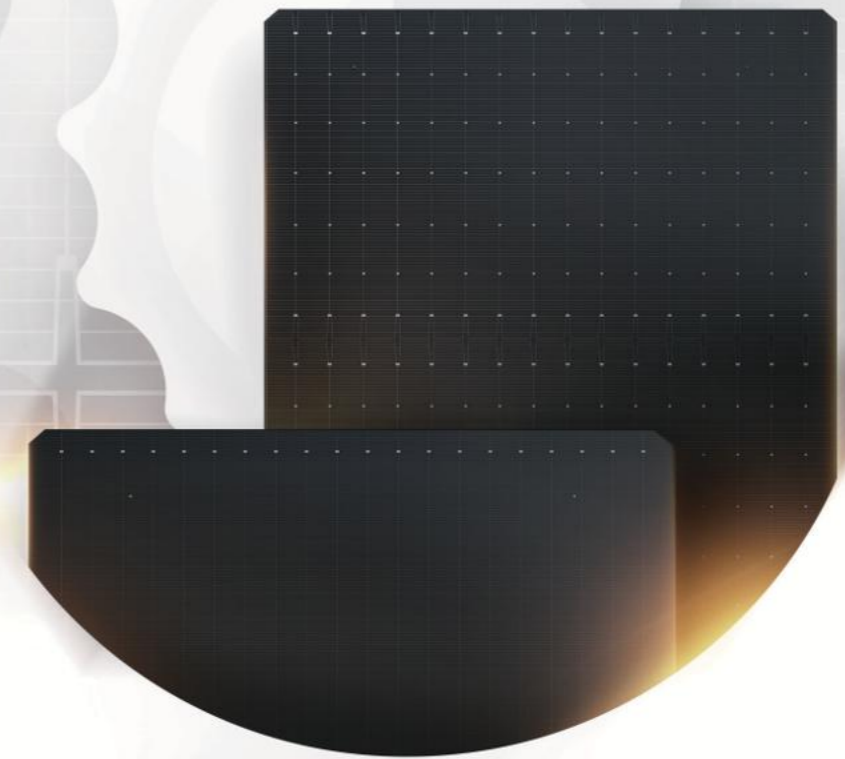


# TONGWEI



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## WHITE PAPER OF TW **TNC** CELL

---

Tongwei Solar Co., Ltd.

Address: No. 588, Middle Section of Tianfu Avenue,  
High-tech Zone, Chengdu, Sichuan  
Postal Code: 610000

Pre-sales Email: [sale02@tongwei.com](mailto:sale02@tongwei.com)

Customer Service Hotline: 028-60666661

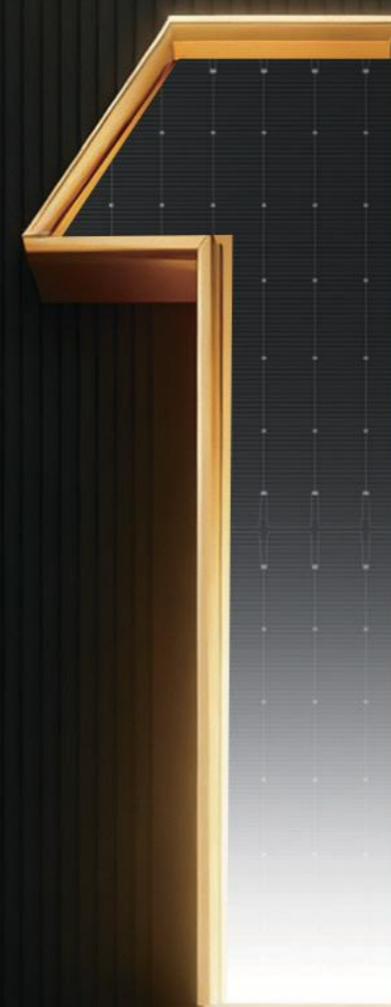
Official Website: <https://en.tongwei.cn/>

# CHOOSE TONGWEI CELLS

PRODUCE HIGH-EFFICIENCY MODULES

Traceable Quality, Reliable Products

— FOR 9 —  
CONSECUTIVE YEARS—GLOBAL  
CELL SHIPMENTS RANKING TOP 1



Our cell shipments have been the world's largest for nine consecutive years since 2017, making Tongwei the first company in the industry to achieve cumulative shipments exceeding 400GW.

Source:  InfoLink  
CONSULTING

## THE FIRST "LIGHTHOUSE FACTORY" IN GLOBAL PV CELL MANUFACTURING

In 2025, we continued to advance carbon footprint certification, reducing the LCA value by

**35.4%** ↓

2024  
**25.004**kg CO<sup>2</sup> eq/ kwp

2025  
**16.153**kg CO<sup>2</sup> eq/ kwp

# CELL-LEVEL TRACEABILITY

## Making Every Cell More Trustworthy

The world's first intelligent manufacturing system in the global PV cell industry

Diffusion Sheet Resistance 4x0Ω

Ingot ID Y2B3xx8X25Xxx1FD0

Silicon Wafer Pallet ID  
N01NM1250XXX01-00XX

Cell ID 175xxxx588

Color Aoi1R 123

Texturing weight loss 0.02g

Cell Efficiency Eta25.8%

PROD25B26XXXXXX57



### Sensor + Data + Algorithm

Data-driven decisions for transparent, trustworthy manufacturing.



### Wafer-level Digital Identity

Unique wafer ID for full-process traceability.



### Full-link Records

Performance comparison, quality verification, process optimization.



### Smart Manufacturing

Empowers supply chain collaboration, customer service, and lifecycle quality management.

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	• 1.2 Integrated Layout of Tongwei PV Industry Chain	/03
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## PART 1

TONGWEI

### Chapter 1 Company Profile



# 1.1 Tongwei Co., Ltd.

## 1.1.1 About Tongwei

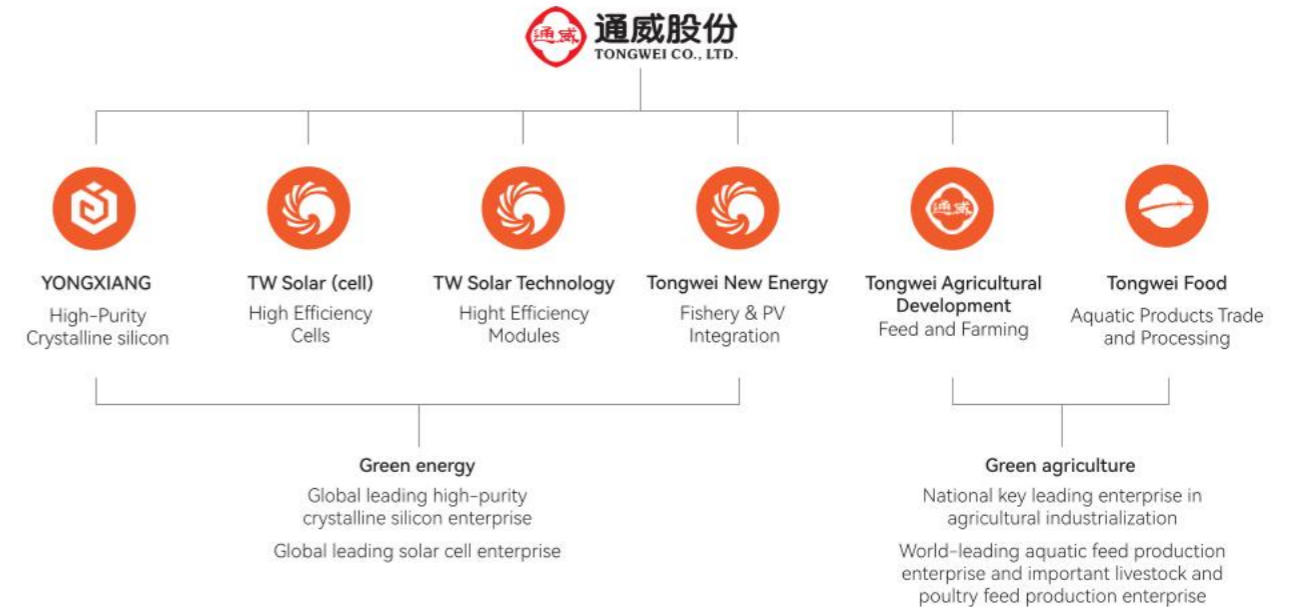
**500**  
**FORTUNE GLOBAL**  
 The first and only one in the PV industry  
 Fortune Global 500 enterprise



Controlled by Tongwei Group, Tongwei Co., Ltd., a large-scale and listed private enterprise, has been specializing in green agriculture and green energy as a high-tech company. So far, Tongwei has over 200 branches and subsidiaries spanning across China and the globe. The annual feed capacity has exceeded 13 million tons, and the capacity of high-purity crystalline silicon is over 900,000 tons. The capacity of solar cells has reached more than 150GW, and the current capacity of modules has exceeded 90GW. Focusing on "fishery-PV integration", 56 PV plants have been constructed in different provinces and cities across China, and the installed and grid-connected capacity of photovoltaic power stations has achieved 5GW accumulatively. After years of leap-frog development, Tongwei has become a leading Chinese enterprise in agricultural industrialization, an important aquatic feed producer, a world leader in aquatic feed production, high-purity crystalline silicon, and solar cell production, and an important livestock and poultry feed producer.

Since its entry into the photovoltaic new energy industry in 2006 and after more than 10 years of rapid development, Tongwei has become a global leading enterprise in integrated PV, forming a full industrial chain layout from upstream industrial silicon to terminal PV power stations. It has significant competitive advantages, leading the industry in terms of production capacity scale, technology R&D, cost control, quality, and brand. It has maintained the first place in global market share in high-purity crystalline silicon and solar cell services for many consecutive years, and its module shipment also ranks among the top five in the world. The Company continues to firmly adhere to the long-term strategic goal of "building a world-class clean energy operator", focusing on core technological innovation and cost reduction and efficiency improvement. Tongwei makes every effort to expand the market, strengthen cooperation with upstream and downstream customers, and continuously enhance its comprehensive competitiveness, consolidating its market position.

# 1.2 Integrated Layout of Tongwei PV Industry Chain



## High-purity crystalline silicon

The core process technology has been iteratively upgraded and applied to the "8th Generation Yongxiang Method". Product purity reaches 99.999999999%. Electronic-grade crystalline silicon has been supplied in batches at home and abroad.

**永祥股份**  
 YONGXIANG CO., LTD.  
 Production capacity  
**Over 900,000 tons**

## High-quality silicon wafer

Independently produce high-quality silicon wafers and sign long-term cooperation agreements with leading silicon wafer manufacturers, relying on the advantage of silicon materials, to ensure supply quality.

