



Progettazione definitiva finalizzata all'autorizzazione di una centrale di energia rinnovabile e delle relative opere di connessione denominata "Sperlinga", costituita da un impianto agrivoltaico di potenza complessiva pari a 50,112 MW [DC] e potenza in immissione pari a 37,75128 MW [AC]. La centrale sarà realizzata in C.da Serravalle nel comune di Chiaromonte Gulfi (RG) – Sicilia

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**IMPIANTI ELETTRICI
SCHEMA TECNICA MODULI FOTOVOLTAICI**

C451 **SP** **D** **EL** **0009** **r00**
Codice commessa Sito Fase Disciplina Numero Revisione



Revisione	Data	Motivo	Redatto	Controllato	Approvato
00	15/05/2024	Emissione	G.C.	U.L.	U.L.




n-type Modules

New Product Introduction

Dr. Guoqiang Xing
CTO, PV Business, Tongwei

Jun. 14, 2023





 Numbers of Tongwei



 ~50,000 global employees

 200+ subsidiaries worldwide

 494 listed in Forbes 2023 Global 2000

 41 years in business since 1982



Numbers of Tongwei – No.1 in PV industry as per revenue and profit

Operating Revenue
(Billion EUR)

18.67

YoY Growth:

119.69%

Net Profit
(Billion EUR)

3.37

YoY Growth:

217.25%

Total Assets
(Billion EUR)

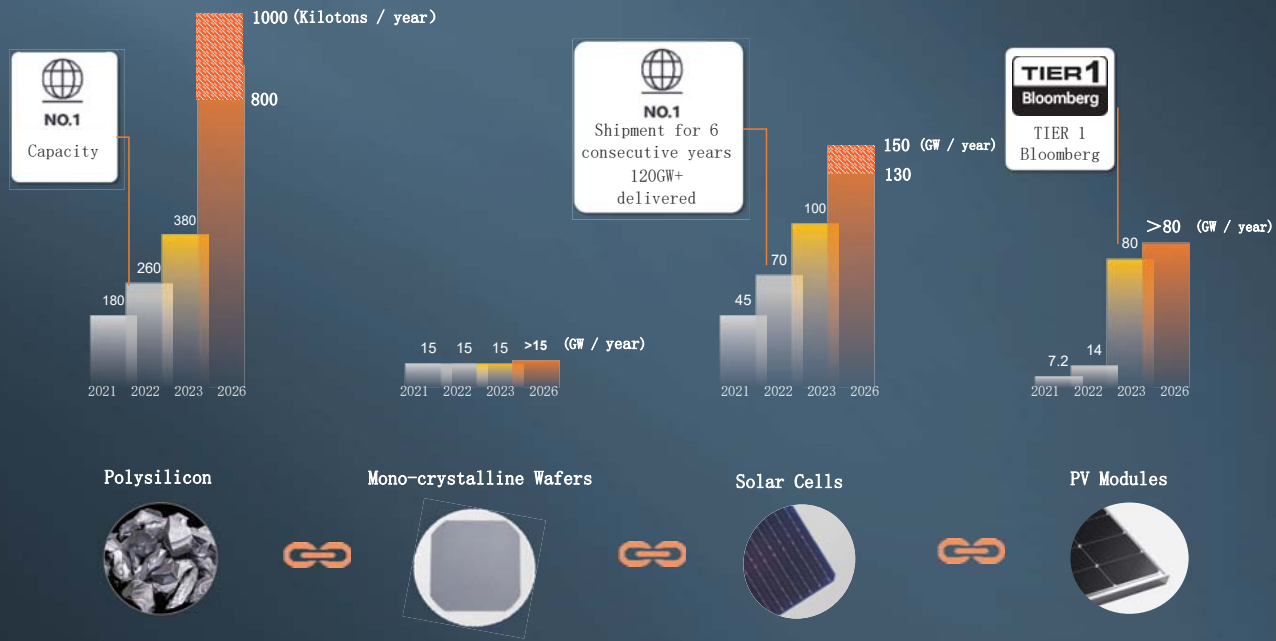
18.95

YoY Growth:

65.25%

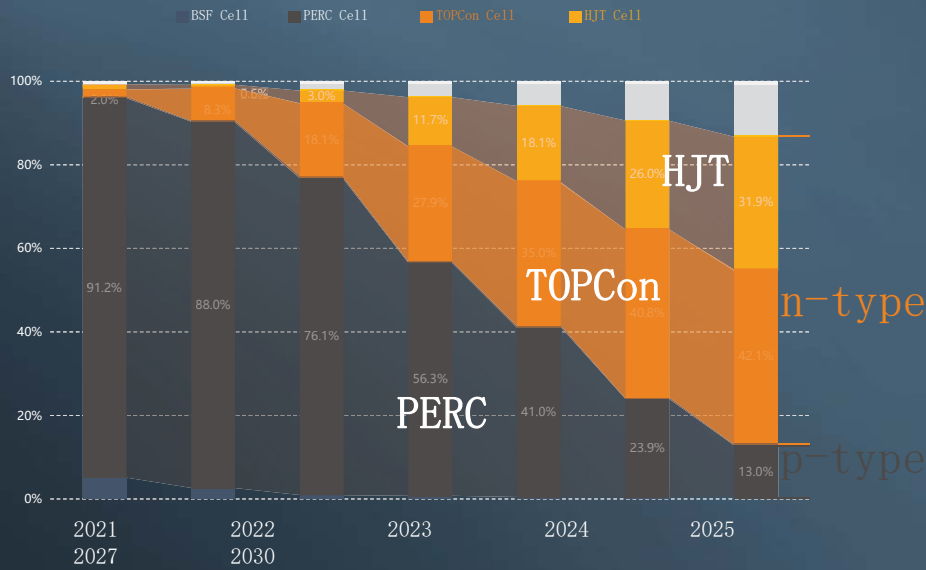
Source: *Tongwei 2022 annual report*, based on EUR/RMB exchange rate of 1:7.6316 on 25/04/2023.

