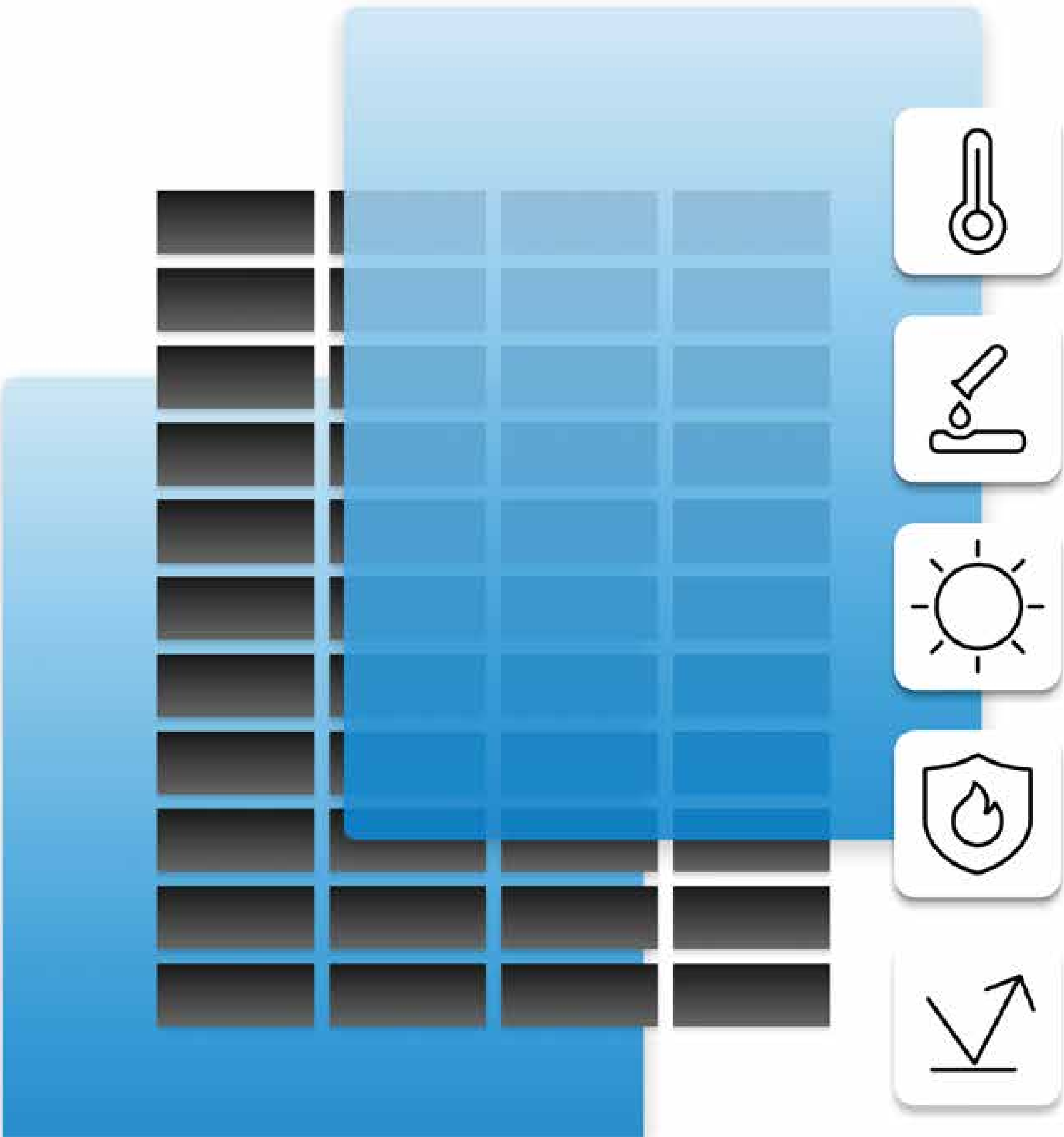
Trinasolar

How **1.6mm Dual-Glass** Enhances Solar Panel Performance

WHITE PAPER



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Introduction

As the technology of photovoltaic modules continuously evolves, dual-glass modules are gradually becoming the mainstream products in the market. Due to temperature uniformity and zero moisture penetration, 1.6mm dual-glass modules show outstanding performance at high temperature and humidity environments. Furthermore, double-glass modules undergo lower power degradation and a reduced stress impact risk after mechanical load testing.

