LONGi
LIFECYCLE QUALITY

Lifecycle Quality Program:

Ensuring Long-term Module Performance and Reliability

Alyssa Huang, LONGi Product Marketing Manager
PV Magazine Roundtables 2023

LONGi

Propelling the transformation

About LONGi

LONGi is committed to being the world's leading solar technology company.

2000
Foundation

60000+
Global Employees

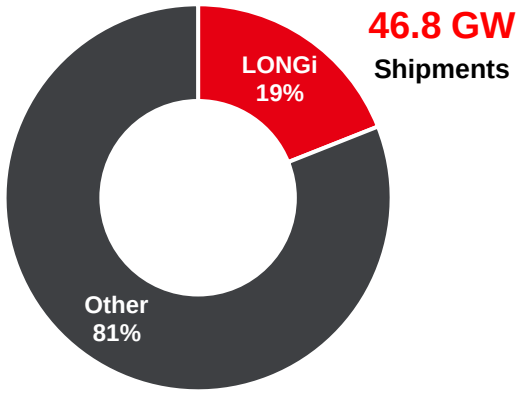
85GW+
Production Bases

141.7GW
Global Module Shipment
Up to 2023Q1

Y2022

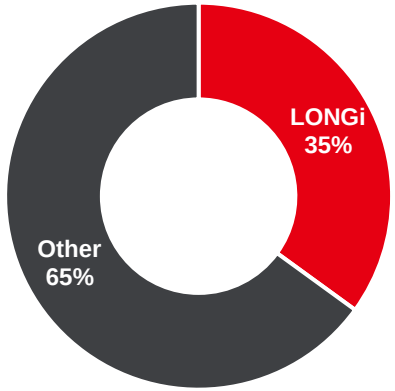
US $20.2B	US $2.3B	US $1.1B
Operating Income	Net Profit	R&D Investment

