Concerns & Solutions – Reliability in Large-Wafer Modules

Daniel Chang | April 8, 2021

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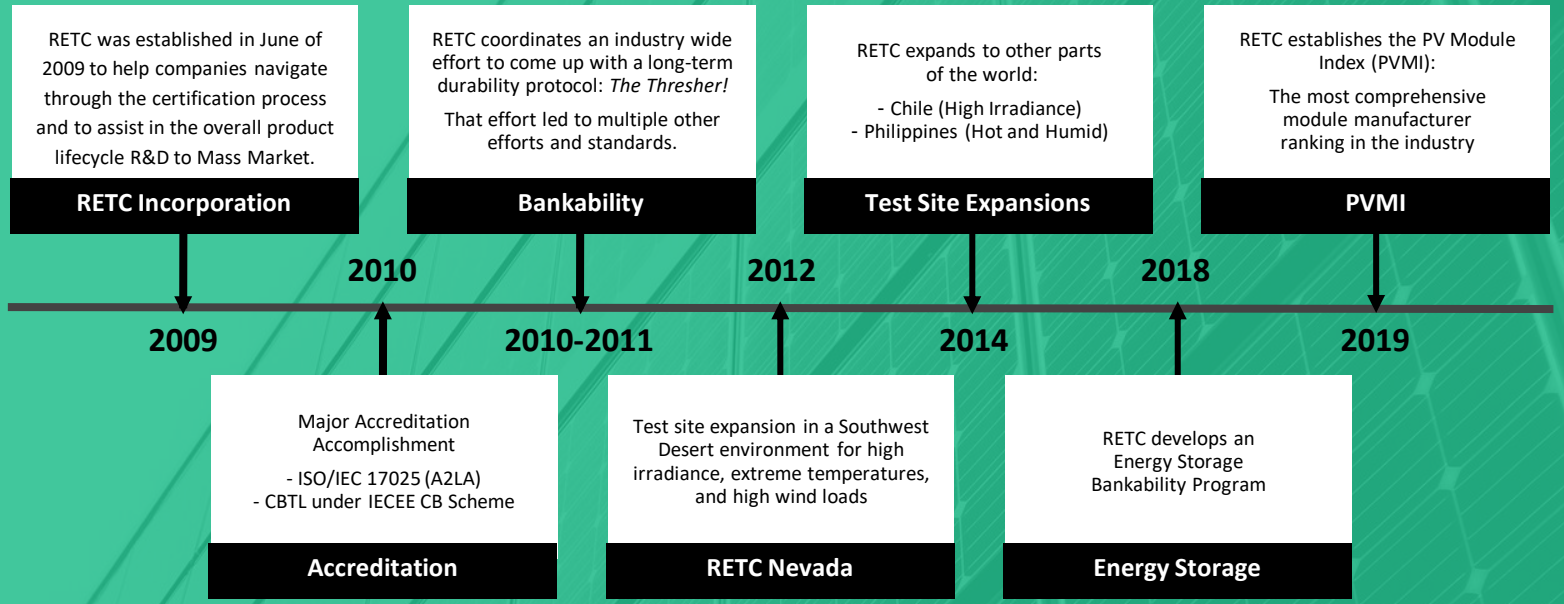
RETC

10+ YEARS OF SERVICE

We test products from a broad range of PV modules and batteries—and we're great at it too!



Modules Are Getting Bigger

- Manufacturers have improved their technology
  - Slow improvements in efficiency
  - Demand for high-power modules continue to be strong
  - The result = larger format modules
    - New risks need to be acknowledged & mitigated