02

Advantages of 1.6mm Dual-Glass

2.1 Excellent Temperature Uniformity

PV modules working at uniform temperature reduce the probability of mismatch and hot spots, contributing to increased power generation. The thermal diffusion coefficient of an object determines its ability to evenly distribute heat. In the case of PV modules, a higher thermal diffusion coefficient indicates that the temperature is more likely to converge to a uniform value. This can be observed by comparing a module with a dual-glass configuration of 1.6mm to one with a glass-backsheet configuration as shown below. The former exhibits a significantly higher thermal diffusion coefficient, leading to better temperature uniformity. This ultimately results in improved performance and efficiency of the PV system.

Materials	Thermal Conductivity (W/m·K)	Density (g/cm^3)	Specific Heat Capacity (KJ/Kg/K)	Thermal Diffusion Coefficient (m^2/s)
1.6mm dual-glass	1.04	2.35	0.75	0.59
Backsheet	0.14	1.37	2.2	0.046

Table 1. Comparison of thermal diffusivity of dual-glass and backsheet modules

In the empirical experiment of the dual-glass module and backsheet module, we have validated this theory. During the one-year experiment in Hainan, China, a thermocouple sensor was installed on the upper and lower parts of each module to continuously monitor the temperature changes during module operation. The annual average temperature change of the modules is shown in figure 1, with the maximum operating temperature difference of 2 °C and the average operating temperature of the dual-glass module being 0.75 °C lower compared to the backsheet module.

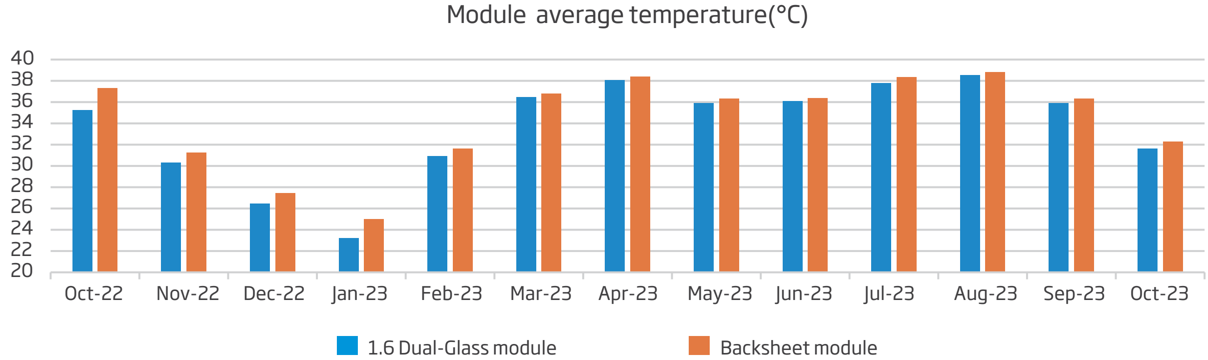

Figure 1. Monthly module temperature(ave.) of dual-glass and backsheet module

2.2 Resistant to corrosive agents, and Zero Moisture Penetration

Dual-glass modules have proven to be more resistant to moisture penetration compared to glass/backsheet modules. This is primarily due to their unique structural design which enhances cell protection and extends their overall lifespan. In addition to structural advantages, the application of glass in these modules improves their overall reliability. Glass, as an inorganic material, exhibits excellent resistance to salt spray, acids, and alkalis. In contrast, backsheets made from plastic polymers are prone to yellowing, cracking, degradation, and chalking when exposed to prolonged air and UV exposure.

