ERTHOS

A Static Hail Damage Mitigation Solution for Solar Power Plants

White Paper

Abstract

A supercell hail storm with a low-shelf cloud hangs over Hale Center, Texas in 2015.

Hailstorms are becoming a major impediment to installing solar power plants in leading solar markets in the US and globally due to the increasing difficulty in obtaining sufficient convective storm hazard insurance. Although single-axis tracker stow-mode approaches have sought to make solar power plants resilient to hailstorms, catastrophic hail events continue to cause major damage to solar assets, with losses in the hundreds of millions of dollars.

Erthos offers a different approach to mitigating hail risk that has already shown to be effective in the lab. Rather than relying on complex mechanical systems, software, weather data, or manual interventions, Erthos simply increases the typical PV module front glass thickness from 2.0 mm to 4.0 mm. This simple modification has been shown to prevent damage to modules subjected to a freezer ice balls (FIB) up to 85mm, the force of which is roughly equivalent to 5” (127 mm) naturally occurring hail (NOH).

This paper will provide further details on the magnitude of the hail problem in the US, the Erthos solution, the testing conducted to date, and details regarding ongoing development and commercial availability. VDE Americas, an Erthos technical advisor and the leading provider of hail risk assessment and mitigation services for solar, performed a peer review of this white paper.

Introduction


Hail severely damaged a solar farm on June 23, 2023. (Courtesy: Nebraska Public Power District)

Prior to 2019, the solar industry enjoyed a relatively soft insurance market, characterized by low rates and generous terms and conditions. In 2019, a severe hailstorm in West Texas caused insurance losses exceeding $70 million. Although other factors contributed, this event marked an inflection point to a much harder insurance market marked by restrictive terms and conditions, including higher prices and lower sublimits. It reshaped how weather risks are modeled, how project owners and operators mitigate against damages, and how underwriters insure projects[1].

In 2022, with major hailstorms continuing to impact solar markets, solar project losses exceeded $300 million in Texas alone[2]. In the wake of these losses, brokers began to struggle to find sufficient insurance coverage of PV plants in the most hail-prone regions of Texas at any price. Then, in early 2024, a massive hailstorm hit a 440 MW solar project in East Texas, causing extensive damage throughout the plant. The impacts of this event on the severe convective storm hazard market are likely to be major and immediate, further hardening the market and making it more difficult to find sufficient coverage, and therefore making it difficult or impossible to finance projects[3].

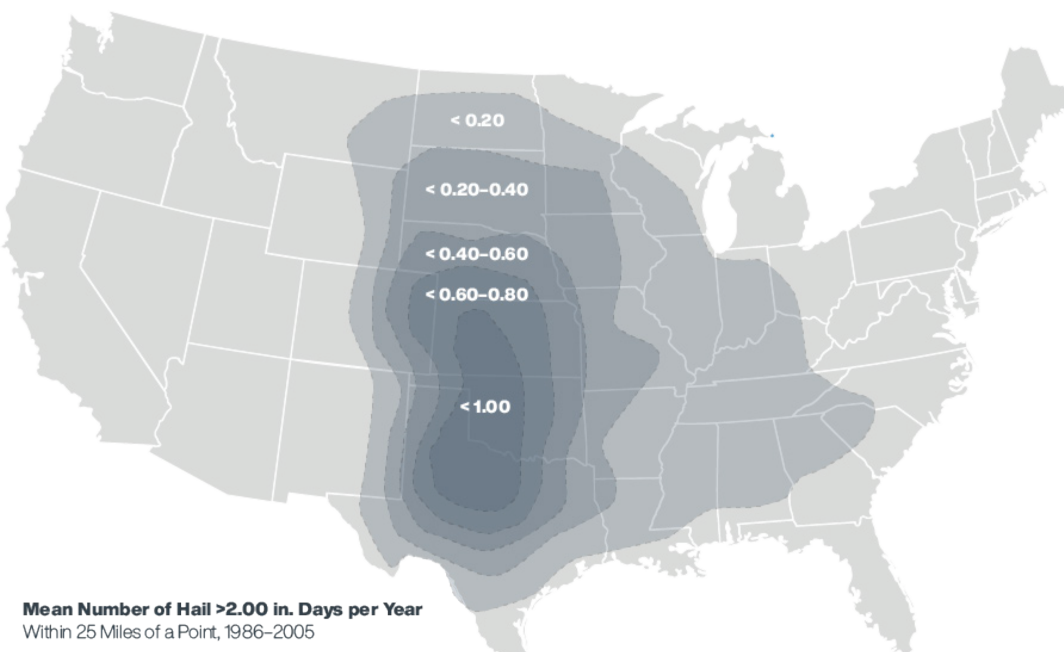
1. Sylvia, Tim. “Storm season has the solar industry looking to protect assets from costly hail damage.” PV Magazine. March 18, 2021. https://pv-magazine-usa.com/2021/03/18/storm-season-has-the-solar-industry-looking-to-protect-assets-from-costly-hail-damage/
2. Van Reyk, Rosa. “Escalating Risk, Delays & Cost in the North American Solar Space.” Presented at the 2023 PV Module Tech Conference. 2023.
3. Wolfe, Sean. “Texas hailstorm damages thousands of solar panels at 350-MW farm.” Renewable Energy World. March 26, 2024. https://www.renewableenergyworld.com/solar/utility-scale/texas-hailstorm-damages-thousands-of-solar-panels-at-350-mw-farm/#gref

