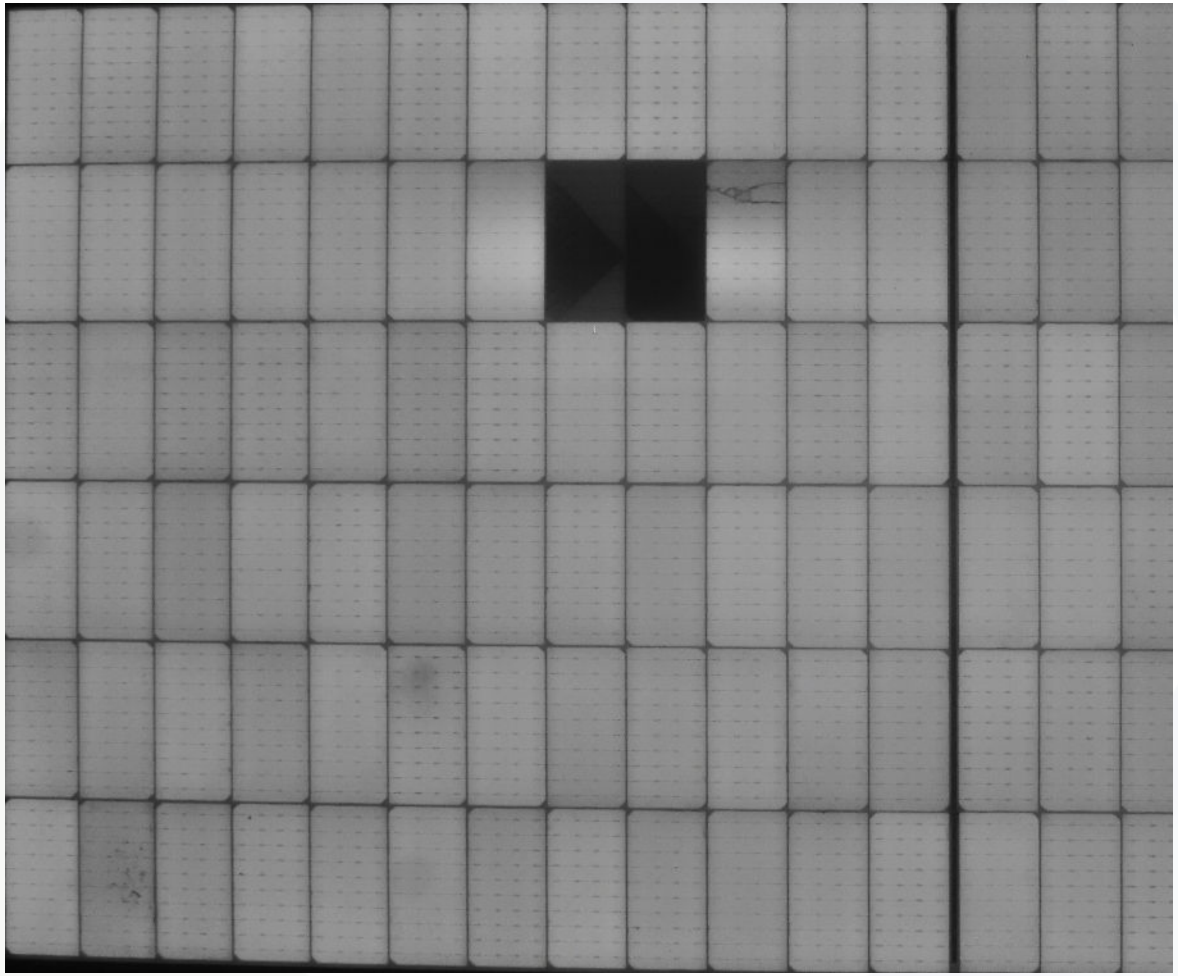
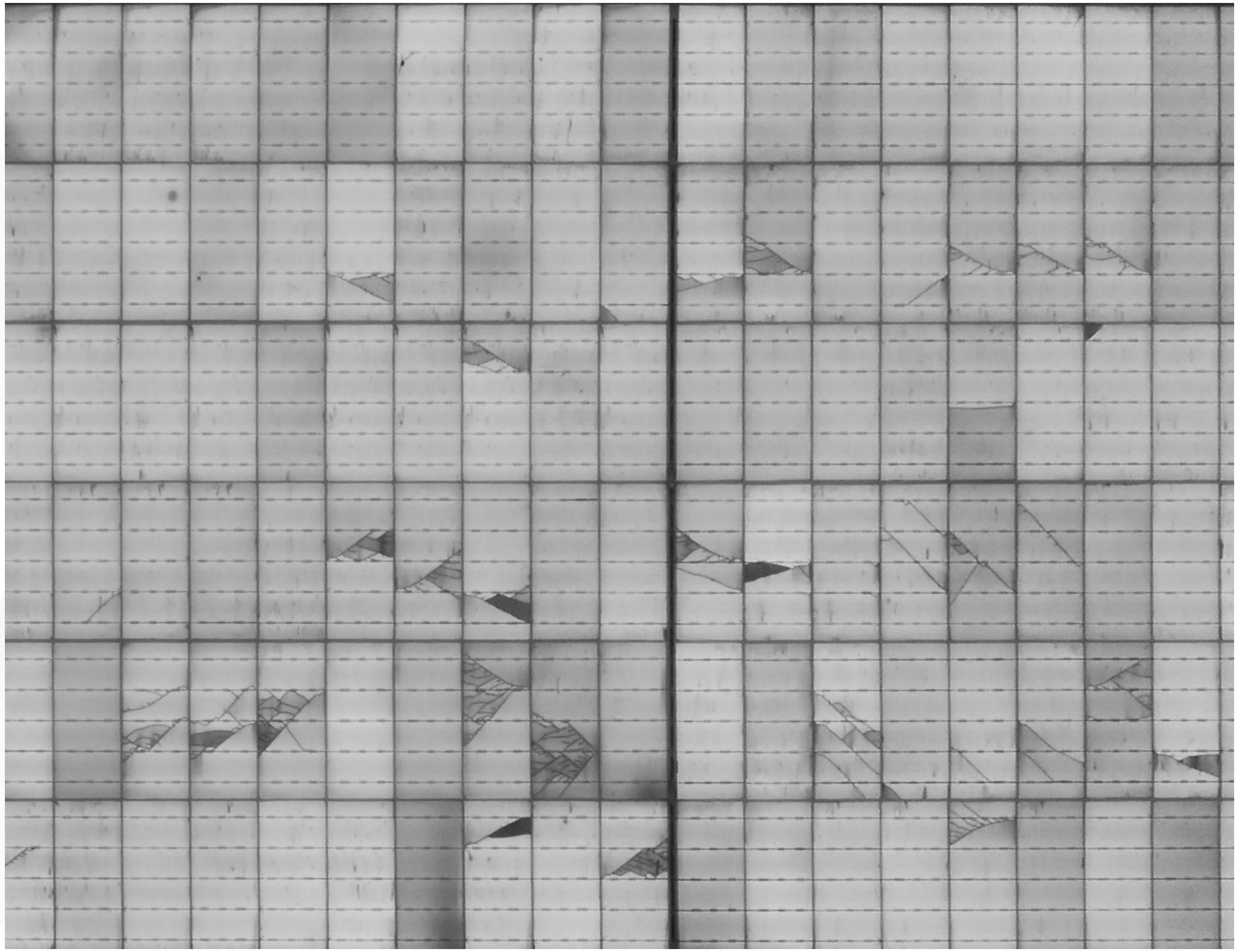
Solar PV Module Quality Risks