Moreover, the structural composition of traditional backsheet modules makes them more susceptible to moisture penetration compared to dual-glass modules. The continuous exposure to moisture can lead to various degrees of damage and cell degradation. This occurs as water vapor reacts with the encapsulant film and undergoes hydrolysis, forming acetic acid. This corrosive substance can degrade the metal components of the module, such as PV ribbons, ultimately resulting in power degradation.

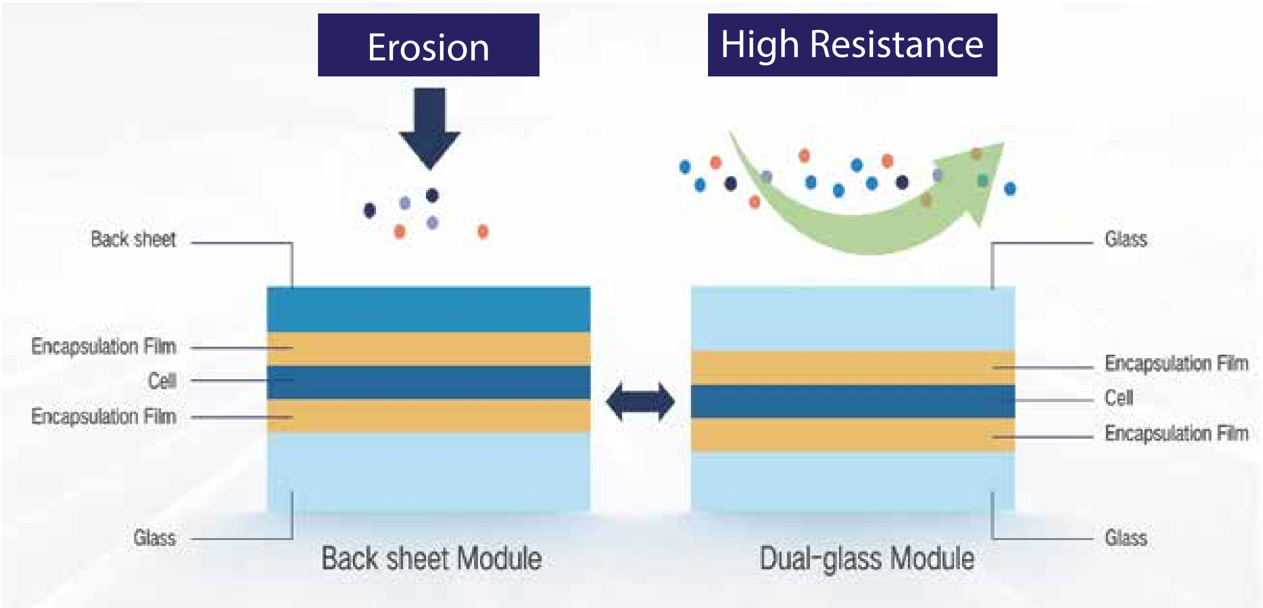

Figure 2. Comparing the structure of backsheet and dual-glass modules

Therefore, the utilization of dual-glass modules offers significant advantages in terms of moisture resistance and overall module performance. By incorporating glass as a protective layer, these modules provide enhanced cell protection, longer lifespan, and improved reliability compared to backsheet modules.

2.3 Suitable for High Temperature and Humidity Scenarios

Dual-glass modules are normally the preferred choice in high temperature and humidity scenarios. For assessing the modules' ability to generate power in this kind of environment, Trinasolar conducted an empirical analysis at a demo project located at Haikou (Hainan), where 1.6mm dual-glass modules were compared to 3.2mm glass plus backsheet reference modules.

From a power generation perspective, 1.6mm dual-glass modules showed better performance than backsheet ones. The annual power generation achieved by backsheet modules was 5984.42kWh (1222.46kWh/kWp). In the case of 1.6mm dual-glass, the annual power generation reached 6466.12 kWh (1259.93 kWh/kWp), 3.07% higher than backsheet modules.

