pv magazine Webinar: Understanding and Mitigating the Dangers Posed by Hail and Wind

Kent Whitfield, VP Quality, Nextracker
Cherif Kedir, CEO, Renewable Energy Testing Center (RETC)

25 January 2022

Summary of Key Takeaways

1. Active hail stow ("failsafe" battery backup) is an effective, proven risk reduction strategy
2. Wind speed coincident with hail is now characterized
3. Less durable module frames impose greater wind risk

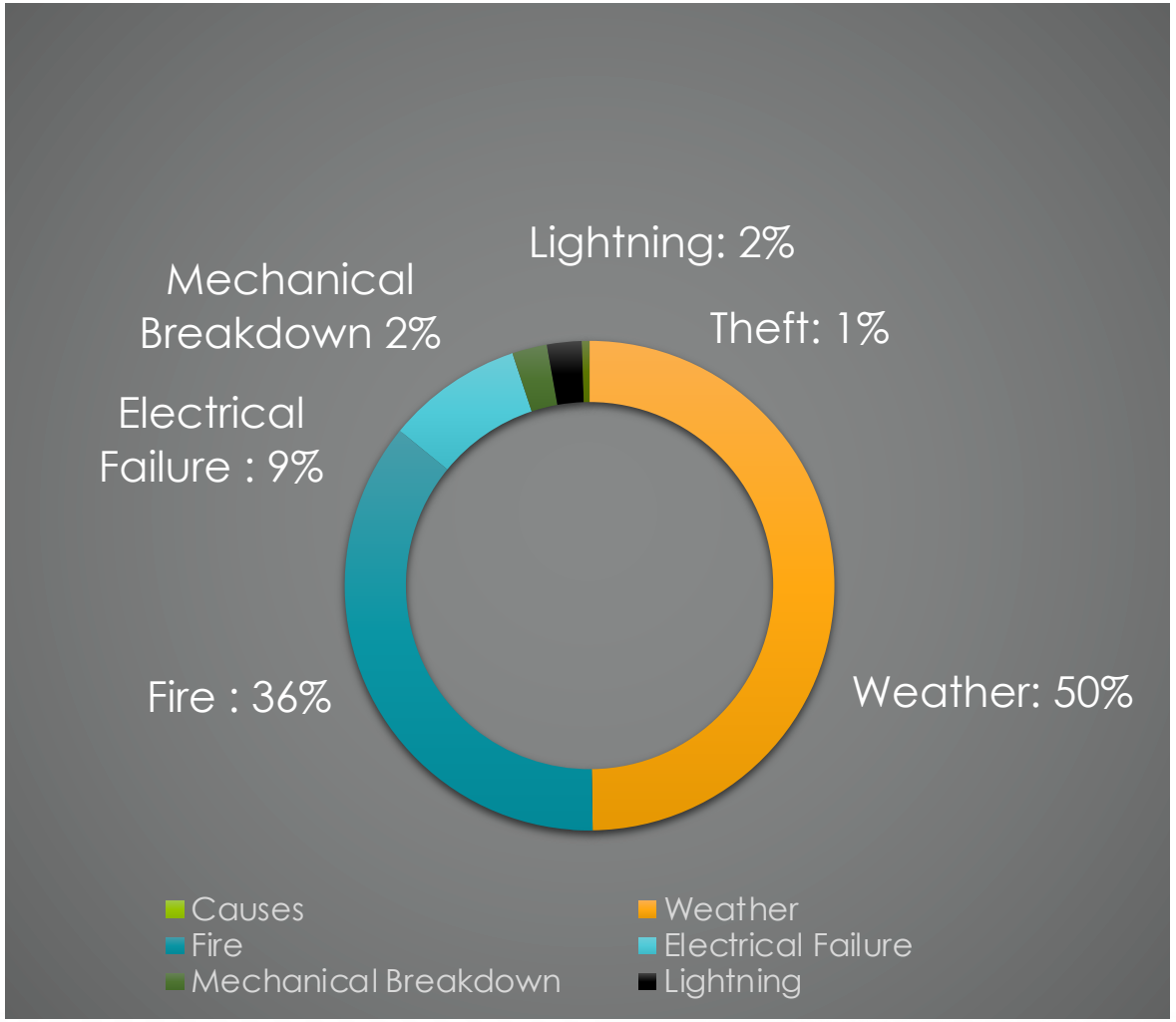
Area for further research:

"Hail-hardened" modules for the most extreme environments

Upon loss of utility power system to moves to stow without operator intervention

Root Causes of PV Failure

- **Weather is the #1 source of PV insurance claims**



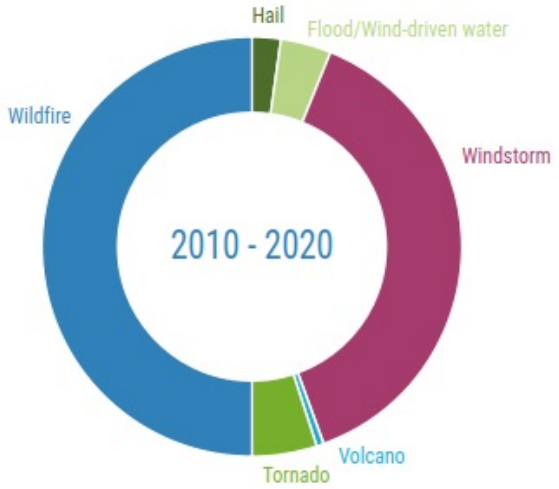
Source: Gcube, 2017

Lessons Learned from Midway, Texas

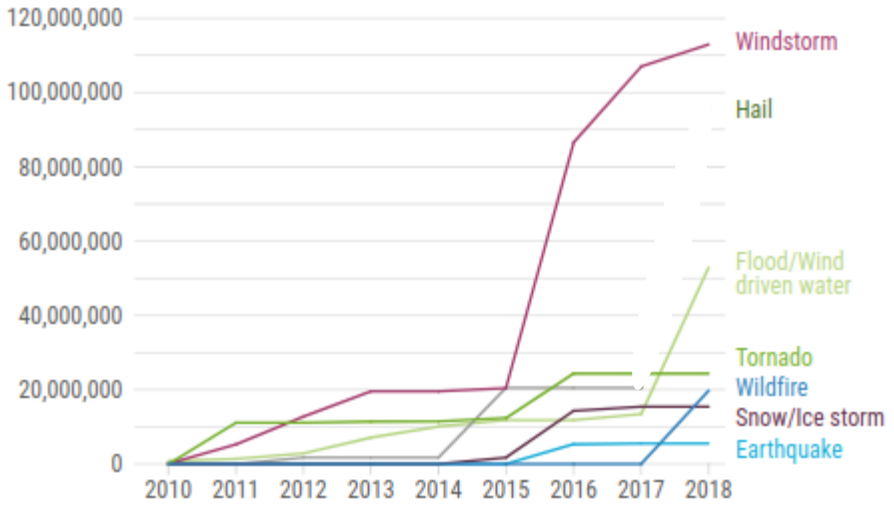
Reduce risk from extreme weather events with intelligent stow