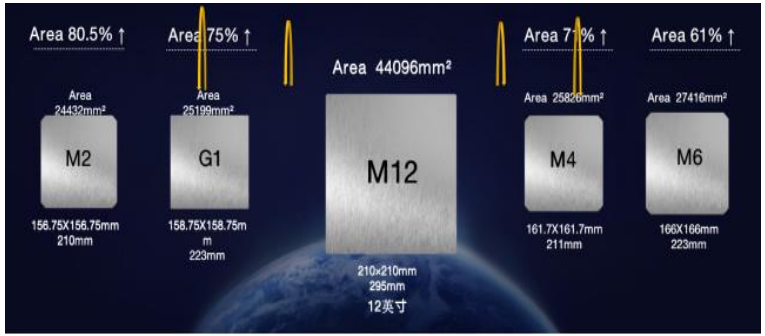


Image: Zhonghuan Semiconductor

- Large modules are just another step the industry has come up with to:
  - reduce cost
  - increase the power density of projects
  - reduce installation costs

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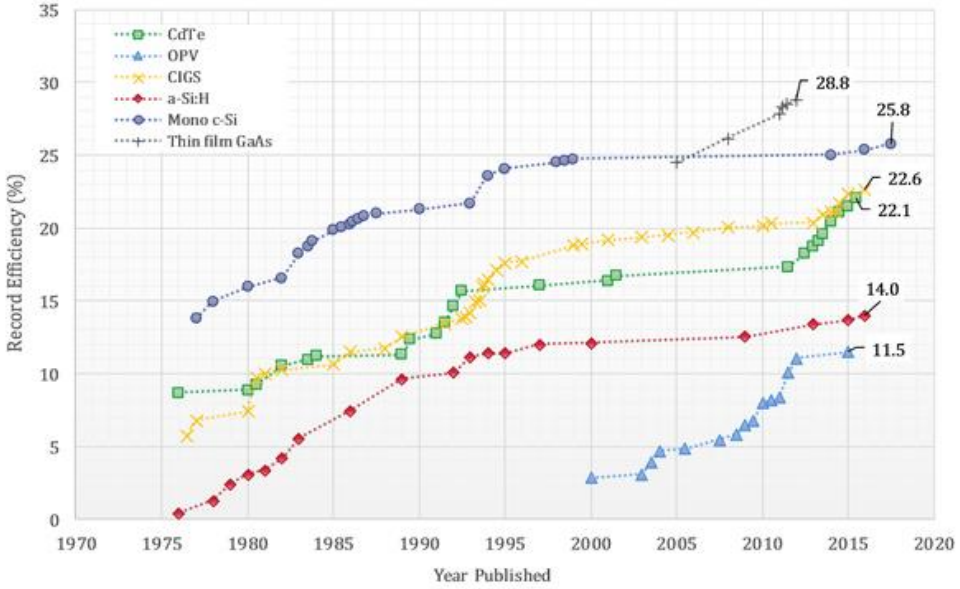
Cell Technology



Source: Emma Spooner, University of Sheffield

- Crystalline-Silicon inching slowly for the past decade.
- World record efficiency has been stagnant
- Improvements made in cell manufacturing to get mass produced cells closer to record efficiencies.
- Now cells are very close to their theoretical max efficiency, module efficiency improvements are a challenge
- Large cell formats dominate recent module developments