Tongwei's PV value chain capacity roadmap



n-type: An inevitable trend

Output shares of various cell technology routes from 2021 to 2030



- The ceiling of PERC efficiency is defined by theoretical limits.
- n-type cells have entered mass production with a threshold value 1% higher than that of PERC cells (absolute value under the same CTM), with this expected to grow to 2% in time.
- The market share of p-type PERC cells is expected to decrease YoY and is forecast to fall below 50% by 2025. n-type TOPCon + HJT will become the mainstream technology.
- TOPCon market share is growing faster than expected, with capacity exceeding 500GW by the end of 2023.

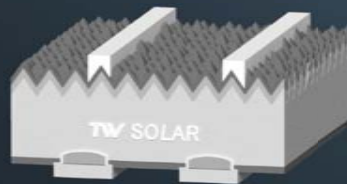
Source: 2022-2023 China PV Industry Development Roadmap, China Photovoltaic Industry Association (CPIA).

Solar cell technology iteration: n-type replaces p-type

n-type technology takes over

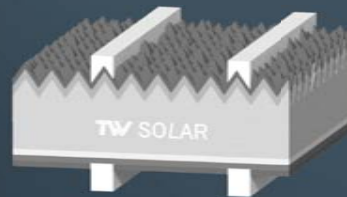
Reducing Costs and Increasing Efficiency

PERC | Industry average efficiency 23.2%



p-type

TOPCon | Industry average efficiency 24.2%



n-type

HJT | Industry average efficiency 24.6%



n-type



World record for PERC efficiency (2021): **23.47%**



The first GW-level HJT production line in China cell efficiency up to **26.18%**



The first pilot copper interconnection plant



G12-series THC bifacial module output up to **732.6W**



The industry's first large wafer size PECVD TOPCon pilot cell plant



Full-area industrialized TOPCon efficiency up to **25.8%**



All-back-contact technology



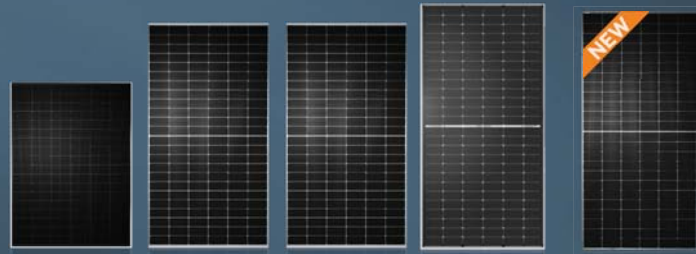
Perovskite/HJT efficiency up to **29.4%**

TPC Shingled Modules



Output power	425 W	445 W
Module efficiency	21.7%	21.4%
Product model	Terra-5K	Terra-5E
Module dimensions	1812*1096*30	1899*1096*30

TNC Modules



Output power	435 W	590 W	585 W	635 W	Up to 625 W
Module efficiency	22.3%	22.8%	22.6%	22.7%	Up to 23.2%
Product model	TWMND-54HB	TWMND-72HS	TWMND-72HD	TWMND-78HD	TWMNG-72HD
Module dimensions	1722*1134*30	2278*1134*35	2278*1134*30	2465*1134*30	2382*1134*30

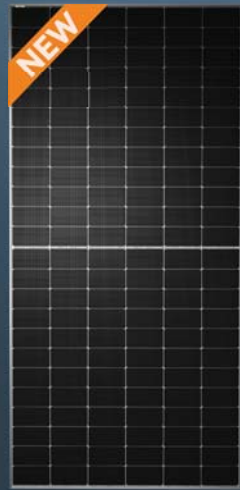
THC Modules



Output power	Up to 730 W
Module efficiency	Up to 23.5%
Product model	TWMHF-66HD
Module dimensions	2384*1303*35