- Hail Stow- Increases the survivability of PV panels from 81.6% to 99.4% in a hailstorm, a 30X increase
- Hurricane Stow- Defense against extreme wind pressure & turbulence

Hail v. Other Natural Catastrophic Risks



Frequency of Nat Cat and Extreme Weather by solar claim



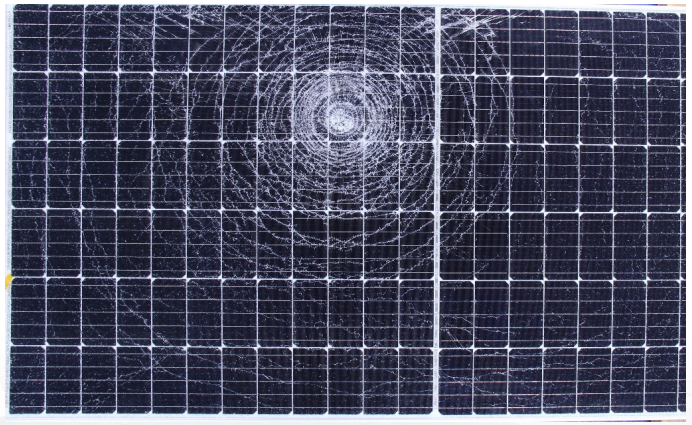
Nat Cat and Extreme Weather, incurred cumulative total (USD)

Source: GCubed Q1 2021 "Hail or High Water"

Some basic unknowns now understood:

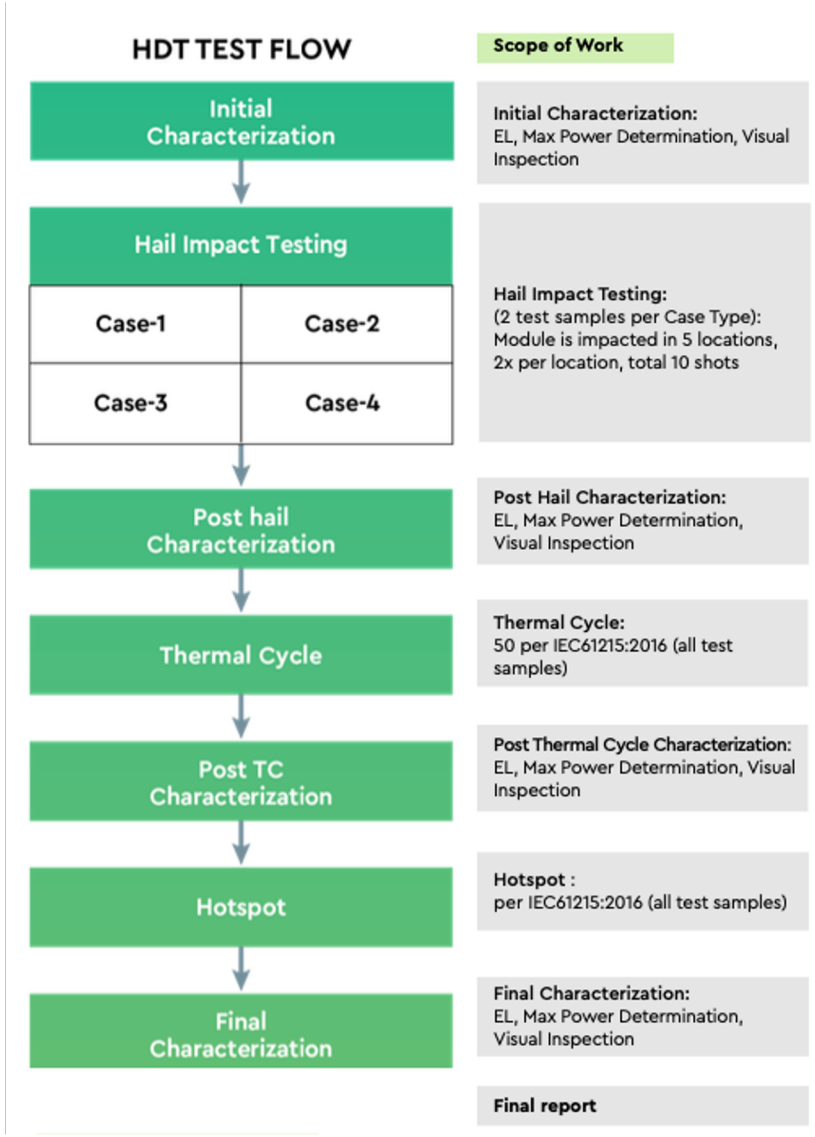
Q: What was the impact energy difference between:

- mono-facial versus bifacial modules at cell breakage?
- mono-facial versus bifacial modules at glass breakage?
- front impact versus back impact?