To meet US renewable energy goals, the solar market must continue to grow. Nowhere is this need being met more than in the state of Texas, which recently surpassed California as the largest utility-scale solar market in the US[4]. However, Texas also has the most hail events of any state in the country, with 1,123 recorded events in 2023 alone[5]. The country's largest utility-scale market is also among its most hail-prone regions, making hail possibly the largest single risk to the US solar industry.

Tracker stowing, today's predominant solution to the problem, attempts to articulate single-axis tracker rows to an angle least-perpendicular to the hail forces – typically up to 75° tilt angle. However, this approach has been shown to be unreliable. Key among the difficulties faced by stow solutions is the speed at which storms can emerge and the rapid and unpredictable nature of wind direction and intensity[6].

Erthos offers a static solution that does not rely on complex mechanical systems, whose efficacy can be characterized in the lab, and whose test data can reliably feed into insurance actuary studies. Erthos thereby offers a simple path to an insurable hail solution.

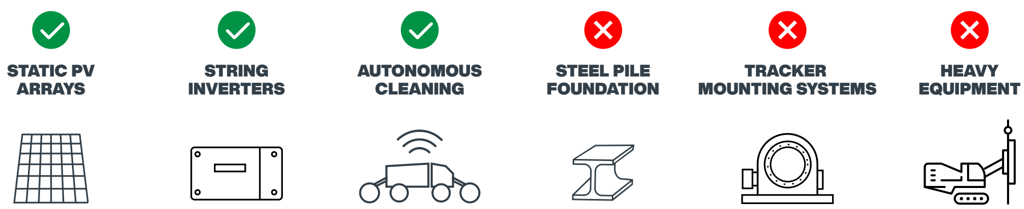
Probability of Greater than 2-Inch Hail



4. Hao, Claire. "Texas leads the nation in solar installed on its power grid, surpassing California." Houston Chronicle. October 27, 2023. https://www.houstonchronicle.com/business/energy/article/texas-most-utility-scale-solar-power-18447562.php
5. "2023 Annual Preliminary Report Summary." NOAA. 2024. https://www.spc.noaa.gov/climo/summary/
6. Previtali, Jon. "Probabilistic & Comparative Hail Risk Assessments." VDE Report. 2023.

Technical Background

Erthos's solar power plant architecture, known as Earth Mount Solar, is a major innovation in the large-scale solar industry. Instead of installing solar modules on steel structures, they are mounted flat on the ground with no underlying structure. They are installed at a 0° tilt relative to grade and on grades up to 15% (8.5°) slope. Although pointing at or tracking the sun (as with fixed-tilt and tracker systems, respectively) results in more energy generated per solar module compared to a PV module at 0° or minimal tilt, an Erthos plant simply adds additional PV modules to reach the same annual energy output. And because there is no row spacing in an Erthos plant, the system is two to three times more energy-dense than a tracker system, resulting in far less land use per MW capacity. This results in the lowest levelized cost of energy of any competing architecture.



When considering hail on an Erthos plant, the primary distinctions are that the solar modules are at a 0° tilt relative to grade, and they do not articulate. This means that rather than relying on motorized mechanical systems aimed at reducing hail forces by reducing the angle of incidence of hail strikes, the Erthos solution simply focuses on increasing the thickness and breakage resilience of the glass.