## Crystalline silicon cell

World-leading high-efficiency crystalline silicon solar cell enterprise  
 The first "lighthouse factory" in the global PV cell industry

**通威太阳能**  
 TW SOLAR  
 Production capacity  
**150+GW**

## High-efficiency modules

TW Solar's module products fully cover various application scenarios

**通威太阳能科技**  
 TW SOLAR TECHNOLOGY  
 Production capacity  
**90+GW**

## "Fishery-PV integration"

The world's first innovative development model of "fishery-PV integration" to achieve "a triple-win outcome" of fishery, electricity, and environmental protection

**通威新能源**  
 TW NEW ENERGY  
 Cumulative installed and grid-connected capacity  
**5GW**

# 1.3 Tongwei Solar

# PART 2

TONGWEI

## Chapter 2 High Quality

### 1.3.1 About TW Solar

TW Solar deeply engages in the R&D, manufacturing, and promotion of core products for solar power generation, and is a world-leading crystalline silicon cell production enterprise. After 13 years of leapfrog development, the Company has achieved the transformation from "following" and "keeping pace" to "leading", with zero major safety accidents and zero major environmental accidents for 13 consecutive years. Up to now, TW Solar has owned Chengdu, Meishan, Jintang, Tonghe, Pengshan, and Zhongwei Companies, with more than 10,000 on-the-job employees and an annual production capacity of over 150 GW. The Company has remained No.1 in the world in terms of cell shipment for eight straight years (statistics from InfoLink Consulting), and has become the first enterprise in the industry with cumulative cell shipment exceeding 300 GW. In 2025, Meishan Company became the first "lighthouse factory" in the global PV cell industry.



### 1.3.2 Corporate Culture of TW Solar



Corporate Mission

PV changes the world



Corporate Vision

Build a world-class clean energy enterprise  
Let solar energy benefit mankind

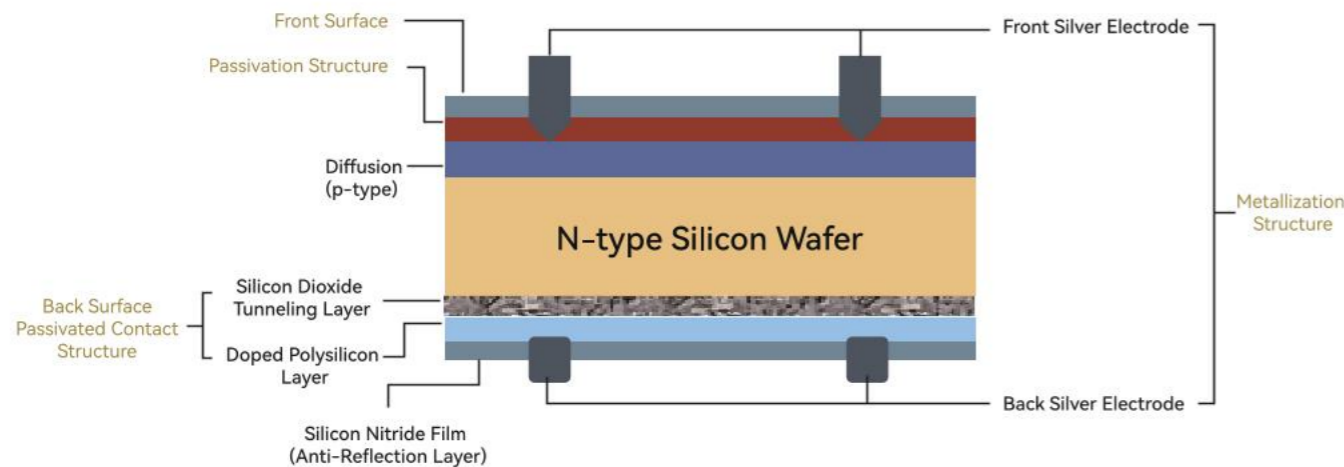
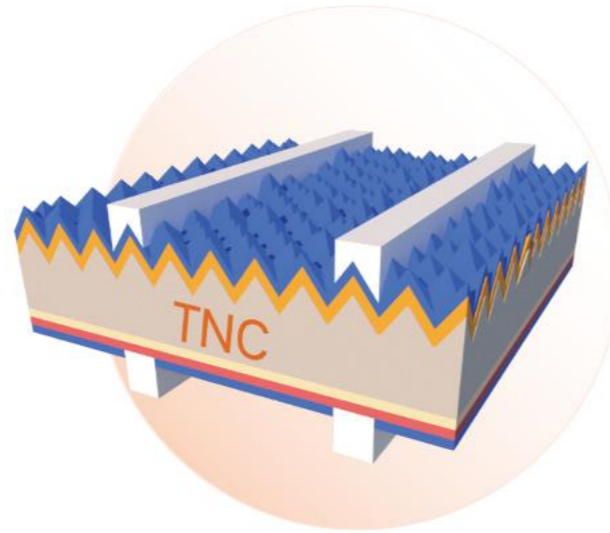
# 2.1 Tongwei Gene

## 2.1.1 TNC Cell: Product Background

TNC (Tongwei N-type Passivated Contact Technology) refers to a high-efficiency N-type passivated contact cell technology independently developed by Tongwei. Tongwei started the development of TNC technology in 2020, established the industry's first 210mm large-size PECVD-Poly cell pilot line in 2021, pioneering the industrial application of large-size PE-Poly technology, and bridging a key technological gap.

In 2023, Tongwei's TNC technology was successfully included in the 2023 Catalogue of Photovoltaic Industry Innovation Achievements due to its industry-first breakthroughs and technical leadership. It remains the only listed N-type passivated contact cell technology, distinguished by its superior customer value, product performance, and mass production feasibility.

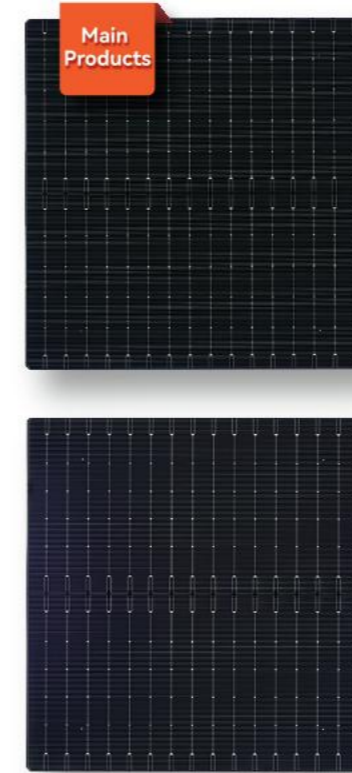
In 2025, Tongwei upgraded TNC technology and launched TNC 2.0 product series, forming an innovative product closed loop of "core process breakthrough, manufacturing system upgrade, product performance leap."



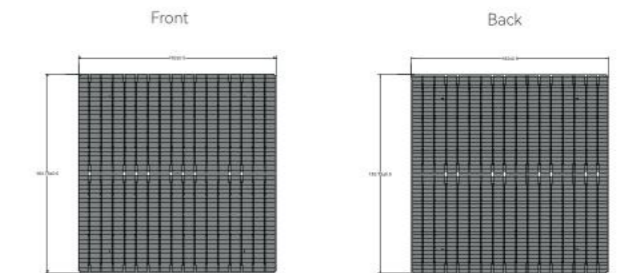
## 2.1.2 TNC Cell Product Overview

TNC "Tongwei Gene" cell products are designed based on the SMBB (Super Multi-Busbar) cell technology platform and cover the mainstream sizes (M10, G12R, and G12).

### TNC -M10



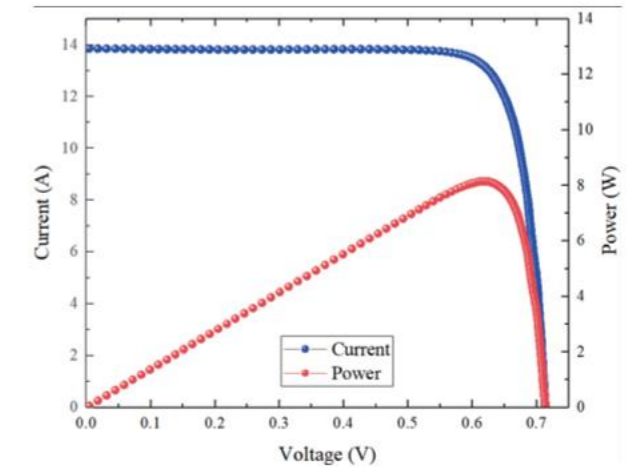
#### Product Appearance (mm)



#### Design

<b>Dimensions</b>	182mm*183.75mm*0.5mm	TkVoltage: $-(0.25\pm 0.01)\%/K$
<b>Thickness</b>	130±13μm	TkCurrent: $+(0.04\pm 0.004)\%/K$
<b>Front</b>	16 busbars (silver), 192 fingers blue anti-reflection film (silicon nitride)	TkPower: $-(0.29\pm 0.025)\%/K$
<b>Back</b>	16 busbars (silver), 200 fingers blue anti-reflection film (silicon nitride)	Rsh≥50Ω Irev2±0.5A

#### IV Curve



#### Front Electrical Performance Parameters

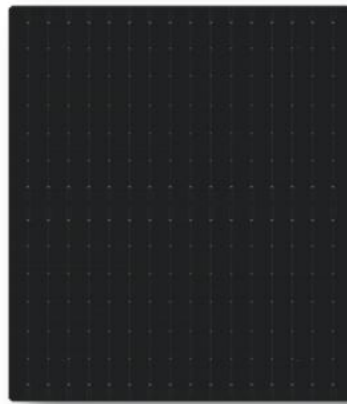
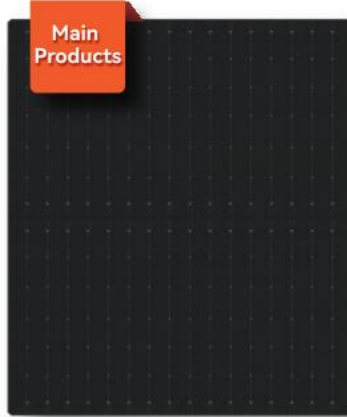
Eff (%)	Pmpp (W)	Vmpp (V)	Impp (A)	Voc (V)	Isc (A)	FF (%)
25.7	8.60	0.635	13.550	0.722	14.119	84.38
25.6	8.57	0.634	13.525	0.721	14.101	84.28
25.5	8.54	0.633	13.488	0.720	14.087	84.15
25.4	8.50	0.632	13.454	0.719	14.066	84.06
25.3	8.47	0.631	13.423	0.719	14.031	83.95
25.2	8.43	0.630	13.387	0.718	14.005	83.88
25.1	8.40	0.629	13.359	0.717	13.983	83.79
25.0	8.37	0.628	13.325	0.716	13.969	83.66
24.9	8.33	0.628	13.272	0.715	13.956	83.51
24.8	8.30	0.627	13.236	0.714	13.936	83.42
24.7	8.27	0.626	13.203	0.713	13.917	83.32
24.6	8.23	0.625	13.174	0.711	13.910	83.26
24.5	8.20	0.623	13.163	0.709	13.906	83.18

#### Back Electrical Performance Parameters

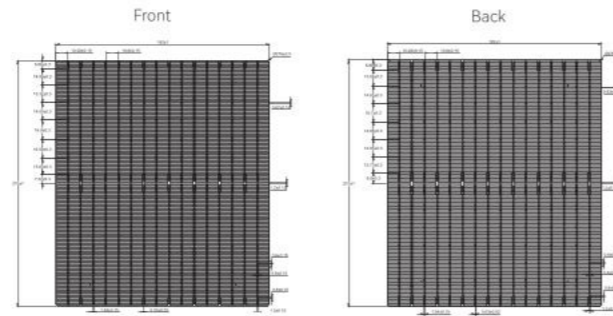
Eff (%)	Pmpp (W)	Vmpp (V)	Impp (A)	Voc (V)	Isc (A)	FF (%)
> 20.5	6.86	0.589	11.644	0.692	12.932	76.68
20.3-20.5	6.79	0.587	11.569	0.691	12.866	76.43
20.1-20.3	6.73	0.584	11.527	0.690	12.819	76.10
< 20.1	6.69	0.582	11.496	0.689	12.799	75.87