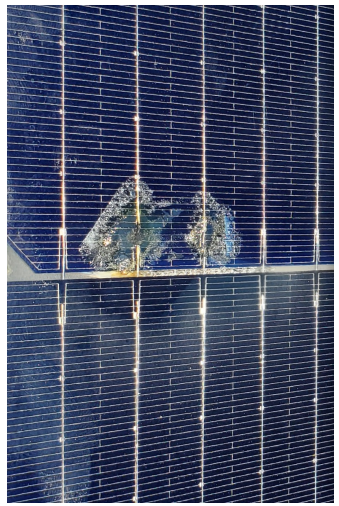
RETC

Hail Durability Test (HDT) Sequence

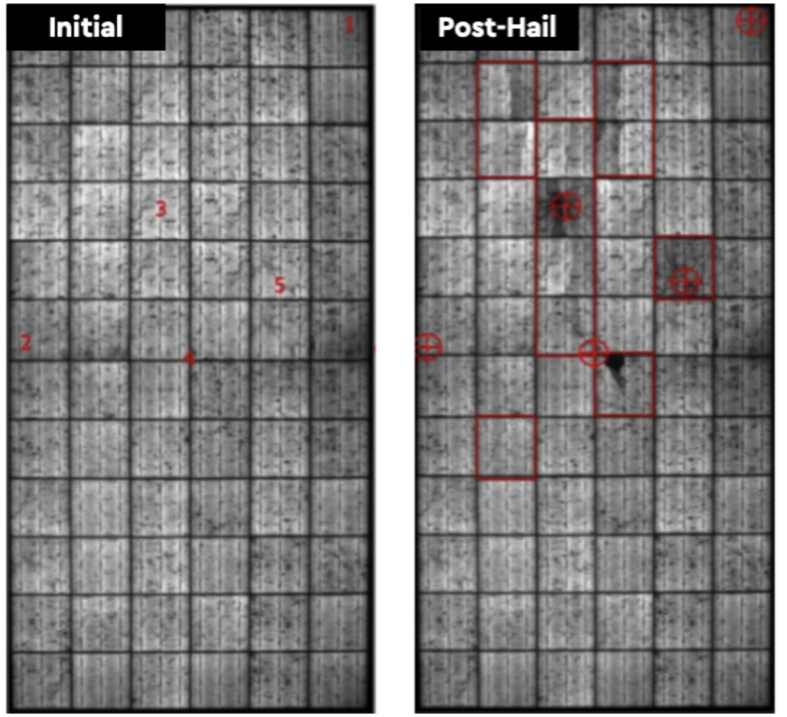


RETC HDT Hail Case Table

Case	Severity	Diameter	Mass	Velocity	KE
1	Moderate	1.4" (35 mm)	20.7g	27.2 m/s	7.66
2	Severe	1.8" (45 mm)	43.9g	30.7 m/s	20.69
3	Severe	2" (50.8 mm)	63.3g	32 m/s	32.41
4	Very Severe	2.2" (55 mm)	80.2g	33.9 m/s	46.08
5	Extreme	2.6" (65 mm)	132g	36.7 m/s	88.89



Hotspot Failure Post HDT



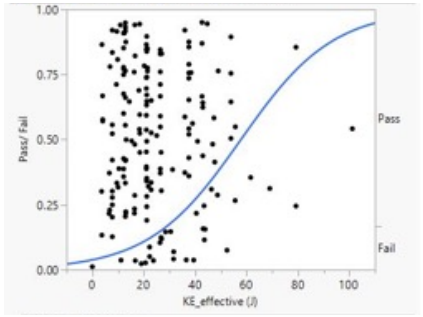
PICTURED ABOVE: varying damages sustained by modules post-HDT

Results:

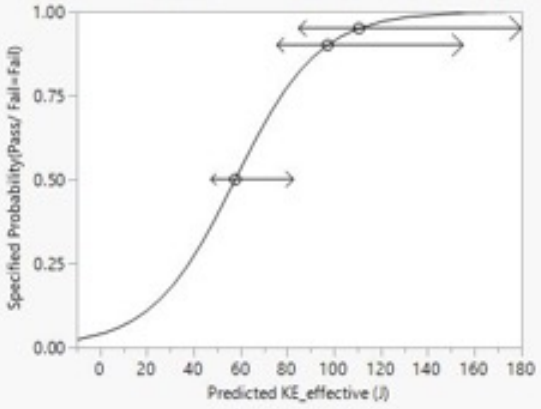
- Module Edge Perimeter
- Center of Cell
- Edge of Cell Bussing
- Ribbon of Cell area
- Free of Cell

Hail Durability Trends

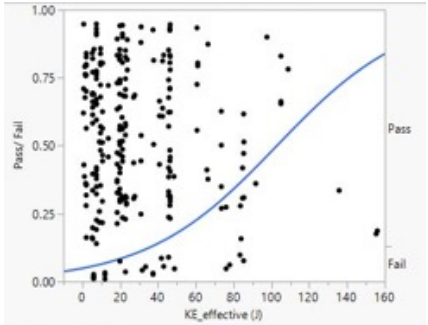
2mm x 2mm Glass/Glass Modules



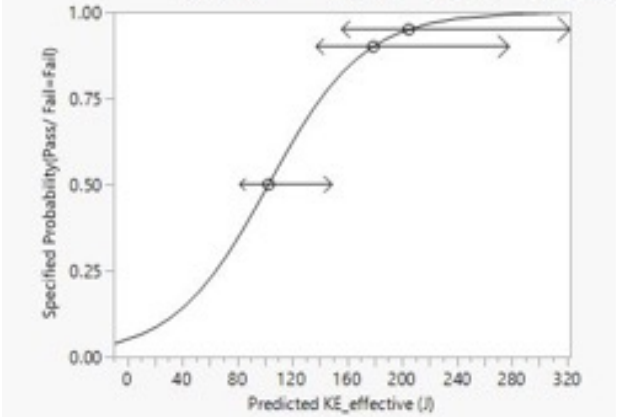
Specified Probability(Pass/ Fail=Fail)	Predicted KE_effective (J)	Lower 95%	Upper 95%
0.5000000	57.8121	47.30348	82.7176
0.9000000	97.2284	75.49869	155.2046
0.9500000	110.6328	84.80169	180.1408



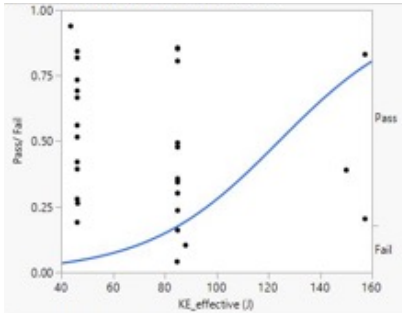
3.2mm Glass/Backsheet Modules



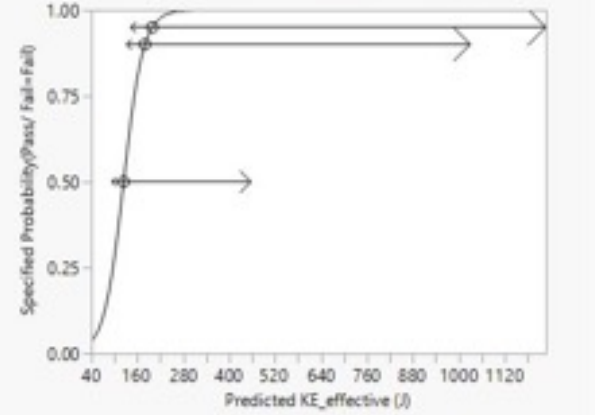
Specified Probability(Pass/ Fail=Fail)	Predicted KE_effective (J)	Lower 95%	Upper 95%
0.5000000	102.9002	81.8283	149.1537
0.9000000	179.1491	137.5186	278.2776
0.9500000	205.0792	156.0595	322.5868