A Summary of CEA's Findings in the Field

Undetected Damage in PV Modules Continues to Pose a Significant Risk to the Solar Industry



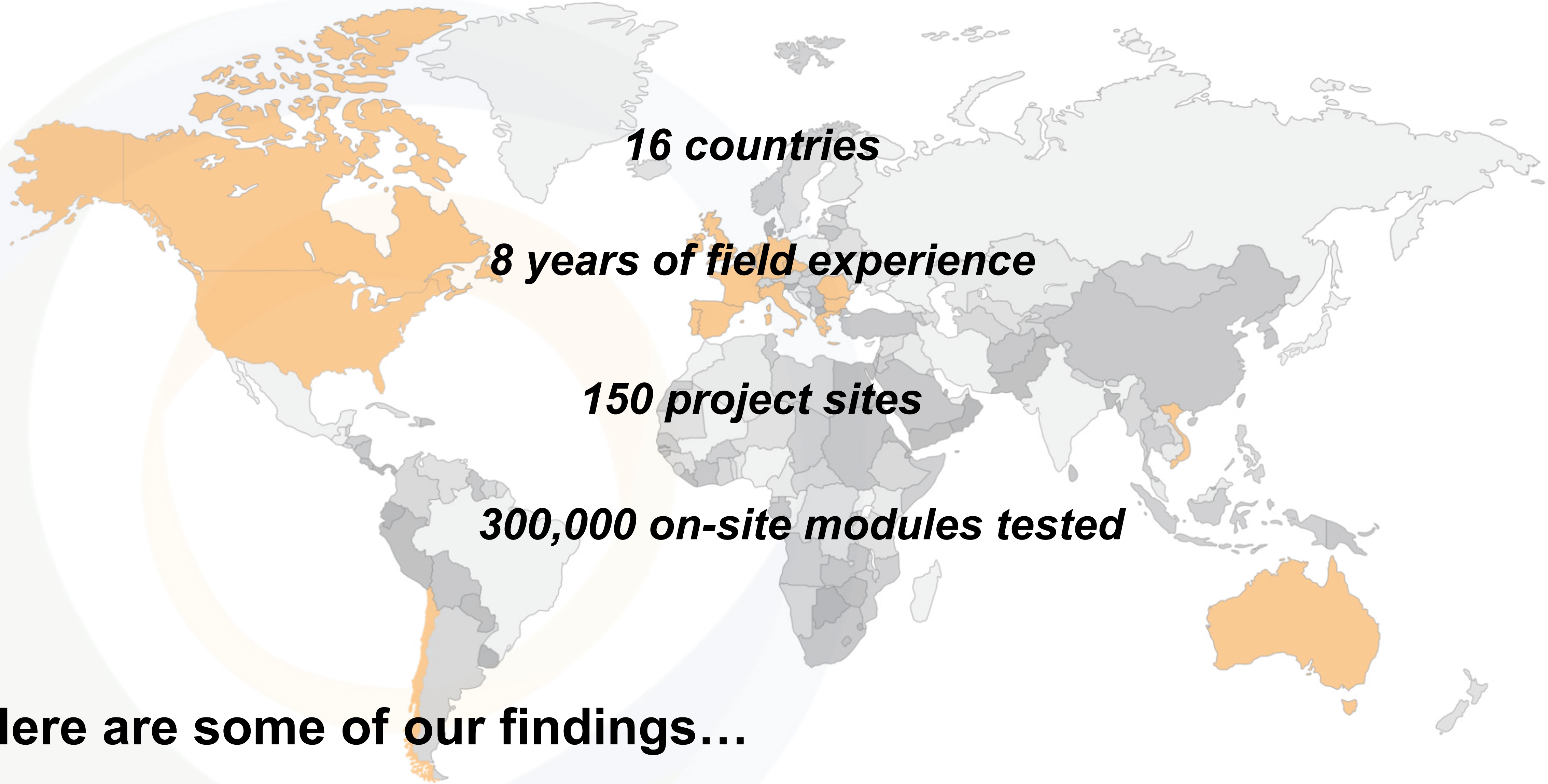


EL Testing is the Most Effective Way to Detect Unseen Damage in PV Modules

What is EL testing?

Electroluminescence (EL) testing is a diagnostic technique used in the solar industry to detect defects in solar cells and modules that cannot be seeing with the naked eye. By passing a current through a solar module in a dark environment and capturing the emitted infrared light with specialized cameras, EL testing identifies issues such as microcracks, broken cells, soldering defects, and inactive areas.

CEA Has Conducted EL Inspections On 300,000+ Modules in the Field



16 countries

8 years of field experience

150 project sites

300,000 on-site modules tested

Here are some of our findings…

1. Damage and Defects Can Occur Throughout the Entire Module Lifecycle

Manufacturing

- Many module buyers are procuring from new and inexperienced suppliers due to supply chain challenges, leading to increased quality issues.
- Many defects CEA finds in the field originated during the manufacturing process.

Shipping & Storage

- Microcracks may occur during shipping, handling, storage in warehouses, and transportation to the project site.
- Shipping and handling may also exacerbate existing module defects.