STC (Standard Testing Conditions): 1000W/m<sup>2</sup>, AM1.5, 25°C

# TNC -G12R



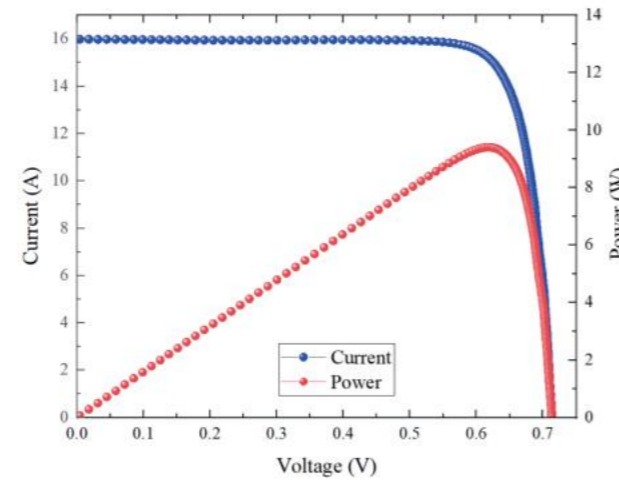
## Product Appearance (mm)



## Design

<b>Dimensions</b>	182mm*210mm±1mm Φ276±0.5mm	TkVoltage: -(0.25±0.01)%/K
<b>Thickness</b>	130±13μm	TkCurrent: +(0.04±0.004)%/K
<b>Front</b>	16 busbars (silver), 310 fingers Blue anti-reflective coating (silicon nitride)	TkPower: -(0.29±0.025)%/K
<b>Back</b>	16 busbars (silver), 252 fingers Blue anti-reflective coating (silicon nitride)	Rsh=50Ω Irev2±0.5A

## IV Curve



## Back Electrical Performance Parameters

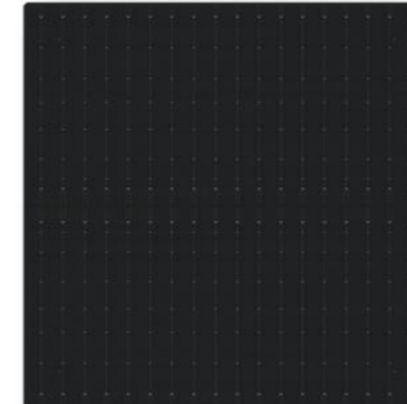
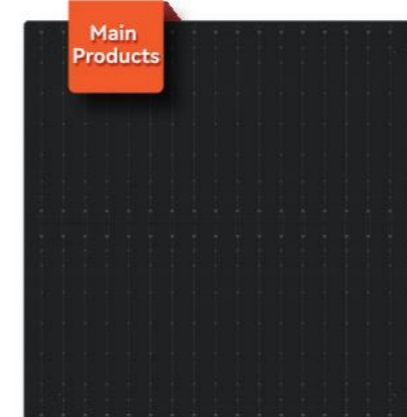
Eff (%)	Pmpp (W)	Vmpp (V)	Imp (A)	Voc (V)	Isc (A)	FF (%)
≥21.5	8.21	0.620	13.242	0.735	13.408	83.31
21.0-21.5	8.02	0.614	13.062	0.730	13.258	82.87
20.5-21.0	7.83	0.609	12.857	0.725	13.213	81.74
<20.5	7.64	0.604	12.649	0.720	13.177	80.53

STC (Standard Testing Conditions): 1000W/m<sup>2</sup>, AM1.5, 25°C

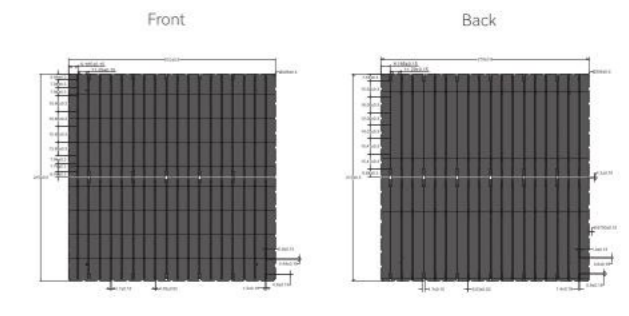
## Front Electrical Performance Parameters

Eff (%)	Pmpp (W)	Vmpp (V)	Imp (A)	Voc (V)	Isc (A)	FF (%)
26.1	9.97	0.628	15.875	0.745	15.987	83.71
26.0	9.93	0.627	15.831	0.744	15.961	83.59
25.9	9.89	0.627	15.768	0.744	15.938	83.41
25.8	9.85	0.626	15.734	0.743	15.919	83.30
25.7	9.81	0.625	15.695	0.742	15.906	83.16
25.6	9.78	0.624	15.672	0.740	15.891	83.14
25.5	9.74	0.623	15.636	0.739	15.872	83.01
25.4	9.70	0.622	15.590	0.738	15.868	82.83
25.3	9.66	0.621	15.553	0.737	15.861	82.64
25.2	9.62	0.620	15.517	0.736	15.851	82.48
25.1	9.58	0.619	15.480	0.735	15.842	82.30
25.0	9.55	0.618	15.453	0.734	15.826	82.20
24.9	9.51	0.617	15.406	0.733	15.824	81.98
24.8	9.47	0.616	15.369	0.732	15.820	81.78
24.7	9.43	0.615	15.332	0.731	15.813	81.59
24.6	9.39	0.614	15.295	0.730	15.811	81.38

# TNC -G12



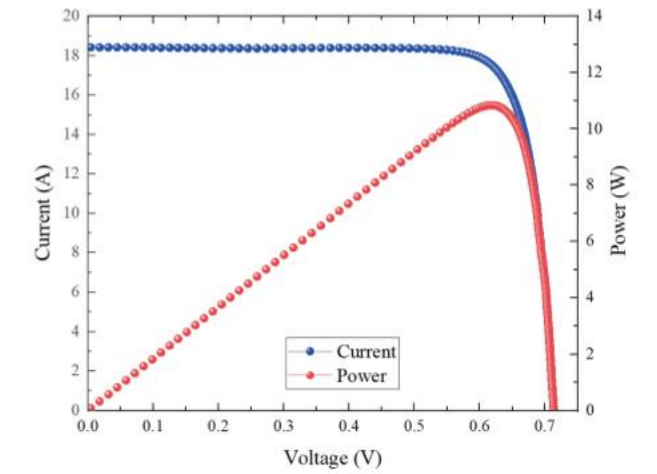
## Product Appearance (mm)



## Design

<b>Dimensions</b>	210mm*210mm±0.5mm Φ295±0.5mm	TkVoltage: -(0.25±0.01)%/K
<b>Thickness</b>	130±13μm	TkCurrent: -(0.04±0.004)%/K
<b>Front</b>	18 busbars (silver), 316 fingers Anti-reflective coating (silicon nitride)	TkPower: -(0.29±0.025)%/K
<b>Back</b>	18 busbars (silver), 312 fingers Anti-reflective coating (silicon nitride)	Rsh=50Ω Irev2±0.5A

## IV Curve



## Back Electrical Performance Parameters

Eff (%)	Pmpp (W)	Vmpp (V)	Imp (A)	Voc (V)	Isc (A)	FF (%)
≥21.5	9.48	0.621	15.266	0.722	16.032	81.90
21.0-21.5	9.26	0.619	14.960	0.722	16.014	80.09
20.5-21.0	9.04	0.618	14.628	0.721	16.002	78.35
<20.5	8.82	0.616	14.317	0.720	16.984	76.63

STC (Standard Testing Conditions): 1000W/m<sup>2</sup>, AM1.5, 25°C

## Front Electrical Performance Parameters

Eff (%)	Pmpp (W)	Vmpp (V)	Imp (A)	Voc (V)	Isc (A)	FF (%)
26.4	11.64	0.657	17.719	0.736	18.495	85.52
26.3	11.60	0.657	17.652	0.736	18.483	85.25
26.2	11.55	0.656	17.611	0.736	18.464	85.01
26.1	11.51	0.656	17.544	0.736	18.449	84.76
26.0	11.46	0.656	17.477	0.735	18.422	84.67
25.9	11.42	0.656	17.410	0.735	18.417	84.37
25.8	11.38	0.656	17.342	0.735	18.406	84.09
25.7	11.33	0.655	17.302	0.735	18.397	83.81
25.6	11.29	0.655	17.235	0.734	18.388	83.64
25.5	11.24	0.655	17.167	0.734	18.364	83.42
25.4	11.20	0.655	17.100	0.734	18.363	83.10
25.3	11.16	0.654	17.058	0.734	18.346	82.85
25.2	11.11	0.654	16.991	0.733	18.331	82.70
25.1	11.07	0.654	16.923	0.733	18.319	82.42

## 2.1.3 Tongwei TNC Cells: Enabling High-Reliability Module Products

"Tongwei Intelligent Manufacturing: Safe and Reliable". Tongwei modules equipped with TNC cells meet twice the requirements of the IEC reliability standards, thus positioning them at the industry's forefront.

# TNC Module

TNC series modules are equipped with TNC cells and multiple cell quality and efficiency enhancement technologies. Tongwei module products undergo stringent reliability tests, with all performance metrics enforced according to Tongwei's internal control standards that double the requirements of IEC standards, achieving benchmark-level performance in the industry.