4.0mm Glass/Backsheet Modules



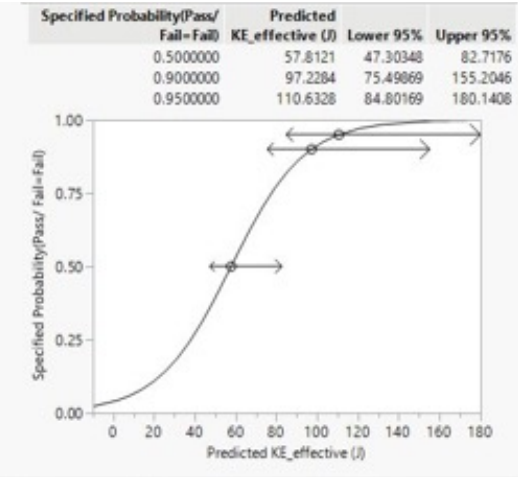
Specified Probability(Pass/ Fail=Fail)	Predicted KE_effective (J)	Lower 95%	Upper 95%
0.5000000	124.1575	93.0789	456.729
0.9000000	179.7870	131.5504	1030.841
0.9500000	198.7051	142.5103	1228.203



- Large dataset of modules with different constructions/sizes and at different impact angles

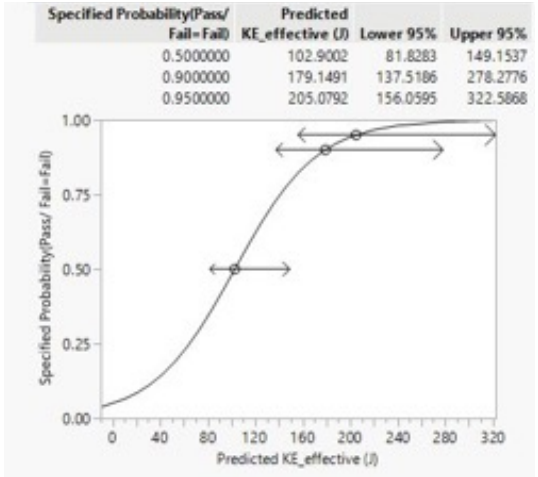
Hail Durability Trends Cont.

2mm x 2mm Glass/Glass Modules



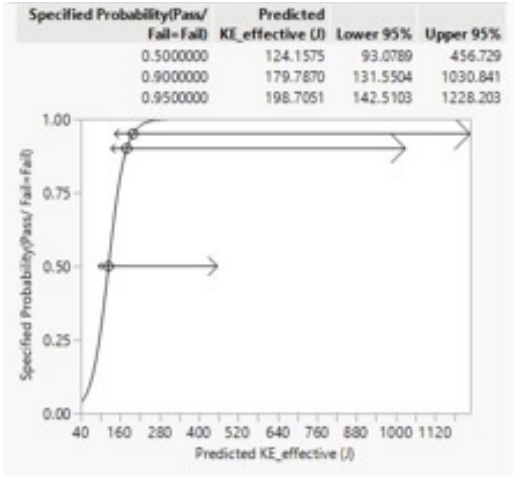
Specified Probability(Pass/ Fail=Fail)	Predicted KE_effective (J)	Lower 95%	Upper 95%
0.5000000	57.8121	47.30348	82.7176
0.9000000	97.2284	75.49869	155.2046
0.9500000	110.6328	84.80169	180.1408

3.2mm Glass/Backsheet Modules



Specified Probability(Pass/ Fail=Fail)	Predicted KE_effective (J)	Lower 95%	Upper 95%
0.5000000	102.9002	81.8283	149.1537
0.9000000	179.1491	137.5186	278.2776
0.9500000	205.0792	156.0595	322.5868

4.0mm Glass/Backsheet Modules



Specified Probability(Pass/ Fail=Fail)	Predicted KE_effective (J)	Lower 95%	Upper 95%
0.5000000	124.1575	93.0789	456.729
0.9000000	179.7870	131.5504	1030.841
0.9500000	198.7051	142.5103	1228.203

Diameter	Mass	Test velocity	KE
mm	g	m×s–1	J
12.5	0.94	16	0.12
15	1.63	17.8	0.26
25	7.53	23	1.99
35	20.7	27.2	7.66
45	43.9	30.7	20.69
55	80.2	33.9	46.08
65	132	36.7	88.89
75	203	39.5	158.37

Effective KE: Transferable Energy during impact.

- P50 Breakage at 57 J
  - Failures as low as 20J (45mm)
- P90 Breakage at 97 J

Effective KE: Transferable Energy during impact.

- P50 Breakage at 100 J
- P90 Breakage at 179 J

Effective KE: Transferable Energy during impact.