Top 1 Global Module Shipment 2022



46.8 GW
Shipments

Top 1 Global Wafer Shipment 2022

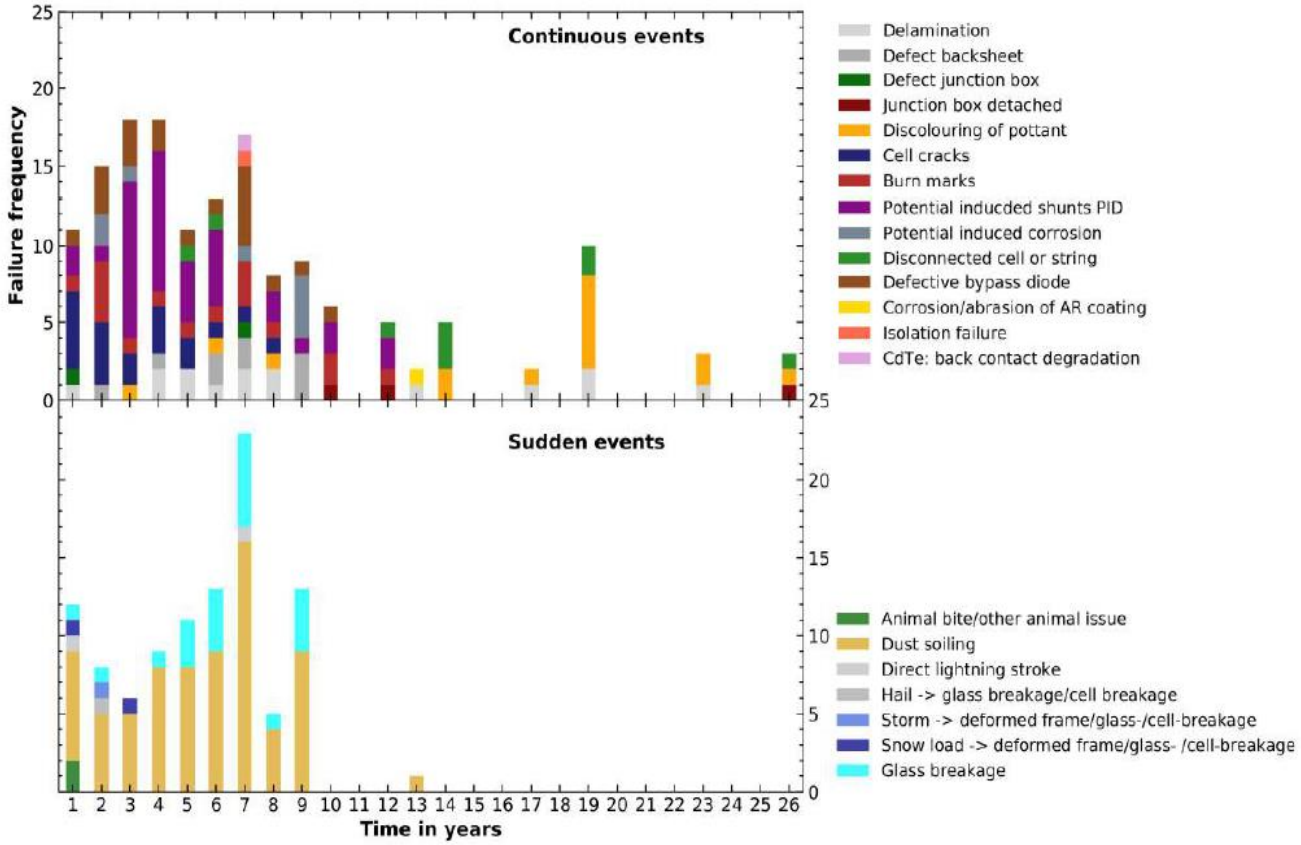


85.1 GW
Shipments

Source: 2022 Annual Report

Impact of Module Reliability on ROI

Ensuring lifetime module reliability is essential to guaranteeing the long-term operation of PV plants and ROI.



Maximize Return on Investment

- **Annual costs:** Lower OPEX cost, including the reliability failure cases
- **System degradation:** Reduce module degradation and yield loss

Total lifecycle cost

$$LCOE = \frac{Initial\ Investment - \sum_{n-1}^{N} \frac{Depreciation^n}{(1+Discount\ Rate)^2} \times (Tax\ Rate) + \sum_{n-1}^{N} \frac{Annual\ Costs^n}{(1+Discount\ Rate)^2} \times (Tax\ Rate) - \frac{Residual\ Value}{(1+Discount\ Rate)^2}}{\sum_{n-1}^{N} \frac{Initial\ kWH/kWp \times (1 - System\ Degradation\ Ration)^n}{(1+Discount\ Rate)^2}}$$

Total energy yield

LONGi's Reliable Design Concept: Upgrading Module Reliability in a Scientific Method

LONGi conducts in-depth studies on failure mechanisms and works to develop a variety of testing methods. These methods simulate a comprehensive set of real-world application scenarios to ensure module long-term reliability.

Step 4
- ✓ New standard implementation

LONGi LIFECYCLE QUALITY

Step 3
- ✓ Mass production verification

Step 2
- ✓ Upgrade & innovate
- ✓ Improve efficiency
- ✓ Construct test sequence

Step 1
- ✓ Failure forensic study
- ✓ Outdoor simulation

Simulation & Failure Study

Ex: Coffin-Manson Equation

$$\underbrace{AF}_{\text{Acceleration Factor}}=\frac{N_{D1}}{N_{D2}}=\left(\frac{\underbrace{f_1}_{\text{Cycling Frequency}}}{f_2}\right)^{-a}\cdot\left(\frac{\underbrace{\Delta T_1}_{\text{Temperature Difference}}}{\Delta T_2}\right)^{-b}\cdot\exp\left[\frac{E_a}{K}\left(\frac{1}{\underbrace{T_{max1}}_{\text{Maximum Temperature}}}-\frac{1}{T_{max2}}\right)\right]$$

Local Glass Thermal Shock Resistance Test to Reduce Hot Spot-Induced Glass Failure