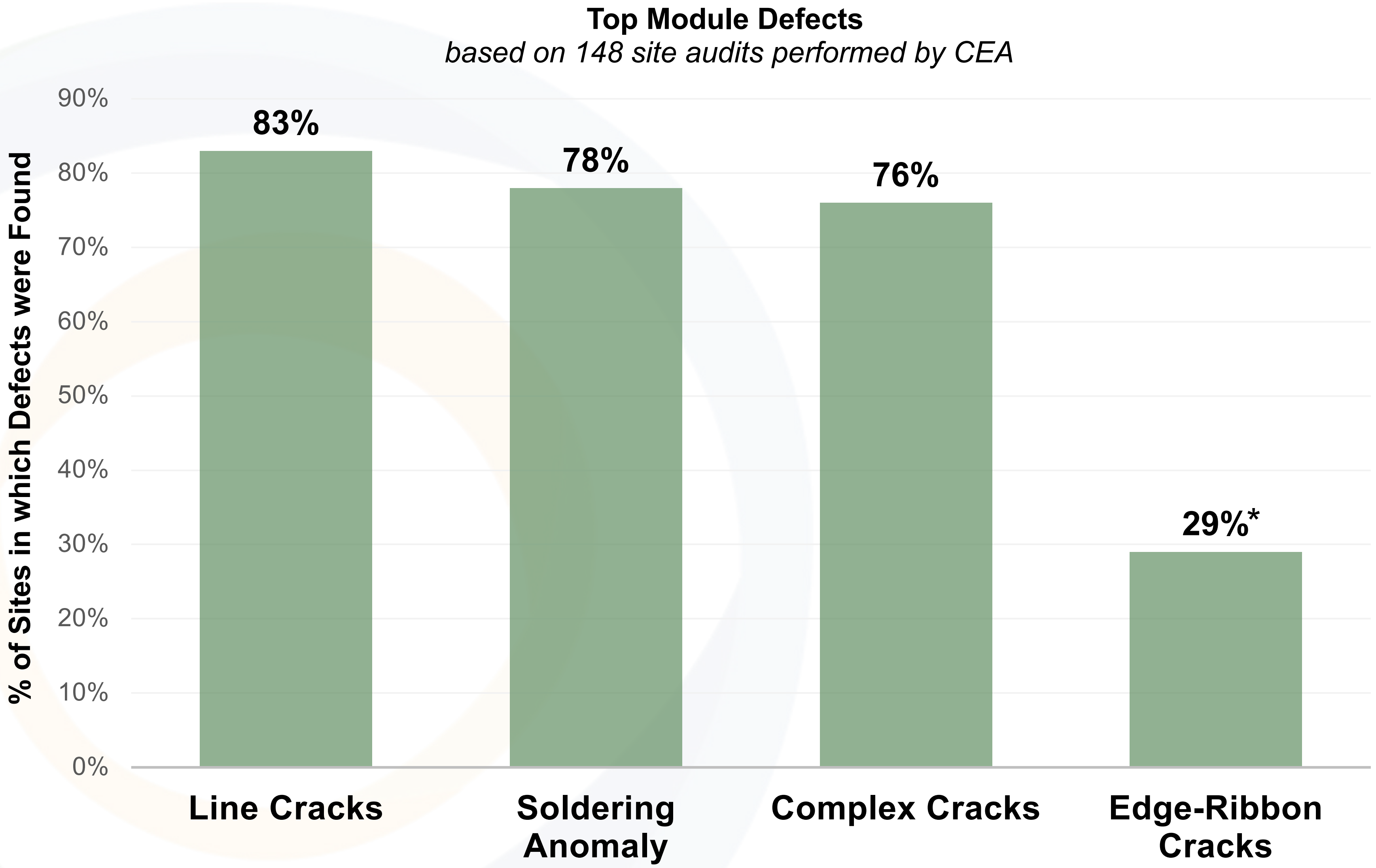
Installation

- Poor installation procedures can lead to module damage.
- Modules might be subjected to incidents, such as being dropped or mishandled. Even if there's no visible damage to the glass or frame, internal microcracks can form.
- CEA is seeing an increase in glass breakage due to glass-glass technology.