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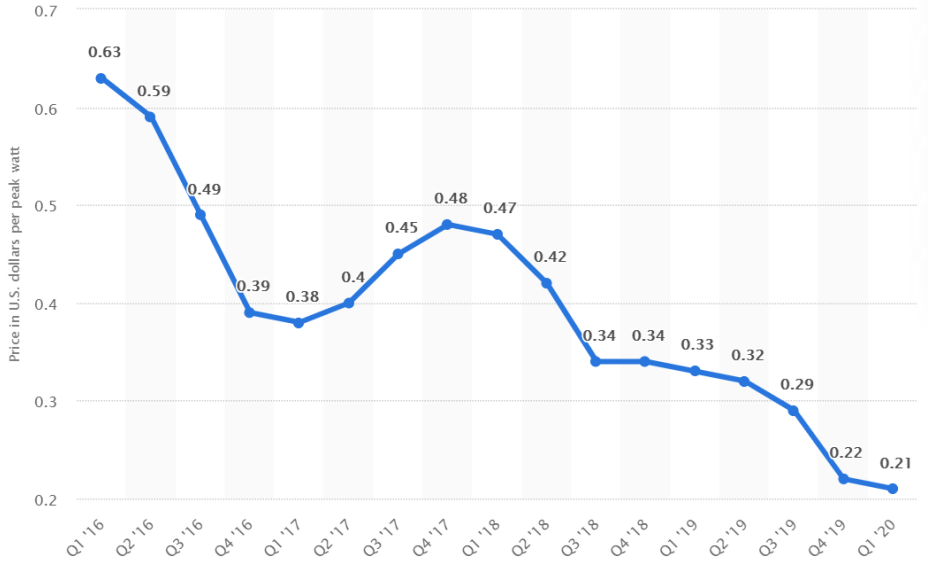
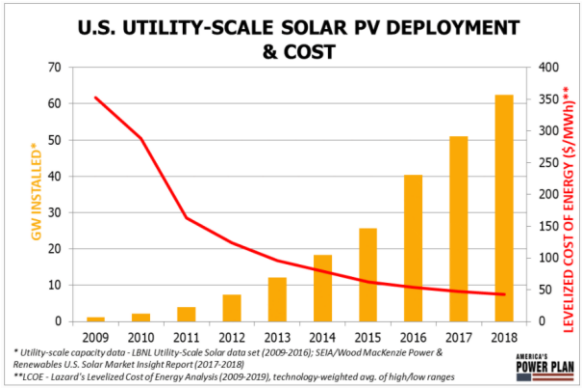
Module Cost Pressures

Lowering prices while increasing quality



- Module prices have been steadily declining for the past two decades
- Grid Parity was the ultimate goal



- Over the past decade:
  - 89% drop in prices
  - Utility Installations growth > 30X
- Cost reduction comes from:
  - Lower materials
  - Lower CAPEX and improved manufacturing
  - Higher Module Efficiency
  - Higher Module Power

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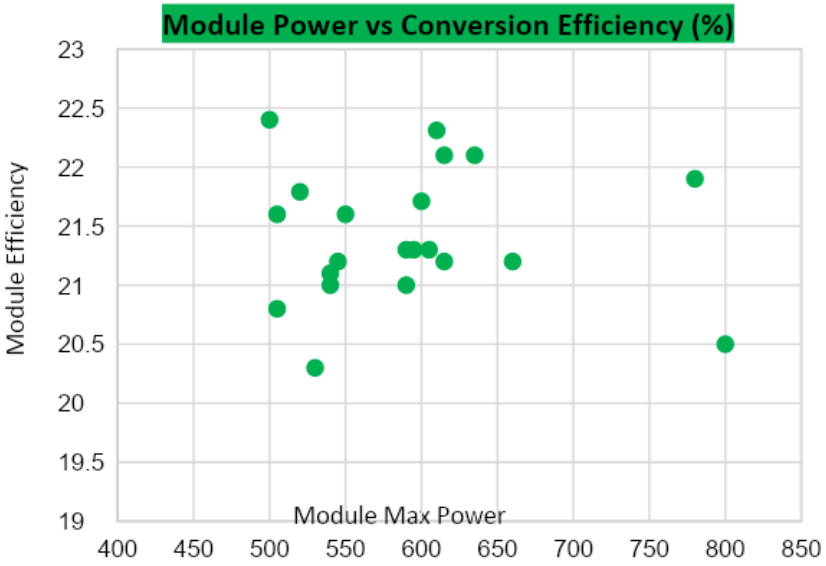
Size Trends vs. Conversion Efficiency



Source: PV Tech

Company	Module Output (W)	Efficiency (%)	Wafer Size (mm)
JinkoSolar	610	22.31	182
DZS Solar	635	22.1	210
Jolywood	615	22.1	210
Tongwei	780	21.9	210
ZNshine Solar	520	21.79	210
HT Solar Group	600	21.71	182
Yingli Green	550	21.6	210
SPIC	505	21.6	158.75
Suntech	605	21.3	210
Canadian Solar	590	21.3	182
HT-SAAE	595	21.3	182
Trina Solar	660	21.2	210
Risen	615	21.2	210
EGing	545	21.2	210
LONGi Solar	540	21.1	182
Talesun	590	21	182
CECEP	540	21	182
GCL-SI	505	20.8	210
JA Solar	800	20.5	210
Seraphim	530	20.3	210