- P50 Breakage at 124 J
- P90 Breakage at 180 J

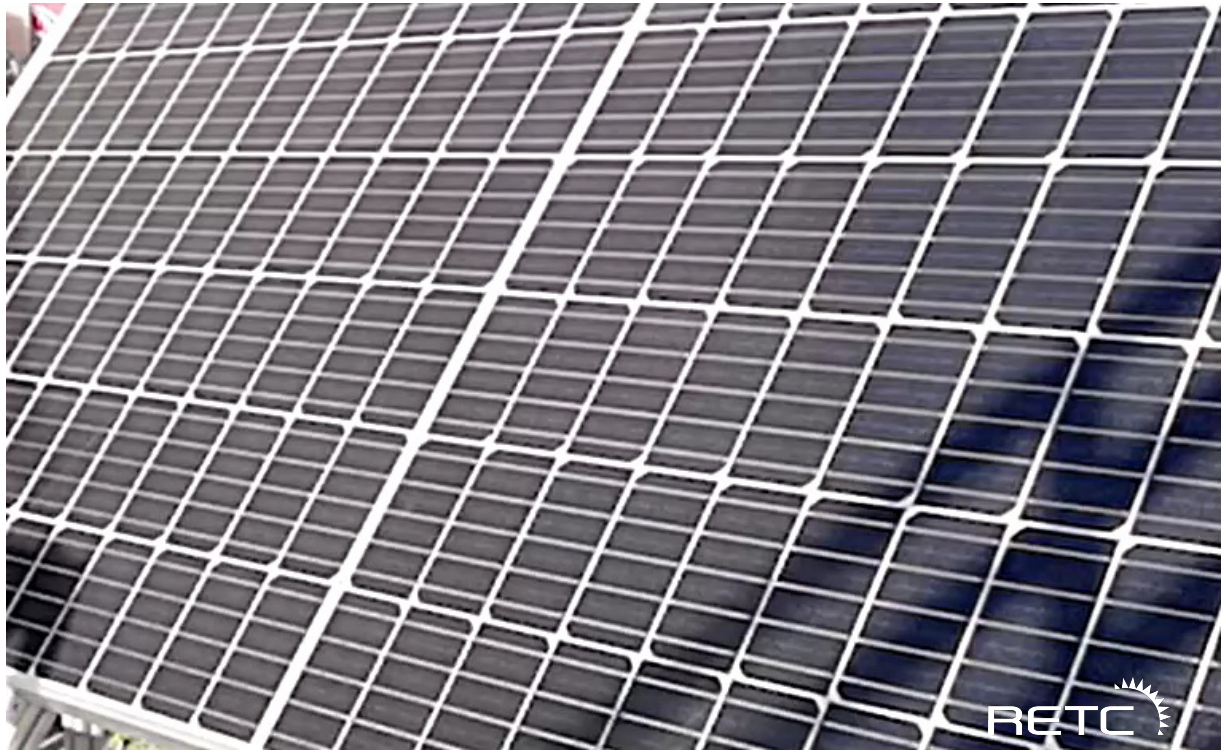
Limited dataset due to module availability.

Kinetic Energy vs Ice Ball Impact size at Terminal Velocity
Source: IEC 61215

Hail Test Findings

2mm vs 3.2mm Impact Test with 75mm Ice Ball

Hail Test 2mm



Hail Test 3.2mm

Active Risk Reduction - NX Navigator

Simplifies Monitoring & Control; Improves Safety & Production

Proven

- *Years of operation on multiple utility-scale plants*

Operational Ease & Improved Availability

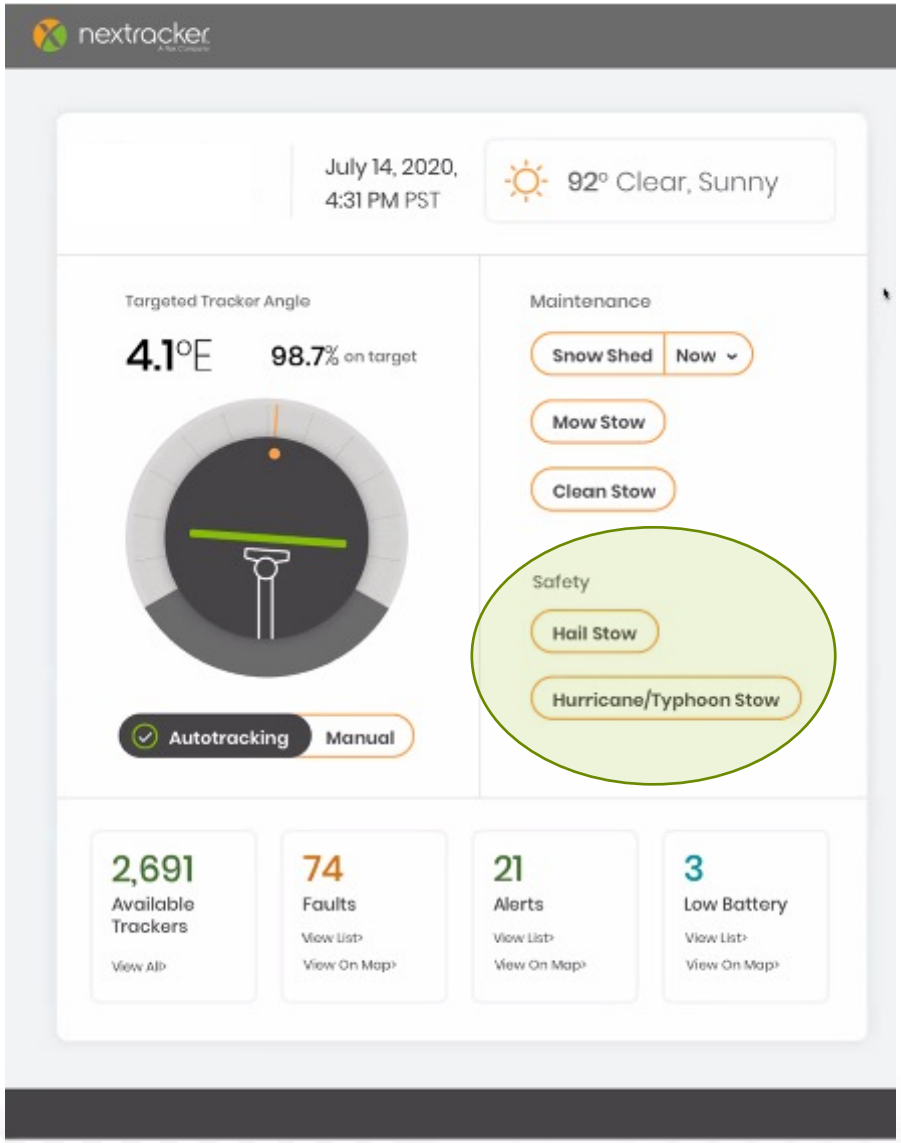
- Map View – *Identifies equipment & their behavior on the site map*
- Detect alerts & faults sooner