Operation

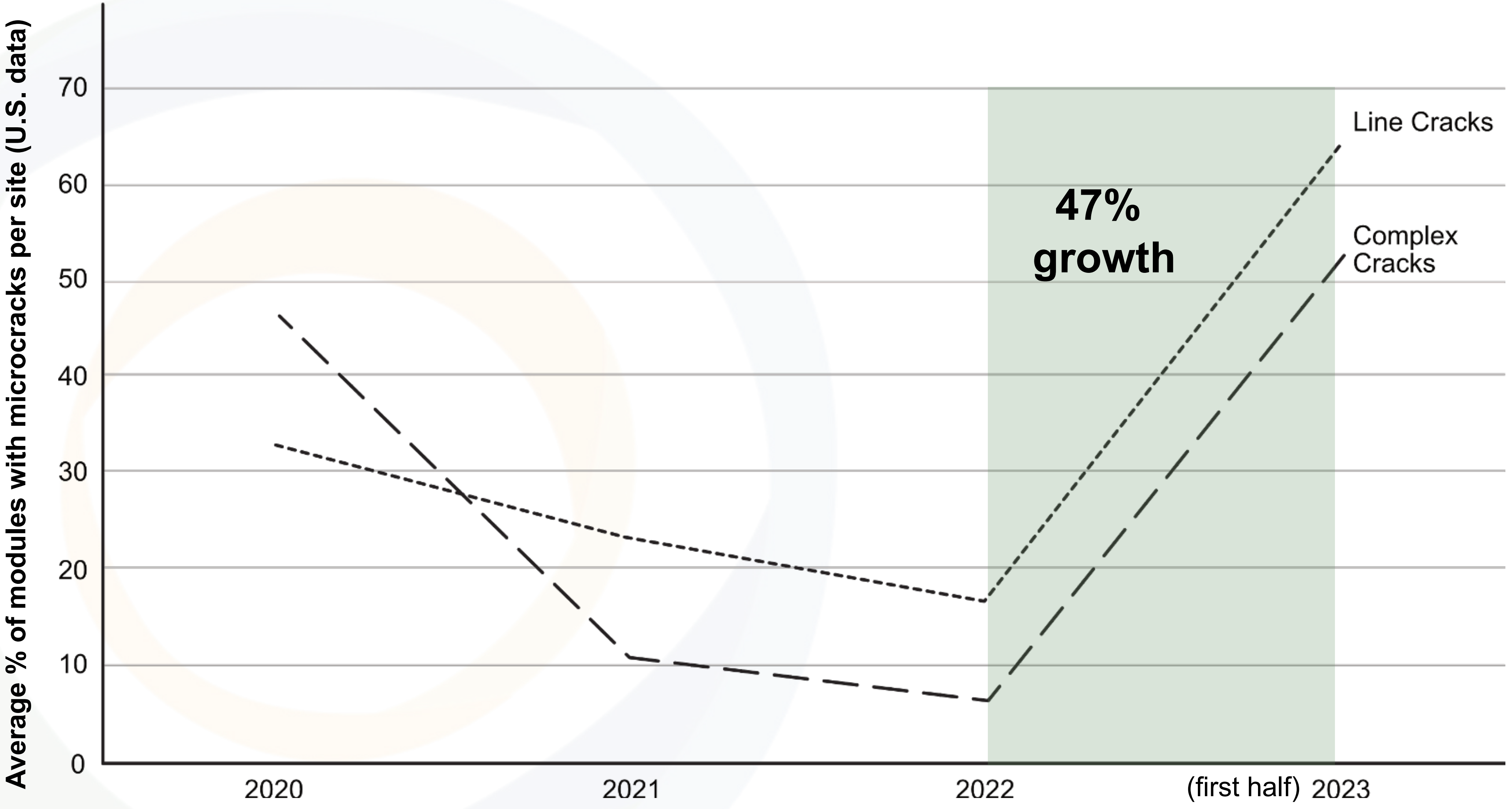
- Microcracks can grow over the course of a module's life, isolating part of a cell and reducing performance. In worst cases, this can lead to risks like module hotspots or underperformance of modules.
- A rise in extreme weather events may lead to increased risk of module damage.