Reliability Certified, Trusted Globally (TÜV Rheinland Certification)

5% IEC Standard



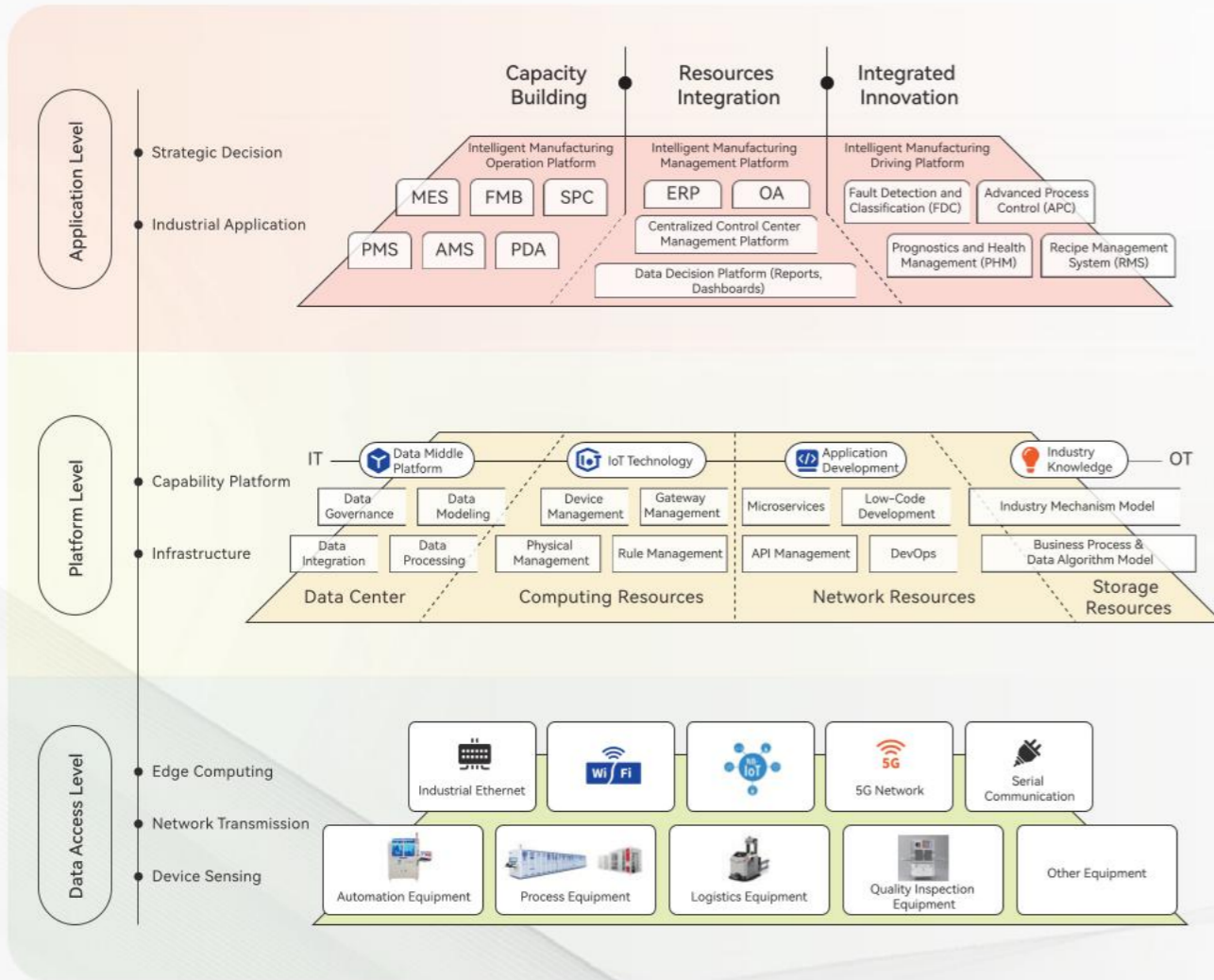
Reliability Performance of TNC Products (Power Degradation: %)

## 2.2 Smart Factory

Centering around the construction of smart factories, TW Solar continuously promotes the digital and intelligent upgrading of its production system. Through automated equipment collaboration, real-time collection and intelligent analysis of production data, it achieves efficient collaboration and lean management and control in the manufacturing process, continuously improves product consistency, production efficiency and operational stability, and provides solid support for large-scale and high-quality manufacturing.



## 2.2.1 Overall Architecture of the Digital Intelligent Factory and the "1+1+3+3" Strategy



\* Overall Architecture of the Digital Intelligent Factory of TW Solar

### "1" Foundational Platform

The Company has established an industrial internet foundational platform encompassing infrastructure, a data middle platform, IoT technology, application development, and integrated industry knowledge. It aims to achieve three key enhancement objectives: informatization foundation, core platform, and collaborative integration, thereby supporting the efficient development and operation of industrial applications.

### "1" Access System

Through the EAP system and digital transformation of equipment, the Company has unified the equipment access standards and specifications to achieve data collection and cell-level traceability. It has also built an industrial control network to enable rapid access and interconnection of automated equipment, process equipment, inspection equipment, and other devices.

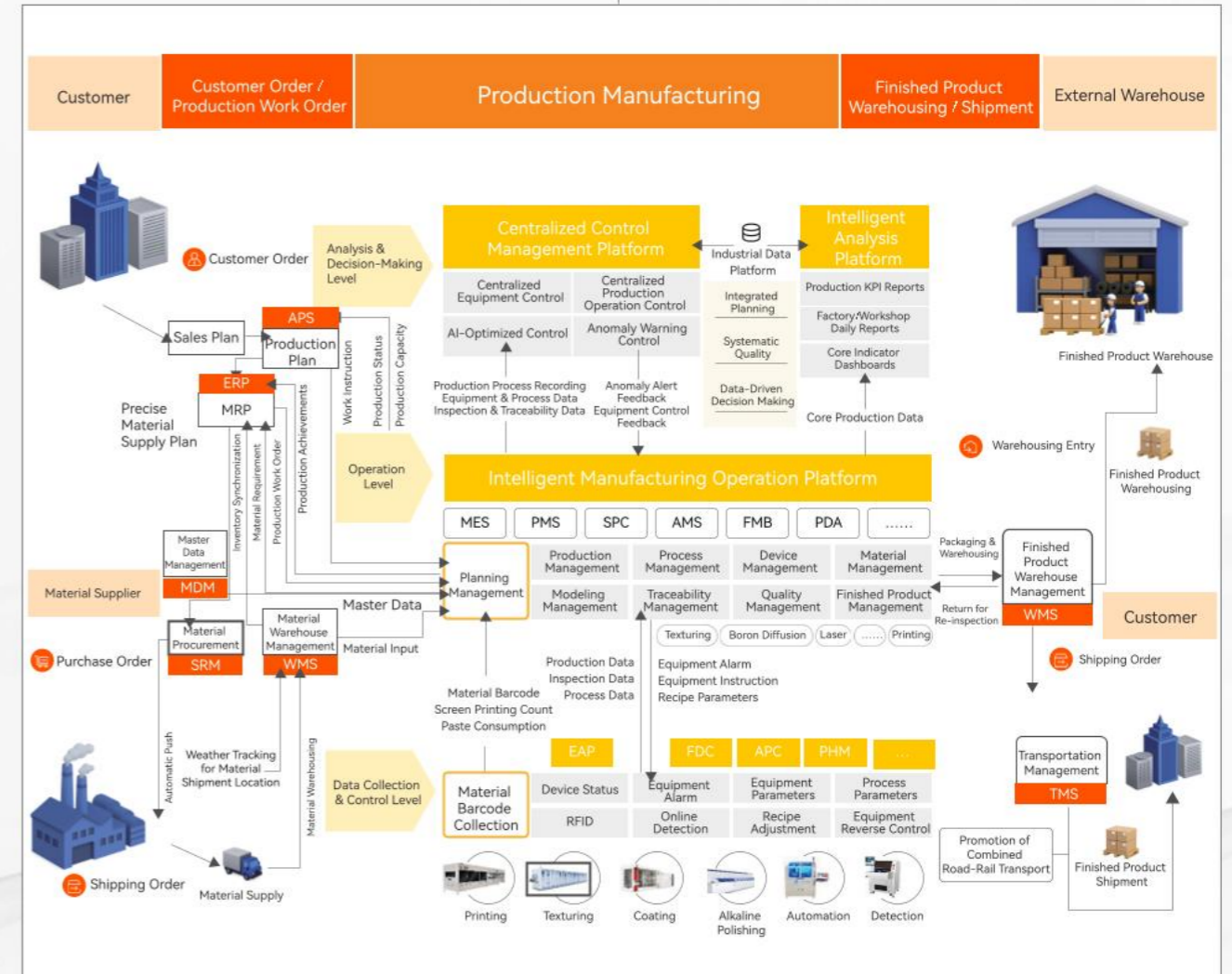
### "3" Improvement Stages

The entire digital transformation process progresses through three enhancement stages: capability building, resource integration, and integrated innovation, accompanied by organizational optimization and transformation within the Company.

### "3" Intelligent Manufacturing Application Platforms

Starting from the improvement of digital basic capabilities and based on the industrial Internet platform, the transformation and upgrading of the enterprise's intelligent manufacturing has been promoted through the three major application segments of intelligent manufacturing operation, management, and empowerment, which are formed based on the integration of existing systems and the development of new industrial applications.

## Intelligent Operation System (ERP + MES + WMS + WCS + ...)



\* TW Solar Intelligent Platform

## 2.2.2 TW Solar: Industry 4.0 Cell Production Workshop

As a company dedicated to integrating the entire PV industry chain as the new "King of PV," Tongwei Co., Ltd. demonstrates industry-leading comprehensive strength in TNC cell manufacturing technology. As early as mid-2021, Tongwei pioneered the industry's first PECVD Poly deposition N-type cell technology route compatible with large-size cells, achieving large-scale mass production in 2022. Tongwei's cell production lines fully adopt an Industry 4.0 intelligent manufacturing system, ensuring standardized, unified, and automated product manufacturing processes, with products being safe, stable, and highly reliable.

