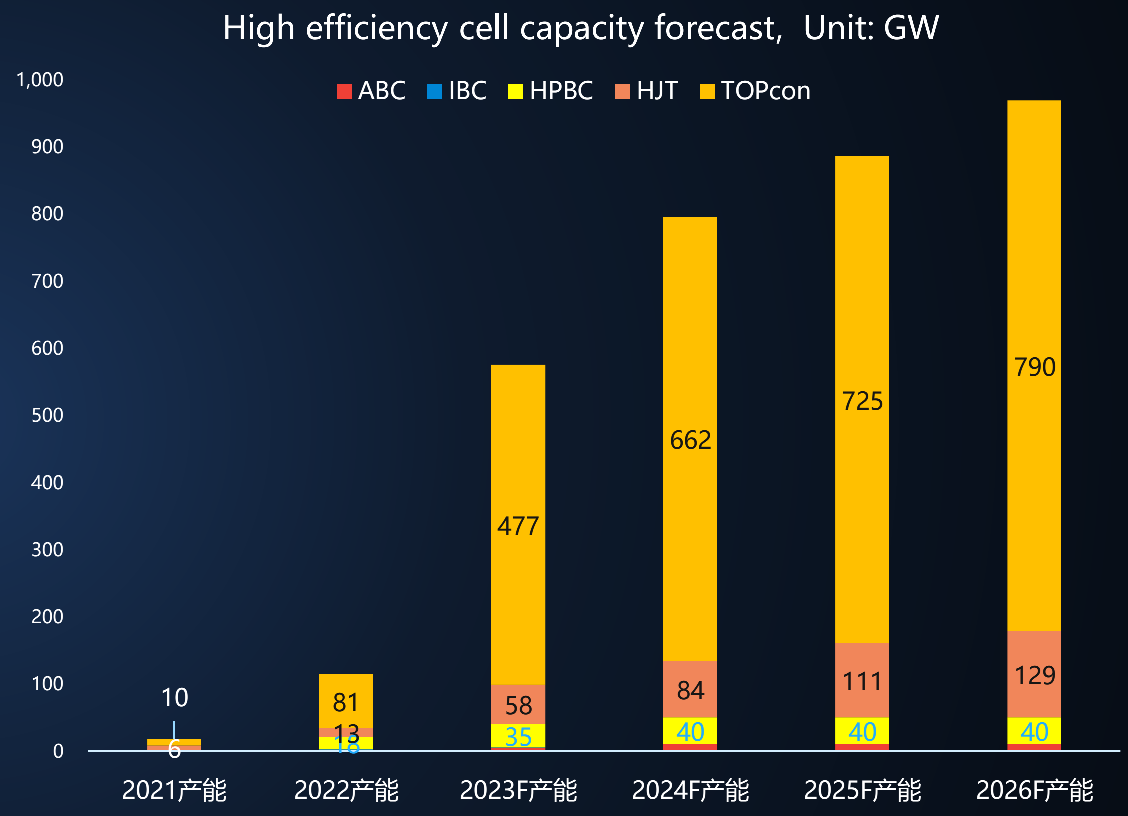


◆ PV LCOE needs to be continuously reduced to accelerate the substitution of fossil fuels

Source: BloombergNEF (22/07)

TOPCon become the main technology





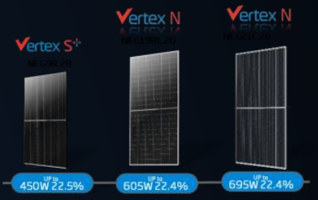
Source: 光伏技术趋势报告，Mar.2023, PV InfoLink

From 2023, N type capacity ratio will exceed 50%, of which TOPCon cell capacity will reach 90%, becoming the another main cell technology of the industry after PERC.

Trina Solar i-TOPCon technology development roadmap

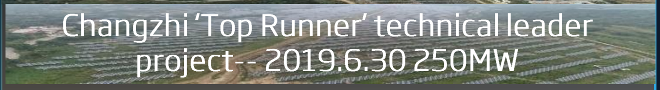
Trinasolar 25TH

- Selective emitter, backside micro-structure reflector, high doping and low composite TOPCon structure. Cell efficiency: 26.2%
- Wafer size：210,210R
- Mass production efficiency 25.5%
- Full-scale mass production，Production Capacity 40GW+
- Comprehensive product portfolio!



- Wafer size 210mm×210mm+ 18BB
- Average mass production cell efficiency 24.5%
- Cell efficiency 25.15% (ISFH certificate)
- 500 MW TOPCon Pilot Line

- Innovative Hydrogen passivation technology， The cell efficiency is 0.2% better than that of the product in the same period
- Wafer size 158.75mm×158.75 mm
- Mass production efficiency 23.5%
- 500 MW production line



2025+
735W | 785W
i-TOPCon ULTRA|TANDEM

2023~2024
Module power up to 710W
i-TOPCon ADVANCED

2020~2022
Module power up to 680W
i-TOPCon PLUS

2015~2019
Module power up to 430W
i-TOPCon

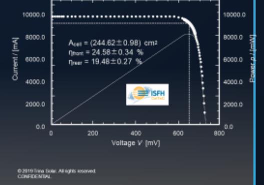
- i-TOPCon + Full frontal passivation contact cell technology： Efficiency >27%
- i-TOPCon + tandem cell Technology: Cell Efficiency >30%

PCE (%)	Voc (V)	FF(%)	Jsc(mA/cm2)
28.5	1.84	75.9	20.4

In 2015, Base on Trina Solar's State Key Laboratory of Photovoltaic Science and Technology(PVST) ,i-TOPNCon Lab was established.

In 2019, the first TOPCon Cell World Record in China, 24.58% (ISFH certification)

Cell efficiency record
- 25.25% (2022/2, ISFH certificate)
- 25.42%(2022/3, ISFH certificate)
- 25.5%(2022/3, China National Metrology Institute certificate)



Vertex N i-TOPCon advanced high efficiency module products

Trinasolar 25TH

G12R (210R)

210mm

182mm

G12 (210)

210mm

Golden Size Small Product

Power 450W
Efficiency22.5%

Vertex S+

G12 R — 48pcs NEG9R.28

UP to 450W

Standardized Medium Size

Power upto 620W
Efficiency 23.0%

Vertex N

G12 R — 66pcs NEG19RC.20

UP to 620W

Product of 700W+ Era

Power 710W
Efficiency 22.5%

Vertex N

G12 — 66pcs NEG21C.20

UP to 710W

Industry average level

425W — 575W — 620W

Trina solar N-iTOPCon Vertex high efficiency series solar modules ,fit for all kinds of application scenarios.

Vertex N i-TOPCon advanced- Vertex S+ roof solar module

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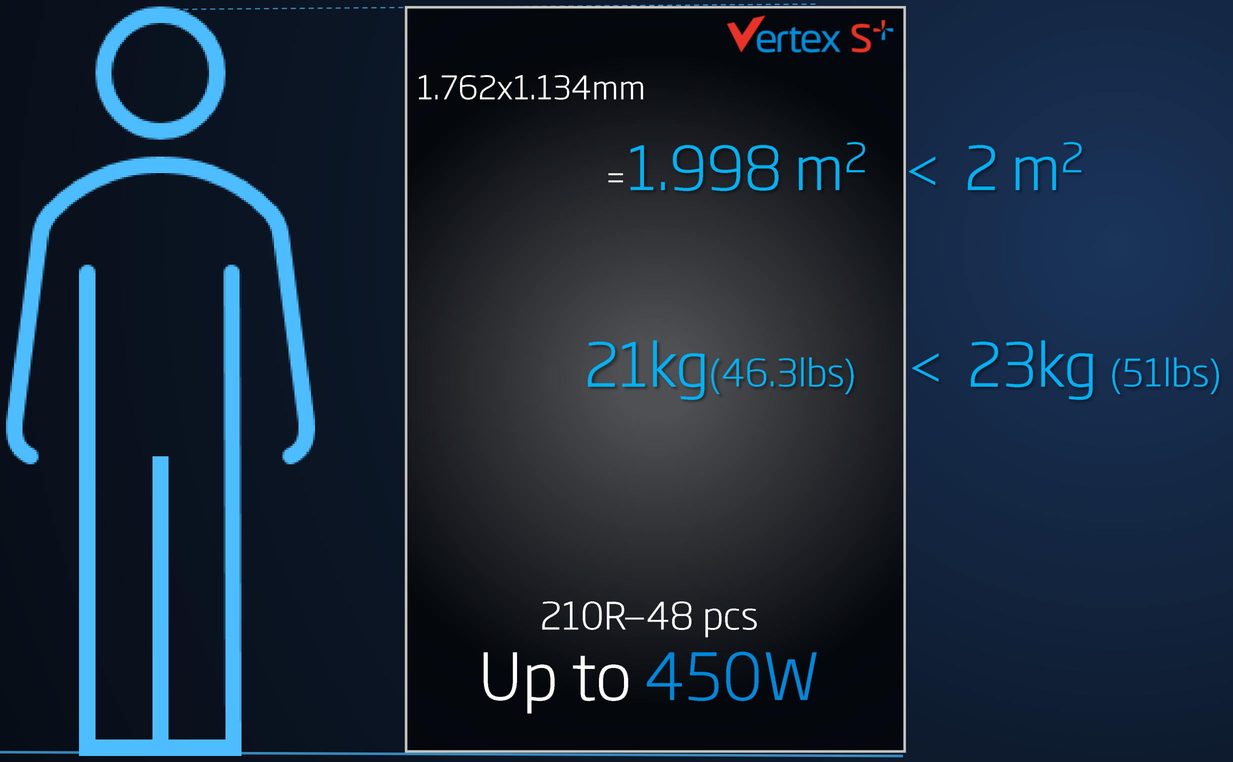
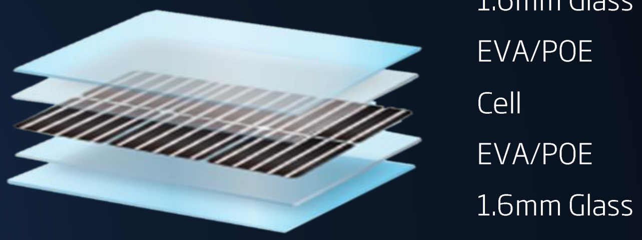
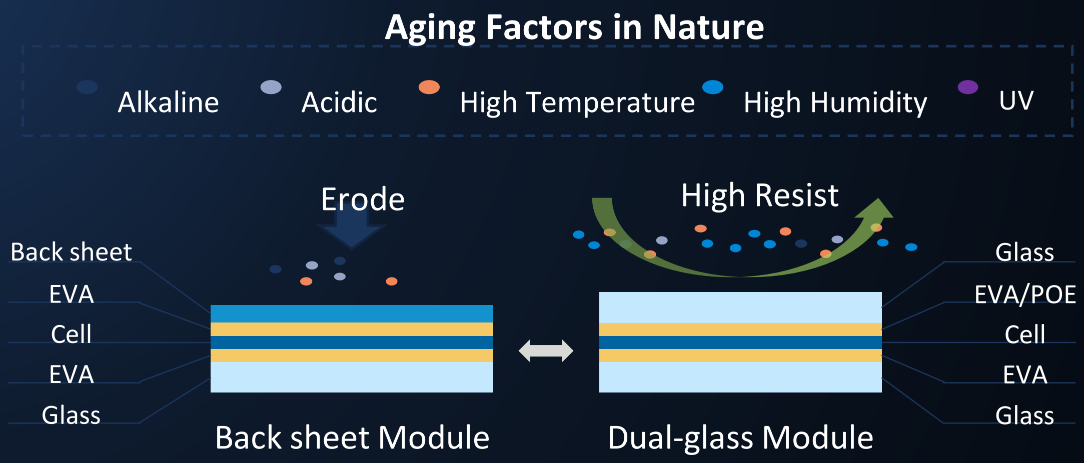
210R -48pcs Golden size :Ultimate small size format design .