Enhanced Safety

- Hurricane/ Typhoon Stow
- Hail Stow – ***User has choice over direction!***

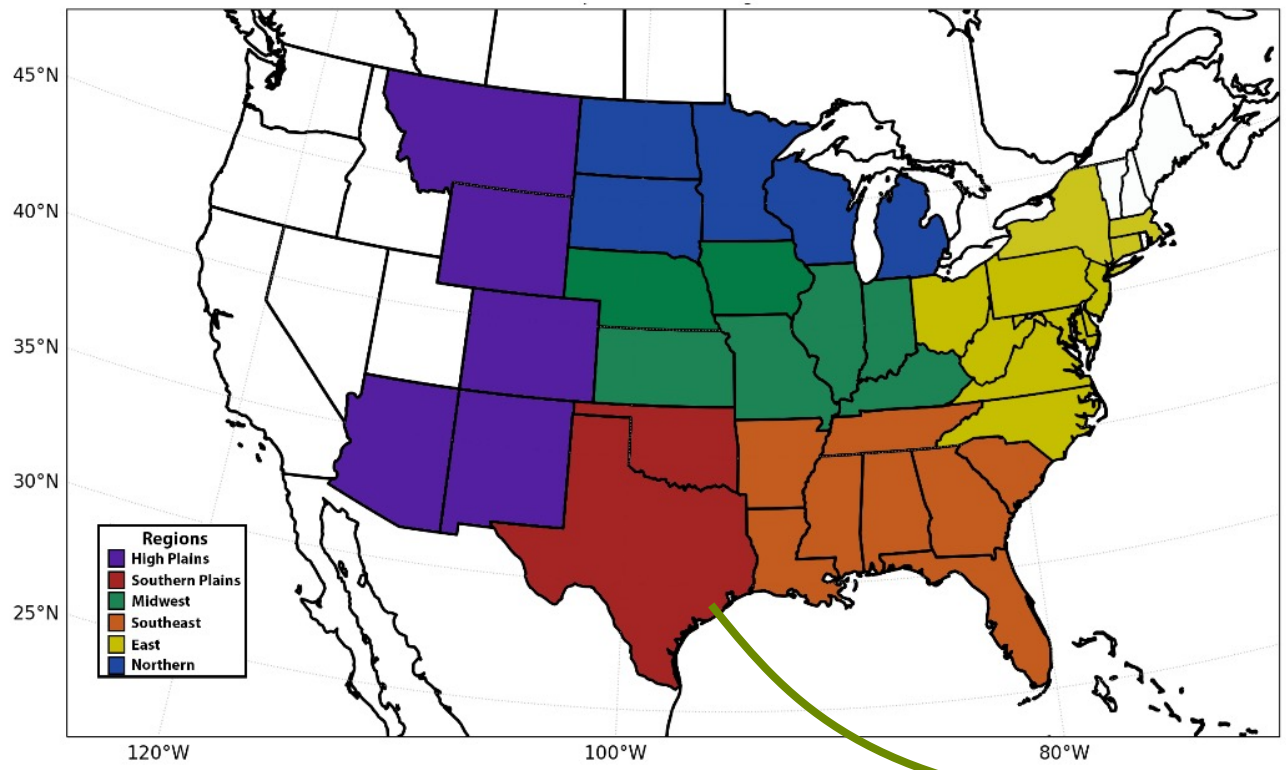
Effective Active Risk Reduction

- *Controllable protection from anywhere, securely (Navigator)*
- *Failsafe – On loss of power, system automatically stows for protection (battery backup)*
- *Fast – When activated, tracker must move (60° in 90 seconds)*

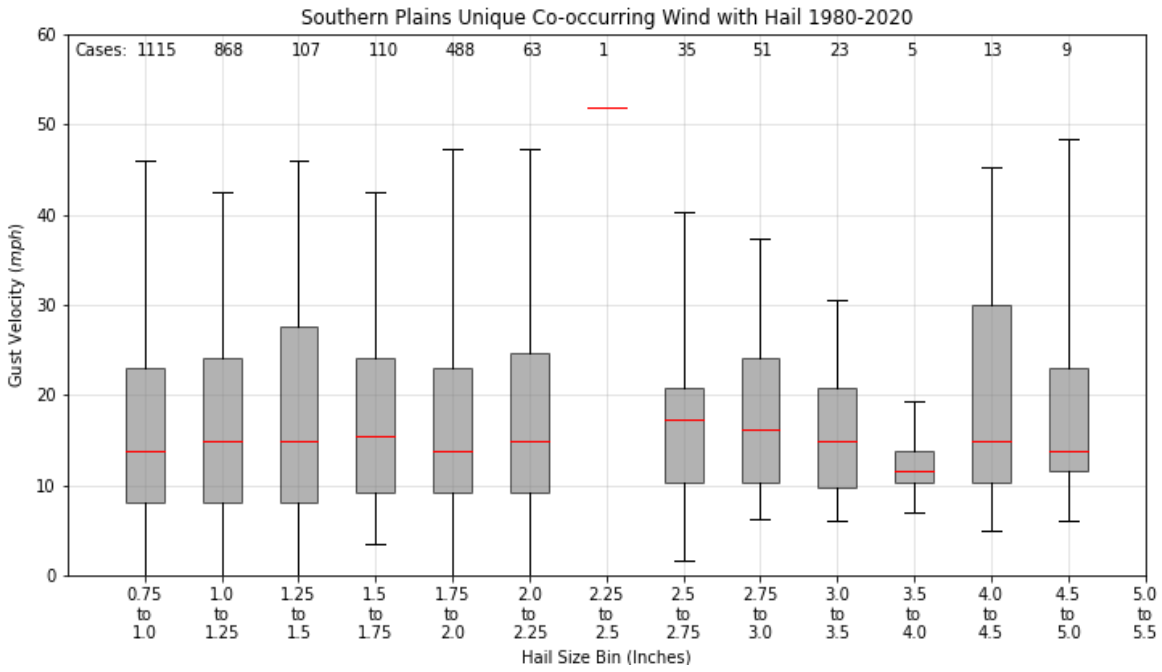


NX Navigator™ Dashboard

Front or Back Stow for Hail with Wind?