### Digital Production Workshop in the Industry 4.0 Smart Park



 **200+**  
Intelligent Manufacturing Lines




**3000+**  
Intelligent Transport Robots 




 **Industry 4.0**  
High-Efficiency Automated Cell Production Line



**Globally Leading**  
5G Application Base in the PV Industry 

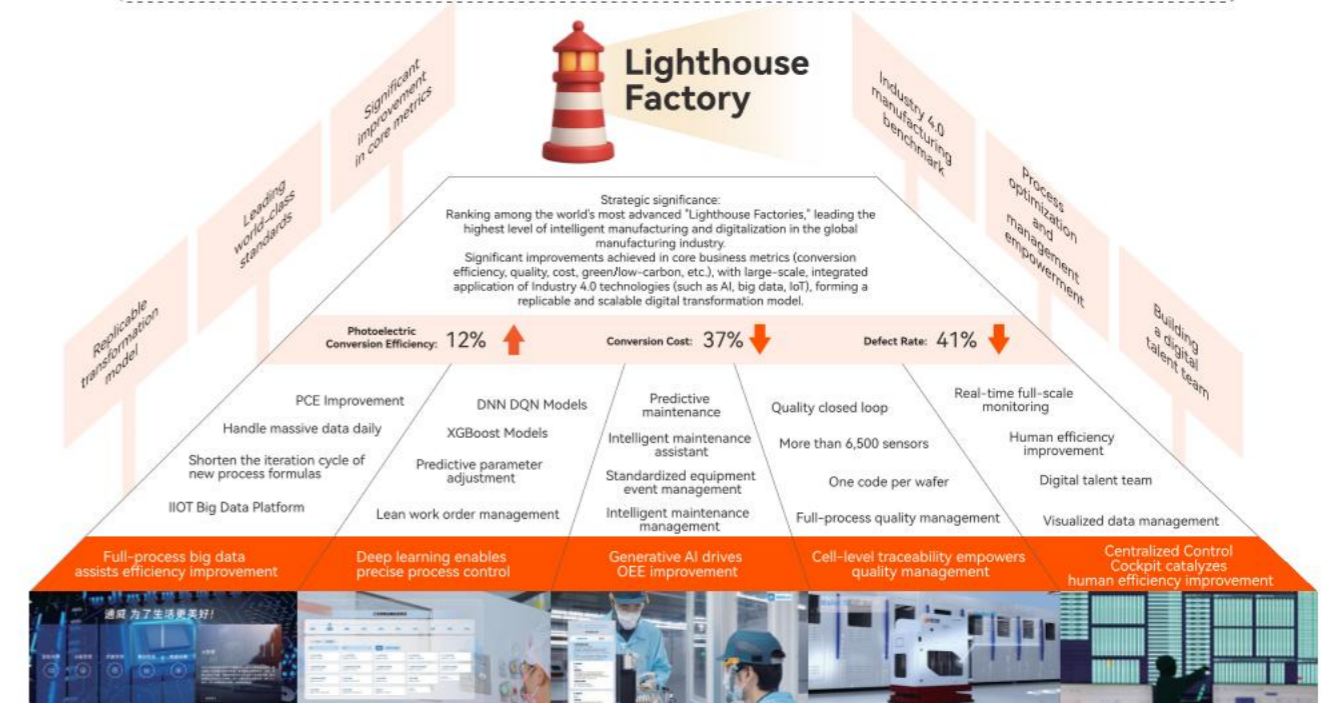


 **5G Dedicated Frequency Band**  
Stability up to 99.999%

## 2.2.3 Panoramic View of Digital Use Cases

Cost Reduction	Efficiency Improvement	Quality Control	Equipment	Supply Chain
<ul style="list-style-type: none"> <li>Full-process multi-objective intelligent scheduling based on operational research models</li> <li>Flexible rework processing based on AOI image recognition and AGV collaboration</li> <li>Tubular equipment automatic closed-loop optimization</li> </ul> <p>Workshop mechanical gauge automatic inspection system</p> <p>Automatic handling system for graphite boats</p> <p>Automatic handling system for quartz boats</p> <p>Automatic unpacking machine</p> <p>FQC finished product automatic collection machine</p> <p>Coating vacuum pump exhaust automatic control system</p> <p>In-house production of desktop paper</p> <p>Cleaning equipment hydrogen content automatic detection and control system</p>	<ul style="list-style-type: none"> <li>End-to-end cell efficiency optimization driven by billion-level big data models</li> <li>Closed-loop efficiency control based on intelligent analysis</li> <li>Deep learning models for optimizing the use of high-value materials</li> </ul> <p>Intelligent management for predicting the lifespan of high-value consumables</p> <p>Wafer ID traceability at the cell level based on data collection</p> <p>Digital monitoring and automated implementation of key processes <li>Intelligent inspection of process parameters</li> <li>Square resistance model prediction</li> <li>SMBB testing renovation project</li> </p>	<ul style="list-style-type: none"> <li>Intelligent detection of coating thickness based on CNN/DNN and optimization control empowered by big data.</li> <li>Closed-loop management of quality issues based on wafer-level tracking</li> <li>Monitoring system for incoming material quality across the entire process</li> <li>Advanced process anomaly diagnosis</li> <li>Comprehensive image diagnosis across the entire process</li> <li>Big data EL intelligent image sorting</li> <li>EL intelligent reconfirmation</li> </ul> <p>Automated screen inspection</p> <p>Automatic square resistance test and analysis</p> <p>Automatic weight loss test and analysis</p>	<ul style="list-style-type: none"> <li>Digital energy management system based on advanced analytics</li> <li>Equipment OEE management based on GenAI expert systems</li> <li>Diagnosis based on equipment proactive alarms</li> <li>Machine health assessment and predictive maintenance recommendations</li> </ul> <p>Alert notification push to functional wristbands</p> <p>Electronic process work orders</p>	<ul style="list-style-type: none"> <li>Intelligent palletizing of cell products</li> <li>IGV trolley process material transfer</li> <li>Outdoor 5G unmanned forklifts</li> <li>Smart Park Management</li> <li>Intelligent warehousing management</li> </ul> <p>Smart financial management</p> <p>Digital ERP4.0</p>
			Plant & EHS	Intelligent Office
			<ul style="list-style-type: none"> <li>Factory intelligent operation and maintenance system</li> <li>EHS safety platform</li> <li>Timely push of alarm information</li> <li>Energy management system</li> <li>Water balance system</li> <li>Efficiency improvement of the refrigeration system</li> <li>Consumable consignment management system</li> </ul>	<ul style="list-style-type: none"> <li>PV Cloud Disk</li> <li>i Tongwei</li> <li>Innovation Center</li> <li>FBC Process Center</li> <li>PV Learning Center</li> </ul>

Through outstanding practices in intelligent manufacturing and excellent enterprise management, we have built an Industry 4.0 digital intelligent factory, creating a data-driven, intelligently operated "Digital Tongwei" and "Smart Tongwei."

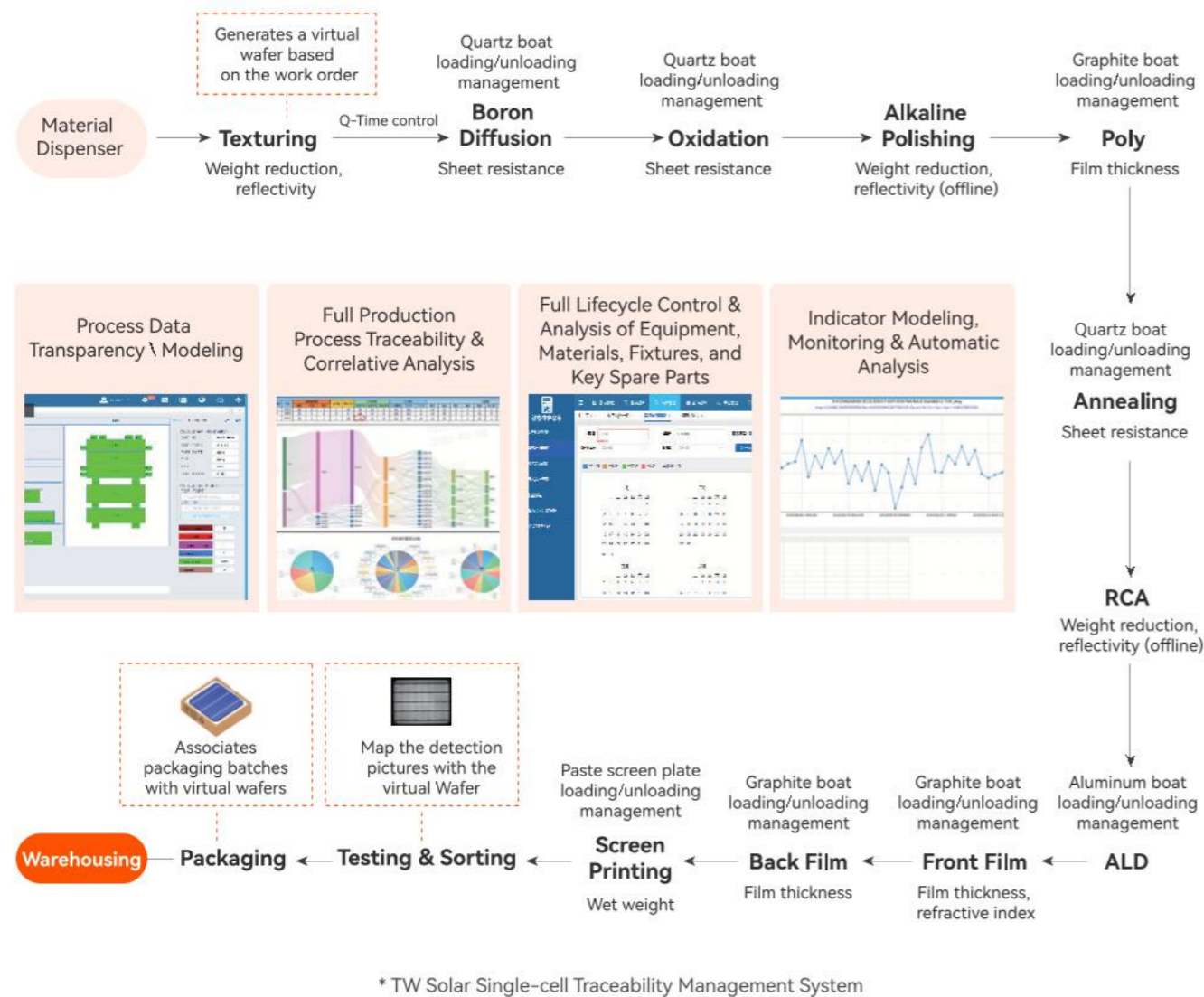


\* TW Solar Lighthouse Factory Intelligent Manufacturing System Diagram

## Cell-Level Traceability

Traditional solar cell traceability operates at the batch or cassette level, resulting in data that is too coarse to pinpoint specific issues. Analyzing and investigating anomalies requires lengthy manual backtracking, hindering rapid root cause analysis.

TW Solar has developed a Wafer-Level Traceability Management System. Through real-time interaction between EAP and equipment, the MES generates virtual IDs for wafers based on predefined rules. It tracks the physical location changes of wafers relative to their virtual IDs, creating comprehensive production records for cells.



This system achieves information traceability down to the individual cell level, capable of pinpointing the specific furnace tube and boat used. It integrates all production data for each cell up to the point of in-factory testing and sorting:

1. On-site personnel can use the single-cell traceability system to quickly locate the position of abnormal cells, enabling rapid response. The average time for root cause localization is <30 seconds. This system significantly improves the accuracy of defect tracking, allowing for timely investigation and handling of anomalies, thereby reducing the continuous production of defective products during the localization period.

2. The system continuously collects big data correlating "product characteristics" with "process characteristics," providing high-quality data support for building and training AI models. It drives the continuous optimization of process and production models, aiding the company's cost reduction and efficiency improvement initiatives.

## 2.2.4 Case Study of Lean Management

### Cases of Improving Cell Efficiency

Improving cell efficiency is a core objective in PV cell manufacturing, and the approaches to achieve this goal are diverse.

Broadly speaking, there are four main dimensions:

1. Optimization of structure and materials at the design end
2. Technological optimization and innovation at the process end
3. Optimization and stabilization of process parameters at the manufacturing end
4. Collaborative optimization of the supply chain