Although a solar module will be subject to greater forces when hit by hail at a higher angle of incidence, there is no guarantee that stow systems will succeed at achieving the intended low angle of incidence. Failure can occur if the tracker fails to achieve stow mode before being impacted by hail, if a malfunction of the stow system occurs, or if high winds cause the fall angle of hail to move away from vertical. In this last case, tilting towards the wind (or similar effect from the wind shifting) will cause the angle of incidence to shift back to normal, significantly reducing the intended mitigation[7]. With the Erthos solution, these problems are eliminated. In fact, with Erthos, lower angles of incidence due to high winds can reduce forces due to a lower angle of incidence relative to the module's 0°- 8.5° slope. Whereas stow system efficacy requires analysis from physical testing as well as consideration of the probabilities of proper functioning of the system, the Erthos system is simply tested at hypothetical worst-case scenario – terminal velocity, 90° angle of incidence. This places a higher level of certainty on Erthos lab results as field conditions will improve resiliency due to wind reducing the angle of impact to glancing blows.

7. Kedir, Cherif. "Hail Durability Test (HDT) Program." RETC Report. 2023.

Because industry-standard 2.0 mm / 2.0 mm glass/glass PV modules are not adequate to withstand heavy hail at high angles of incidence, the Erthos system increases the front glass to a 4.0 mm thickness and thus increases resiliency against FIB up to 85mm, forces that correlate to 5" (127 mm) NOH. This advantage would not in itself differentiate the Erthos solution, as a tracker could, in theory, also increase front glass thickness to 4.0 mm. However, the added weight of the thicker glass requires additional steel to support the additional loads, adding cost[8]. One mitigation to this could be to use a clear polymer backsheet instead of the more standard 2.0 mm back glass. Although this strategy maintains a similar weight compared to a 2.0 mm / 2.0 mm glass/glass construction, and although the front glass will be resilient up to 85 mm FIB, there is a higher chance of cell cracking with a polymer backsheet[9]. Therefore, to add additional thickness to the front glass and to avoid additional risk of cell damage, tracker systems would need to employ thicker front glass while maintaining a 2.0 mm back glass. This would result in a roughly 50% increase in glass weight and cause the system to incur additional steel costs to support the added weight. In an Erthos system, other than the minimal additional cost of the glass itself, there are no added system-level costs since the solar modules are supported by the earth and not by steel structures.

Laboratory Testing

In August of 2025, comprehensive hail resiliency testing to a new, advanced Hail Resiliency Curve (HRC) test-to-failure methodology, developed by leading hail experts at VDE Americas, was carried out at the Renewable Energy Test Center (RETC) test lab in Fremont, California. The HRC test simulates real-world conditions in which PV modules face numerous impacts from a range of hailstone sizes and wind speeds during severe hailstorms. This new test methodology therefore better represents the continuous nature of PV module glass failure probability experienced during real hailstorm conditions as compared to traditional IEC 61215 binary pass/fail protocols at predetermined impact locations using limited energy ranges. The HRC test involves firing a series of small to large hailstones at PV modules at low to high speeds until glass fracture occurs. Based on test results, VDE generates continuous probability distributions of glass breakage across a broad spectrum of hail impact energies, providing statistically robust data for risk assessment, insurance modeling, and operational planning. Testing employed Weibull statistical analysis with randomized impact locations targeting both central and edge regions of the modules (see Figure 1).

Thirty samples of Erthos 4.0 mm/2.0 mm dual glass, hail resilient modules with fiberglass reinforced polymer (FRP) frames were subjected to progressive Freezer Ice Ball (FIB) impacts with diameters ranging from 45mm to 85mm until failure. Two of the sample modules survived multiple 85 mm FIB impact(s) and were unable to be brought to failure, sustaining up to 246 joules of kinetic energy. The remaining 28 modules ultimately failed with FIB impacts ranging from 70 mm up to 85 mm in diameter. A summary of the test results is shown below in Table 1. Together, all this test data was used to create the Hail Resiliency Curve shown in Figure 2.