Tongwei n-type new product introduction

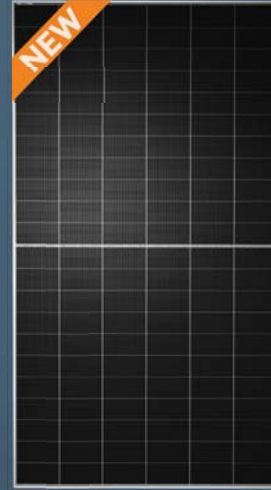
TNC
Module
625W



UP TO
23.2%
Module efficiency

2382mm * 1134mm

THC
Module
730W



UP TO
23.5%
Module efficiency

2384mm * 1303mm



TNC
Module

625W

UP TO
23.2%
Module efficiency

TNC Module

Superior choice
for reduced LCoE

TNC Module 625W

72 cell-series TNC bifacial module

Advantages



Maximum power
625W



Ultra-high output,
higher returns



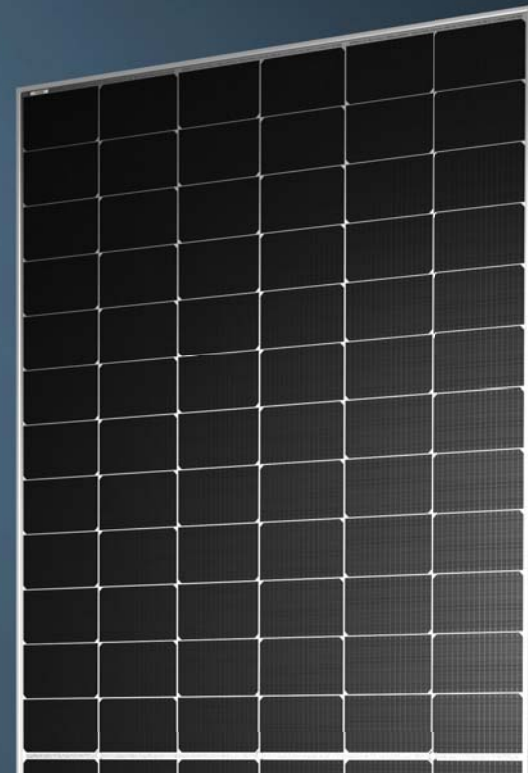
Ultra-low degradation,
higher reliability



Optimized dimensions,
applicable for all
scenarios

Power	Up to 625W
Efficiency	Up to 23.2%
Dimensions	2382*1134*30 mm
Weight	33.2 kg

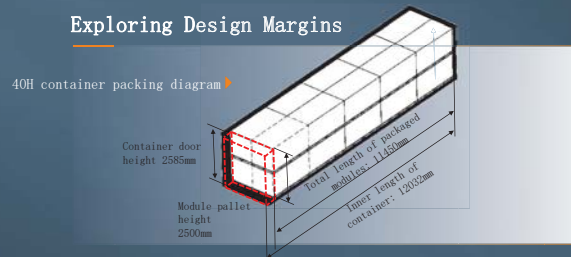
Note: There is a tolerance in module dimensions, where the long side is ± 4 mm and the short side is ± 2 mm.



Advantages of the 625W TNC module

The new 625W TNC product is designed and optimized from the traditional M10 72-series, integrating Tongwei's high-efficiency TNC technology and large-scale rectangular silicon wafer. The ultra design ensures greater product and customer value.

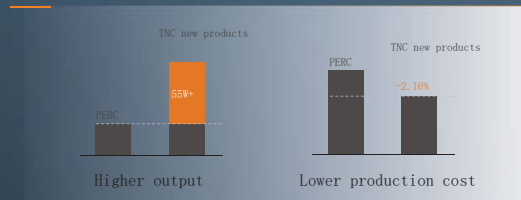
Exploring Design Margins



Module dimensions need to be adapted to the size of containers. The module height has been optimized,

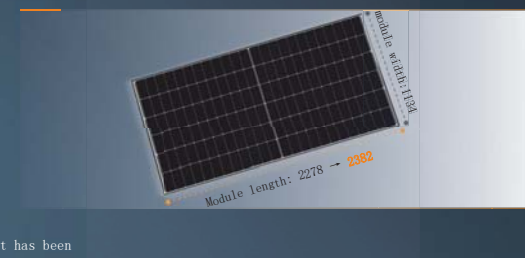
and the length can be further optimized to improve the utilization rate of the container.

Higher Product Value

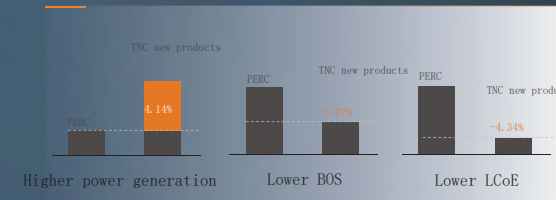


PERC is based on M10 72-series (550W) module.

Optimizing Module Design



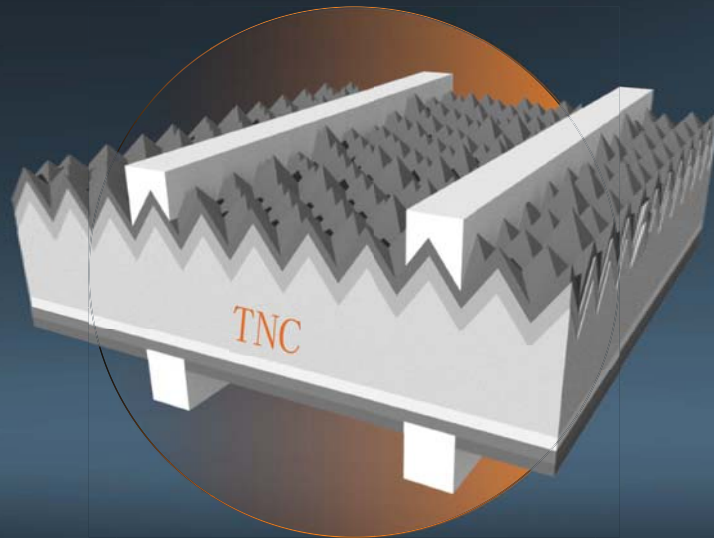
Higher Customer Value



Tongwei n-type TNC: The industry's first self-developed PECVD technology

Tongwei initiated TNC cell research in 2020 and developed the industry's first large wafer size **PECVD polysilicon technology** route.