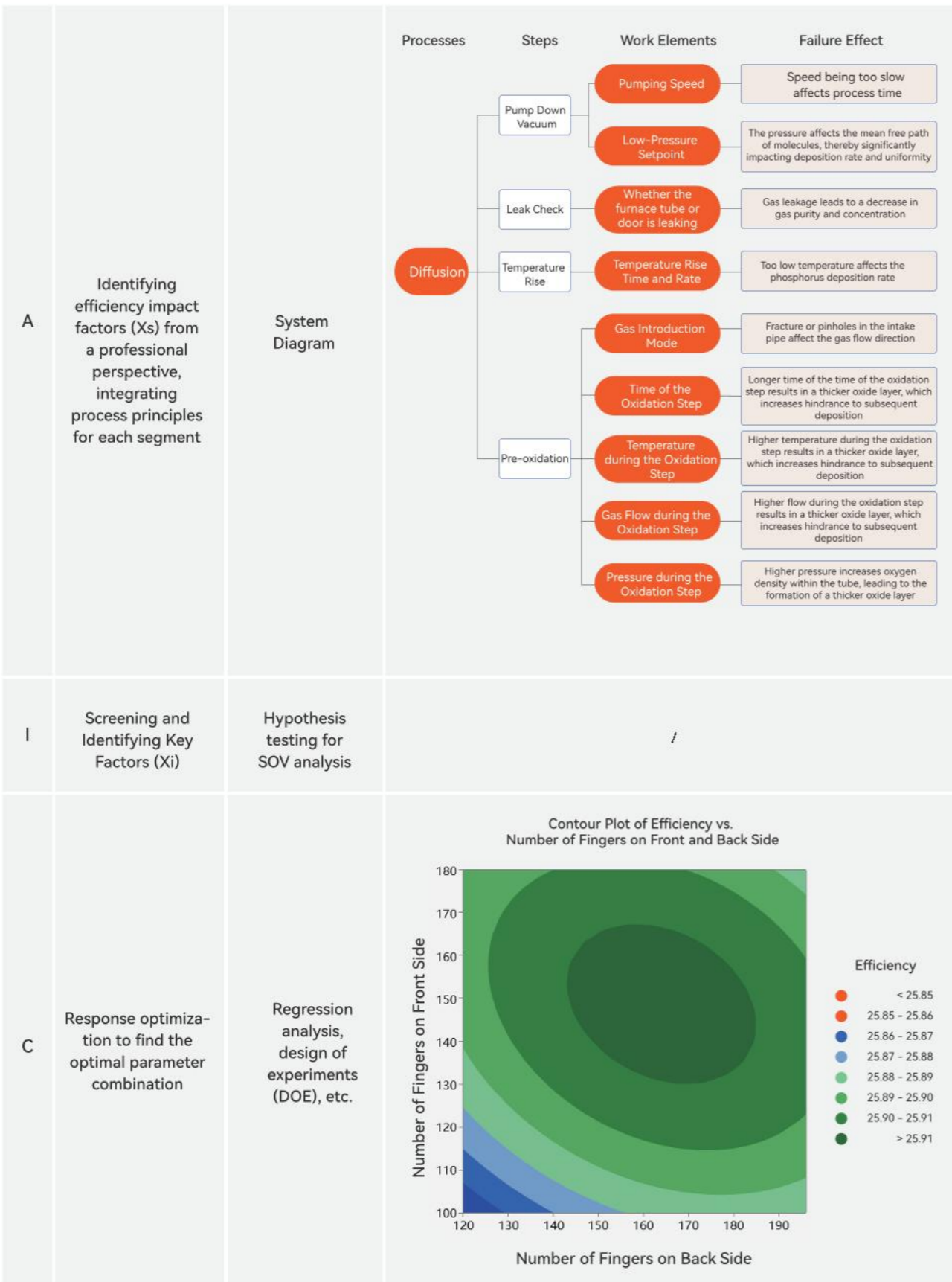
This case study discusses how to improve efficiency from the manufacturing dimension, while also considering the impact on metrics such as UV reliability and wet weight.

Solution Logic:

1. Explode the cell structure
2. Identify corresponding efficiency factors
3. Pinpoint the range of manufacturing processes and process factors for improvement
4. Verify the impact on efficiency

Core Tool Recommendations: Exploded view diagram + Microscopic flowchart + Source of Variation (SOV) analysis + Hypothesis testing + Design of Experiments (DOE)

Methodology	Techniques	Tools	Example
D	Definition and Decomposition of Target Y (Efficiency)		$Y: \text{Conversion Efficiency} = \frac{\text{Cell power}}{\text{Cell area} \times \text{Illumination intensity}} = \frac{\text{Open-Circuit Voltage (Voc)} \times \text{Short-Circuit Current (Isc)} \times \text{Fill Factor (FF)}}{\text{Cell area} \times \text{Illumination intensity}}$ <p>Note: The cell area and the illumination intensity per unit area are fixed values.</p>
M	Analyze the Cell Structures Related to Target Y (Efficiency)	Exploded View Diagram	
	Analyze the main structures affecting Y1: Voc (Open-Circuit Voltage)		
	Analyze the main structures affecting Y2: Isc (Short-Circuit Current)		
	Analyze the main structures affecting Y3: FF (Fill Factor)		
	Based on the cell structures affecting efficiency, identify the relevant manufacturing processes and prioritize them to define the project scope.	Flowchart	

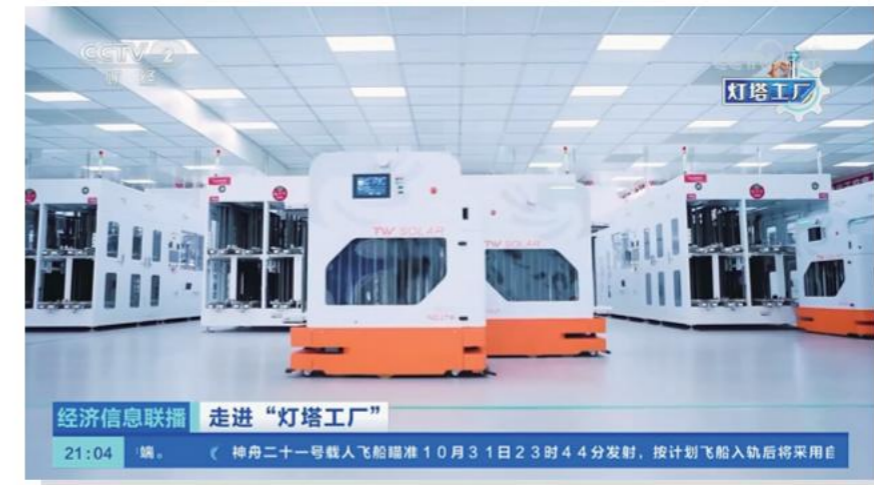


Primary reference: 2023 Q3 Meishan Company TOPCon SE Efficiency Improvement Project. (Internal document, used with authorization)

## 2.2.5 Tongwei's "Lighthouse Factory"

On September 16, the World Economic Forum (WEF) unveiled its latest batch of "Lighthouse Factory" designations, with 12 new factories worldwide earning this prestigious recognition. Among them, Meishan Company stands out as the sole representative from the global PV industry in this cohort, marking the birth of the first "Lighthouse Factory" in the global PV cell manufacturing sector. This achievement not only represents the first "Lighthouse Factory" among local enterprises in Sichuan Province also signifies that China's PV industry has once again taken the lead globally in intelligent manufacturing and digital transformation.

Meishan Company has deployed over 50 Fourth Industrial Revolution (4IR) application cases, most of which are based on artificial intelligence: utilizing machine learning for process optimization, leveraging generative AI for maintenance, and employing advanced AI algorithms for defect analysis. This transformation has increased the cell photoelectric conversion efficiency by 12%, reduced the defect rate by 41%, lowered conversion costs by 37%, and decreased carbon dioxide emissions by 33%.



CCTV Finance Highlights Tongwei Solar Meishan's "Lighthouse Factory" in Its Visiting "Lighthouse Factories" Series (Oct 30, 2025).



# PART 3

# TONGWEI

## Chapter 3 High Efficiency

## 3.1 Leading the Industry

### 3.1.1 Core Manufacturing Technologies

#### Tongwei N-Type Cell Technology

TNC cells use N-type silicon wafers as substrates, which display excellent minority carrier lifetime and strong resistance to light-induced degradation. The front surface is coated with SiN<sub>x</sub> anti-reflective coating (ARC) and AlO<sub>x</sub> passivation layer to optimize light absorption and surface passivation. The back surface incorporates a passivated contact structure, consisting of an ultra-thin tunneling silicon oxide layer and a doped polysilicon layer, significantly reducing surface recombination and metal contact recombination while improving conversion efficiency.

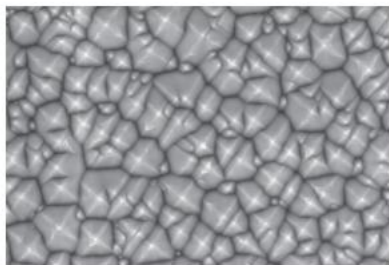
#### Three Key Characteristics of Tongwei TNC Cells



## Core Technologies in TNC Cell Manufacturing

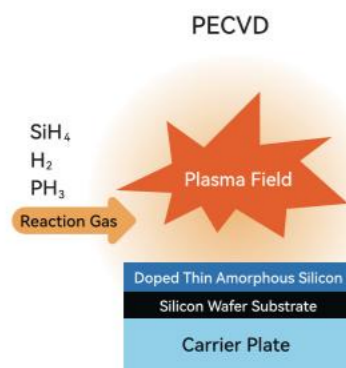
Since the mass production of the TNC series began in 2022, TW Solar has continuously optimized its independently developed N-type cell platform, achieving remarkable results in conversion efficiency and reliability.

### Advanced Texturing Technology



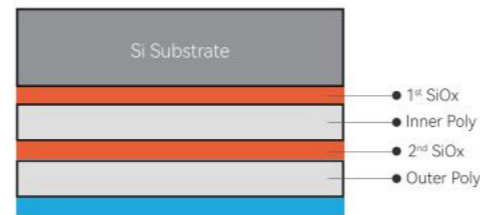
Tongwei's independently developed advanced secondary texturing technology effectively optimizes the pyramid microstructure on the cell surface, resulting in a more uniform distribution, reducing reflectivity to below 9%, thereby enhancing the light absorption capacity and improving the cell efficiency.

### PE-Poly Mass Production Technology



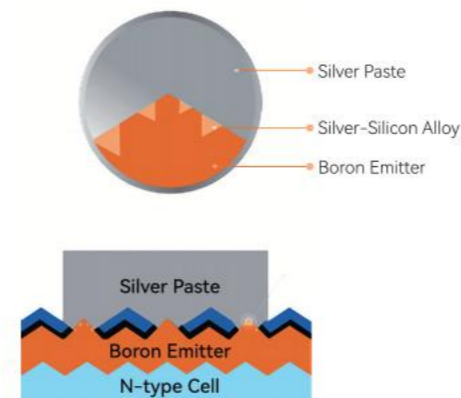
Tongwei's PECVD technology route has become the mainstream route for TOPCon cells. Compared with the LPCVD technology, Tongwei's PE-Poly mass production technology offers higher efficiency, lower energy consumption, and higher yield.

### Dual Tunneling Technology



The dual tunneling technology effectively reduces the risk of film explosion and the internal diffusion of doped atoms. The ratio of cells with light-dark variation decreases by over 50%, the efficiency increases by 0.05%, and at the same time, the product reliability can be significantly improved.

### Secondary Sintering Technology



Relying on the advantages of Tongwei's self-developed specialized sintering equipment in terms of energy concentration and controllability, it reduces metal recombination and contact resistance, increasing cell efficiency by 0.3%-0.4%.

## 3.1.2 TNC Cell Technology Platform

TW Solar provides customized high-efficiency cell solutions for module customers



**TNC**  
Cell Efficiency Upgrade!

Relying on the collaborative advantages of the entire PV industry chain, TW Solar advances coordinated improvement and upgrade plans from silicon material, silicon wafers, cells, to module technology, flexibly responding to and meeting customer demand for high-power cell products.

In the future, Tongwei will keep enhancing its TNC cell technology and is dedicated to improving the quality and efficiency of TNC cells!



#### Man — Professional Team

Tongwei's quality system is supported by a team of professionals covering the entire chain of R&D, process, testing, quality control, and customer service. With systematic training and competency certification, the team ensures that every step is controllable, robust, and professional.

#### Machine — Advanced Equipment & Automation Capability

Through automated and 5G intelligent production equipment, product consistency, high efficiency and large-scale stable output are ensured.

#### Material — Material Quality Management System

A strict material quality control system is established for the entire process from supplier selection to incoming inspection, ensuring stable and reliable input for cell production.

