# Understanding and Mitigating the Dangers Posed by Hail and Wind

**A realistic assessment of hail & wind damages** on PV modules with tests influenced by **real-world applications** in an **independent test lab**

## INTRODUCTION

To meet user standards, PV modules must be able to withstand decades installed in the field. Studies have consistently shown a strong positive correlation between quality and return on investment and other profitability indicators (*2022 PV Module Index Report, RETC*).

Products that appear similar on paper may perform very differently in the real world. A manufacturing commitment to quality often accounts for these differences. essential components of a manufacturing quality program include:

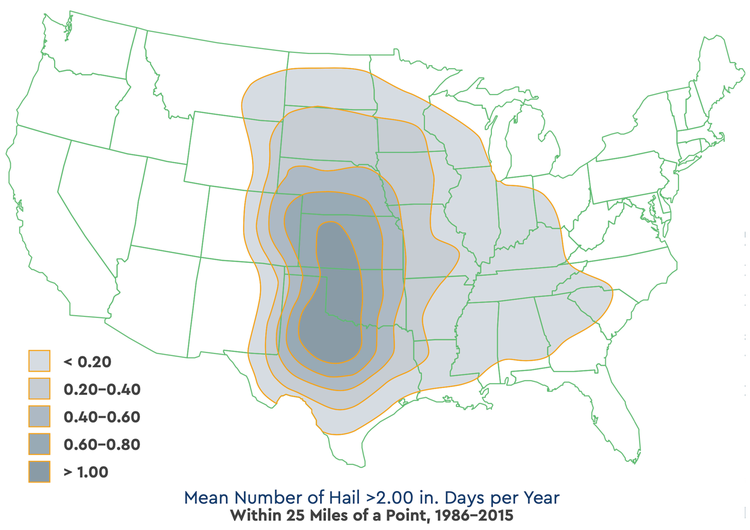
- Beyond-qualification testing
- Product conformity analysis
- Random sampling program
- Third-party factory audits

Mitigating site-specific risk requires the strategic application of products and technologies. A one-size-fits-all approach to product design and project development invariably increases project risk profiles. Strategic product differentiation improves project resilience.

Robust modules and system designs mitigate project risk in hail-prone regions like West Texas. Product and system designs that resist dynamic wind effects reduce project risk in high-wind locations worldwide. Product and system designs that resist high static mechanical loads lessen catastrophic failure risks in extreme-snow locations. Corrosion-resistant products extend operating lifetimes in coastal areas.

In May 2019, hail damaged some 400,000 modules at the Midway Solar generating facility in West Texas, resulting in a previously unimaginable $80 million in insured losses (*2022 PV Module Index Report, RETC*). Recognizing that basic certification test standards are inadequate to identify and quantify the project risks associated with hail, RETC developed its innovative Hail Durability Test (HDT) program. By expanding upon existing UL and IEC standards, the HDT program helps project stakeholders better understand hail effects on PV modules in real-world applications.

PROBABILITY OF GREATER THAN 2-INCH HAIL




Mean Number of Hail >2.00 in. Days per Year
Within 25 Miles of a Point, 1986–2015

### KEY TAKEAWAYS

- Weather-related solar insurance claims and premiums are on the rise.
- Data-driven approaches to product selection mitigate weather risks.
- Active defensive stow and load shed protocols can further reduce risks.
- Probabilistic analyses can quantify the financial value of risk mitigation.

| Module HDT Classification | Impact Characterization |
|---|---|
| **Class A** | No abnormalities that can lead to premature drop in power. Low to no power loss. |
| **Class B** | A few abnormalities that do not lead to premature drop in power. |
| **Class C** | Increased abnormalities that may lead to premature drop in power and risk of hot spot. |
| **Class D** | Negative properties that can directly lead to a drop in power with an elevated risk of hot spot. |

## METHOD

### WHAT IS THE BASIC SCOPE & STRUCTURE OF THE HDT?

**8** **modules** act as randomly selected test samples used to characterize the initial condition based on EL testing, visual inspection and maximum power measurement.

**10** **hail impacts**

**5** **impact locations**

**4** **test cases** that vary based on hailstone diameter, mass, impact velocity and kinetic energy are used to understand how impact severity affects outcomes

### HAIL DURABILITY TEST (HDT) PROCEDURE

**INITIAL CHARACTERIZATION**

Electroluminescence testing; maximum power determination; visual inspection

**HAIL IMPACT TESTING**

Two test samples per case; ten shots total (5 impact locations per module with 2 impacts per location)

| Case | Diameter | Mass | Velocity | Kinetic Energy |
|---|---|---|---|---|
| 1 | 45 mm | 43.9 g | 30.7 m/s | 20.69 J |
| 2 | 50.8 mm | 63.3 g | 32.0 m/s | 32.14 J |
| 3 | 55 mm | 80.2 g | 33.9 m/s | 46.08 J |
| 4 | 65 mm | 132.0 g | 36.6 m/s | 88.89 J |