Extremely safe, distributor , installer friendly , easy to handle and install

Vertex N

Globally leading i-TOPCon advanced technology

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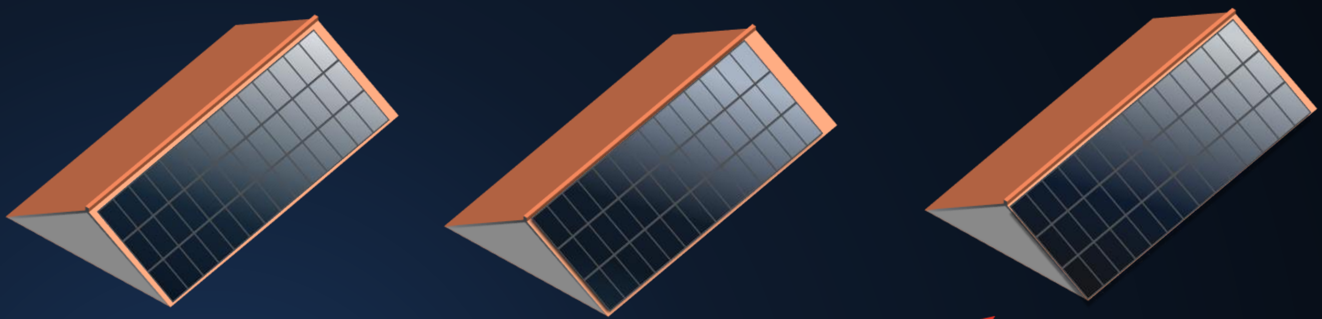
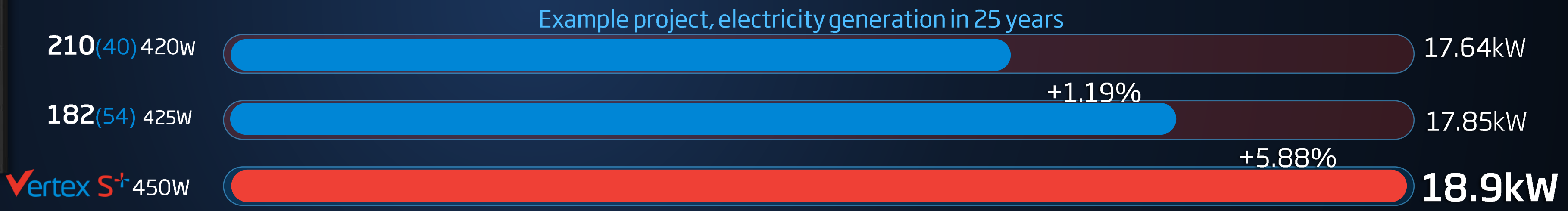
i-TOPCon advanced   i-TOPCon plus



210(40) 420W
42pcs(3*14)
17.64kW

182(54) 370W
42pcs(3*14)
17.85kW

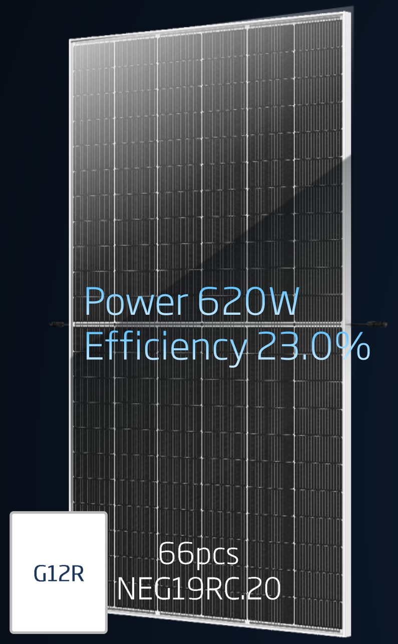
Vertex S+ 450W
42pcs(3*14)
18.9kW



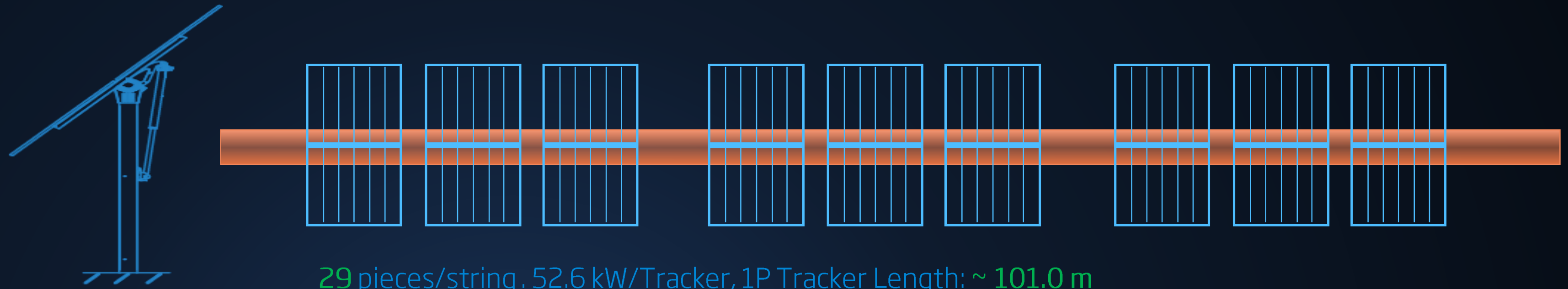
Product Name	Vertex-S	Vertex-S	182-54pcs N
Module Size(mm)	1762 X 1134 X 30 (golden size)	1770 X 1096 X 30	1722 X 1134 X 30
Module Area (German regulated limitation 2m^2)	1.998 m^2	1.940 m^2	1.953 m^2
Module design	210R-48 one-third cell 1.6+1.6 dual glass	210-40 one-third cell 1.6+1.6 dual glass	182 half cut cell backsheet
Cell technology	i-TOPCon advanced	i-TOPCon plus	182 TOPCon
Module Efficiency	450W (+5.9%)	420W (-1.2%)	425W (BL)

Vertex N

i-TOPCon advanced- 210R Utility & C&I module

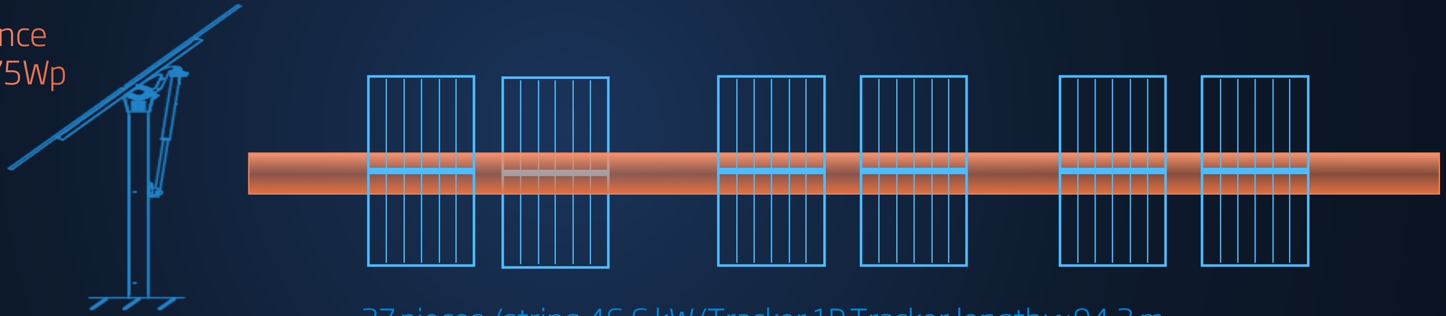


210R-N
620Wp



29 pieces/string . 52.6 kW/Tracker, 1P Tracker Length: ~ 101.0 m
Voc Lower 3.6V, accommodate 2 more pieces， Power+13%/per Tracker

Reference
182N 575Wp



27 pieces./string,46.6 kW/Tracker,1P Tracker length: ~94.2 m

Product Name	Vertex N	182-72pcs N
Module Size(mm)	2384x1134x30 （golden size）	2278x1134x30
Module design	210Rx66 half cut Dual glass	182x72 half cut Dual glass
Cell technology	i-TOPCon advanced	182 TOPCon
Module Power output	620W（+5.2%）	575W（BL）
Container space utilization	98.5%	94.5%
Total power/ container	435,600(+5.2%)	414,000

Vertex N

i-TOPCon advanced- 210 Utility module

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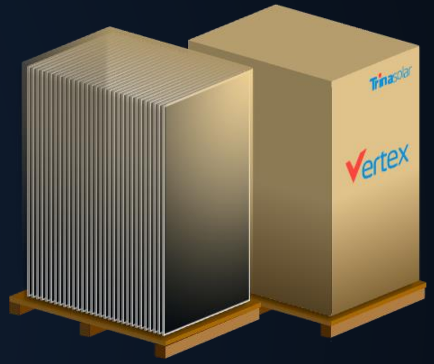
i-TOPCon plus

i-TOPCon advanced



Product Name	Vertex N (2023)	Vertex N (2022)	182-78pcs N
Module Size(mm)	2384x1303x33 (golden size)	2384x1303x33	2465x1134x30
Module design	210-66 half cut cell 2+2 bifacial dual glass	210-66 half cut glass 2+2 bifacial dual glass	182 half cut glass Bificial
Cell technology	i-TOPCon advanced	i-TOPCon plus	182 TOPCon
Module Efficiency	710W (+12.9%)	680W (+10.6%)	620W (BL)
Container space utilization	97.6%	97.6%	81.4%
Total power/ container	594PCS = 415,800(+16.4%)	594PCS = 403920(+13.1%)	576PCS = 357,120(BL)

Vertex N Value assessment: BOS,LCOE assessment Dubai, UAE

Trinasolar 25

Project Information

Scenario	Ground-mounted
Location	Dubai, UAE
AC capacity	4 MW (Standard single array)
Type of inverter	Central inverter
Mounting	NX Horizon 1P tracker
Type of module	Bifacial module

PV System Configuration (Standard single array)