Furthermore, the Erthos PV module hail resiliency can be compared with other standard modules on

8. Aragon, Heidi and Schreiber, Daniel. "Solar Farm Hail Damage: The Perfect Storm." J.S. Held. 2022. https://jsheld-prod.imgix.net/Solar-Farm-Hail-Damage-The-Perfect-Storm_2023-12-12.pdf

9. Karin, Erion-Lorico, Perron. "Microcracking in PV Modules: Separating Fact from Fiction". PVEL Kiva, Brown & Brown Webinar. January 31, 2024.

the market that use 2.0 mm / 2.0 mm dual glass or 3.2 mm front glass / backsheet construction. Figure 3 illustrates the fact that the Erthos 4.0 mm / 2.0 mm dual glass module is dramatically more resilient, showing approximately 10% probability of glass breakage at 112 joules of kinetic energy (~4.25" or 108 mm naturally occurring hail) compared to 57% probability of glass breakage for the 3.2 mm front glass / backsheet module and 100% probability of glass breakage for the 2.0 mm / 2.0 mm dual glass module.

Test Definition

PV Module Sample Qty:	30
PV Materials:	144 half-cell bifacial PERC mono
PV Module Size:	2278 mm x 1134 mm x 35 mm
Front Glass:	4.0 mm heat tempered with AR coating
Back Glass Thickness:	2.0 mm heat strengthened
Testing Equipment:	Vertically oriented hail impact cannon
Projectile:	45 mm to 85 mm freezer ice balls
Kinetic Energy Impact	20 joules to 246 joules
Projectile Velocity:	Varying velocities
Number of Impacts:	Multiple strikes with increasing size FIBs and kinetic energy