LONGi

LONGi LIFECYCLE QUALITY

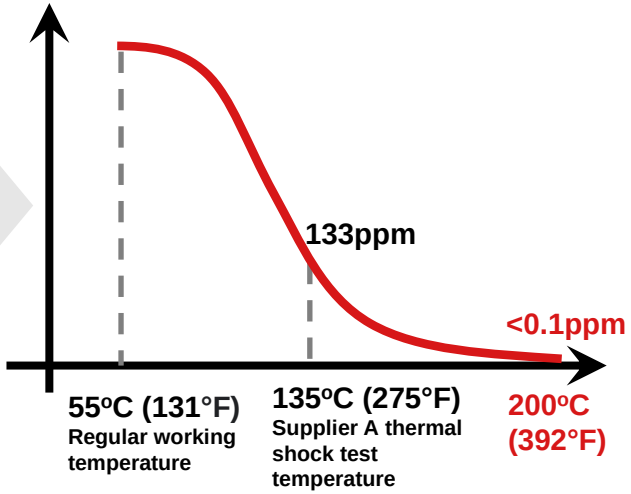
Pioneered full-size photovoltaic glass local thermal shock resistance test standards with 200°C (392°F) test temperature.

The new standard more effectively filtered out unqualified suppliers

Supplier	Conventional standard (300*300)	Thermal Shock Test Temperature °C	Hot Spot Temperature °C	Supplier	Conventional standard (300*300)	Thermal Shock Test Temperature °C	Hot Spot Temperature °C
Supplier A	OK	96.2	187.7 (NG)	Supplier E	OK	187	188.8 (OK)
	OK	127.7	193.3 (NG)		OK	> 200	192.6 (OK)
	OK	138.4	184.5 (NG)		OK	193.3	188.4 (OK)
	OK	135.9	179.1 (NG)		OK	> 200	192.1 (OK)
	OK	172.5	185.6 (NG)		OK	191.06	185 (OK)
Supplier B	OK	> 200	194.1 (OK)	Supplier F	OK	> 200	174.9℃ (OK)
	OK	> 200	188.7 (OK)		OK	> 200	183.4℃ (OK)
	OK	> 200	190.9 (OK)		OK	> 200	195.5℃ (OK)
	OK	> 200	191.4 (OK)		OK	194.6	185.8℃ (OK)
	OK	> 200	197.1 (OK)		OK	> 200	181.6℃ (OK)
Supplier C	OK	> 200	191.7℃ (OK)	Supplier G	OK	> 200	192 (OK)
	OK	195	191.4℃ (OK)		OK	> 200	193.5 (OK)
	OK	137.65	183.6℃ (NG)		OK	> 200	198.8 (OK)
	OK	191.06	191.4℃ (NG)		OK	> 200	192.9 (OK)
	OK	/	176.3℃ (OK)		OK	> 200	201.3 (OK)
Supplier D	OK	> 200	184.7℃ (OK)	Supplier H	OK	> 200	180.4 (OK)
	OK	> 200	179.3℃ (OK)		OK	> 200	186.9 (OK)
	OK	> 200	185.8℃ (OK)		OK	> 200	195.8 (OK)
	OK	> 200	191.7℃ (OK)		OK	> 200	193 (OK)
	OK	196	190.5℃ (OK)		OK	> 200	195.5 (OK)

Increase test temperature = reduce glass failure rate

Reduced glass breakage failure



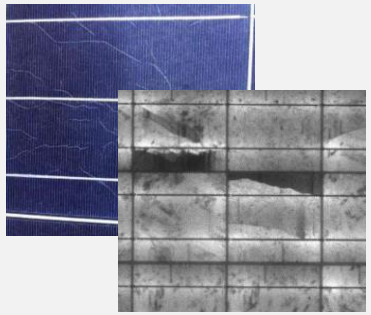
Four-Point Cell Bending Test Standard to Minimize Cell Crack and Mechanical Load Failure

LONGi

Propelling the transformation

NEED: Standardized Quality Cell Testing

- Effectively select high-quality cells at early stage
- Accurately predict module's mechanical load performance
- Minimizing cell crack and ML failure



CHALLENGE: Inconsistent Results of Cell Bending Tests

- Lack of standardization
- Test approach varies by supplier
- Difficult to compare results and raises concerns about accuracy

SOLUTION: LONGi Lifecycle Quality Program

- Lead the formulation of 4-point cell bending testing standard
- Accurately and efficiently screen high-quality cells
- Predict the module's ML performance at an early stage

LONGi LIFECYCLE QUALITY

Four-Point Cell Bending Test Standard to Minimize Cell Crack and Mechanical Load Failure