Item	Module type	NEG19RC.20 (Vertex N)	182N-72pcs (Reference 182-N)
Module	Module power	605W	575W
	Module size (mm)	2384×1134×30	2278×1134×30
	Open circuit voltage	48.7 V	51.27 V
	Short circuit current	15.83 A	14.31 A
Mounting	Installation	NX Horizon 1P tracker	
	Pitch	E-W 6.91m	E-W 6.60m
Inverter	Inverter type	MVPS 4000	
	Inverter power (AC)	4000 kW	
	Inverter number	1	1
Layout	Module/string	30	28
	String power	18,150W (+13%)	16,100W
	Tracker configuration	1V90 Portrait	1V84 Portrait
	String/tracker	3	3
	String number	279	315
	Tracker units	93	105
	Module number	8370	8820
	GCR (%)	34.50%	34.50%
Capacity	DC capacity (kW)	5063.85	6071.5
	AC capacity (kW)	4000	4000
	DC/AC ratio	1.266	1.268

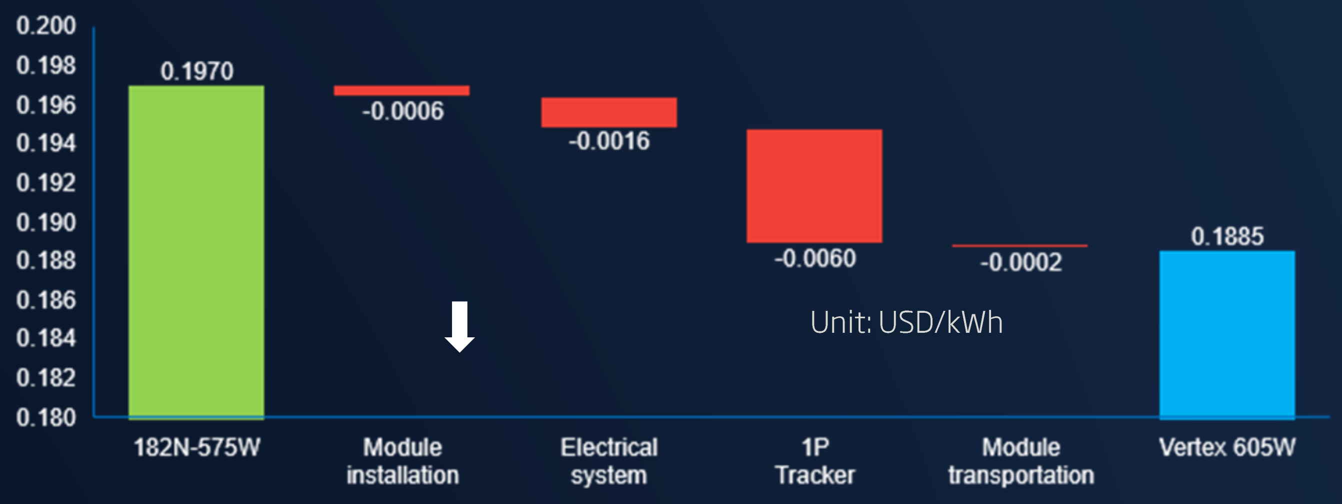
Vertex N Value assessment: BOS,LCOE assessment Dubai, UAE

Unit: USD/Wp

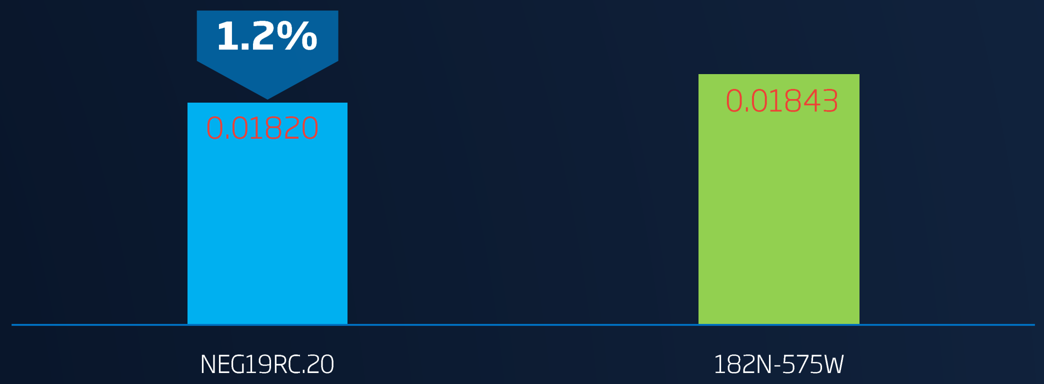
Module type	NEG19RC.20	182N-575W
Module installation	0.0116	0.0122
Solar inverter	0.0439	0.0439
Combiner box	0.0039	0.0039
TS4 connector	0.0003	0.0003
PV cable	0.0097	0.0105
LV cable	0.0103	0.0109
Cable trench	0.0023	0.0025
Electrical system	0.0704	0.0720
1P Tracker	0.1027	0.1087
Module transportation	0.0039	0.0041
Total BOS*	0.1885	0.1970
BOS saving	-0.0085	Baseline

*includes only the components which make difference with different modules.

BREAKDOWN OF BOS* SAVING



LCOE savings



The result shows that the Vertex NEG19RC.20-605W module performs better, with a saving of 0.85 $ct in CAPEX and 1.2% in LCOE than 182N-575W.

Vertex N i-TOPCon advanced 210: BOS,LCOE assessment

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Project Information

Scenario	Ground-mounted
Location	Gonghe, Qinghai
AC capacity	3.2 MW (Standard single array)
Type of inverter	String inverter
Mounting	35° tilt
Type of module	Bifacial module

PV System Configuration (Standard single array)

Item	Module type	NEG21C.20	182N
Module	Module power	695W	620W
	Module size (mm)	2384×1303×33	2465×1134×30
Mounting	Installation	35° tilt	
	Pitch	N-S 10.616m	N-S 10.975m
Inverter	Inverter type	SG320HX	
	Inverter power (AC)	320 kW	
	Inverter number	10	10
Layout	Module/string	28	24
	String power	19,460W (+31%)	14,880W
	Tracker configuration	2V28 Portrait	2V24 Portrait
	String/tracker	2	2
	String number	209	271
	Module number	5852	6504
Capacity	DC capacity (kW)	4067.14	4032.48
	AC capacity (kW)	3200	3200
	DC/AC ratio	1.27	1.26

Vertex N

i-TOPCon advanced 210: BOS,LCOE assessment

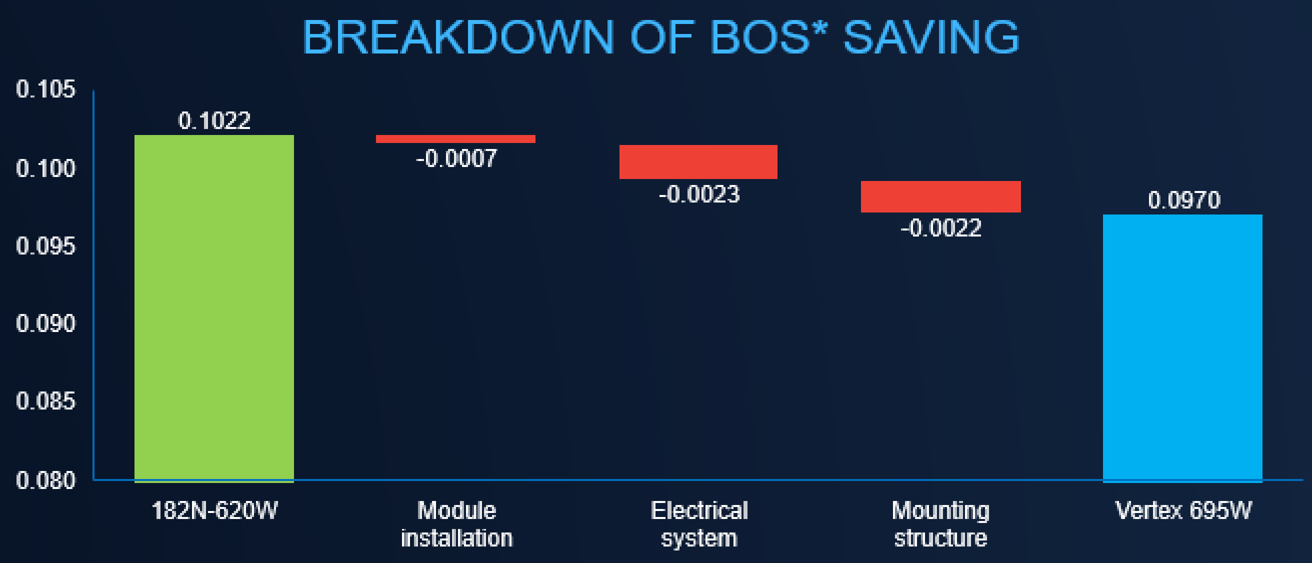
Trinasolar 25TH

Unit: USD/Wp

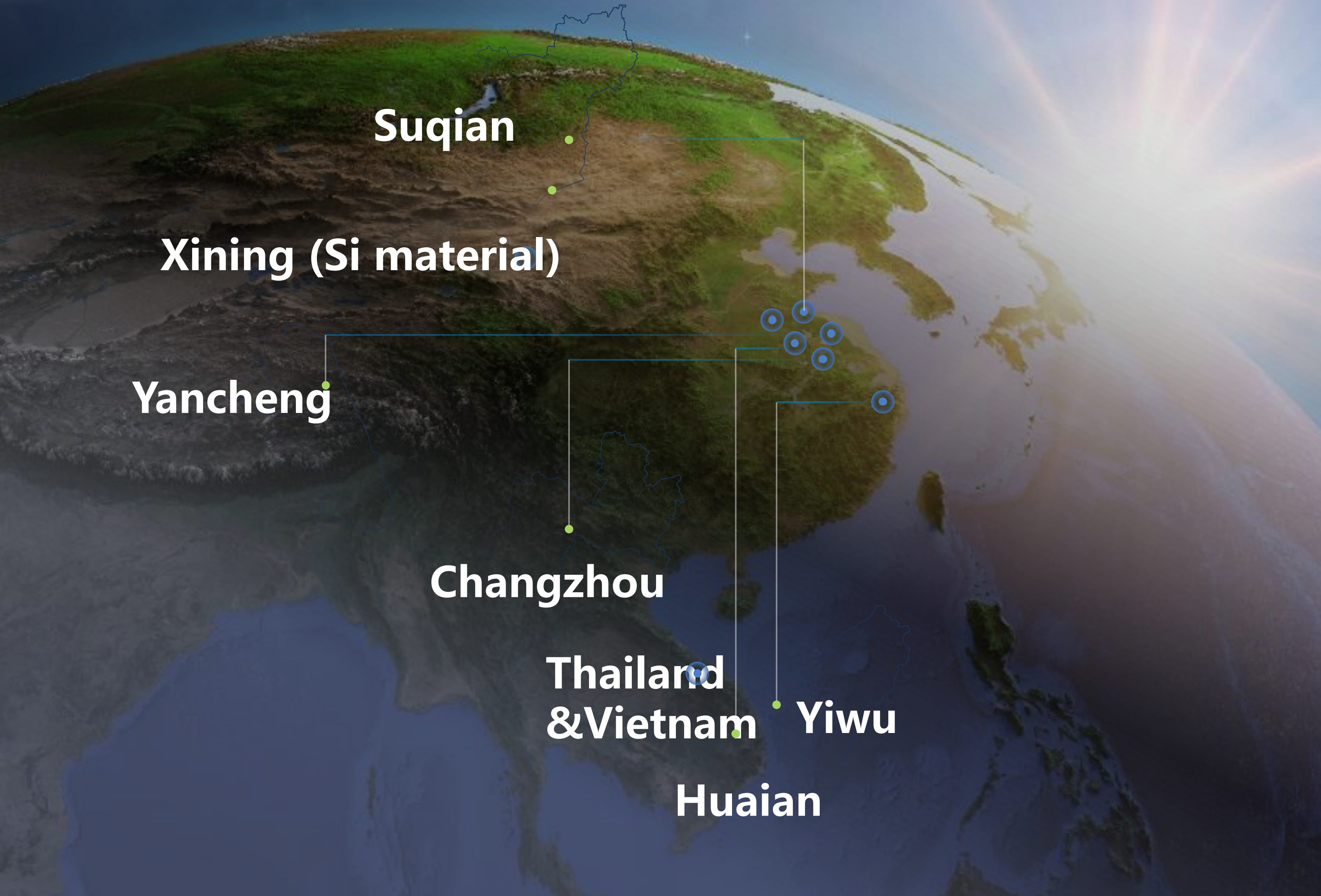
Module type	NEG21C.20	182N-620W
Module installation	0.0055	0.0062
Solar inverter	0.0159	0.0160
TS4 connector	0.0007	0.0009
PV cable	0.0045	0.0061
LV cable	0.0044	0.0045
Grounding Cable	0.0002	0.0003
PVC tube	0.0006	0.0008
Cable trench	0.0021	0.0021
Electrical system	0.0285	0.0308
Mounting structure	0.0630	0.0652
Total BOS*	0.0970	0.1022
BOS saving	-0.0052	Baseline