By 2021, mass production conversion efficiency had reached **24.65%**, with this further improving **25.3%** in 2022 and **25.5%** in April 2023.



High efficiency:

Mass production conversion efficiency now exceeds **25.5%**

Module power = **580W** (M10 72-series)

Technical issues mitigated under n-type-passivation contact mass production conditions.

High reliability:

Low temperature coefficient

High bifaciality

Excellent low irradiance performance

High power generation per W_p

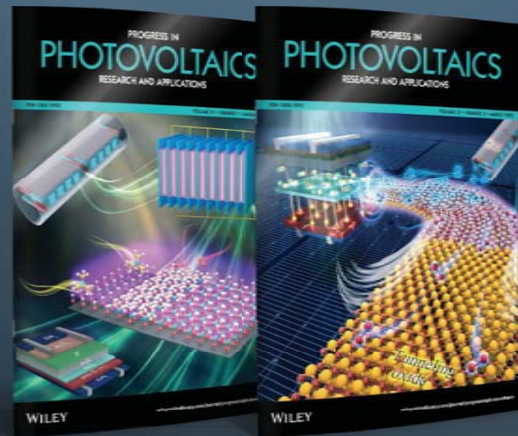
Low LCoE

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



Cover of Jan. 2023

Cover of Mar. 2023



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

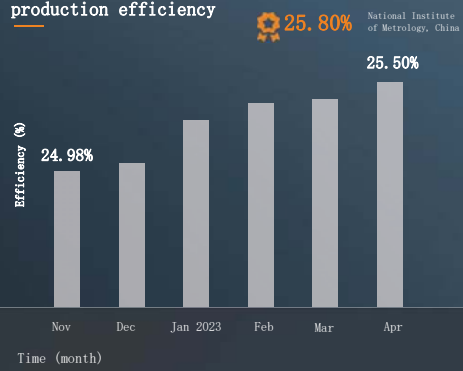
- China's achievements in tube-based PE-Tox & Poly closed the industry gap.
- Widely recognized and appraised internationally (incl. two cover articles of PIP journal).
- Innovative breakthroughs and leadership in TOPCon cell production technology.



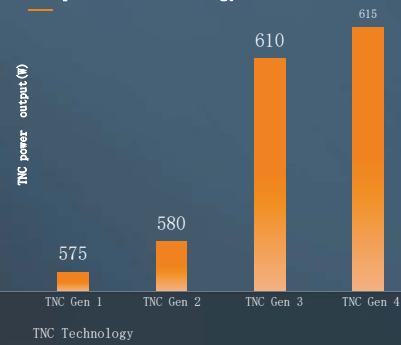
9GW TNC capacity – Mass production efficiency > 25.5%, module power > 580W

- In December 2020, Tongwei optimized the first technology development of the PECVD poly route for mass production, solving PE-poly mass production issues and continuing with improved efficiency.
- The first TNC module of the Meishan Phase III project rolled off the production line at the end of November 2022, recently achieving a mass production efficiency of 25.50%, representing the top level in the industry.
- The efficiency of Tongwei's "champion", the M10 TNC, is 25.80% (certified by the National Institute of Metrology, China).
- Tongwei has optimized the performance of SE technology and has completed a number of projects, including the development of TNC4.0 bifacial poly, further improving industry competitiveness.

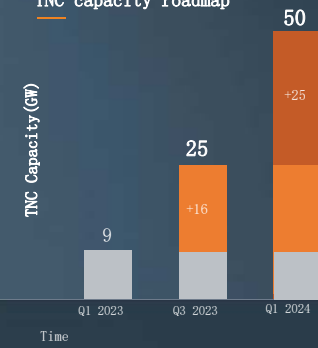
Trend of TNC mass production efficiency



TNC product technology



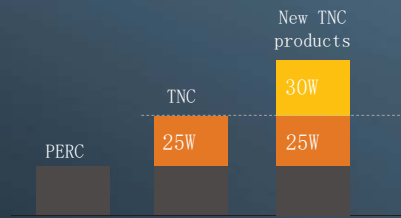
TNC capacity roadmap



Tongwei TNC module :
55W+ higher than PERC and better temperature coefficient



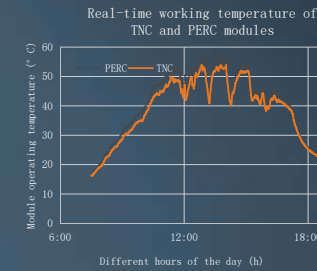
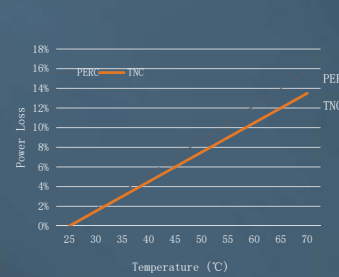
Higher power output



As in the case of the M10-72 bifacial module, the power of the TNC module is **25W** higher than PERC. The new TNC product is further enhanced, with power **increased by an additional 30W**.



Better temperature coefficient

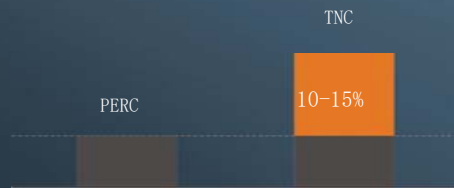


The temperature coefficient of the PERC module is $-0.35\%/^{\circ}\text{C}$, with that of the TNC module optimized to $-0.30\%/^{\circ}\text{C}$, Power generation is remarkably higher in high-temperature environments.

