THIN FILM VS. C-SI SOLAR MODULES: CELL CRACKING RISK

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LEADING THE WORLD’S SUSTAINABLE ENERGY FUTURE
FIRST SOLAR AT A GLANCE

- **Over 25 GW** shipped worldwide and over **$17B** in project financing facilitated

- **Partner of choice** for leading utilities and global power buyers since 1999

- Solar energy that is **economically competitive** with fossil fuel

- **Strongest financial stability & bankability** in the industry

- **Lowest environmental impacts** of all PV technologies on a life cycle basis

- **Industry-leading** global PV recycling program
COMPARISON OF PV MODULE CELL TECHNOLOGIES

First Solar

Our semiconductor layer is 3% of the thickness of a human hair and <2% of the thickness of a silicon cell

First Solar Fully Integrated, Automated & Continuous Process

1 Barnes, et. al, High Efficiency Flexible CdTe Superstrate Devices; Photovoltaic Specialist Conference (PVSC), 2014 IEEE 40th; 2014

1 Factory <3.5 HRS
First Solar’s thin-film CdTe cells are immune to cell cracking due to their minimal thickness that cannot fracture under stress.

https://www.enrg-inc.com/solar-pv

- First Solar’s thin-film semiconductor cells are just a few microns thick and conform to substrate surfaces.
- Multiple applications of thin-film PV cell technologies like CdTe in flexible solar applications have been demonstrated.
OVERVIEW OF CELL CRACKING

- Cell-cracking has been a known failure mode for decades, heightened by recent trends like thinner wafers and increased narrow-mount tracker applications
- Results in several percent field power loss
- Can happen throughout life-cycle
- Damage is not easily observed by naked eye
- Common PV module standards have a ‘blind spot’ — they do not test for effect of continued environmental stresses after c-Si module cell-cracking failures and therefore fail to test sufficiently for cell-cracking power output loss

C-Si module cell-cracking is a critical issue in the PV industry
HOW DO CRACKED CELLS OCCUR?

RISK THROUGHOUT ENTIRE LIFE-CYCLE

Cell Fab

Shipping

Cracked c-Si Cells

Handling/Installation

Mounting

Hail

Snow

Wind
HAIL DAMAGE
HAIL RISK IS A GLOBAL CONCERN

HAIL ZONES

- **Moderate** (Hail size < 1.75 in. (44mm))
- **Severe** (Hail size ≥ 1.75 in. (44mm) and < 2 in. (51mm))
- **Very Severe** (Hail size ≥ 2 in. (51mm))
- **No Data**

15 yr. mean recurrence interval


HAIL IMPACT TESTING PER IEC 61215-2 MQT 10.17 STANDARD

11 Impacts, Various Locations

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<th>Diameter (mm)</th>
<th>Mass (g)</th>
<th>Velocity (m/s)</th>
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Minimum Criteria

Leading Global Module Suppliers Hail Impact Competitor Datasheet Survey: Aug 2019

First Solar S4 Test Oct 2019 (pictured) and S6 Test Jan 2020 per IEC 61215-2 MQT 10.17 75mm diameter hail
Power loss due to cell cracking in c-Si modules may not manifest immediately or to its full extent after mechanical loading or hail impact, but with subsequent thermal cycling and humidity freeze cycling (‘HF10’ per MQT 10.12) simulating real world stress over time, power loss is observed. These post-crack environmental stressors are NOT currently required in certification testing.

- Primary required PV module standards: IEC 61215-2: 2016 and UL 61730-2: 2017
- Mechanical load test (MQT 10.16) and Hail impact test (MQT 10.17) referenced by both standards do NOT test for effect of continued environmental stresses after c-Si module cell-cracking failures and therefore fail to test sufficiently for cell-cracking power output loss.
Cell cracking is a phenomenon that **only occurs in c-Si PV modules** and **cannot be seen by the naked eye**.

It **can occur throughout the entire life-cycle** of the module and as a result of fabrication, shipping, installation, wind, snow, and hail.

It could result in significant **STC power loss** and **further incremental energy production loss therefore** loss of owner revenue.

PV plants built with **First Solar modules** are **not subject to cell cracking** and therefore represent a lower risk profile in this regard.

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**SELECT AN INHERENTLY IMMUNE MODULE TECHNOLOGY** (like First Solar).

Advocate **stringent as-delivered component requirements** and **warranty terms** that adequately protect you **against power/energy loss risk**.

Join First Solar in advocating for **more thorough module evaluations** and **stronger PV module standards** that remove cell cracking blind spots.
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