*includes only the components which make difference with different modules.

The result shows that the Vertex NEG21C.20-695W module performs better, with a saving of 0.52 $ct in CAPEX and 1.1% in LCOE than 182N-620W.



Manufacturing capacity of Trina



2023 module capacity

95 GW

2023 cell capacity

75 GW

i-TOPCon 40GW

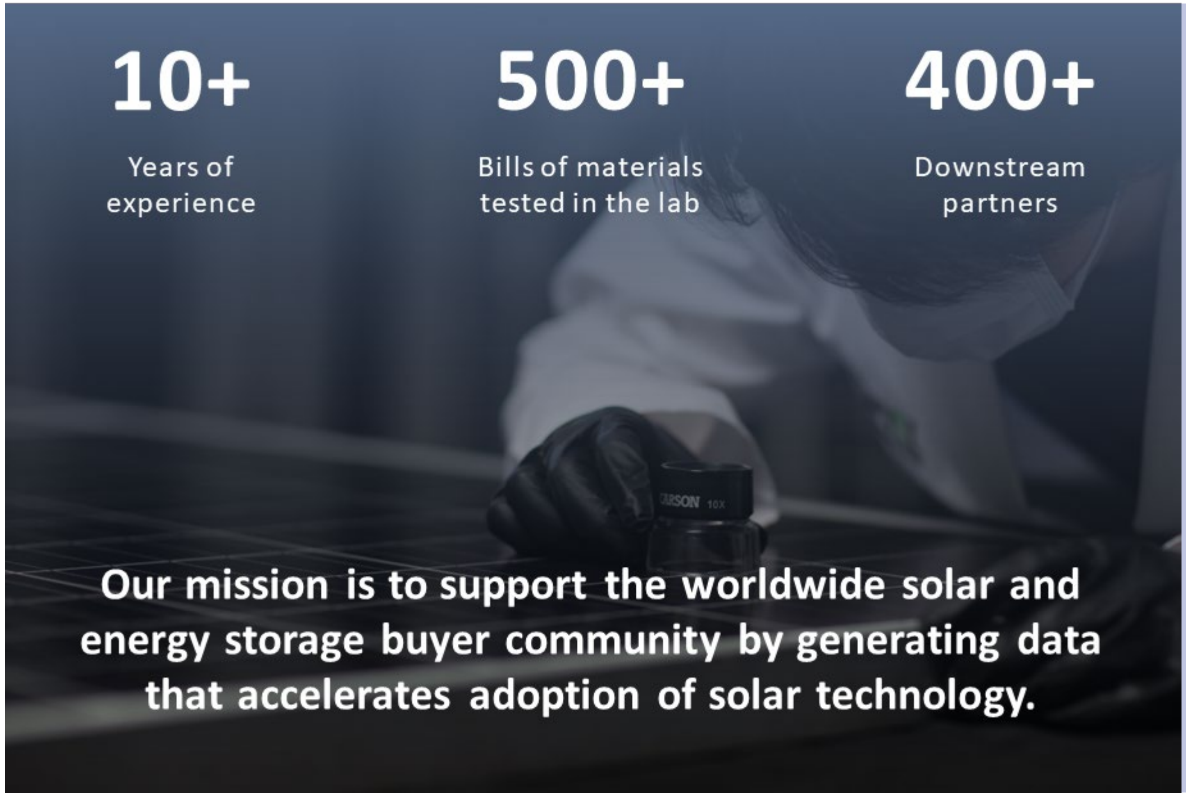
2023 Si ingot capacity

50 GW

数据截至2022年12月31日

THANKS!

PV Evolution Labs (PVEL) is the Independent Lab of the Downstream Solar Market



Services at a glance:

- Extended reliability and performance testing for PV modules
- Outdoor testing at PVUSA, an iconic grid-connected research site
- Data services for PV buyers and investors
- Field testing and EL imaging for operating assets

In 2021 PVEL became a member of the Kiwa Group, along with PI Berlin who joined in 2022.

Module PQP Test Sequence

The Product Qualification Program (PQP) test streams are reviewed regularly and evolve based on feedback from PVEL's downstream partners, module manufacturers, and the industry's collective understanding of module failure modes and test mechanisms.

Factory Witness, Characterizations and Light-Induced Degradation Measurement

Thermal Cycling	Damp Heat	Backsheet Durability Sequence	Mechanical Stress Sequence	Hail Stress Sequence	Potential-Induced Degradation	LETID Sensitivity	PAN File & IAM Profile	Field Exposure
TC 200	DH 1000	DH 1000	Static Mechanical Load	Hail	85°C, 85%RH MSV (+ and/or –) 192 hrs	LETID 162 hrs (75°C, Isc-Imp)	PAN File	Field Exposure 6 Months
Characterization	Characterization	UV 65 kWh/m^2	Dynamic Mechanical Load	Characterization	Characterization	Characterization	IAM Profile	Characterization
TC 200	DH 1000	Characterization	Characterization	Dynamic Mechanical Load		LETID 162 hrs (75°C, Isc-Imp)		Field Exposure 6 Months
Characterization	Characterization	TC 50 + HF 10	TC 50 + HF 10	Characterization		Characterization		Characterization
TC 200	Stabilization 80°C, Isc, 48 hrs	UV 65 kWh/m^2	Characterization	TC 50 + HF 10		LETID 162 hrs (75°C, Isc-Imp)		
Characterization	Characterization	Characterization		Characterization		Characterization		
		TC 50 + HF 10						
		UV 65 kWh/m^2						
		Characterization						
		TC 50 + HF 10						
		UV 6.5 kWh/m^2						
		Characterization						

PVEL conducts additional field exposure studies and rear side characterizations to evaluate the performance of bifacial modules.

Supplementary testing is available for extended hail stress and tracker-specific mechanical stress evaluations.

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Scorecard Eligibility

TOP PERFORMER 2023
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PV MODULE RELIABILITY SCORECARD

To be eligible for the Scorecard, manufacturers must have:

- Completed the PQP sample production factory witness within 18 months of the Scorecard year.
- Submitted at least two factory-witnessed PV module samples to all PQP reliability tests, as per PVEL's BOM test requirements.

Top Performers in each of the reliability tests appearing in the Scorecard must have **< 2% power degradation** following the particular test, and not have experienced a wet leakage failure, 'major' defect during visual inspection, or a diode failure for that particular testing.

PAN Performance Top Performers must place in the **top quartile for energy yield** in PVEL's PVsyst simulations.

2023 Scorecard: Cell Technology Trends

Some strong results were seen from TOPCon and HJT in the 2023 Scorecard test population, although the sample size for BOMs with these technologies isn't as robust as PERC BOMs.

PQP Test	2023 Scorecard Findings
TC600	PERC and TOPCon equally reliable; some HJT has opportunity for improvement.
DH2000	Average degradation was 1.2 to 1.7% across CdTe, HJT, PERC and TOPCon.
MSS (SML+DML+TC50+HF10)	Average degradation was 0.5 to 0.7% across crystalline cell technologies.
PID192	Median degradation was 0.7 to 1.1% for PERC, HJT and TOPCon. More outliers observed with PERC modules, mainly driven by PID-p failure types.
LID+LETID	CdTe and n-type BOMs had an average power loss of 0.0% and a median of 0.2%.
PAN	Median Pmax temperature coefficients were: −0.26 %/°C for HJT, −0.30 %/°C for TOPCon, and −0.33 %/°C for PERC. No clear advantages for low light performance across HJT, TOPCon and PERC

2023 Scorecard: PAN Result Spotlight, PERC vs. TOPCon

A PERC BOM was factory witnessed in early 2021, and a TOPCon BOM from the same manufacturer was produced 18 months later.

All performance aspects of the TOPCon BOM improved compared to the PERC BOM, including the temperature coefficients, low light performance and bifaciality, leading to a specific energy yield being an impressive 2.3% higher than PERC for the Las Vegas simulation, and 1.1% higher for the Boston simulation.

PAN Report Specification	PERC BOM	TOPCon BOM
Pmax Temperature Coefficient (%/°C)	-0.32	-0.30
Low Light Performance (relative efficiency deviation at 200 W/m^2)	-4.0%	-2.7%
Bifaciality (rear side efficiency ÷ front side efficiency)	67.1%	77.7%
Specific Energy Yield - Las Vegas (kWh/kWp)	2,100.5	2,149.9
Specific Energy Yield - Boston (kWh/kWp)	1,246.3	1,259.7

Trina in the PVEL Scorecard

Trinasolar

9x Top Performer:

- 2014
- 2016
- 2017
- 2018
- 2019
- 2020
- 2021
- 2022
- 2023

247 model types from 35 manufacturers are named as 2023 Top Performers.

TOP PERFORMER 2023 PVEL kiwa PV MODULE RELIABILITY SCORECARD

Filter through this year's Top Performers by PQP Test, Manufacturer Name, Module Type, Cell Technology, and more.