2. Most Common Defects Are Only Detectable Via EL Inspections



*<u>**81% of sites with half-cut cells**</u> were affected by edge-ribbon cracks

3. The Most Surprising Finding Was the Recent Massive Increase in Microcracks



83% of Sites Had LINE CRACKS

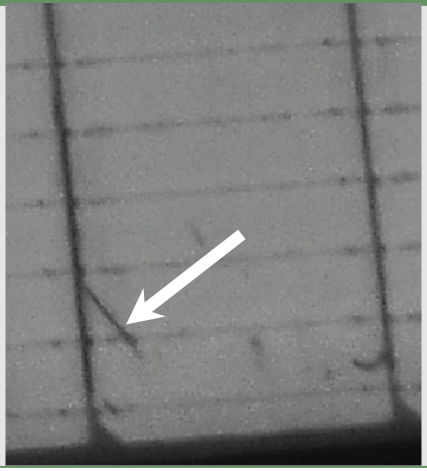
Why/How Does It Happen

1) Wafer imperfections
2) Light impacts to the cell/module
3) Pressure on the cell during module manufacturing:
   - Stringing
   - Lamination

Risk

1) Increase in internal series resistance leading to minor power loss.

Example



73% of Sites Had SOLDERING ANOMALIES

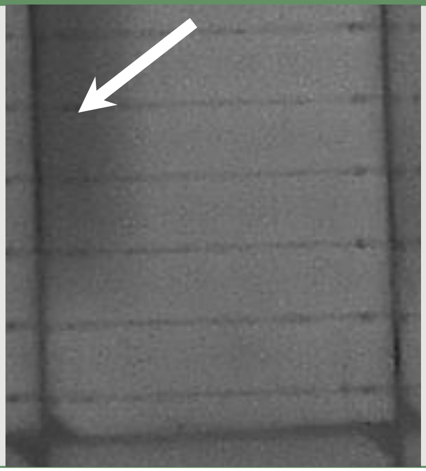
Why/How Does It Happen

1) Indicative of poor soldering process control during manufacturing.
2) Occurs when one or more of the busbars that connect each cell to the adjacent cell are not adhered properly.

Risk

1) Reduce the cell efficiency
2) In severe cases, hotspots can form and cause damage to the modules.

Example



76% of Sites Had COMPLEX CRACKS

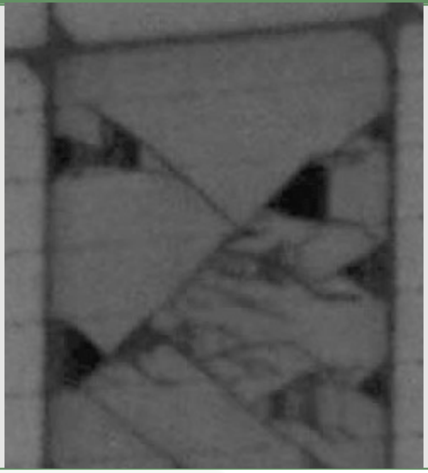
Why/How Does It Happen

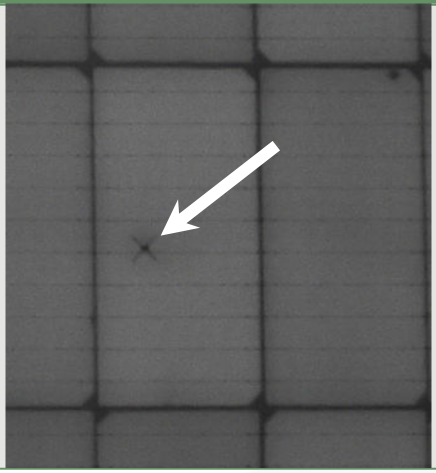
1) Stress on the module from handling, severe weather, etc.
2) Impacts to the modules, caused by:
   - Tools used during installation
   - Hail or storm debris
3) Microcrack growth