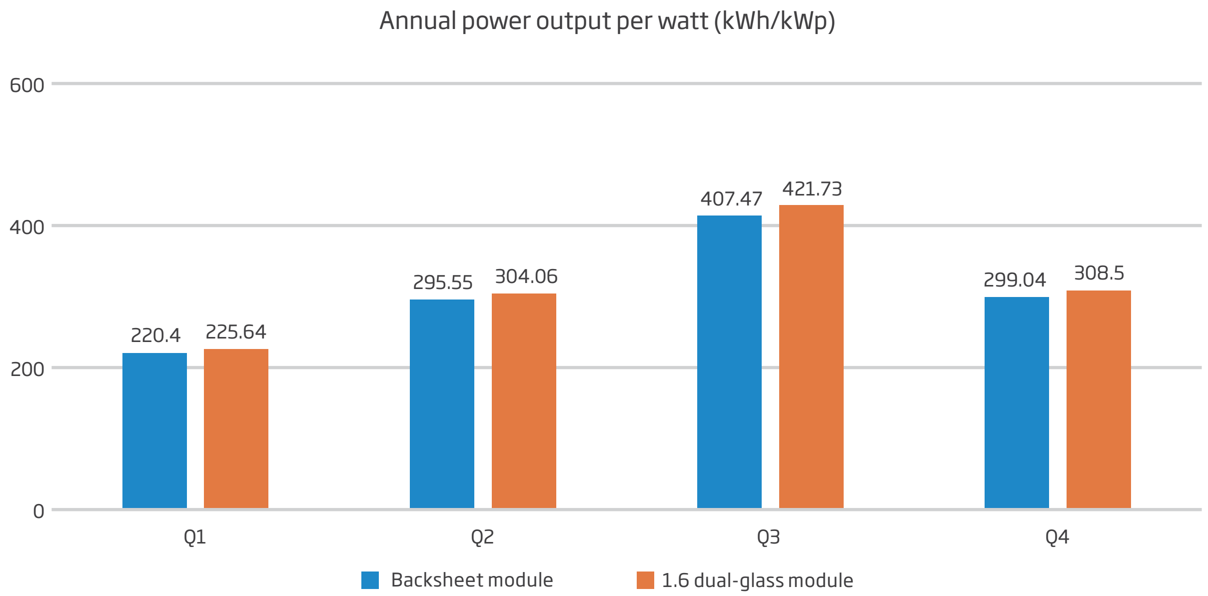

Figure 3. Energy yield at Haikou (backsheet versus 1.6mm dual-glass)

2.4 Fire Resistance

The 1.6mm dual-glass PV modules exhibit higher fire resistance compared to backsheet modules. According to tests conducted in compliance with IEC 61730-2 (UL 790 test protocol), these dual-glass modules have achieved a Class A rating in the spread of flame test, meaning the fire spread over the module is less than 1.8 meters during a 10-minute test. Additionally, during the burning brand test, the modules successfully passed the Class C test without any issues.

The ignitability of PV modules must be considered since when installed on rooftops, they are part of the building structure. EN 13501-1 is a European standard that specifies a system for classifying the fire performance of construction products and building elements. It requires PV modules installed on buildings to comply with strict fire safety standards to prevent the risk of fire spreading. Vertex S+ modules have achieved an EN 13501-1 Class E rating, demonstrating a commitment to high fire safety standards in the manufacturing of PV modules, benefiting manufacturers, builders, and end users.

2.5 Hail Resistance

Hail resistance performance is another indicator for assessing the reliability of solar modules. 1.6mm dual-glass modules have passed a 35mm hail test, which is more critical compared to the IEC standard test of 25mm hail.

Hail Size	Mass (g)	Test velocity (m/s)
25mm	7.53	23.0
35mm	20.7	27.2

Figure 4. Comparison of hail size and test velocity

In particular, the Swiss Hail impact test has been widely recognized and applied by institutions and European countries, especially in countries such as Switzerland, Austria and Germany facing extreme weather conditions. Modules that meet the Swiss hail test requirements could provide installers and end users additional certainty in terms of mechanical stability. Additionally, the Swiss hail test controls dimension and weight of the hail balls more accurately than IEC standards. So far, the Trinasolar Vertex S+ NEG9R series modules (NEG9R.28, NEG9R.25, and NEG9RC.27) have successfully achieved the HW3 rating.