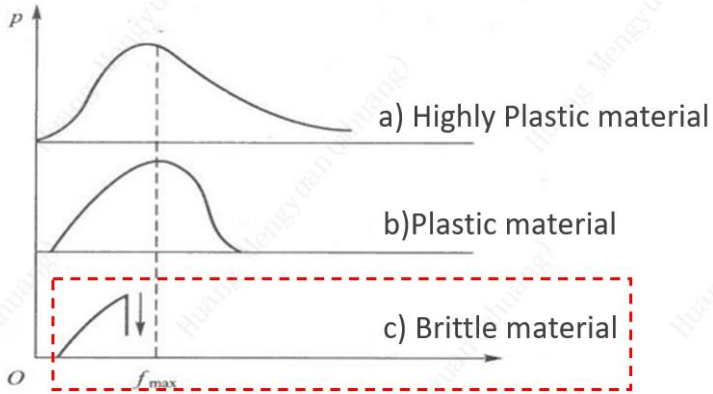


Figure 1. Solar cell is characterized as brittle material.

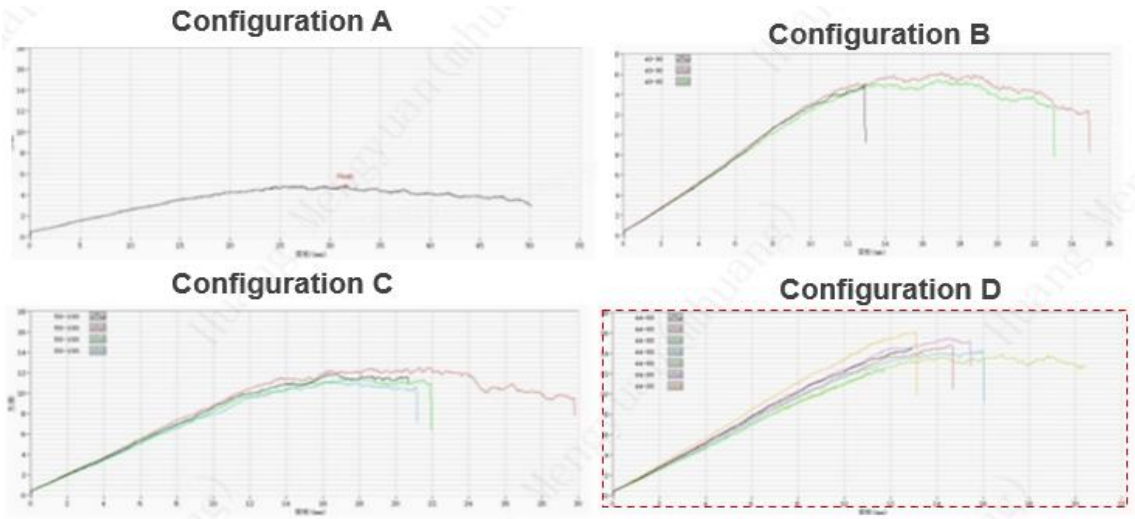
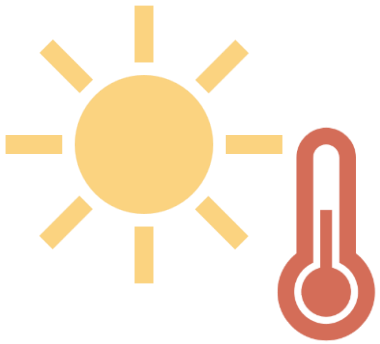


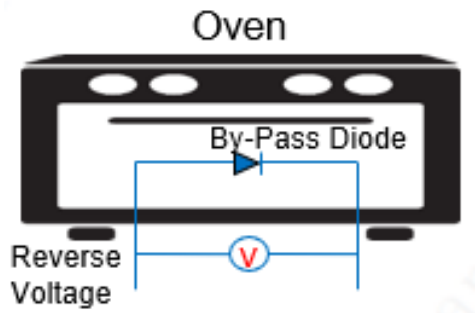
Figure 2. Load vs. deflection of various materials. Configuration D represents solar cell.