Tongwei TNC module :
10-15% higher in bifaciality than PERC and lower power degradation



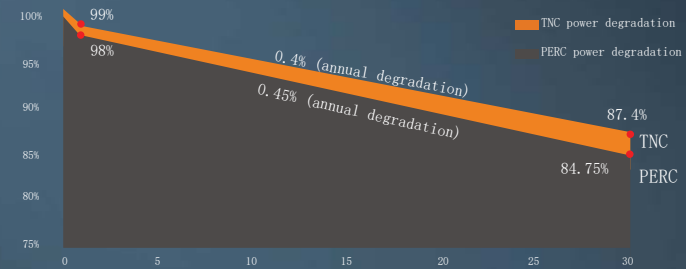
Higher bifaciality



Bifaciality of TNC module is **10-15%** higher than that recorded in PERC modules (same M10-72 version).



Lower power degradation



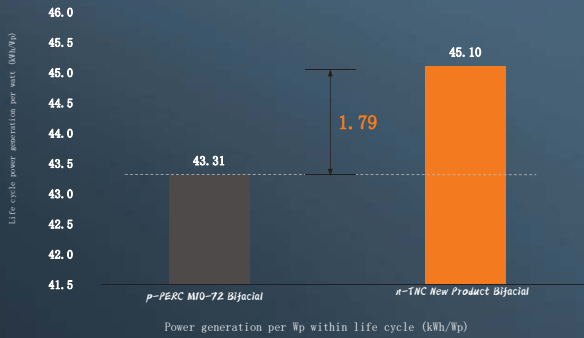
The annual degradation of the TNC module is **1% in Year 1**, with subsequent annual degradation **not exceeding 0.4%**. Following 30 years of use, resulting output should be no lower than **87.4%** of the initial output.

Both monofacial and bifacial TNC modules have a 30-year warranty.

(PERC annual degradation: 2% in 1st year, 0.45% for bifacial and 0.55% for monofacial in annual degradation.
 PERC output warranty: 30 years for bifacial and 25 years for monofacial)

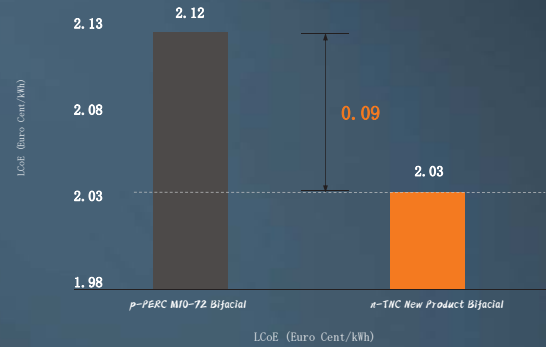
Tongwei TNC module :
 4.14% higher power generation and 4.34% lower LCoE

↑ 4.14% power generation per Wp (within life cycle)



Class II area (Gonghe Base in Qinghai, China), system capacity 120.0 MWp, capacity ratio 1.20, fixed support bracket, module angle 33°, ground centralized string inverter system.

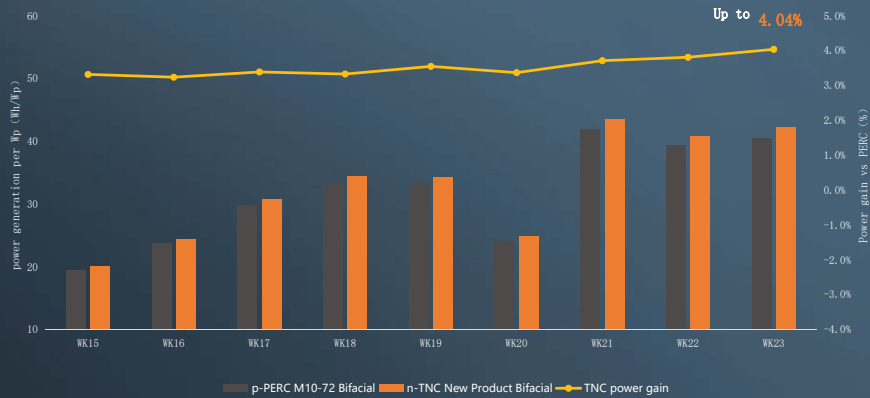
↓ 4.34% LCoE



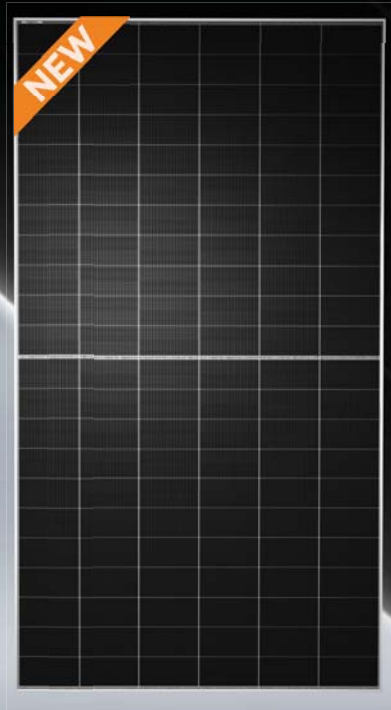
Based on EUR/RMB exchange rate of 1:7.6185 on 06/02/2023. The percentage data is calculated in RMB.