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The Need to Go Beyond the Standards

- Key manufacturers are going above and beyond to make sure they do the due diligence of vetting/testing their products.
- These manufacturers not only put their products through the minimal standards of testing, but have continuously requested additional tests that would increase confidence in their BOM’s
- When companies take this approach to quality and product design, the risk is inherently lower.

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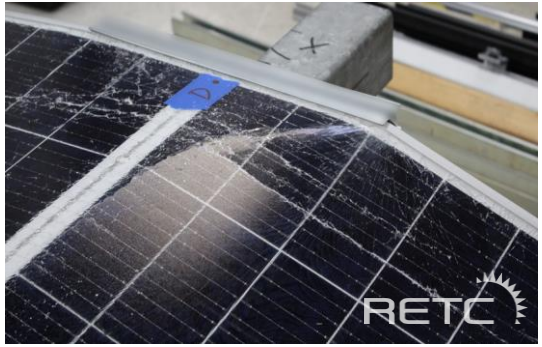
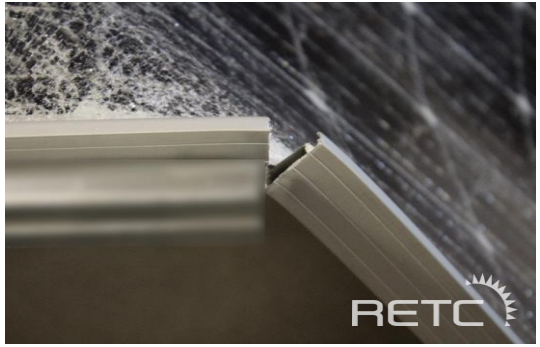
Large Modules Present Some Challenges

- High Wind and Snow Load testing revealed some weakness due to:
  - Thinner glass
  - Thinner frame
- Racking and Tracker manufacturers compensate with larger stronger rails for a positive outcome
- Resistance to Hail Damage





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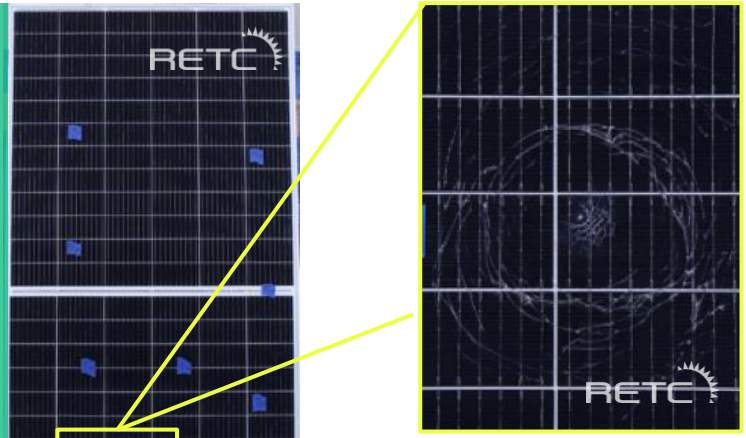
2.0 and 3.2mm Front Glass