Search results are listed in alphabetical order by the manufacturers' number of Scorecard appearances. A check mark means the module type is a Top Performer in that test. Both tested model types and their variants for which the results are representative are included in the list of Top Performers. In some cases, test results were not available at the time of publication.

Filters: Trina Solar

Export CSV

Manufacturer Name

trina

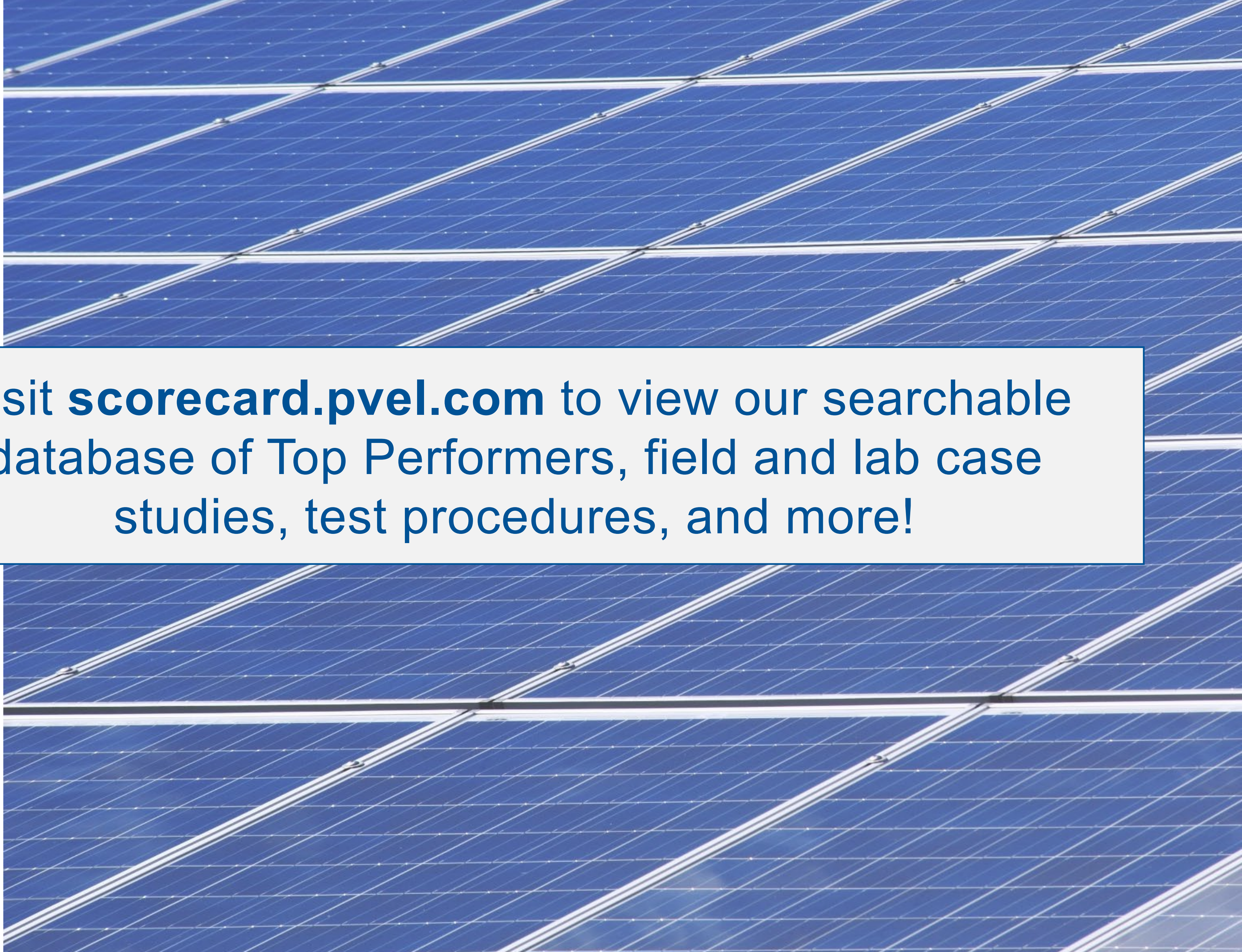
☑ Trina Solar

PQP Test

Module Design

Cell Technology

MANUFACTURER	MODEL TYPE	TC	DH	MSS	PID	LID+LETID	PAN	MODULE DESIGN	CELL TECI
Trinasolar	TSM-xxxDE19	✓		✓		✓		monofacial - glass//backsheet	p-type PE
Trinasolar	TSM-xxxDE21	✓		✓		✓		monofacial - glass//backsheet	p-type PE
Trinasolar	TSM-xxxDEG19C.20		✓	✓	✓	✓		bifacial - glass//glass	p-type PE
Trinasolar	TSM-xxxDEG21C.20			✓		✓		bifacial - glass//glass	p-type PE
Trinasolar	TSM-xxxNEG19RC.20		✓	✓	✓	✓		bifacial - glass//glass	n-type TO



Visit **scorecard.pvel.com** to view our searchable database of Top Performers, field and lab case studies, test procedures, and more!

Tristan Erion-Lorico

VP of Sales and Marketing

PVEL member of group kiwa

Challenges on Power Rating of N-type c-Si PV Modules

10th Oct. 2023, PV Tech Webinar

Dr. Jason Qi Gao - Technical Expert

Solar and Commercial Products Greater China

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Outline

1. Background
2. Hysteresis and Meta-stability Effect
3. Spectral Mismatch
4. I-V Correction
5. Conclusion

Background

Market and Development of N-type PV

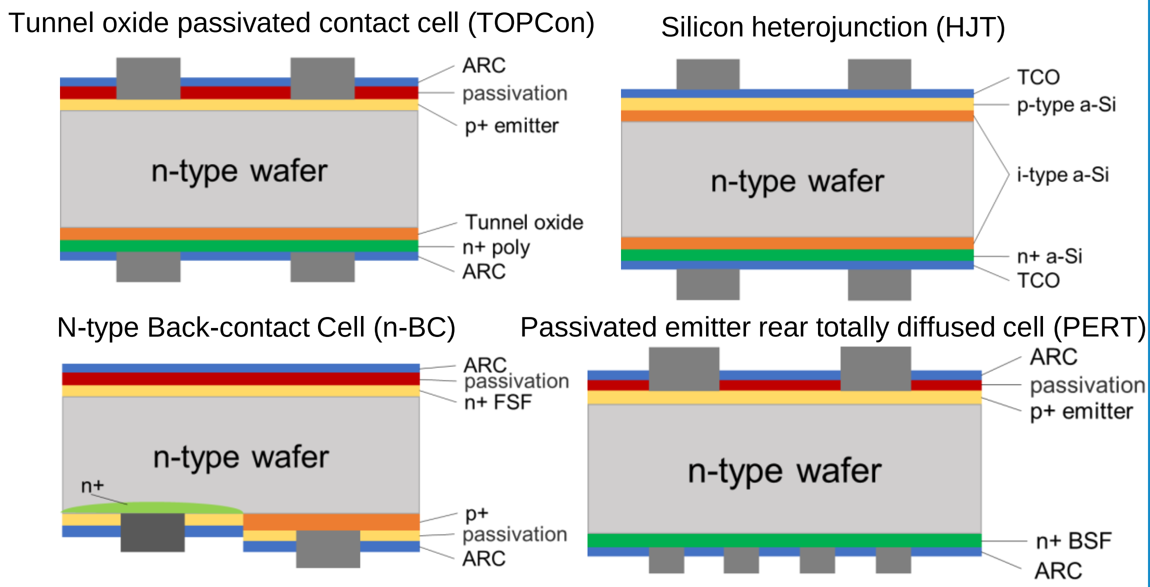
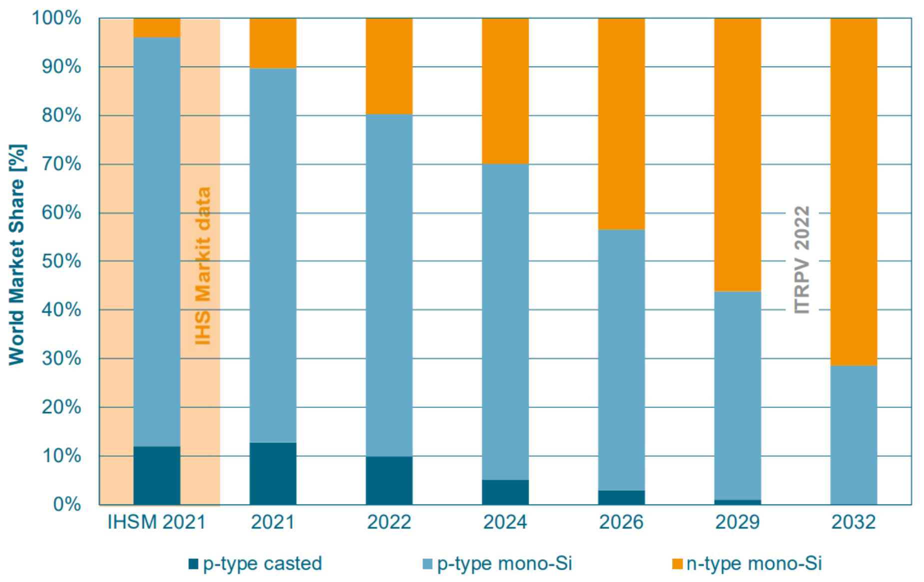


Figure 1. Some of the major n-type solar-cell technologies



- The development of N-type PV technology benefits from the application and progress of passivation, back contact technologies and silicon wafer production.
- N-type PV technologies will dominate the mainstream PV market;

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Background

Factors Affecting Power Rating of N-type PV Devices

Reference Solar Device
• Calibration uncertainty of reference device
• Implementation of reference device
• Accuracy and calibration of temperature sensor
• Long-term drift and stability of reference device
• Repeatability of reference irradiance acquisition
• Reproducibility of reference irradiance acquisition

Solar Simulator Performance
Non-Uniformity of Irradiance: • Non-uniformity • Measurement accuracy
• Temporal instability of irradiance (LTI & STI)
• Electronic accuracy of I-V measurement channels
• Accuracy and calibration of temperature sensors
• Repeatability of solar simulator
• Reproducibility of solar simulator

Operator Technique / Measurement Procedure
• **Calibration and measurement procedure**
• **I-V corrections**
• **Spectral mismatch**
• **Meta-stability**
• Optical mismatch between reference module and DUT
Temperature: • Control and non-uniformity
• Connection technique
Operation: • System maintenance • Human error

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Background

TÜV Rheinland Test Capability of PV Measurements

Traceability

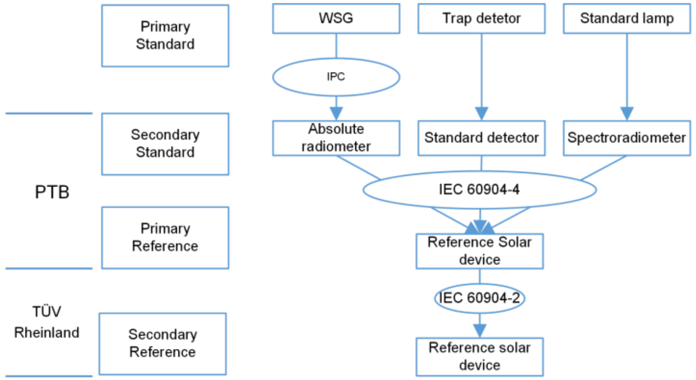
- Benchmark traced to PTB by using WPVS cell
- International round-robin to keep stable testing level