Risk

1) Hot spots that can lead to thermal damage
2) Large inactive areas significantly reduce performance

Examples





29% of Sites Had EDGE RIBBON CRACKS

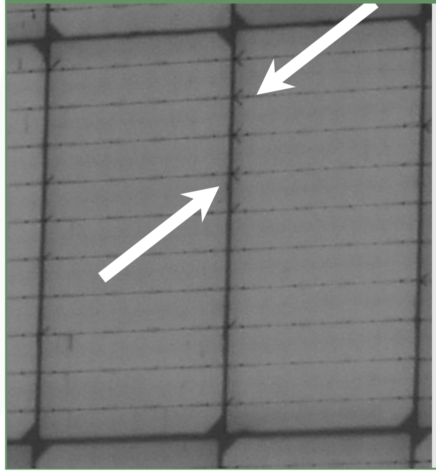
Why/How Does It Happen

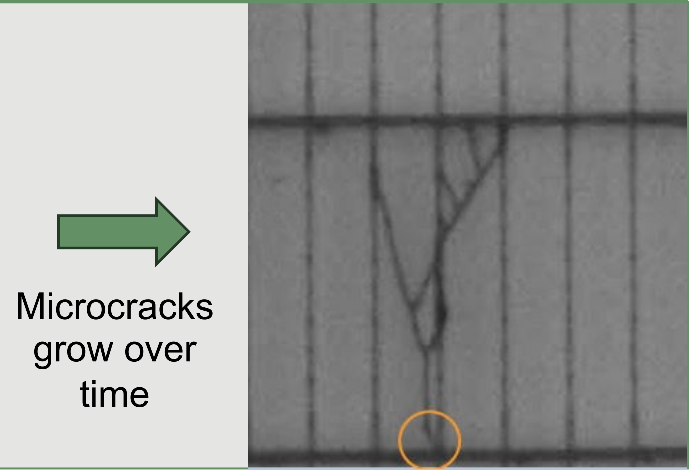
1) Form where the interconnect ribbon (or wire) crosses the edge of the cell.
2) They often start as a tiny line or V-crack and can grow during the solar module's lifetime.
3) Highest risk in half-cut cells, 81% of sites with half-cut cells have this defect.

Risk

1) Based on CEA's experience, edge ribbon cracks are more likely to grow (compared to other microcrack types).
2) Impact on safety and performance (isolated areas, diode activation, hot spots).