Tongwei TNC module field test :
 4.04% higher actual power generation gain than PERC

↑ 4.04% actual power generation gain



- **Monitoring period:**
4/10/2023-6/9/2023
- **Field test location:**
Sanya (18° 31N;109° 56E),
Hainan province, China
- **Modules compared:**
72 cell-series TNC bifacial module
M10-72 series PERC bifacial module
- **Climate type:**
Tropical monsoon climate
- **Average temperature:** 25.7°C
- **Average daily irradiation:** 5.35 kWh/m²



THC
Module
730W

UP TO
23.5%
Module efficiency

THC Module

Pursuing the epitome
of quality and
performance

THC module 730W

G12-66 series THC bifacial module

Advantages

730W Maximum Power up to 730W

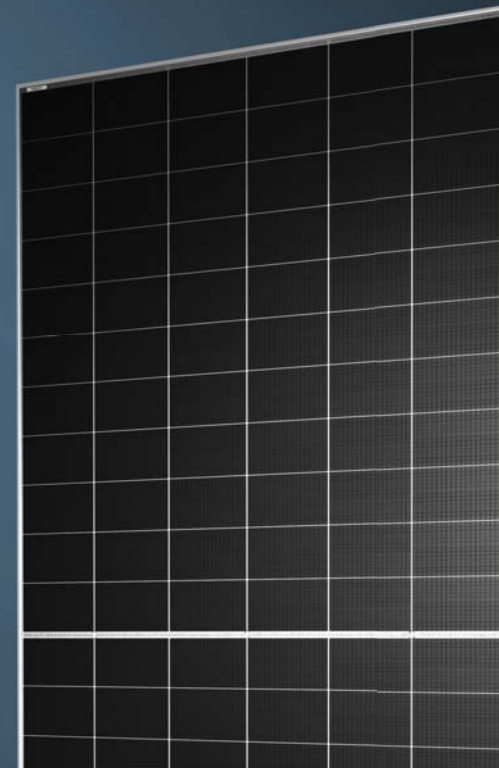
Ag Silver-free technology, cost-effective & high-efficiency

Ultra-high output, higher returns

Ultra-low degradation, higher reliability

Power	Up to 730W
Efficiency	Up to 23.5%
Dimensions	2384*1303*35 mm
Weight	38.7 kg

Note: There is a tolerance in module dimensions, where the long side is ± 2 mm and the short side is ± 2 mm.





Power of Tongwei 210 THC bifacial module reaches

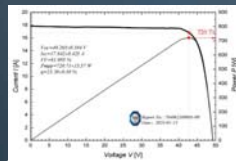


732.6W

Certified by TÜV SÜD

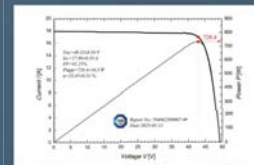
01/18/2023

720.7W



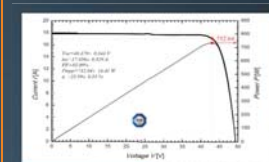
05/12/2023

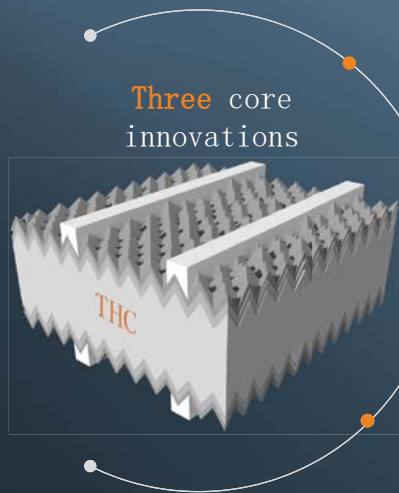
728.4W



05/15/2023

732.6W





Three core innovations

Bifacial nanocrystalline silicon

With high light transmittance, lower defects and higher conductivity, nc-Si is suitable for replacing doped amorphous silicon, achieving an efficiency improvement of about **1%**

Copper metallization

Production costs are lower and efficiency improved by more than **0.2%** compared to screen printing