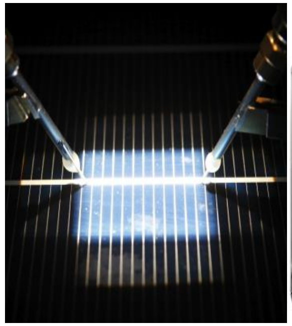
Hardware

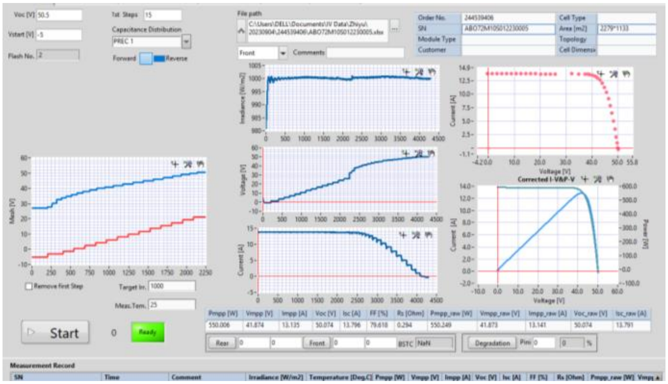
- Triple A+ solar simulator
- High-accuracy SR tester
- Automated measurement process for GTE matrix

Software

- Dynamic IV + Multi-flash for HC module
- Highly customized operation and data processing software with IPR
- Professional data process tool for SP-MMF







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Hysteresis and Meta-stability Effect

Hysteresis Effect

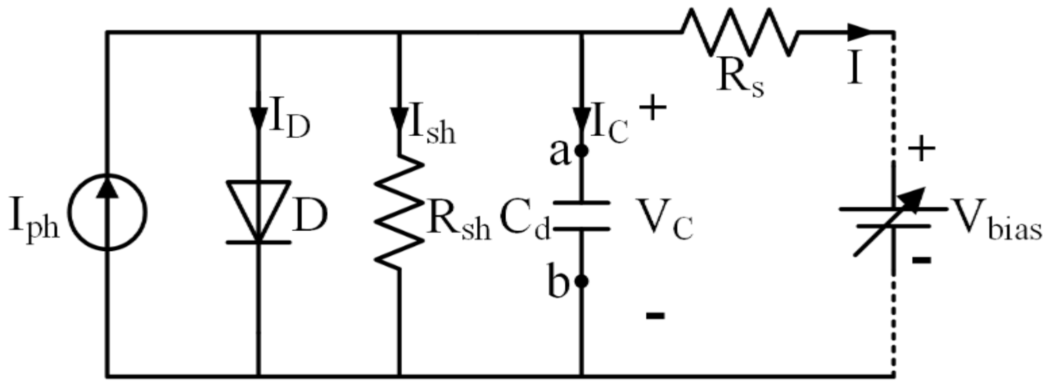

Figure 1. The single diode model of PV devices dominated by capacitance

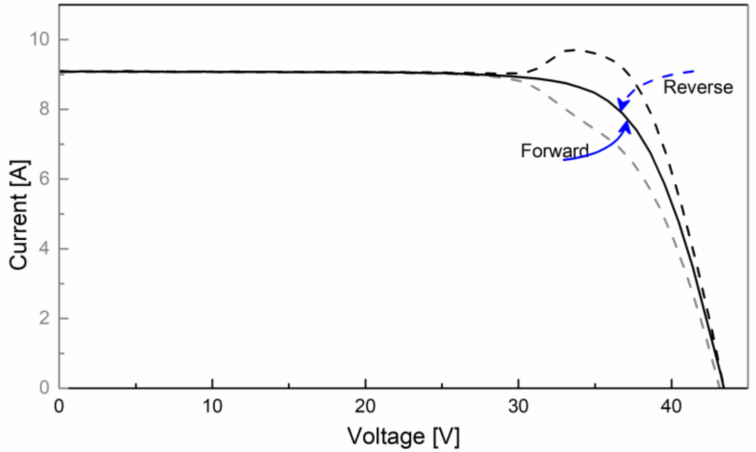

Figure 2. Typical hysteresis error caused by capacitance.

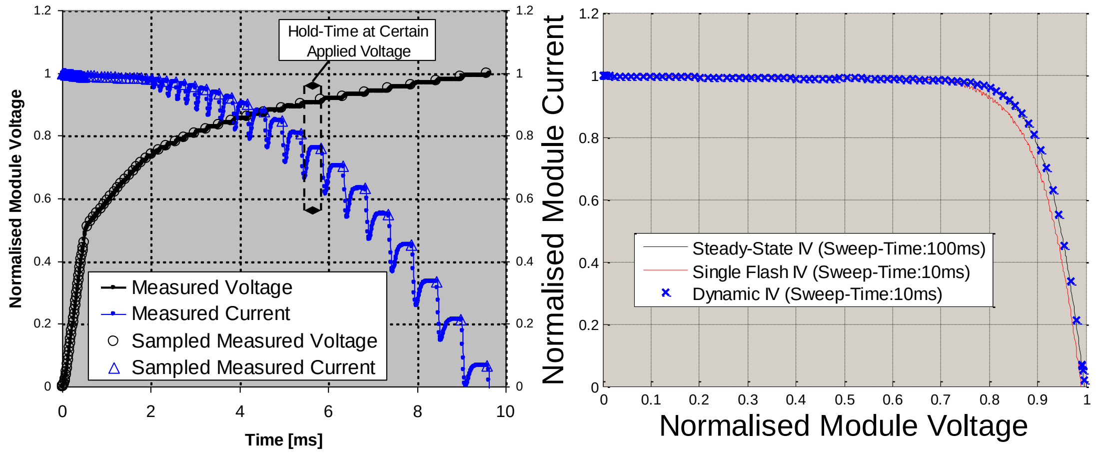

Figure 3. Dynamic IV method.

- N-type c-Si PV devices always have large internal capacitance, which will cause a certain delay effect in the I-V measurement, thus affecting the accuracy of the final results.
- The voltage is upheld constant, while the current stabilises to its capacitance-free response (dI/dt→0) for Dynamic IV.

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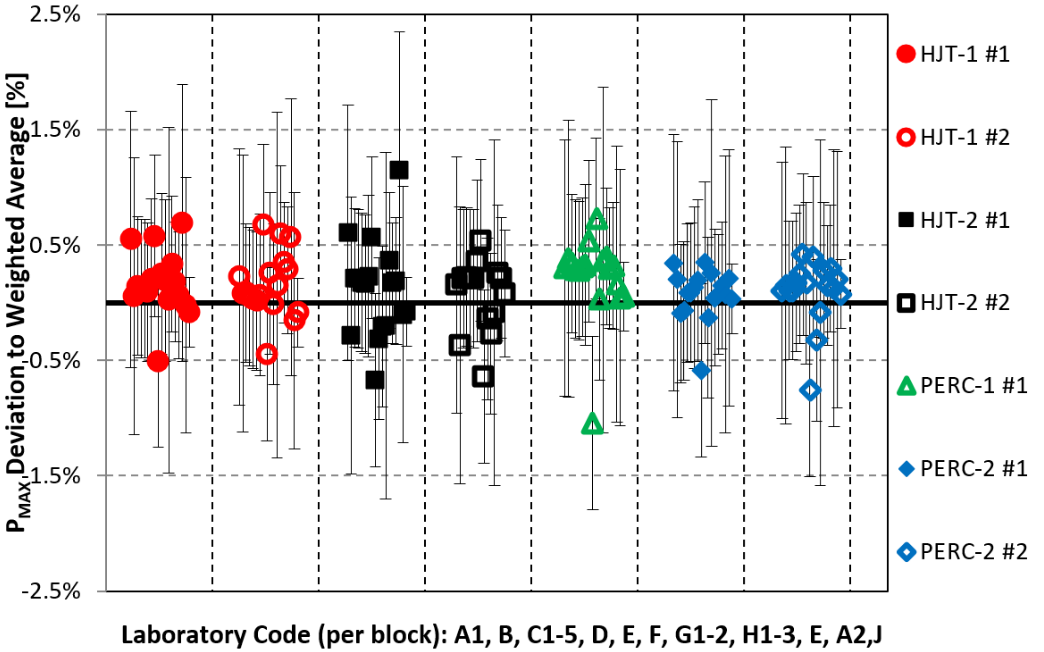
Hysteresis and Meta-stability Effect

International Round Robin



Maximum power point deviations to the weighted mean for all high-efficiency modules as measured blindly by each laboratory at predefined I_{SC} condition at 25°C.

- An interlaboratory comparison, which was organized by TÜV Rheinland and Trina Solar, was performed by ten laboratories based in Asia, Europe and North America with respect to their measurement methods of high-efficiency PV modules.

- According to the proficiency test, the En numbers for P_{MAX} for TÜV Rheinland is within ±0.15 at predefined ISC condition at 25°C.

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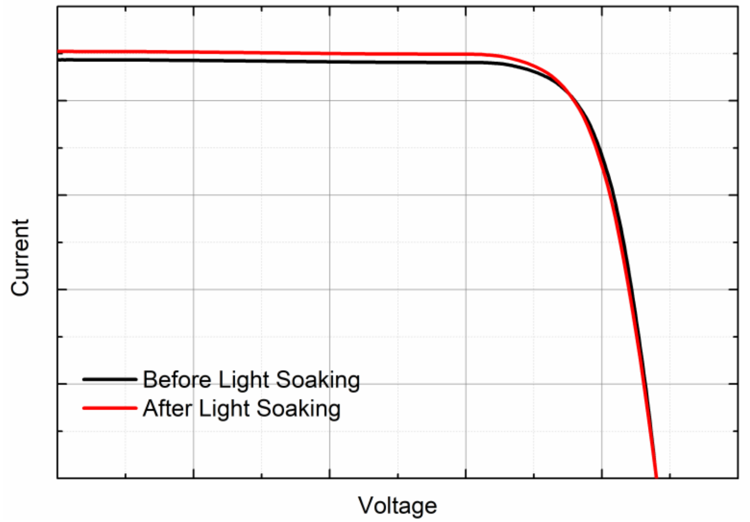
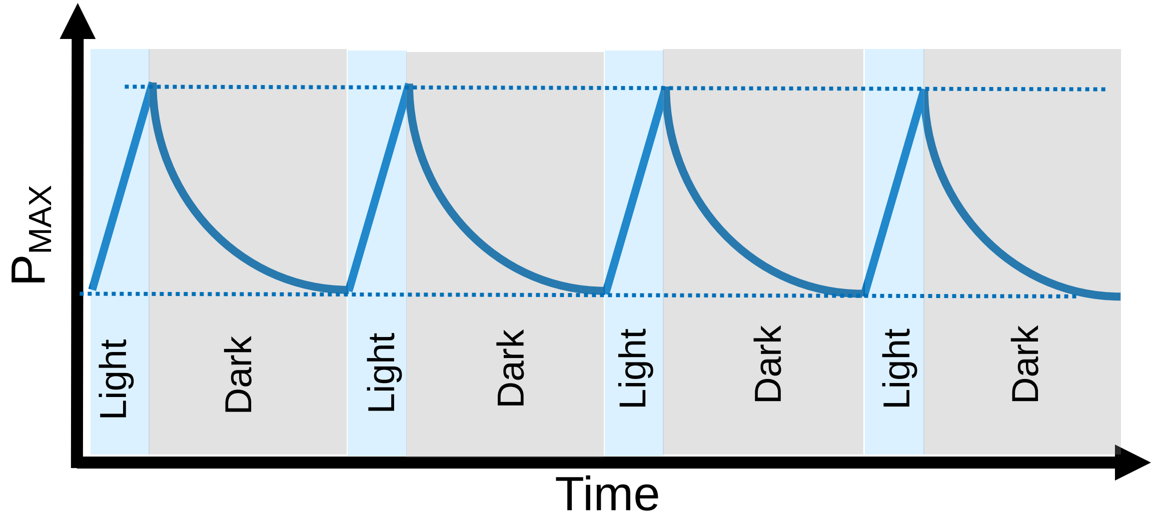
Hysteresis and Meta-stability Effect