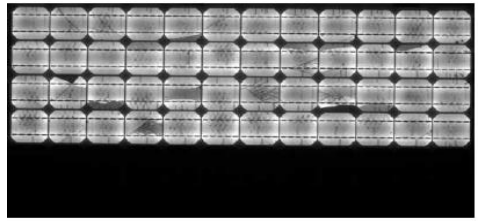
No.	Main Test Verification	Description
1	3-point/ 4-point test procedure selection	Evaluate the effectiveness of the test method
2	Indenter spacing determination	Conduct verification tests to determine the feasibility of parameters with various cell sizes
3	Indenter diameter selection	Small effect on the accuracy of the test
4	Indenter set up selection	Fixed set up
5	Loading speed determination	Small effect on the accuracy of the test

High Temperature Reverse Bias Standard to Reduce Bypass Diode Failure



Module's high operating temperature in field (>85 °C/ 185°F) may cause diode failure.





LONGi has taken the lead in raising the temperature of the diode reverse bias test to 100°C (212°F).

- Screen out unqualified diode at raw material selection stage

- Reduce thermal failure risk of diodes

- Reduce power production loss & fire hazards

LONGi's Testing Standard to Ensure Long-Term Field Performance

LONGi

Propelling the transformation

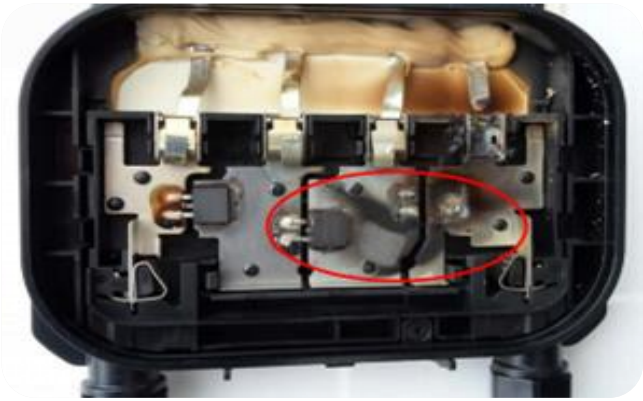
PV Glass
Innovation, Pioneering

Local thermal shock resistance test
→ **Reduce hot spot-induced glass failure**

Four-point bending strength test
→ **Reduce external load-induced failures**

Standardized management of coatings
→ **Reduce degradation per coating defects**

Junction Box
Optimized, Dependable

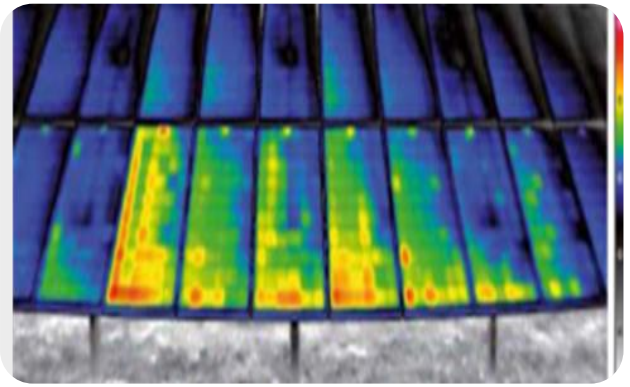


Thermal runaway standard
→ **Further reduce hot spot failure**

High temperature reverse bias standard
→ **Reduce failure rate of bypass diode**

Cable riveting compression ratio
→ **Reduce cable loss & arc-faults**

Cell & EVA
Revolutionary, Benchmark



Cell Four-point bending standards
→ **Reduce cell crack & mechanical failure**

Co-extrusion POE standard
→ **Reduce PID risk**

EVA acetic acid content standard
→ **Reduce busbar/ ribbon corrosion risk**

Conclusion

To ensure the lifetime operation of PV plants and return on investment, raw material and module evaluation standards of PV modules need continuous research and optimization.

The industry needs to conduct more research and studies on standardizing the process for addressing module failures, including cause validation and solution implementation. Then, corresponding evaluation and testing standards can be developed to minimize failures.

It is currently unclear whether the existing mainstream testing standards can validate 30 years of product reliability. Continuous research by professionals in the PV industry is needed to evaluate the potential of scientifically based testing standards that avoid overkill and minimize testing costs and cycles.

Alyssa Huang, Product Marketing Manager
mhuang@longi.com