No break at 55/65mm hail stones

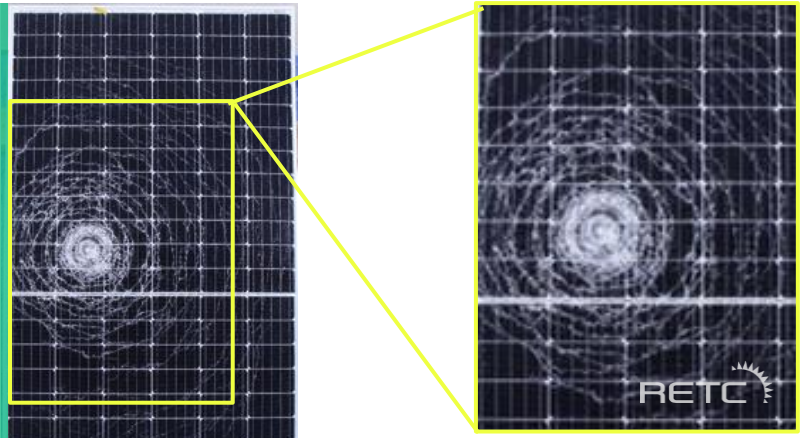
2.0 mm



Front side impact with 55mm Hailstone resulted in break front and back glass

Module Construction:
2.0mm Front Glass
EVA Encapsulant
½ cut cells
EVA Encapsulant
2.0mm Back Glass

3.2 mm



Front side impact with 75mm hailstone

Module Construction:
3.2mm Front Glass
EVA Encapsulant
½ cut cells
EVA Encapsulant
Polymeric Backsheet

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WHAT IS HDT?

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What is HDT?

- HDT assesses the characteristics of the PV modules, their Bill of Materials (BOM), and their constructions when subjected to installations in hail-prone regions.

- PV modules undergo a simulation of conservative wind speeds and are checked for their performance near the threshold of damage, just over the threshold (repairable damage), and at material failure.

- The HDT program maximizes test result confidence by using repeatable speeds & consistency in ice ball quality. The results are categorized by hail size, velocity, and the resulting kinetic energy (Ke).

Moments before the ice ball hits the module during a RETC Hail Durability Test (HDT)

A look into our RETC's HDT process

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Current Standards & Relevance

"The renewable energy insurance market is facing a possible $70 million to 80 million loss after hail damaged a solar farm in West Texas in May"

"...'one of the biggest losses' in the renewable energy market and that it had 'caused a lot of their people to reflect on their exposure.'"

(Source: Bradshaw, Gavin, "Texas solar farm faces likely $70M- $80M hail loss," *The Insurance Insider*, October 25, 2019)

Figure 12 – Hail-test equipment

Table 4 – Ice-ball masses and test velocities

Diameter mm	Mass G	Test velocity m/s	Diameter mm	Mass g	Test velocity m/s
25	7,53	23,0	55	80,2	33,9
35	20,7	27,2	65	132,0	36,7
45	43,9	30,7	75	203,0	39,5

- Increasing demand from the PV industry to provide an industry standard that understands hail for insurance providers, developers, and financiers.
- Solution: RETC has built out/improved current UL and IEC standards:
  - *UL 1703 Section 30*
    - Test: 2-inch steel sphere impact from a drop height of 51-in. above the module
    - Results: This impact energy of this test is a single 5 ft · lb (6.78 J) strike and the majority of modules survive this test. Cell damage is uncommon but may occur.
  - *IEC 61215-2 MQT 17*
    - Test: 11 impacts of a 1 in. (25 mm) ice ball travelling at 51.4 mph (23 m/sec).
    - Results: The impact energy of this test is 1.47 ft · lb (1.99 J) for which modules rarely, if ever, fail and cell damage is very uncommon.