Examples



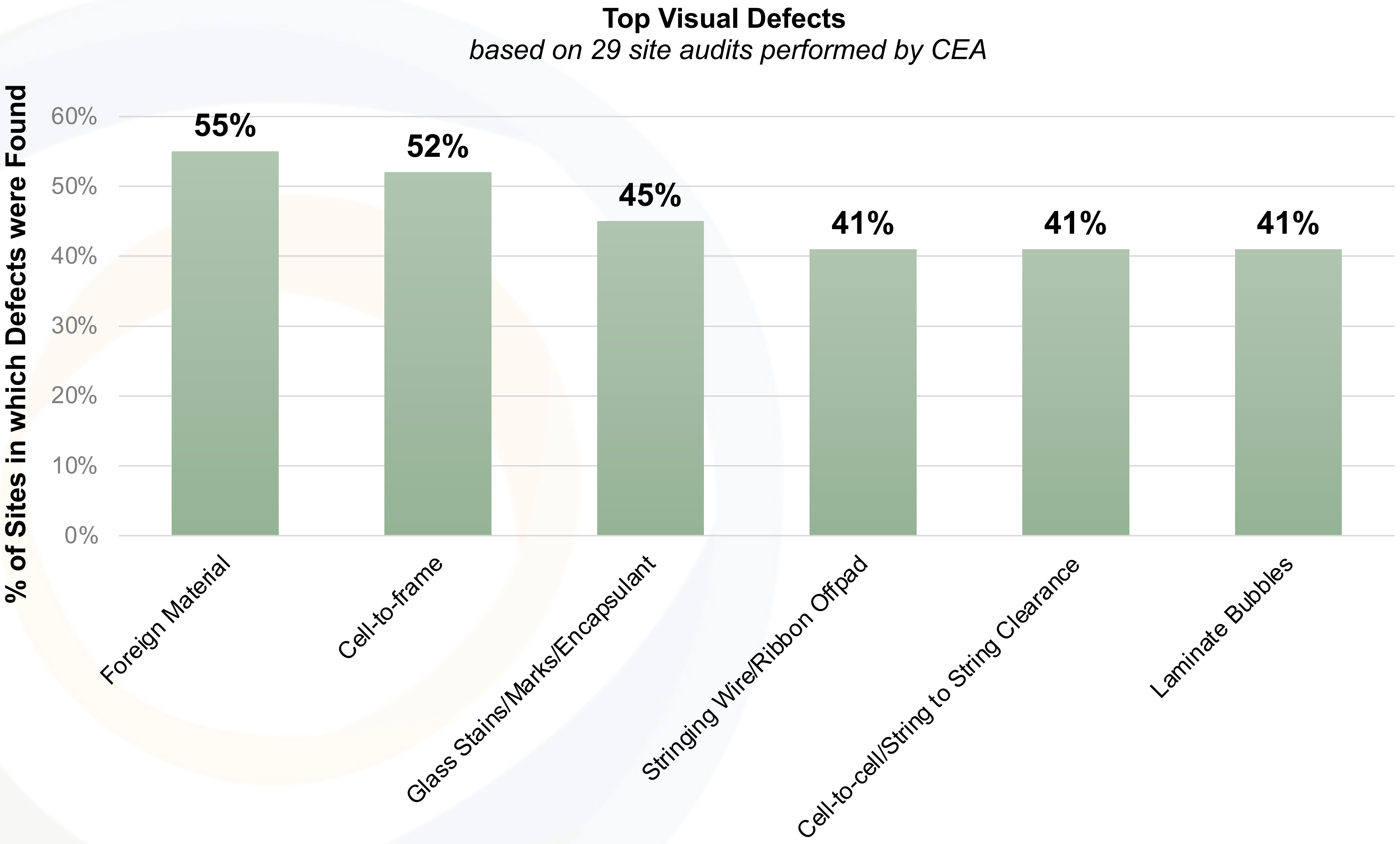


Detailed Visual Inspections Complement EL Testing By Identifying Additional Issues

What is a Visual Inspection?

Visual inspection is a process that involves examining the module with the naked eye under daylight conditions. Potential defects are measured, photographed, and cataloged. All potential defects are documented along with a description of the defect and an assessment of the potential to impact safety and/or performance. In cases where factory criteria has been provided, the potential defects are categorized per that criteria.

4. Most Common Defects in Solar Modules That Are Visible to the Naked Eye



55% of Sites Had FOREIGN MATERIALS

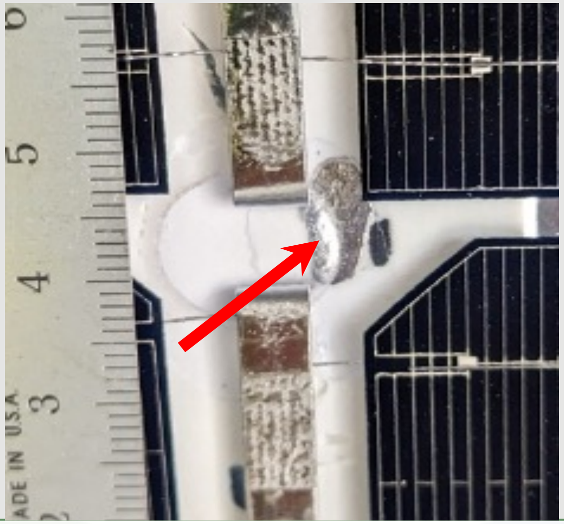
Why/How Does It Happen

- Unwanted substance or debris that's present within the module.
- It results from dirt, dust, debris, or other particles getting into the module during manufacturing.

Risk

- Reduced efficiency and potential degradation over time.
- May reduce internal creepage/clearance distances required for safety.

Examples



52% of Sites Had CELL TO EDGE OF GLASS DEFECTS

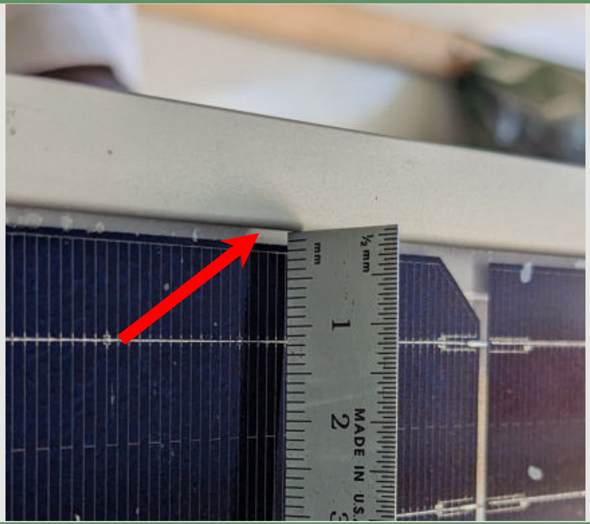
Why/How Does It Happen

- The minimum distance between internal components and the edge of the glass is determined by the module design to ensure sufficient electrical insulation and to certify the module to the IEC safety standards.
- This defect can arise from manufacturing inconsistencies, misalignment during assembly.