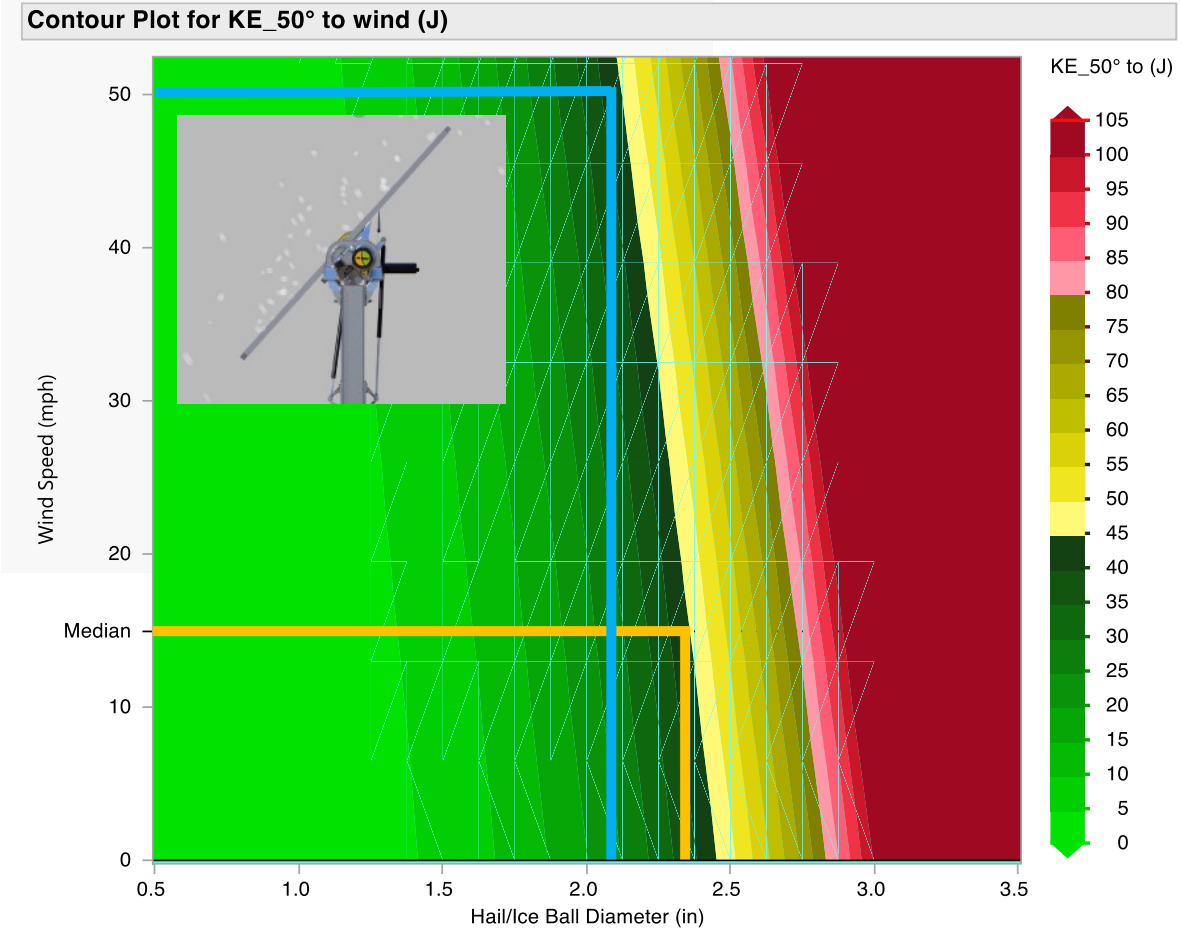
Source: NX and Allen Weather Risk, LLC 2021

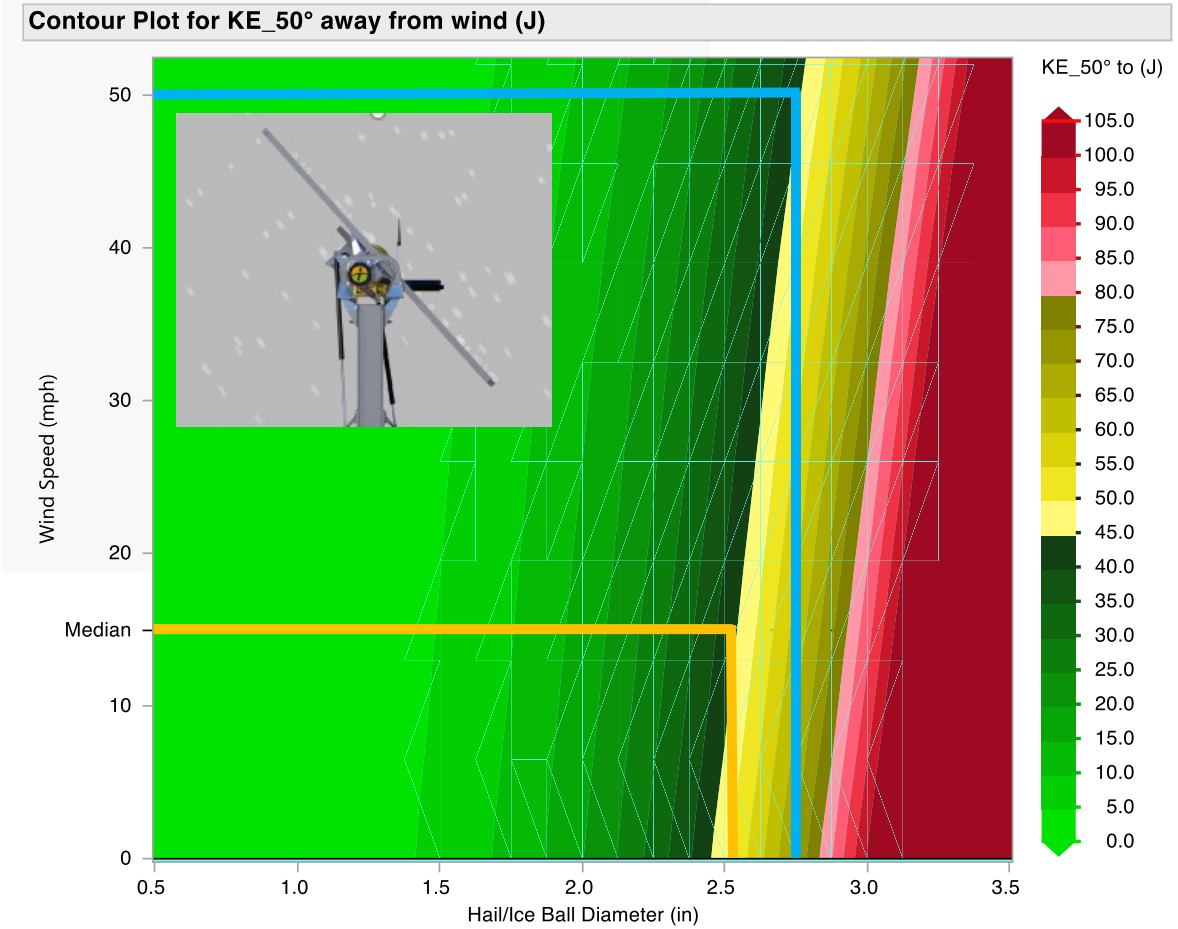


Texas – Oklahoma Region (most extreme region)