SMBB module technology

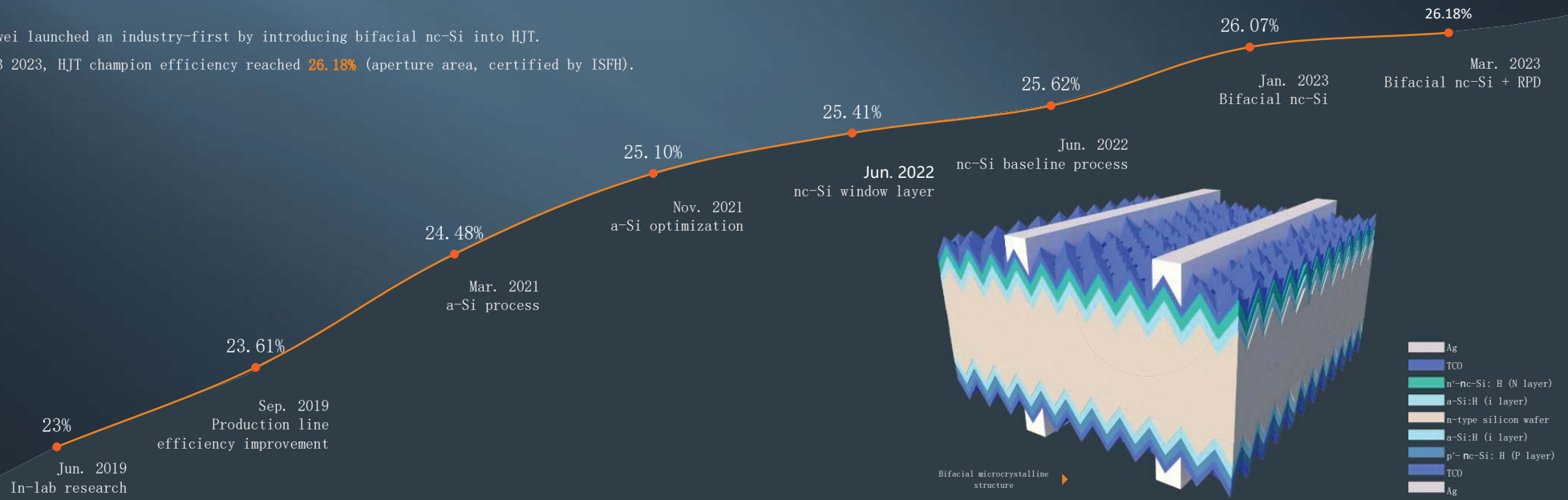
Reduced power loss due to microcracks
Reduced internal cell consumption loss
Enhanced aesthetics

Product Advantages

-  **Higher** power output
-  **Higher** bifacial gain
-  **Lower** power degradation
-  **Improved** temperature coefficient

Nanocrystalline silicon window layer with superior transparency and carrier selectivity

- Tongwei began researching HJT technology in 2018, building its first GW-level HJT production line in China in 2021.
- Tongwei launched an industry-first by introducing bifacial nc-Si into HJT.
- By Q3 2023, HJT champion efficiency reached **26.18%** (aperture area, certified by ISFH).

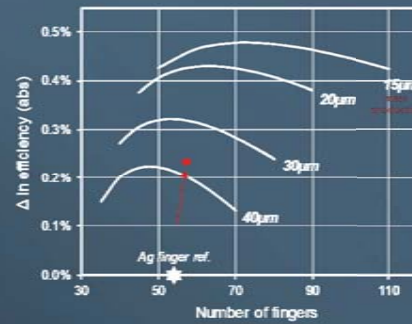
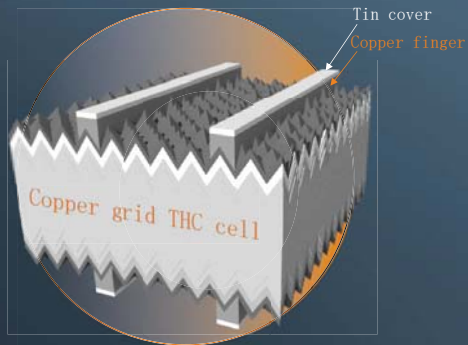


Copper metallization: Silver-free, plus 0.2% efficiency bonus

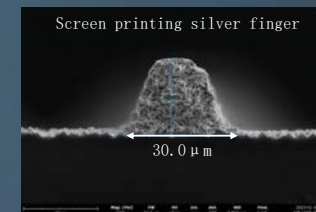
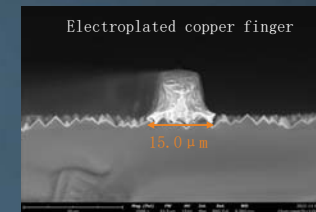
Tongwei built the industry's first G12 half-cut copper interconnection pilot plant and fully developed equipment, technology and materials.

Currently, the width of the finger has been reduced to less than $15\ \mu\text{m}$, enhancing the efficiency is 0.2% in comparison to the printing process.

Tongwei will consider a GW-level expansion once the mass production feasibility demonstrated.



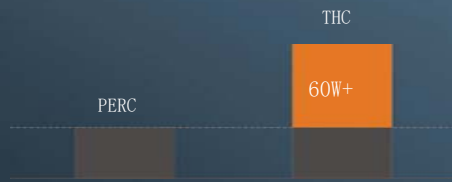
Copper grid line has greater efficiency improvement space compared to screen printed silver grid line



Tongwei THC module :
60W+ higher than PERC and **-0.26%/°C** temperature coefficient



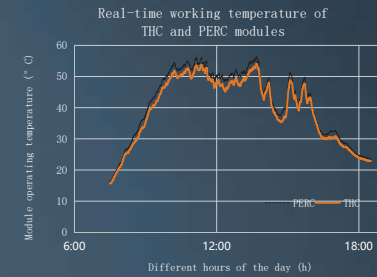
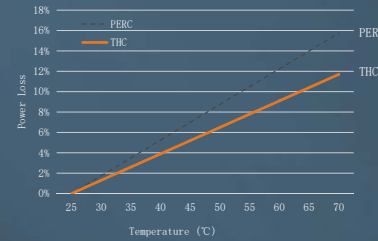
Higher power output



G12-66 bifacial module THC module output is **60W+** higher than the PERC module.



Better temperature coefficient

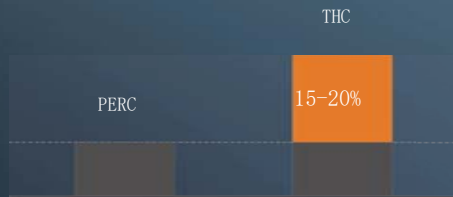


The temperature coefficient of the PERC module is **-0.35%/°C**, with that of the n-type THC module **-0.26%/°C**. Power generation is noticeably higher in high-temperature environments.