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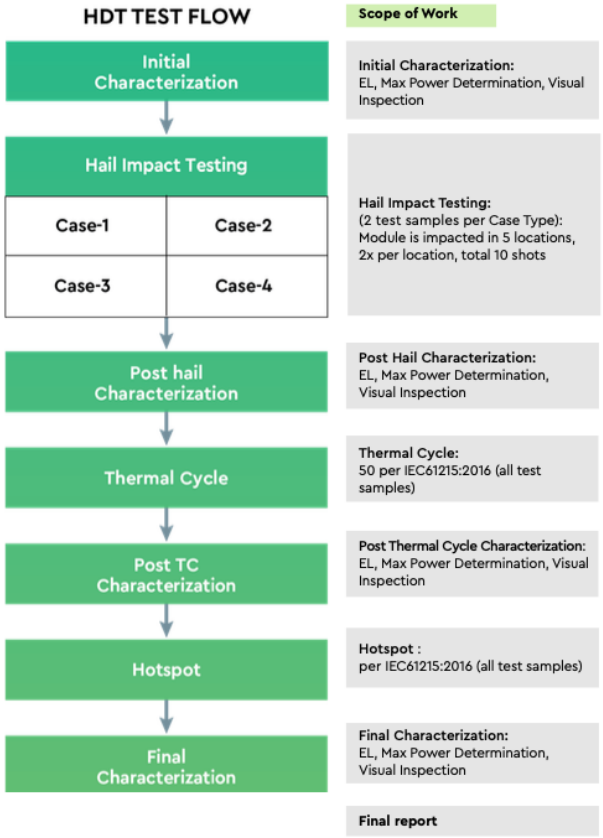
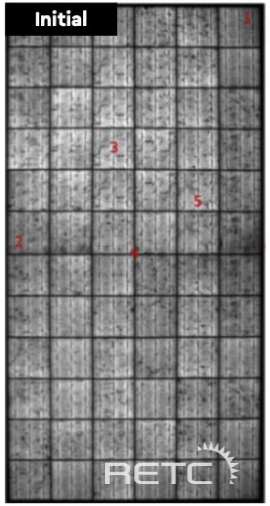
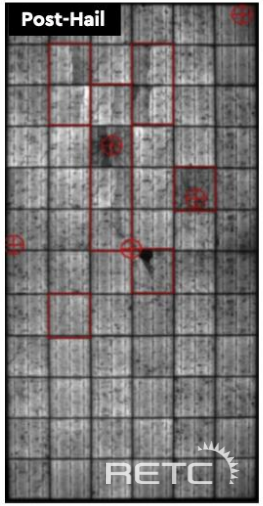
Scope of Work



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





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

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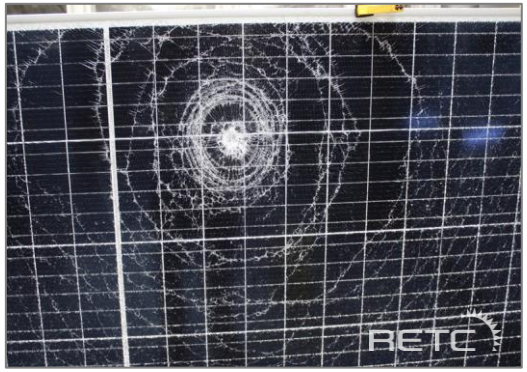
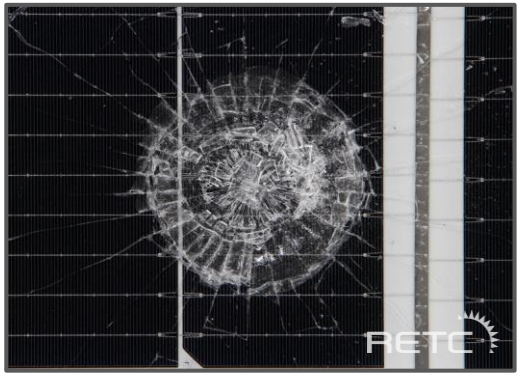
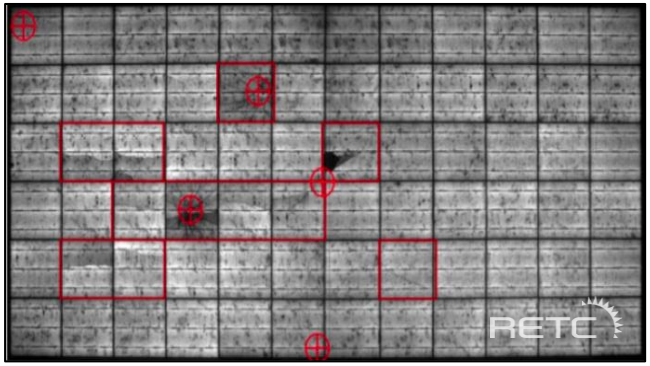
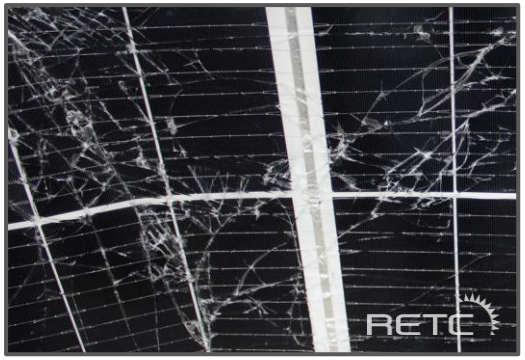
What does our testing show?

