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

Shimeng Wei
Vice President, Renewables - PV & ESS & PCS
TUVNORD

Jason Xia
Director of Module R&D Department
TW SOLAR

Moderated by Ben Willis
Acting editor in chief
PVTECH
Repower N

Upgrade Your Power With TONGWEI Module

Jason Xia     Tongwei’s Director of Module R&D Department
About Tongwei
About Tongwei

- **Global employees**: ≈ 50,000
- **Subsidiaries worldwide**: 200+
- **2023 Fortune Global 500**: 476
  - World’s First PV Company Listed
- **Years in business**: 42
  - Established in 1982
PV industry chain capacity roadmap

No.1 Shipments

- Polysilicon
  - 2021: 180,000
  - 2022: 260,000
  - 2023: 420,000

No.1 Shipments for 6 consecutive years

- Solar Wafer
  - 2021: 15
  - 2022: 15
  - 2023: 15

- Solar cell
  - 2021: 45
  - 2022: 70
  - 2023: 90

- PV module
  - 2021: 7.2
  - 2022: 14
  - 2023: 63

1,000,000 (tons/year)
800,000

> 47 (GW/year)

150 (GW/year)

> 100 (GW/year)
### Module

Continuous rise from 2022 to 2023 H1

<table>
<thead>
<tr>
<th>Rank</th>
<th>Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>InfoLink</td>
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<td>2</td>
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<td>InfoLink</td>
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<td>5</td>
<td>InfoLink</td>
</tr>
<tr>
<td>6</td>
<td>Tongwei</td>
</tr>
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<td>7</td>
<td>InfoLink</td>
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<td>InfoLink</td>
</tr>
<tr>
<td>9</td>
<td>Tongwei</td>
</tr>
</tbody>
</table>

### Solar Cell

Ranked No.1 for 6 consecutive years

<table>
<thead>
<tr>
<th>Rank</th>
<th>Company</th>
</tr>
</thead>
<tbody>
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<td>1</td>
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<td>4</td>
<td>InfoLink</td>
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<tr>
<td>5</td>
<td>InfoLink</td>
</tr>
</tbody>
</table>

1H23 Cell shipment ranking

<table>
<thead>
<tr>
<th>Rank</th>
<th>Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tongwei</td>
</tr>
<tr>
<td>2</td>
<td>InfoLink</td>
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<tr>
<td>3</td>
<td>InfoLink</td>
</tr>
<tr>
<td>4</td>
<td>InfoLink</td>
</tr>
<tr>
<td>5</td>
<td>InfoLink</td>
</tr>
</tbody>
</table>
According to PV infolink’s prediction, with the rapid growth of TOPCon capacity, TOPCon capacity will fully surpass PERC in the first half of 2024, and its market share will exceed 60%, making N-type products the absolute mainstream in the market.

Data Source: New Technolog Market Report_InfoLink_Aug-23
Tongwei-Excels in producing customer-centric products

- Lower BOS
- Lower LCOE
- Higher Customer Value

TONGWEI
Company I
Company II
Company III
Company IV

VS

182*210 (G12R)

182*19X (G11L)

Company V
Company VI
Company VII
Company VIII
Company IX
Tongwei's New Generation
N-Type Products
Tongwei’s New Generation Flagship Product

<table>
<thead>
<tr>
<th>Product Model</th>
<th>Module Dimension</th>
<th>Module Power Output</th>
<th>Module Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>TWMNH-48HC</td>
<td>1762<em>1134</em>30</td>
<td>440W</td>
<td>22.0%</td>
</tr>
<tr>
<td>TWMNH-48HD</td>
<td>1762<em>1134</em>30</td>
<td>445W</td>
<td>22.3%</td>
</tr>
<tr>
<td>TWMNH-66HD</td>
<td>2382<em>1134</em>30</td>
<td>610W</td>
<td>22.8%</td>
</tr>
<tr>
<td>TWMNH-66HS</td>
<td>2382<em>1134</em>35</td>
<td>615W</td>
<td>23.0%</td>
</tr>
</tbody>
</table>
**G12R - Tongwei Latest N-type TNC module**

**615W**

**66 TNC Module**

**Advantages**

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

<table>
<thead>
<tr>
<th>Power</th>
<th>Up to 615W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency</td>
<td>Up to 23.0%</td>
</tr>
</tbody>
</table>
| Dimensions     | 2382*1134*30mm (Bifacial)  
                  2382*1134*35mm (Monofacial) |
| Weight         | 33.2kg/29.0kg |

Note: module dimension has tolerances of ±4mm on the long side and ±2mm on the short side.
Advantages of the New Generation N-type Products
Domestic Tube-based PE-Tox & Poly TOPCon technology plays a key role in Tongwei’s TNC cells

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

- China’s achievements in Tube-based PE-Tox & Poly closed the industry gap.