- Median Coincident Wind 12-18 mph for hail > 2"
- 99th percentile < 50 mph

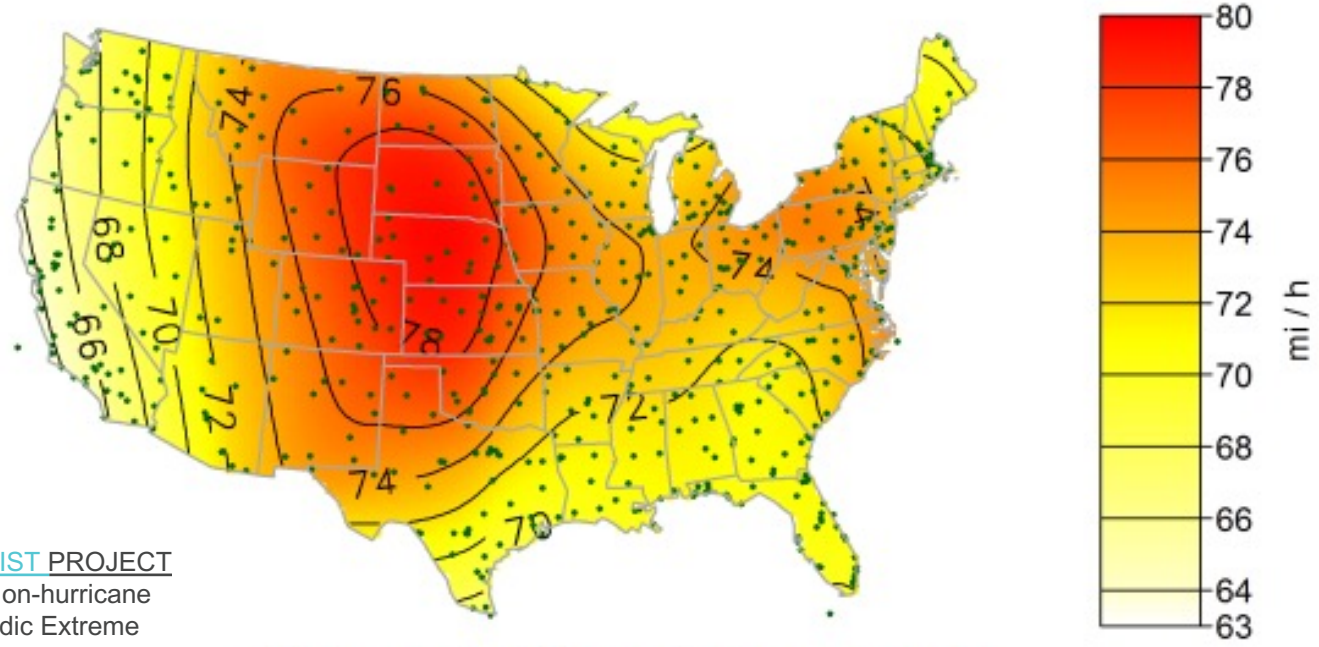
Damage Risk – P50





- Median wind indicates a ¼" size difference – stow direction agnostic
- 99th percentile indicates a ¾" size difference for damage – could make a difference, but this **may be above safety thresholds – user should verify!**

Wind Risk



(a) Map of estimated expected 10-year return values.

Source: NIST PROJECT
Maps of Non-hurricane Non-tornadic Extreme Wind Speeds for the Contiguous United States

Twisted modules illustrate the damage incurred at the Oakey 2 site in October 2018.
Photo: Provided on an anonymous basis

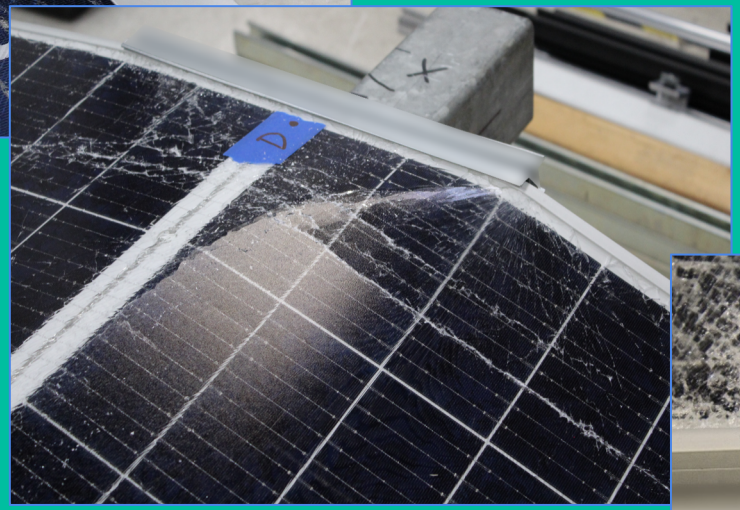
Source PV Magazine

Risk of high-speed wind ubiquitous…

Majority of tracker failures are NOT due to static load at code wind speed.

Dynamic instability failures at wind speeds as low as 40 mph.

Wind and Snow Resilience Testing



Source: RETC Lab Data

Module breakage observed in the field

Recommendations for De-Risking in Hail-Prone Regions

Recommended Stow Positions

- High wind (50 mph) with hail shows benefit from a back-winded stow position if structure is rated for it.
- System should not transition through 0° - NX avoids dynamic failures.
- Speed of transition is VERY important - NX system <90 seconds for 60° travel
- Active protection needs a failsafe - NX uses battery back-up
- Median wind speeds - risk suggests a front-stow – but **User Has Choice**

Summary Review of Key Takeaways:

1. Active hail stow ("failsafe" battery backup) is an effective, proven risk reduction strategy
2. Wind speed coincident with hail is now characterized
3. Less durable module frames impose greater wind risk

Recommendations for De-Risking in Hail-Prone Regions Cont.

Understand Project Site Probability for Significant Hailstorm Risk

- Understand your module's actual Hail Tolerance by BOM: Significant variability by module type (RETC's Hail Durability Test program)
- Find out if "hail-hardened" products are available or planned if project in high hail risk area.
- Understand your site risks
  - VDEA Developed multiple weather risk tools
  - Return interval of Hail (by size and frequency)
  - Return interval of co-probability Hail + Wind
  - Financial Loss Model
    - Average Annual Loss
    - Probable Maximum Loss (PML)
  - Contact: John Sedgwick, John.Sedgwick@vde.com
- Devise a mitigation technique (hail stowing) especially in hail prone regions.

Thank You / Q&A

Contact:
Kent Whitfield: kwhitfield@nextracker.com
Cherif Kedir: cherif@retc-ca.com