2.6 Reliability in the Long Run: Lower Power Degradation

To compare the degradation rate in different module topologies, Trinasolar performed several reliability tests on them, and we made sure modules for testing were produced using cells from the same manufacturer. Results coming from three different sets of tests conclude that the power degradation for dual-glass modules is significantly lower than that of backsheet modules (Figure 5).

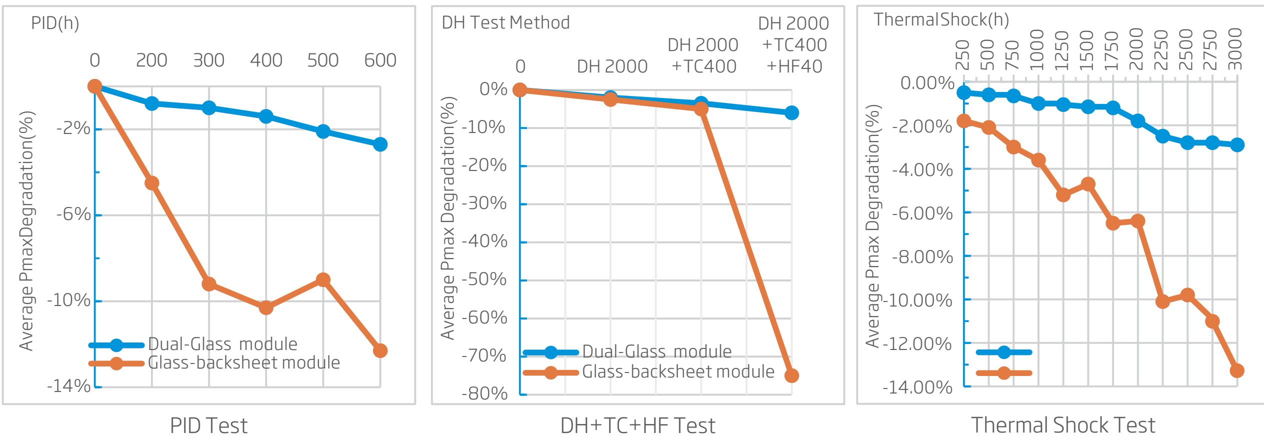

Figure 5. Pmax degradation of dual-glass module and backsheet module after long endurance test

Similarly, the degradation rate of backsheet modules was higher than that of dual-glass configurations after the DH 1000 test (1000 cycles of damp heat). For this DH 1000 test, temperature was 85°C ± 2°C and humidity was 85% ± 5%. It can be concluded that the dual-glass modules demonstrated excellent performance in high temperature and high humidity test environments, resulting in lower attenuation rates (Table 2).

Product type	Degradation (%)
1.6mm dual-glass modules	-0.86%
glass-backsheet modules	-1.96%

Table 2. Degradation rate of modules after DH1000 testing

According to the "PV Magazine Test" published by PV Magazine (Figure 6 & 7), the Trinasolar NEG9RC.27 Vertex S+ module (1.6mm dual-glass module) demonstrated superior performance in terms of appearance, electroluminescence (EL), potential-induced degradation (PID), and light-induced degradation (LID) compared to PERC, HJT, and BC modules. As of April 2024, it achieved the 1st place in energy yield ranking and 3rd place in average score.

Specific energy yield ranking for April 2024

Figure 6. PV magazine test energy yield ranking
(source: PV Magazine photovoltaic markets & Technology, 06/2024/78538)

Product	Type	Name plate power (W)	Visual Grade	EL Grade	Low Irradiance Grade	Pmax temperature coefficient Grade	PID Loss Grade	Average
TSM-685NEG21C.20	Bifacial TOPcon	685	100	100	79	102	100	95
[illegible]	Bifacial HJT	715	100	100	77	114	84	93
TSM-NEG9RC.27 425W	Bifacial TOPcon	425	100	100	70	98	100	92
[illegible]	Bifacial TOPcon	695	100	100	69	104	89	90