- Cutting-edge development and industry-leading production process of TOPCon cells.
PCE of mass produced TNC cell > 26.1%, module power > 585W

- In December 2021, Tongwei optimized the PECVD poly route for mass production.
- At the end of October 2023, a PCE of 26.1% was achieved from mass produced TNC cells.
TNC Field test: 3.34% actual power generation gain than PERC

- Monitoring period: 2/15/2023-19/11/2023
- Field test location: Sanya (18°31N,109°56E), Hainan province, China
- Modules compared: New TNC bifacial module M10-72 series PERC bifacial module
- Climate type: Tropical monsoon climate
- Average temperature: 25.7°C
- Average daily irradiation: 5.35 kWh/m²
Transportation Advantage of G12R module

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

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

40H container packing diagram

- Container door height: 2585mm
- Module pallet height: 2500mm
- Module width: 1134mm
- Total length of packed modules: 14420mm
- Final length of container: 12530mm

4% cost reduction for 40' HQ, 17.5m, 13m Flat

G12R-66 bifacial vs 182-72 bifacial
System Advantages of G12R module

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

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

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

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

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

**BOS:** G12R vs G11L, \(-1.11\%\); G12R vs M10, \(-2.01\%\).

**LCOE:** G12R vs G11L, \(-0.63\%\); G12R vs M10, \(-1.19\%\).

*Using TOPCon M10-72 Bifacial Module as BSL*
Warranty for Material: 15 years for G12R-48 modules, and 12 years for G12R-66 modules.

Warranty for Linear Power Output: 30 years

System Certification:
- ISO9001
- ISO14001
- ISO45001
- IEC62941

Product Certification:
- CE
- CEC

Tongwei TNC modules strict reliability test performance:
- JEC test standard line: PLS 5%
- Tongwei strict test standard line: PLS 3.5%
ESG goals – To achieve operational carbon neutrality

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

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

TONGWEI PV R&D CENTER
Performance & reliability evaluation of n-type high-efficiency PV modules

Shimeng Wei | BF Renewables | 23.01.2024
Topics

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

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

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Global solar LCOE and capture price
Emerging technology

- Cell technology
  - TOPCon
  - HJT
  - XBC
- Structure design
  - Larger dimensions
Topics

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

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Outdoor performance test

Location: Yinchuan, China
N 38°27′ 55.38″; E 106°6′ 7.90″

- Abundant sunlight for more than 3200h / year
- Typical xerothermic climate at average altitude of 1100m
- Solar spectrum is highly consistent with AM1.5 spectrum
- Equipped condition for PV monitoring and testing
Outdoor performance test

Python data analysis tool

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

Distribution of module output power with irradiation

Distribution of differences between module operating temperature and average temperature
Outdoor performance test

Power generation

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

Temperature coefficient

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

Low-irradiance behaviour

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

Operation temperature

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

## LID

<table>
<thead>
<tr>
<th>LID (10kWh/m²)</th>
<th>Min</th>
<th>Max</th>
<th>Ave</th>
</tr>
</thead>
<tbody>
<tr>
<td>n-type Topcon</td>
<td>+0.37%</td>
<td>-0.66%</td>
<td>-0.08%</td>
</tr>
<tr>
<td>PERC</td>
<td>-0.17%</td>
<td>-0.96%</td>
<td>-0.55%</td>
</tr>
</tbody>
</table>