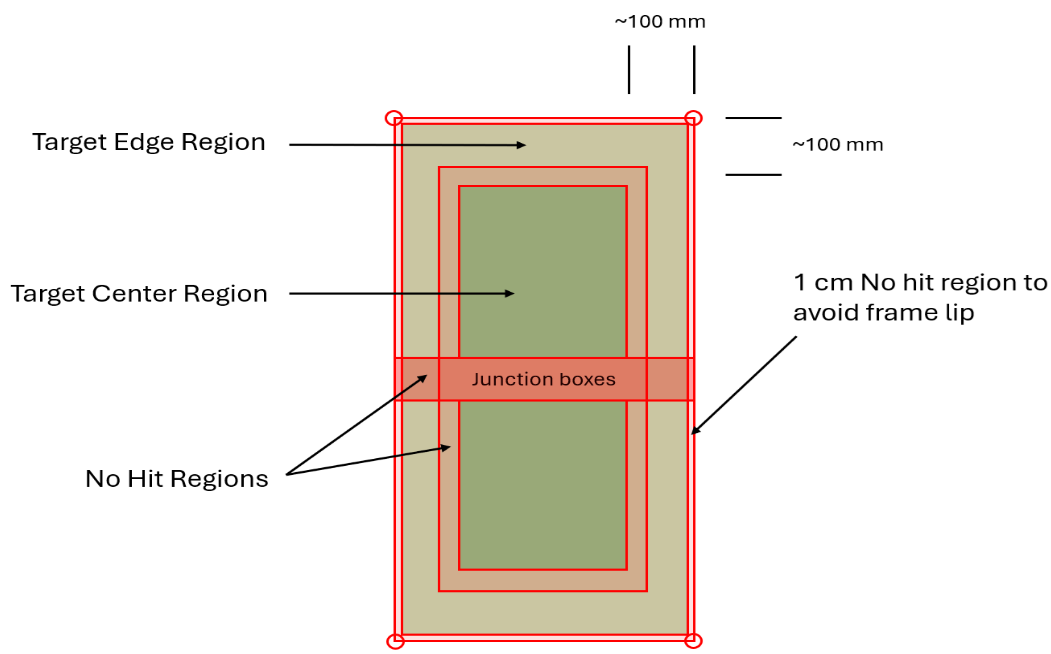


Figure 1: Module Target Areas

Test A (Central Region Impact) Samples	Kinetic Energy (Joules)	Max. passing FIB diameter in mm / (inches) prior to glass breakage	Correlating P50 NOH diameter in mm / (inches)		Test B (Edge Region Impact) Samples	Kinetic Energy (Joules)	Max. passing FIB diameter in mm / (inches) prior to glass breakage	Correlating P50 NOH diameter in mm / (inches)
1	246.6	85 mm (3.35")*	135 mm (5.33")		1	102.6	70 mm (2.76")	106 mm (4.16")
2	155.2	75 mm (2.95")	119 mm (4.67")		2	94.4	70 mm (2.76")	103 mm (4.06")
3	173.0	80 mm (3.15")	122 mm (4.82")		3	157.3	80 mm (3.15")	119 mm (4.69")
4	98.1	70 mm (2.76")	104 mm (4.11")		4	90.6	70 mm (2.76")	102 mm (4.01")
5	139.2	80 mm (3.15")	115 mm (4.53")		5	159.2	80 mm (3.15")	120 mm (4.71")
6	106.0	70 mm (2.76")	107 mm (4.20")		6	87.6	70 mm (2.76")	101 mm (3.98")
7	139.7	75 mm (2.95")	115 mm (4.54")		7	140.0	75 mm (2.95")	115 mm (4.54")
8	180.2	80 mm (3.15")	124 mm (4.87")		8	161.2	80 mm (3.15")	120 mm (4.72")
9	112.6	70 mm (2.76")	108 mm (4.27")		9	167.2	80 mm (3.15")	121 mm (4.77")
10	144.6	75 mm (2.95")	116 mm (4.58")		10	82.0	65 mm (2.56")	99 mm (3.90")
11	184.2	80 mm (3.15")	125 mm (4.90")					
12	214.0	85 mm (3.35")*	130 mm (5.12")					
13	134.0	75 mm (2.95")	114 mm (4.48")					
14	167.4	80 mm (3.15")	121 mm (4.77")					
15	165.7	80 mm (3.15")	121 mm (4.76")					
16	186.9	85 mm (3.35")	125 mm (4.92")					
17	170.3	80 mm (3.15")	122 mm (4.80")					
18	111.5	75 mm (2.95")	108 mm (4.26")					
19	87.5	70 mm (2.76")	101 mm (3.97")					
20	142.1	75 mm (2.95")	116 mm (4.56")					

* Samples that did not result in broken glass after multiple impacts at maximum FIB size