Figure 7. PV magazine test result
(source: https://www.pv-magazine.com/pv-magazine-test-results/)

2.7 Mechanical Load Capacity

Extensive tests, theoretical calculations, and experimental analyses were conducted to assess the mechanical load capacity of different module configurations, such as 1.6mm dual-glass and glass-backsheet modules. For example, Figure 8 shows the differences in module deformation after Finite Element Modeling (FEM) simulation for dual-glass compared to glass-backsheet topologies. The deformation experienced by backsheet modules is significantly more severe than that of dual-glass modules under the same test conditions. FEM simulation results indicated that the deformation of dual-glass modules is less than 30mm, while backsheet modules reach up to 50mm.

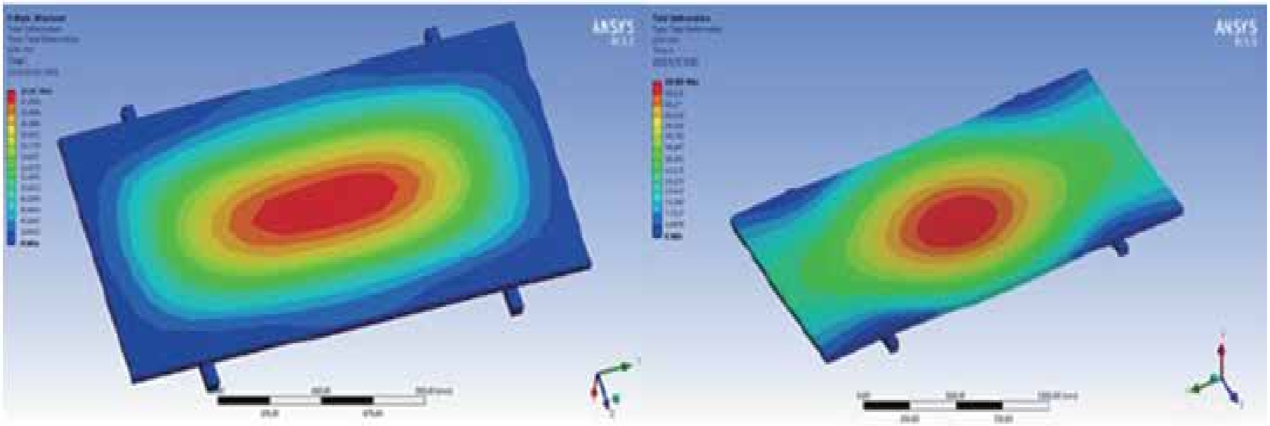

Figure 8. Deformation of backsheet (left) and dual-glass modules (right)

Moreover, Trinasolar analyzed the power attenuation and EL results of two types of modules (3.2mm glass-backsheet module and 1.6mm dual-glass module) after performing mechanical load testing. Both types were mounted with screws under maximum acceptable loads of 6000 Pa on the front side and 4000 Pa on the back side (Table 3). The analysis clearly concluded that power degradation is lower for the dual-glass module compared to the backsheet module. After mechanical load testing, the power loss for the 1.6mm dual-glass module was 0.28%, whereas the 3.2mm glass/backsheet module exhibited a power loss of 0.48%. According to the EL test results, there were no hidden cracks in the modules with 1.6mm glass. However, the backsheet modules showed slight cracks in some areas.

Both theoretical analysis and experimental data demonstrate that dual-glass modules are more reliable than backsheet ones in terms of mechanical load capacity. This is because the deformation and power attenuation of dual-glass modules are lower than those of backsheet modules under the same test conditions.

Glass Thickness	Installation Methods	Load Requirement	Mounting Components	Load Status	PMAX Change Rate [%]
3.2mm (backsheet)	Crossbeam Screws	+6000Pa -4000Pa	M8 screws, 18mm gasket	PASS	-0.48%
1.6mm (dual-glass)	Crossbeam Screws	+6000Pa -4000Pa	M8 screws, 18mm gasket	PASS	-0.28%

Table 3. Mechanical load test results for dual-glass and backsheet modules

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