Meta-stability Effect





- Meta-stability effect can be seen in the I-V measurement of N-type PV modules;
- After light soaking, the Isc and Pmax can increase, and then gradually decrease in dark condition.
- Metastable effects pose challenges for measurement of PV modules in third-party laboratories and simulators check on production lines.

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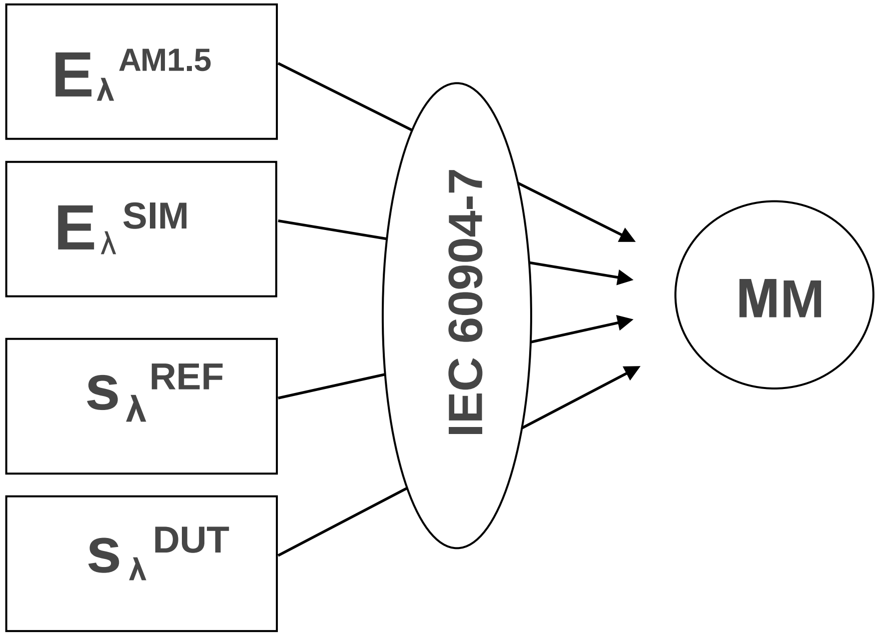
Spectral Mismatch

IEC 60904-7: Spectral Mismatch Calculation

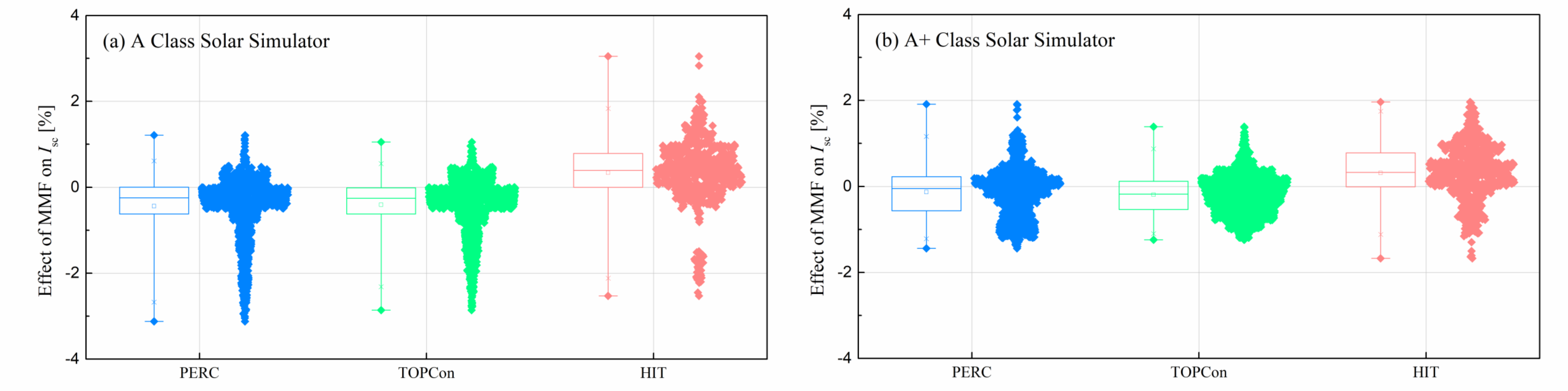
- $E_\lambda^{AM1.5}$ AM1.5 reference spectral irradiance (IEC 60904-3)
- E_λ^{SIM} Spectral irradiance of the solar simulator
- s_λ^{REF} Relative spectral response of reference device
- s_λ^{DUT} Relative spectral response of the module under test



! The spectral mismatch factor (MM) is a correction factor for irradiance (lamp power) of the solar simulator measured with a calibrated reference device (module, cell). The effective irradiance to the test module is increased or decreased accordingly to match its output under STC.

Spectral Mismatch

Effect of Spectral Mismatch on Power Rating



- Statistical analysis were conducted with SR of 6 primary monocrystalline reference cells, the spectral irradiance of 21 industrial solar simulators (7 A+ class, 14 A class), and SR of 63 solar cells with different technologies (22 PERC, 33 TOPCon and 8 HJT) ;
- The effect of spectral mismatch can exceed 3% with measurement equipments in the market;
- Spectral mismatch correction is necessary for the accurate measurement of N-type c-Si cells.

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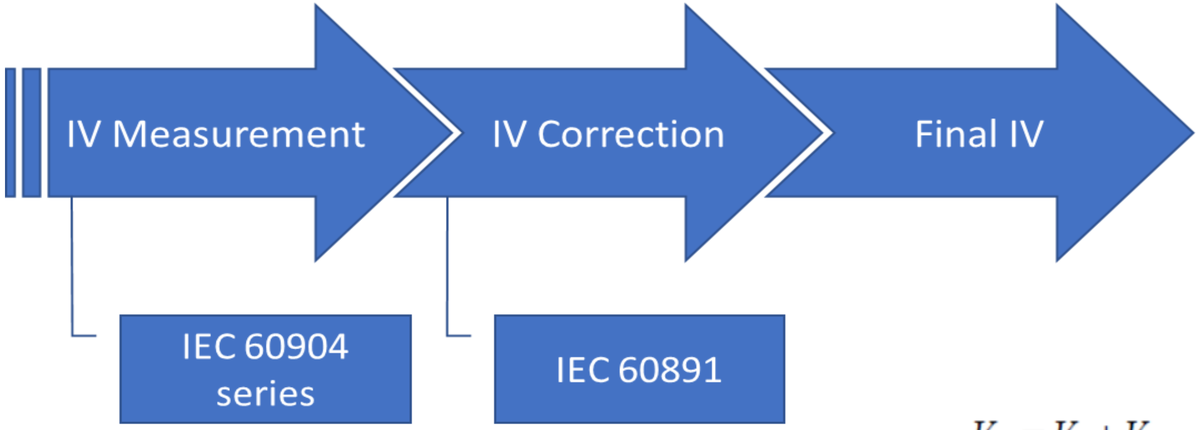
I-V correction

Review of Correction Procedures in IEC 60891



I-V correction procedure

Procedures 1

$$I_2 = I_1 + I_{SC} \cdot \left(\frac{G_2}{G_1} - 1 \right) + \alpha \cdot (T_2 - T_1)$$

$$V_2 = V_1 - R_S \cdot (I_2 - I_1) - \boxed{\kappa} \cdot I_2 \cdot (T_2 - T_1) + \beta \cdot (T_2 - T_1)$$

Procedures 2

$$I_2 = I_1 \cdot (1 + \alpha_{rel} \cdot (T_2 - T_1)) \cdot \frac{G_2}{G_1}$$

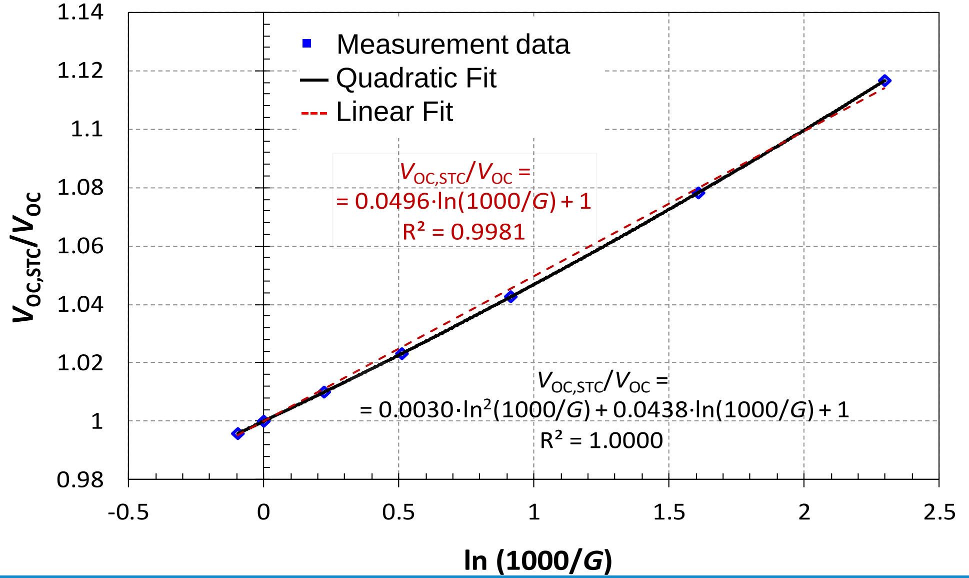
$$V_2 = V_1 + V_{OC1} \cdot \left(\beta_{rel} \cdot (T_2 - T_1) + \boxed{a} \cdot \ln \left(\frac{G_2}{G_1} \right) \right) - R'_S \cdot (I_2 - I_1) - \kappa' \cdot I_2 \cdot (T_2 - T_1)$$

- In 1987 the 1st edition of IEC 60891 was published. Based on single diode model, the procedure 1 was introduced. IEC 60891；
- Correction procedures 2 and 3 were introduced in the 2nd edition of the standard published in 2009. Procedure 2 is the most widely used, since it always produces complete I-V curves when translating to higher irradiance.