#### Method — Process & Quality Control Methods

Centered on standardization, process orientation, and digitalization, systematic methods ensure process stability, product consistency, and production line controllability.

#### Environment — Manufacturing Environment & Cleanliness Management

A high-quality manufacturing environment is the prerequisite for high consistency and efficiency of cells. Tongwei ensures product quality from the environmental aspect through environmental, cleanliness, and safety controls.

#### Measurement — Tongwei PV Testing Center

Built in accordance with CNAS standards, TW PV Testing Center has a complete testing capability covering materials, cells, and modules, and serves as a crucial foundation for product quality stability.

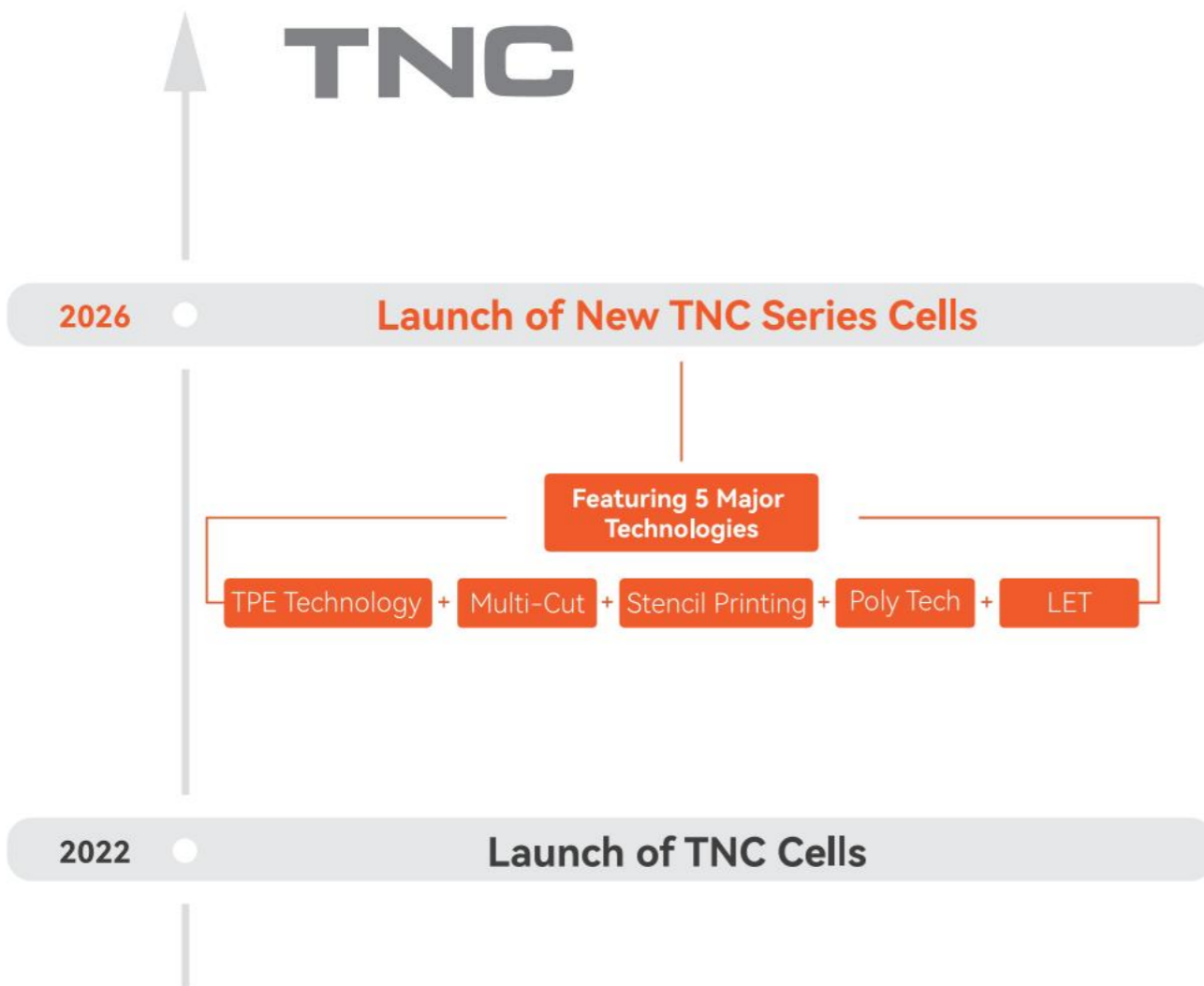
Multiple cell quality and efficiency improvement plans to satisfy customers' customized requirements for high-efficiency cells. Please contact TW Solar's cell technology team for specific efficiency improvement plans and details.

## 3.2 Breaking through and Innovating

### 3.2.1 The High-Quality, High-Efficiency, Value-Added Product Roadmap of TNC Cells

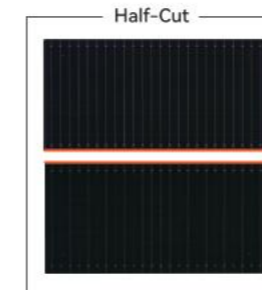
TW Solar will continue to focus on enhancing the quality, efficiency, and value of TNC cell products. It is projected that TNC cell efficiency will surpass 27% by December 2026.

TNC Series  
Conceptual Diagram of Cell Products



### TPE Half-Cut Cell

Suitable for module customers with a direct demand for half-cut cells



Conventional module manufacturing process requires cell cutting, which causes edge damage to the cell and leads to module power loss.

To address this issue, Tongwei innovatively developed the TPE (Tongwei Passivated Edge) half-cut cell technology. The cutting process is completed during the cell production, and a passivation film is deposited on the sidewalls of the cut edges, completely repairing the dicing damage.

Products utilizing TPE half-cut cell technology have seen a 0.25% increase in label efficiency. Furthermore, the passivation protective layer shields the cell edges from environmental factors, thereby extending the cell's service life.

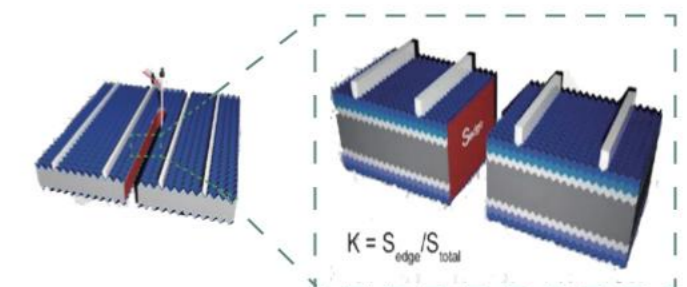


#### Half-Cut TNC Cells with TPE Technology

Compared with Conventional Whole TOPCon Cells

- ✓ Half-cut cell delivery omits the cutting process during module production
- ✓ Absolute efficiency of half-cut cells increases by **0.25%**
- ✓ Comprehensive manufacturing cost per watt decreases by approximately **0.003 RMB/W**
- ✓ Weather resistance and reliability significantly improved

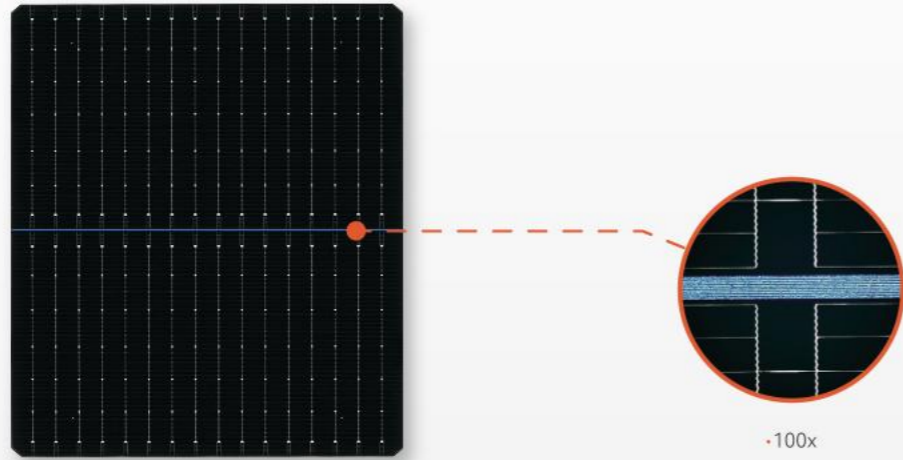
#### TPE Half-Cut Cell Schematic Diagram



Note: The data is sourced from Tongwei's internal laboratory.

## LET

TW Solar provides customized high-efficiency cell solutions for module customers



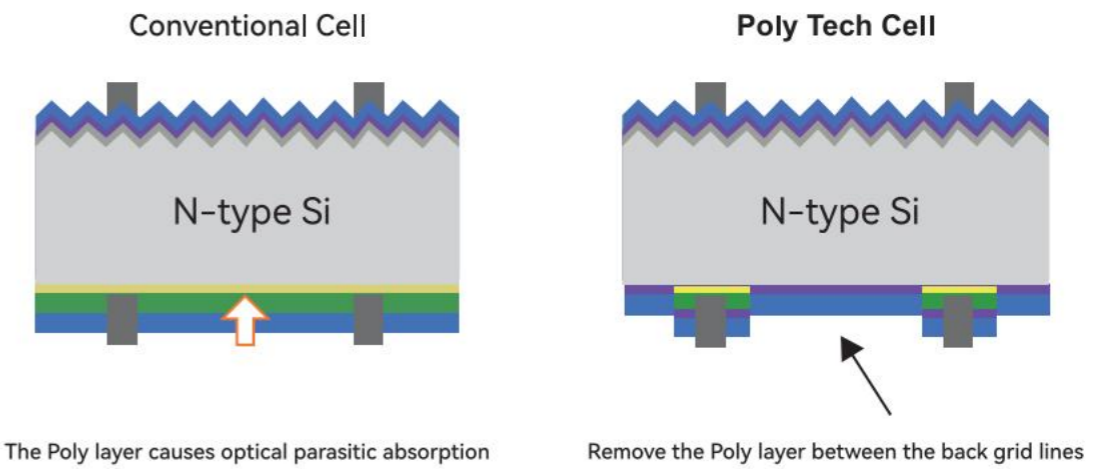
## Poly Tech High Bifaciality Cell Technology

TW Solar provides customized high-bifaciality N-type cell product solutions for module customers.

The polysilicon film layer on the back of the TOPCon cell will cause optical parasitic absorption, resulting in a decrease in the long-wavelength light response and optical loss.

To solve this problem, Tongwei has developed Poly Tech technology. By removing the excess polysilicon between the grid lines, the optical loss caused by parasitic absorption is reduced, and the back passivation film layer is added to ensure the reliability of the product.

The efficiency of the TNC cell using Poly Tech technology is increased by 0.15%, while the module bifaciality increases by 5%.