**POST-HAIL CHARACTERIZATION**

Electroluminescence testing; maximum power determination; visual inspection

**THERMAL CYCLING**

TC 50 testing per IEC 61215:2021 for all test samples

**POST-THERMAL CYCLE CHARACTERIZATION**

Electroluminescence testing; maximum power determination; visual inspection

**FINAL CHARACTERIZATION**

Electroluminescence testing; maximum power determination; visual inspection

**HAIL CLASSIFICATION**

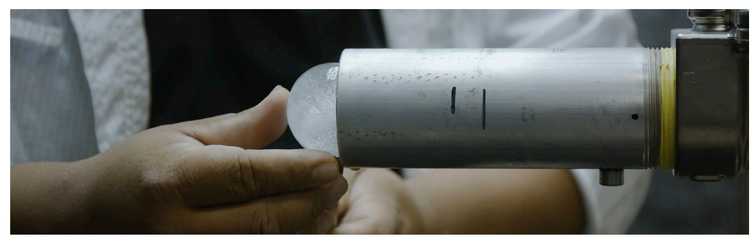
| Module HDT Classification | Impact Characterization | | |
|---|---|---|---|
| | Uncritical | Critical | Very Critical |
| **Class A** | <10% | 0% | 0% |
| **Class B** | <20% | <10% | 0% |
| **Class C** | ≥20% | ≥10% | <10% |
| **Class D** | >10% | >10% | ≥10% |

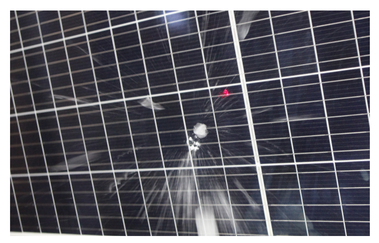
## RESULTS

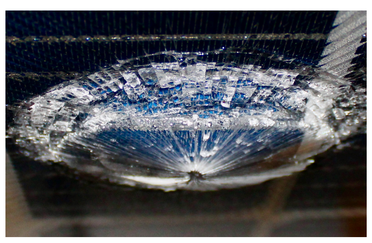
Products that receive a Class A rating in RETC's HDT program experience less than 1% power degradation and do not display any meaningful abnormalities upon completion of the test sequence. Resistance to kinetic impact energy is the ultimate measure of a hail-hardened PV module. Products that withstand kinetic energy of at least 20 joules have effectively demonstrated resistance to a 45-millimeter (1.8-inch) ice ball traveling at a terminal velocity of 30.7 meters per second.

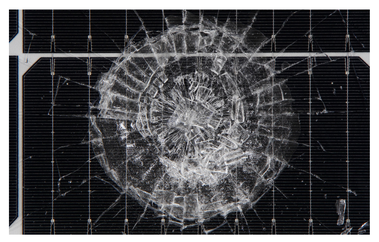
Note that front glass thickness is strongly correlated to ballistic-impact resistance. Many manufacturers have reduced front glass thickness to control weight as module aperture areas have increased. Glass-on-glass bifacial module designs also use relatively thin module glass.

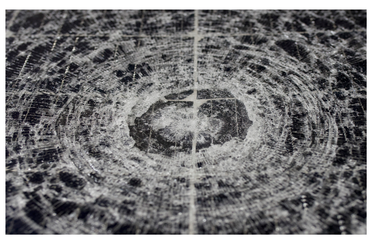
A side effect of thinner module glass is a decrease in hail-impact resistance. Glass manufacturers need a minimum thickness of roughly 3 millimeters to temper glass for maximum strength. The thinner 2mm glass used for many of today's large-format or bifacial modules is not conventionally tempered during manufacturing; it is heat-strengthened glass only, which increases the likelihood of breakage due to hail.











### KEY TAKEAWAYS

- **IMPLEMENT RISK-MITIGATION STRATEGIES IN BOM, INSTALLATION & IN THE FIELD**
  Project stakeholders can prevent or mitigate many extreme weather losses by exercising reasonable care and foresight in system design and product selection with careful consideration of BOMs. Moreover, risk mitigation specialists can help tax equity investors and insurance companies understand the financial risks associated with severe weather.

- **COMPARATIVE TESTING**
  Strategic product selection is an essential first step for mitigating the leading causes of extreme weather losses. RETC's bankability and beyond-certification testing results demonstrate how different PV module designs or combinations of modules and racking resist these different types of environmental stresses. These differences are mission critical in the context of extreme weather risk mitigation.

- **DEFENSIVE STOW STRATEGIES**
  As weather-related insurance claims have increased, industry-leading tracker manufacturers have implemented novel software-control responses, such as threat-specific defensive stow or load shed modes. Many large-scale PV systems integrate intelligently controlled single-axis trackers that use software to follow the sun while avoiding self-shading.

- **PROBABILISTIC RISK ASSESSMENT**
  Though the insurance industry has long relied on probabilistic risk assessments to provide coverage sustainably, the challenge posed by solar projects is twofold. First, limited historical data is available to understand extreme weather risks, especially considering the rate of technological change and market expansion. Second, the natural catastrophe data that insurers typically rely on do not capture "uncategorized" extreme weather events.

RETC

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