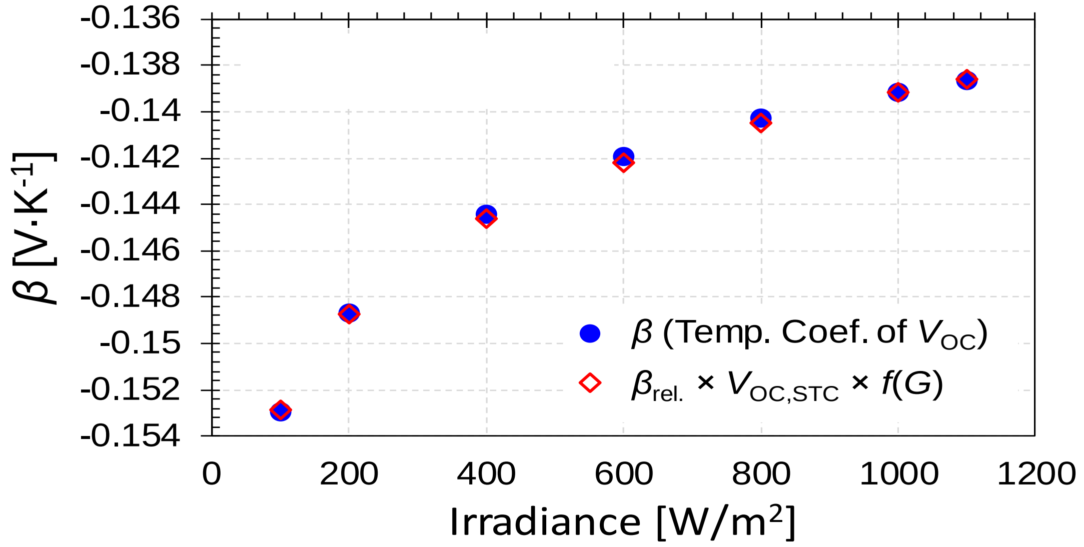
I-V correction

Improvement of I-V Correction Method

Non-linear Scaling of V_{OC} against Irradiance



Irradiance-dependent Temperature Coefficient, β



- Experimental data showed that a quadratic logarithmic model can provide improved accuracy in the irradiance scaling of voltage translation for both measurements and simulations.
- The temperature coefficient of voltage decrease at lower irradiance and N-type PV technologies are more susceptible to this effect.

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I-V correction

Revised IV Correction Procedure 2

Revised Formulae for Correction Procedure 2

$$I_2 = \frac{G_2}{G_1} \cdot I_1 \cdot \frac{(1+\alpha_{\mathrm{rel}} \cdot (T_2 - 25^{\circ}\mathrm{C}))}{(1+\alpha_{\mathrm{rel}} \cdot (T_1 - 25^{\circ}\mathrm{C}))}$$

$$V_2 = V_1 + V_{\mathrm{OC,STC}} \cdot \left\{ \begin{array}{l} \beta_{rel} \cdot \left[\begin{array}{l} f(G_2) \cdot (T_2 - 25^{\circ}\mathrm{C}) - \\ f(G_1) \cdot (T_1 - 25^{\circ}\mathrm{C}) \end{array} \right] \\ + \dfrac{1}{f(G_2)} - \dfrac{1}{f(G_1)} \end{array} \right\} - R'_{S1} \cdot (I_2 - I_1) - \kappa' \cdot I_2 \cdot (T_2 - T_1)$$

$$\text{where } f(G) = \frac{V_{\mathrm{OC,STC}}}{V_{\mathrm{OC}}(G)} = B_2 \cdot \ln^2\left(\frac{1\,000 Wm^{-2}}{G}\right) + B_1 \cdot \ln\left(\frac{1\,000 Wm^{-2}}{G}\right) + 1$$

$$R'_{S1} = R'_S + \kappa' \cdot (T_1 \text{-} 25^{\circ}\mathrm{C})$$

$$\text{and } V_{\mathrm{OC,STC}} = \frac{V_{\mathrm{OC1}} \cdot f(G_1)}{1 + \beta_{\mathrm{rel}} \cdot (T_1 - 25^{\circ}\mathrm{C}) \cdot f^2(G_1)}$$

- The deviations between translated and measured I-V curves are reduced with the updated formulas. The improvements are particularly noticeable in V_{OC}, where accuracy gains up to 2.5% have been observed. Smaller in magnitude (up to 0.3%) but systematic accuracy gains were also observed in P_{MAX}.

Cooperation between TÜV Rheinland and Trina Solar

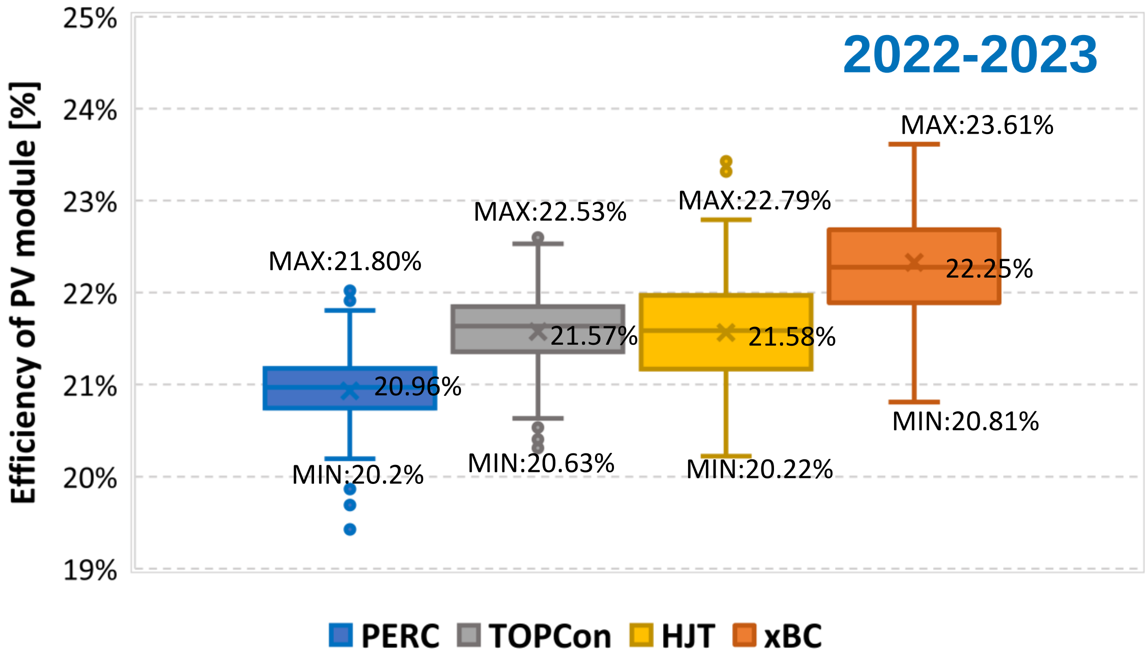

Figure 1 Efficiency distribution of various PV module types measured at TÜV Rheinland

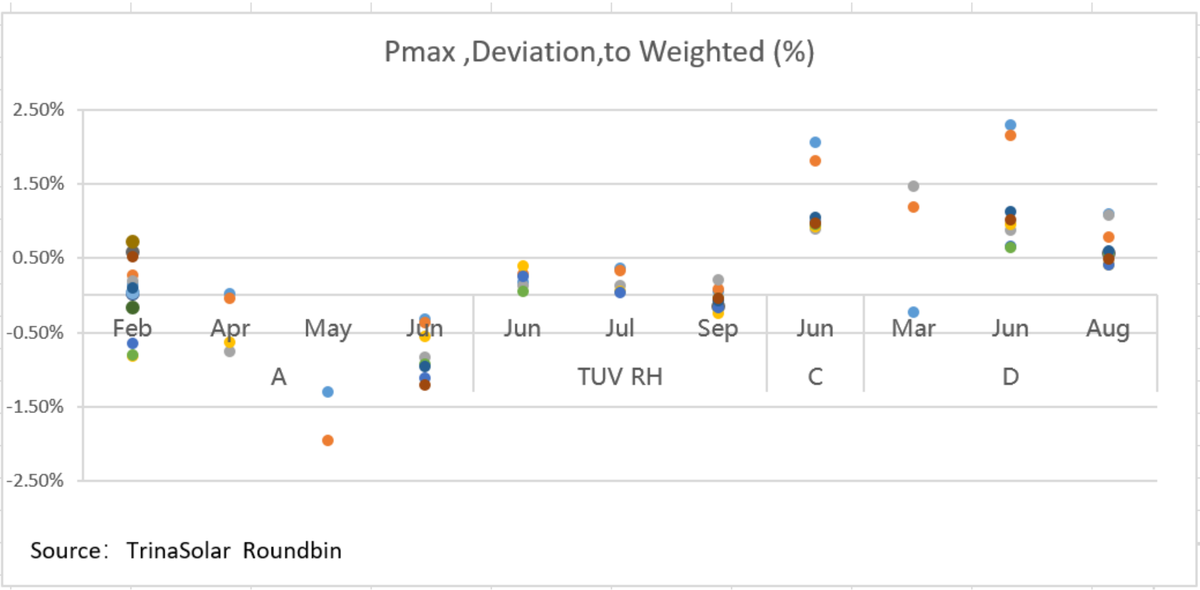

Figure 2 Inter laboratory comparison of N-type module power measurements, the test results found TÜV Rheinland stable.

- Recently, TÜV Rheinland released the PV module measurement data statistics from last year.
- TÜV Rheinland and Trina Solar are collaborating on developing advanced measurement techniques for n-type PV modules. They will jointly work towards regulating n-type PV module measurements and standardization. A related international round-robin measurement is underway.

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Conclusion

Power measurements of novel n-type photovoltaic technologies i.e. heterojunction, back contact or TOPCon can be affected by considerable measurement errors comparing to conventional technologies.

The high-precision measurement of PV modules is critical to the development of the entire industrial chain in the photovoltaic industry. A complete traceability chain, scientific measurement methods and standardized operation procedures are the key to ensuring accurate measurements of photovoltaic modules.

Dynamic IV is a novel technique developed by TÜV Rheinland R&D, which can accurately rate the power of high capacitance n-type PV modules in even a single flash.

As an authoritative power measurement institution with global recognition, TÜV Rheinland is the drafter of several important IEC standards in the field of PV measurement, as well as the organizer and participant of multiple global Round-robin tests, who is committed to improving the measurement accuracy of PV modules in the industry and releasing relevant data periodically.

Thank you for your attention!

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