Table 1: HRC Test Results Summary

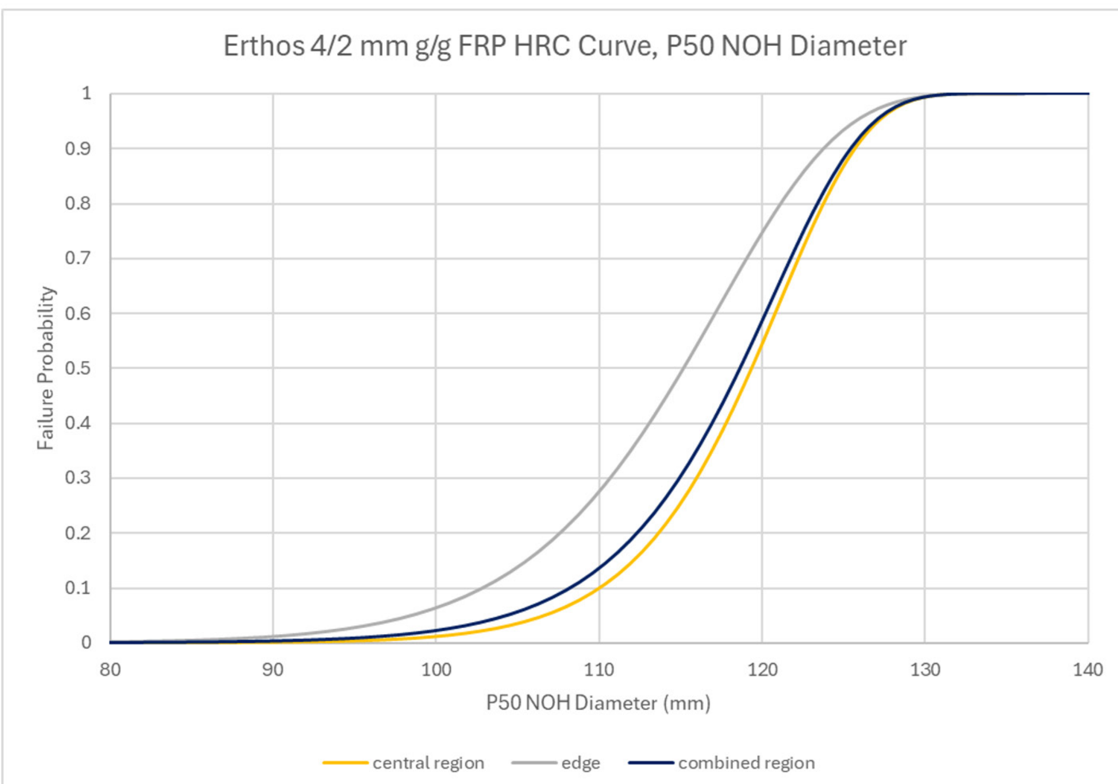


Figure 2: NOH Heymsfield P50 (Median) Hail Size Distribution

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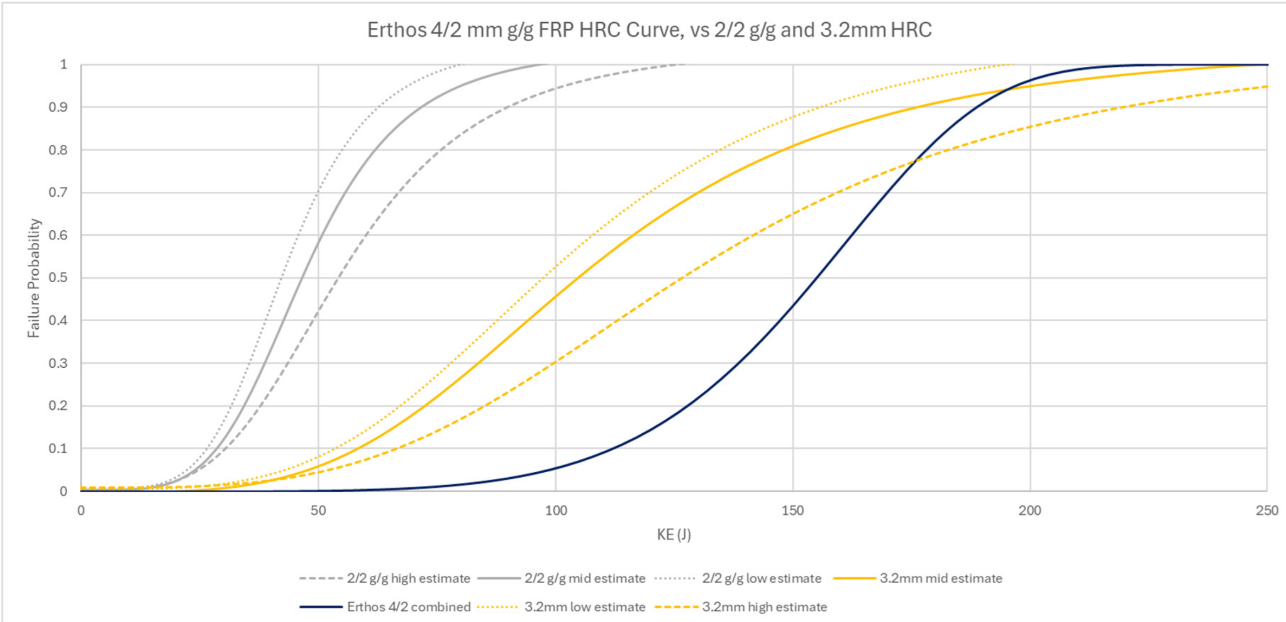

Figure 3: PV Module Performance Comparison

Ongoing Development

Having completed statistically significant impact testing data through the VDE/RETC Hail Resiliency Curve Testing protocol, Erthos is currently working with a leading module manufacturer to certify the 4.0 mm / 2.0 mm hail resilient module to UL/IEC 61730. Erthos is also working with Cirrus Advisors, VDE Americas, RETC, and New Energy Risk to establish statistical significance, confidence intervals, actuarial studies, and testing protocols aimed at producing an insurable solution for severe hail risk.

Conclusion

Hailstorms pose a significant risk to the US and global solar industries. With current solutions failing to prevent catastrophic loss, new solutions are needed. Erthos has identified a solution that offers dramatic improvements in hail resiliency compared to standard modules offered on the market. Erthos is working closely with PV module manufacturing partners, technical advisories, testing labs, insurance experts, and the insurance underwriting community to bring this solution to market in conjunction with insurance products that enable solar development in severe hail regions.