Tongwei THC module :
15-20% higher in bifaciality than PERC and lower power degradation



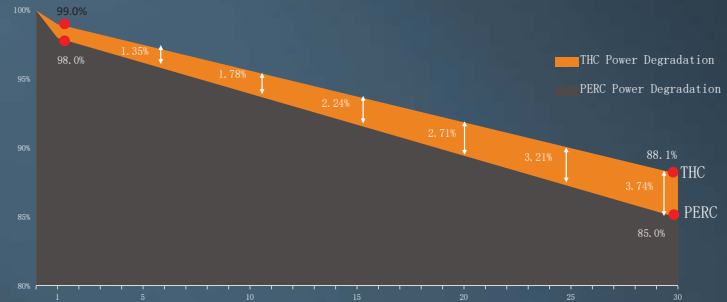
Higher bifaciality



For the G12-66 bifacial product, the bifaciality of the THC module is **15-20%** higher than that of the PERC module.



Lower power degradation



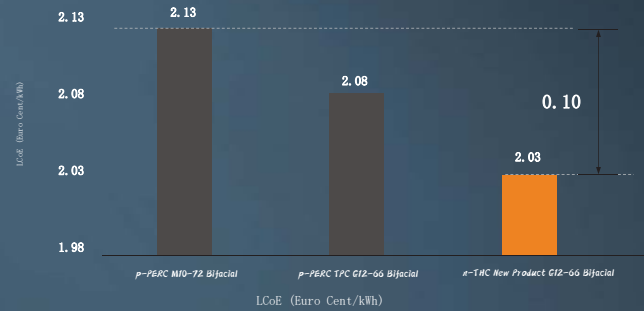
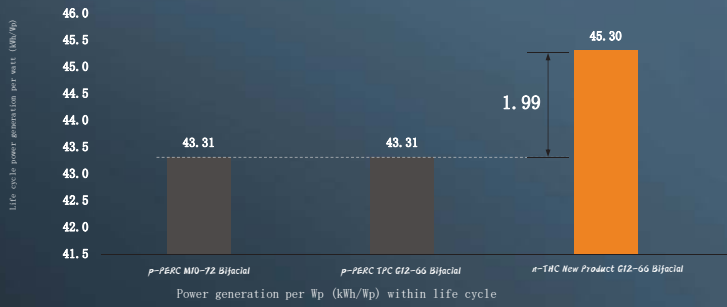
The annual degradation of the THC modules is **1% in Year 1**, with subsequent annual degradation **not exceeding 0.375%**. Following 30 years of use, resulting output should be no lower than **88%** of the initial output.

THC modules have a 30-year warranty.
(PERC annual degradation: 2% degradation in 1st year, 0.45% annual degradation for bifacial. PERC power warranty for bifacial is 30 years)

Tongwei THC module :
 4.60% higher power generation and 4.53% lower LCoE

↑ **4.60%** Power generation per Wp (within life cycle)

↓ **4.53%** LCoE

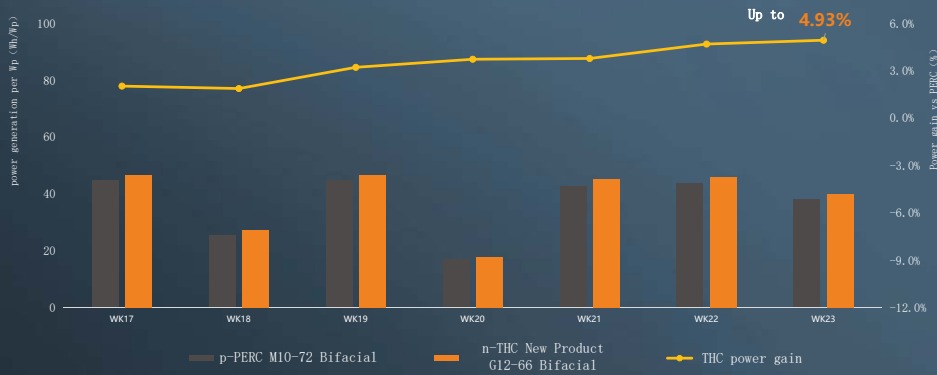


Class II area (Gonghe Base in Qinghai, China), system capacity 120.0 MWp, capacity ratio 1.20, fixed support bracket, module angle 33°, ground centralized string inverter system.

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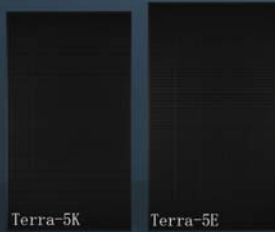
Tongwei THC module field test :
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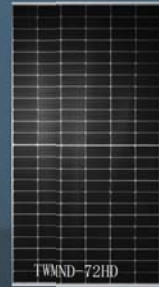


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- **Field test location:**
Liangshan (28° 17N; 102° 93E),
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- **Modules compared:**
G12-66 series THC bifacial module
M10-72 series PERC bifacial module
- **Climate type:**
Subtropical monsoon climate
- **Average temperature:** 10.9°C
- **Average daily irradiation:** 4.80kWh/m²

PV CHANGES THE WORLD



TPC Shingled Modules



TNC Modules

THC Modules