![Initial 10kwh/m² LID](image)
Outdoor performance test

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

<table>
<thead>
<tr>
<th>Energy Efficiency Class</th>
<th>Subtropical arid</th>
<th>Temperate coastal</th>
<th>Temperate continental</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>EEI(_m) &gt; 566</td>
<td>EEI(_m) &gt; 257</td>
<td>EEI(_m) &gt; 330</td>
</tr>
<tr>
<td>B</td>
<td>496 &lt; EEI(_m) ≤ 566</td>
<td>226 &lt; EEI(_m) ≤ 257</td>
<td>291 &lt; EEI(_m) ≤ 330</td>
</tr>
<tr>
<td>C</td>
<td>426 &lt; EEI(_m) ≤ 496</td>
<td>195 &lt; EEI(_m) ≤ 226</td>
<td>252 &lt; EEI(_m) ≤ 291</td>
</tr>
<tr>
<td>D</td>
<td>356 &lt; EEI(_m) ≤ 426</td>
<td>164 &lt; EEI(_m) ≤ 195</td>
<td>213 &lt; EEI(_m) ≤ 252</td>
</tr>
<tr>
<td>E</td>
<td>310 &lt; EEI(_m) ≤ 356</td>
<td>140 &lt; EEI(_m) ≤ 164</td>
<td>182 &lt; EEI(_m) ≤ 213</td>
</tr>
<tr>
<td>F</td>
<td>265 &lt; EEI(_m) ≤ 310</td>
<td>117 &lt; EEI(_m) ≤ 140</td>
<td>151 &lt; EEI(_m) ≤ 182</td>
</tr>
<tr>
<td>G</td>
<td>EEI(_m) ≤ 265</td>
<td>EEI(_m) ≤ 117</td>
<td>EEI(_m) ≤ 151</td>
</tr>
</tbody>
</table>

**TOPCon have better conversion efficiency**

**Per annum:**
- 160 kWh/m\(^2\)
- 206 kWh/m\(^2\)
- 344 kWh/m\(^2\)

**TOPCon have better operating temperature**
Performance & reliability evaluation of n-type high-efficiency PV modules

- 01 Background
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- 03 Characterization
- 04 Reliability evaluation
- 05 Conclusion
Emerging technology

Emerging technology

Cell technology

- TOPCon
- HJT
- XBC

Structure design

Larger dimensions
Characterizations of n-type modules with new cell technology

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

Production efficiency
23.9%-24.6%

Theoretical efficiency
27.5%-28.5%
Characterizations of n-type modules with larger dimensions

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

<table>
<thead>
<tr>
<th>PV module</th>
<th>Size (mm)</th>
<th>Pmax (W)</th>
<th>Isc (A)</th>
<th>Voc (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>156.75 (144 half-cut)</td>
<td>2007x992</td>
<td>390</td>
<td>9.79</td>
<td>49.28</td>
</tr>
<tr>
<td>158.75 (144 half-cut)</td>
<td>2031x1008</td>
<td>420</td>
<td>10.70</td>
<td>48.74</td>
</tr>
<tr>
<td>166 (144 half-cut)</td>
<td>2117x1052</td>
<td>475</td>
<td>11.46</td>
<td>51.25</td>
</tr>
<tr>
<td>182 (156 half-cut)</td>
<td>2465x1134</td>
<td>620</td>
<td>14.30</td>
<td>55.34</td>
</tr>
<tr>
<td>210 (132 half-cut)</td>
<td>2384x1303</td>
<td>720</td>
<td>17.74</td>
<td>49.20</td>
</tr>
</tbody>
</table>
Topics
Performance & reliability evaluation of n-type high-efficiency PV modules

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Accurate power testing

The internal capacitance leads to a strong hysteresis effect in I–V measurements. This hysteresis introduces a significant error in measurement results.

The test results of the multi-flash and DB methods are basically consistent with those of the long pulse simulator.
Moisture

Damp-heat test simulation

<table>
<thead>
<tr>
<th></th>
<th>DH1000</th>
<th>DH2000</th>
<th>DH3000</th>
<th>TC200</th>
<th>TC400</th>
<th>TC600</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>n-type double glass</strong></td>
<td>-1.96%</td>
<td>-3.22%</td>
<td>-3.37%</td>
<td>-0.37%</td>
<td>-1.53%</td>
<td>-1.72%</td>
</tr>
<tr>
<td><strong>n-type double glass</strong></td>
<td>-1.95%</td>
<td>-3.51%</td>
<td>-3.88%</td>
<td>-0.58%</td>
<td>-1.23%</td>
<td>-1.38%</td>
</tr>
<tr>
<td><strong>n-type single glass</strong></td>
<td>-2.70%</td>
<td>-4.42%</td>
<td>-4.97%</td>
<td>-1.38%</td>
<td>-1.43%</td>
<td>-2.14%</td>
</tr>
<tr>
<td><strong>n-type single glass</strong></td>
<td>-3.30%</td>
<td>-4.91%</td>
<td>-5.79%</td>
<td>-1.66%</td>
<td>-1.83%</td>
<td>-2.30%</td>
</tr>
</tbody>
</table>
Accurate power testing