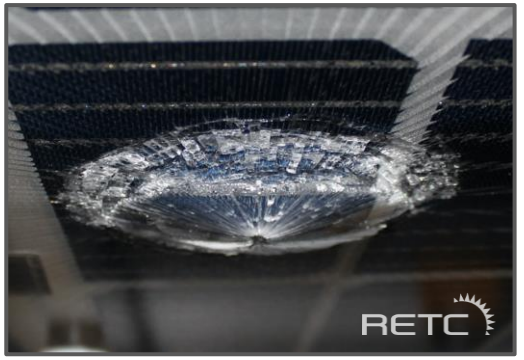
- Direct impact of large (50.8mm / 2”) ice projectiles result in inevitable damage
- Similar testing on previous generations (4mm and 3.2mm front glass) resulted in much fewer failures
- Front glass thickness reduced to 2.5mm – heat strengthened rather than tempered











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HDT Classification

Hail Impact Characterization

Uncritical Critical Very Critical

Class A No abnormalities that can lead to premature drop in power
Low to no power loss

<10% 0% 0%

Class B A few abnormalities that do not lead to a premature drop in power

<20% <10% 0%

Class C Increased abnormalities that may lead to a premature drop in power and risk of hotspot

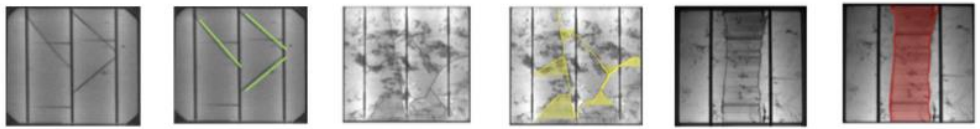
≥20% ≥10% <10%

Class D Negative properties that can directly lead to a drop in power with an elevated risk of hotspot

>10% >0% ≥10%

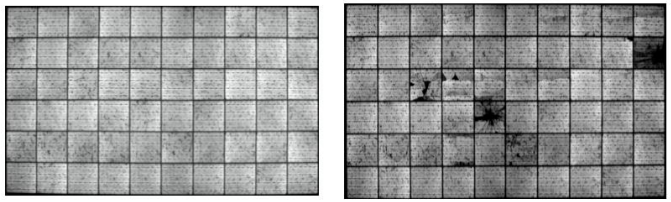
Hail Damage Samples

PICTURED: Cell crack types determine module class judgement with electroluminescence (EL) test



Uncritical Critical Very Critical

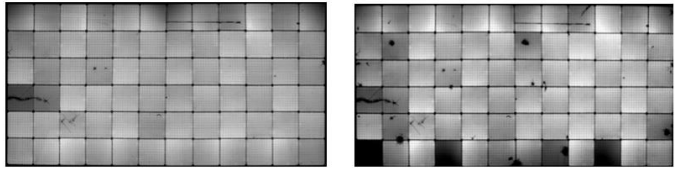
HDT Module Class C



% Degradation

SN	Condition	Voc	Vmp	Isc	Imp	Pmax	FF
XXXXXX	Hail	-0.28%	-0.54%	-0.33%	-1.05%	-1.59%	-1.00%

HDT Module Class D



% Degradation

SN	Condition	Voc	Vmp	Isc	Imp	Pmax	FF
XXXXXX	Hail	-0.36%	-0.74%	0.07%	-2.10%	-2.93%	-2.63%

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