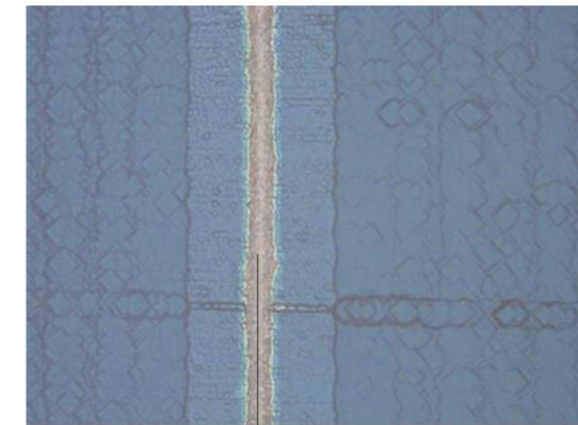


### TNC Cells with Poly Tech Technology

Compared with Conventional TOPCon Cells

- ✓ Cell efficiency increases by **0.15%**
- ✓ Module manufacturing cost per watt decreases by approximately RMB **0.002/W**
- ✓ Module bifaciality increases by **5%**

### Rendering of the Back of Poly Tech Cells



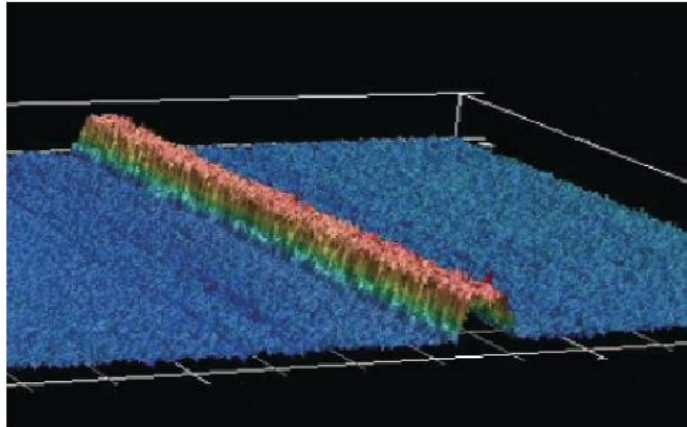
● Rear Gridlines




Note: The data is sourced from Tongwei's internal laboratory.

## Stencil Printing

TW Solar provides customized high-efficiency cell solutions for module customers

### "Tongwei Gene" TNC Cell Manufacturing Core Technology





-  Grid lines with stencil printing are fuller in shape and have lower line resistance
-  Printing with steel stencils allows for narrower line widths and lower shading.
-  Results in higher cell efficiency and better reliability.

Tongwei employs more advanced stencil printing technology with finer and more precise printing quality for cell manufacturing. Compared with conventional screen printing processes, stencil printing enhances the current conduction capability of the grid lines and effectively reduces the shading area of the front grid lines, significantly improving the electrical performance of the cells.

## Introduction to Multi-Cut



-  **Increase Power**  
The power loss in a module is  $Q=I^2R$ . The multi-cut technology reduces current, leading to a power increase of **> 10W**.
-  **Enhance Safety**  
The hot-spot temperature is reduced by 10–20°C, lowering the risk of thermal runaway and achieving inherent module safety.

## 3.2.2 The High-Quality, High-Efficiency, Value-Added Product Roadmap of TNC Cells

### PV Technology R&D Layout · Sichuan

#### Chengdu Shuangliu Global Innovation R&D Center

TNC R&D Line  
HJT/THL Pilot Line  
TBC Pilot Line  
Perovskite/c-Si Tandem Cell Laboratory  
Module R&D Center  
Wafer R&D Line  
Material Physical and Chemical Laboratory  
Cell Test Laboratory  
PV Test Center (Module)

#### Leshan

Yongxiang Silicon Material R&D Center  
Crystal Growth R&D Line

#### Yancheng Terrestrial Module Test Site

Hainan Terrestrial Module Test Site

### PV Technology R&D Platforms & Qualifications

National Enterprise Technology Center  
Engineering Technology Research Center in Sichuan Province  
Sichuan Provincial Engineering Research Center  
Chengdu PV Testing Center (CNAS Certified)  
Hefei PV Experimental Center (CNAS Certified)

### PV Technology R&D Intellectual Property

3521 Authorized Patents  
(as of December 2025)  
National Intellectual Property Advantageous Enterprise  
China Patent Excellence Award  
First Prize of Sichuan Provincial Patent Award

### R&D Team

Dr. Xing Guoqiang, Chief PV Technology Officer of Tongwei Co., Ltd.: A well-known technical expert in the industry, who served as the person-in-charge and chief expert of the National 863 Program.

Tongwei has gathered over 1,300 senior R&D technicians, forming a core technology innovation team with comprehensive expertise, strong technical capabilities, exceptional R&D skills, and a forward-looking perspective.

\*As of the end of 2025, our R&D system includes 25 PhDs and 146 Master's degree holders.

### 3.2.3 Patent Certificates



▲ CD2320422-2023112890963-250923  
Certificate of Invention Patent  
Preparation method of perovskite thin film, thin film, perovskite cell and tandem cell

▲ CD2421237-2025105624086-250923  
Certificate of Invention Patent  
Solar cell and its preparation method, PV module

▲ AH2210353-2022114818481-250411  
Certificate of Invention Patent  
Laser grooving processing system and its processing method



▲ AH2210362-2022115188395-250121  
Certificate of Invention Patent  
Solar cell and its preparation method

▲ AH2210360-2022110662188-241011  
Certificate of Invention Patent  
Texturing and cleaning process of silicon wafer, solar cell and its preparation method

▲ Certificate of Invention Patent  
-2021101773967  
An HJT cell with high photoelectric conversion efficiency and its preparation method

**\*Overseas Patent Coverage**  
Covering more than **20 countries** and regions, including China, the US, Germany, France, the UK, the Netherlands, Austria, Japan, SouthKorea, Australia, India, Turkey, Saudi Arabia, etc.

**\*Covered Technical Fields**  
Encompassing multiple areas such as TOPCon, BC, HJT, perovskite tandem, half-cut modules, 0BB modules, etc.

**\*As of December 2025, the PV sector has a total of 3521 authorized patents.**

# PART 4

TONGWEI

## Chapter 4 Value Addition



# 4.1 Power Gain

## 4.1.1 Adding Value for Customers



## 4.1.2 Application Scenarios

### Residential



Guangxi Skyworth Xiaoyang Building PV Project  
Project Capacity | **199.8kW**



New Zealand Residential Rooftop Project  
Project Capacity | **240.78kW**



Australian Commercial Shop Rooftop Project  
Project Capacity | **30.71kW**

### Utility



900,000 kilowatts Qinghai Gonghe PV Project  
Project Capacity | **900MW**



Netherlands Ground Power Station Project  
Project Capacity | **13.62MW**



China Huadian Maizhokunggar Zhaxue Pastoral-Solar Complementary PV Project  
Project Capacity | **100MW**

Industrial & Commercial



China Huadian Suining Anju JAC Phase I PV Project

Project Capacity | 194.5kW



Anhui Tongling Enterprise and Institution PV Project

Project Capacity | 10MW



Switzerland Industrial and Commercial Rooftop Project

Project Capacity | 1MW

Fishery-PV Integration



Jiangsu Nanjing Longpao Power Station

Project Capacity | 53MW



Shandong Dongying Yellow River Estuary Power Station

Project Capacity | 195.5MW



Tianjin Dagang Power Station

Project Capacity | 72MW

## 4.2 Green and Low-Carbon

### 4.2.1 Tongwei Carbon Footprint Certification



French ADEME Carbon Footprint Certificate



Bureau Veritas Carbon Footprint Certificate



TÜV Rheinland Carbon Footprint Certificate



CQC Carbon Footprint Certificate

## 4.2.2 Capable of Various Traceability Orders

### Order (Clean Supply Chain)

- In principle, our company can trace from the module back to the silicon material. Based on specific order requirements, traceability can extend to silicon powder/metallurgical grade silicon;
- Considering production schedules across various processes, confirmation of order traceability feasibility generally needs to be finalized 30 days prior to order placement.

### Documentation (Digitalized Traceability Management)

- Documentation Logic: The purchase and sales contracts link each process; within the process, the "batch number" links the procurement, production, and sales links.
- Level of Informatization: The procurement, production, sales, and transportation links can be traced through information systems such as ERP, MES, and WMS.

### Factory Audits (Recognition of Traceability Capability by Authoritative Bodies)

Successfully passed traceability audits conducted by multiple authoritative organizations:

- TÜV Rheinland
- PI BERLIN
- STS
- SINOVOLTAICS

## 4.3 ESG

### Environmental Performance

Environmental Protection  
Investment RMB **1.245** billion

Carbon Footprint & EPD  
**26** Certifications

Proportion of Recycled & Reused  
Water  
**98.04%**

Increase of Renewable Energy  
Electricity Usage (YoY)  
**28.00%**

Proportion of Renewable Energy  
Electricity Used  
**64.01%**

Reduction of the Total Carbon  
Emissions of Scope 1, 2 & 3 (YoY)  
**16%**

Reduction of the Hazardous Pollutant  
Emissions (YoY)  
**27.97%**

Reduction of the Wastewater  
Pollutant Emissions (YoY)  
**33.96%**

Reduction of the Total Waste  
Discharge (YoY)  
**19.98%**

### Social Performance

Increase of R&D Personnel (YoY)  
**26.94%**

Average Employee Training Hours  
per Person  
**82.03** hours

R&D Investment  
RMB **2.673** billion

Increase of New Authorized  
Invention Patents (YoY)  
**88.66%**

Proportion of Key Raw Material  
Suppliers for PV Business Signing  
Social Responsibility Commitments  
**100%**

Proportion of Key Raw & Auxiliary  
Material Suppliers for PV Business  
Signing Conflict Minerals Procure-  
ment Commitments  
**100%**

### Governance Performance

Proportion of Female Board  
Directors  
**33.33%**

Proportion of Independent  
Board Directors  
**33.33%**

Business Ethics Audits  
Conducted  
**117**

Resolution Rate of Internal  
Audit Issue  
**100%**

Litigation Cases Related to Unfair  
Competition  
**0**

ISO 37301 Compliance Management  
System Certifications Obtained  
**6**

### Response to International Sustainable Development Initiatives



Tongwei Co., Ltd. joined the UN  
Global Compact (UNGC)



Tongwei Co., Ltd. signed the UN Women's  
Empowerment Principles (WEPs)



Tongwei Co., Ltd. joined the "ISSB Partnership  
for Early Awareness of Sustainability-Disclosure  
Today" (P4EAST)



Supplier ESG Rating SHOW | Tongwei Co., Ltd.  
(5-Star Outstanding)



Tongwei Co., Ltd. joined  
RE100



Tongwei Co., Ltd. joined  
the China ESG Alliance



Tongwei Co., Ltd. joined the  
Corporate Carbon Neutrali-  
ty Action (CCNA)

- Tongwei Co., Ltd. co-initiated and signed the International Climate Action Initiative for Digital Ecological Civilization
- Tongwei Co., Ltd. co-launched the "Capacity Building Project for Sino-Africa Collaboration on Renewable Energy Development."
- Tongwei Co., Ltd. co-initiated and signed the "Synergistic Empowerment Plan for Pollution Reduction, Carbon Mitigation and Efficiency Improvement"

# PART 5

## Chapter 5

### Win-Win Cooperation

# TONGWEI

## 5.1 Global Partners



# HONORS AND AWARDS GRANTED BY CUSTOMERS (RECENT YEARS)

## | DOMESTIC HONORS



... And more...

## | OVERSEAS HONORS



... And more...