Temperature co-efficient

55°C - 25°C
\( \alpha = -0.352\% \)

40°C - 10°C
\( \alpha = -0.312\% \)

45°C - 15°C
\( \alpha = -0.285\% \)

Regular natural cooling + 10ms pulse single flash

Low temperature area + 10ms pulse single flash

Temperature control box + accurate test

Pmax T.C.
Installation

Installation method
• The position of mounting holes
• The amount of mounting holes
• Tracker or Fixed bracket

Extreme climate
• Rainy, snowy, hailing, windy weather
Packaging & transportation

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

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

<table>
<thead>
<tr>
<th>Test Method</th>
<th>Load Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random vibration testing</td>
<td>Dynamic mechanical load</td>
</tr>
<tr>
<td>Inclined impact test</td>
<td>Thermal cycles</td>
</tr>
<tr>
<td>Rotational edge drop test</td>
<td>Humidity freeze</td>
</tr>
<tr>
<td>Vertical shock test</td>
<td>Mechanical load</td>
</tr>
<tr>
<td>Horizontal impact test</td>
<td></td>
</tr>
</tbody>
</table>
Mechanical properties

- Large size modules are with wider sides, requiring higher toughened quality control on the edges of the glass.
- Dynamic changes of strong wind pressure may cause the failure of components and installation systems.
- Risk increases with the greater size.
- The bottom frame suffers greater non-uniform snow load as the modules become wider.

Static & dynamic Mechanical Load

Non-uniform Snow Load

Wind tunnel test

Hail impact test

Static & dynamic Mechanical Load

Non-uniform Snow Load

Wind tunnel test

Hail impact test

Dynamic changes of strong wind pressure may cause the failure of components and installation systems.

Large size modules are with wider sides, requiring higher toughened quality control on the edges of the glass.
Electrical safety

Current-related tests for bifacial PV modules

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

<table>
<thead>
<tr>
<th>Module Size</th>
<th>Isc-BSI (A)</th>
<th>Imp-BSI (A)</th>
<th>MQT 18 Bypass diode testing: 1.4*Isc-BSI at 75°C 1hour, according to IEC TS 63126 level 2</th>
<th>MST 26 Reverse current overload test: 1.35*fuse rating 2hours, according to IEC 61730-2</th>
<th>MQT 11 Thermal cycling test: Imp-BSI, according to IEC 61215-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>166mm (144 half-cut)</td>
<td>13.87</td>
<td>12.52</td>
<td>27.19</td>
<td>27.00</td>
<td>12.52</td>
</tr>
<tr>
<td>182mm (156 half-cut)</td>
<td>17.30</td>
<td>16.24</td>
<td>33.91</td>
<td>40.50</td>
<td>16.24</td>
</tr>
<tr>
<td>210mm (132 half-cut)</td>
<td>21.47</td>
<td>20.57</td>
<td>42.08</td>
<td>47.25</td>
<td>20.57</td>
</tr>
</tbody>
</table>
Electrical safety

Thermal cycling test

Normal operation

Bypass diode fails

Junction box melt after thermal cycling
Electrical safety

Bypass diode thermal test

<table>
<thead>
<tr>
<th></th>
<th>Degradation</th>
<th>132 half-cut cells 210mm</th>
<th>408 segmented cells 210mm</th>
<th>414 segmented cells 210mm</th>
<th>110 half-cut cells 210mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-0.30%</td>
<td></td>
<td>1.40%</td>
<td>-0.41%</td>
<td>0.42%</td>
</tr>
</tbody>
</table>

Power degradation after bypass diode thermal test
Topics

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Conclusion

• LCOE continues to decrease, which is becoming the most important factor of global PV projects.

• n-type PV modules with larger dimensions is an emerging technology.

• Outdoor performance test shows the power generation advantages of n-type PV modules.

• Risks come along with the benefits of high-efficiency PV modules with larger dimensions and larger current, solutions are already available and therefore additional care need to be taken.
Do you have questions?

Shimeng Wei
T.: +49 (0)160 888 5840
M.: swei@tuev-nord.de