Risk

- Internal arcing (risk of fire)

Examples



45% of Sites Had GLASS STAINS/MARKS/ENCAPSULANT DEFECTS

Why/How Does It Happen

- Glass stains, marks, or encapsulant residue that cannot be cleaned off.
- Some stains/marks can occur at the site (e.g. aluminum smears), but they can also be an indicator of inadequate quality assurance at the factory.

Risk

- Can increase module soiling and decrease performance

Examples

41% of Sites Had STRINGING WIRE/RIBBON OFFPAD DEFECTS

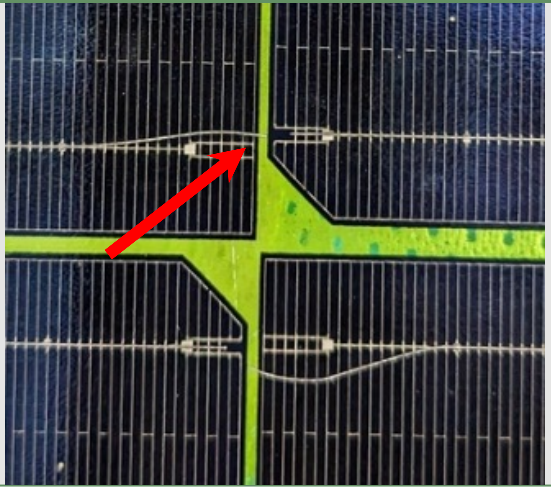
Why/How Does It Happen

- An off-pad ribbon is a segment of the ribbon or string that is not connected to the solder pads, either on the cell or on the bussing ribbon.
- This results in an area that is not properly electrically connected to the rest of the string and may have high series resistance.

Risk

- Performance loss
- Risk of hot spot development (severe cases)

Examples



41% of Sites Had CELL to CELL DEFECTS

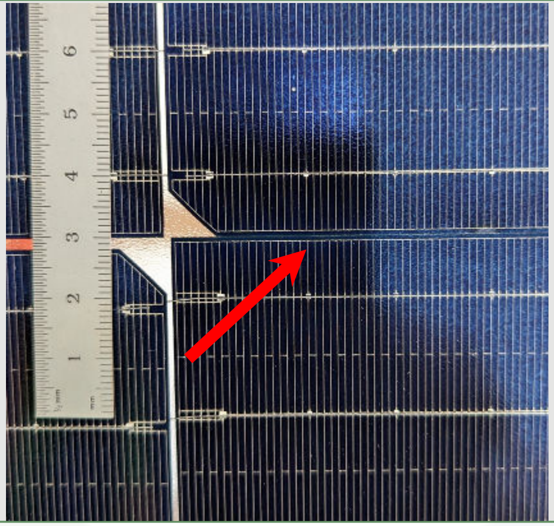
Why/How Does It Happen

- Cell to cell defects refer to misalignment affecting the distance between cells
- These defects can arise from manufacturing inconsistencies, misalignment during assembly

Risk

- Reduced efficiency and hot spot development

Examples



41% of Sites Had LAMINATE BUBBLES

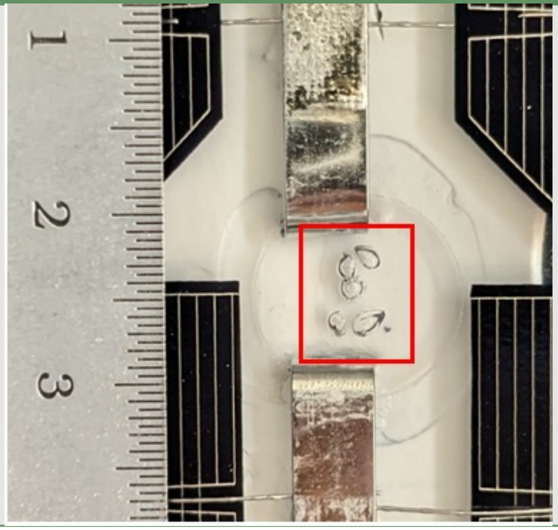
Why/How Does It Happen

- Voids or bubbles are small pockets of air or gaps trapped within the layers of the solar module.
- They can form during the manufacturing process if the layers of the module don't bond together perfectly.

Risk

- Reduced efficiency and weakening of the modules.
- Depending on location, internal short circuit and risk of fire

Examples



Most Visual Defects We See In the Field Originated During Manufacturing

Third-Party Factory QA Can Help Prevent These Defects

What Can You Do To Ensure the Long-term Financial Health of Your Solar Assets?

Awareness and Timely Action

There's a need for awareness on the increasing quality issues seen in PV modules. It's essential to address these issues on time, preferably before the project is installed, to ensure optimal performance.

Factory Quality Assurance (QA)

A robust QA process by a third-party inspector during module manufacturing will help prevent manufacturing defects that can lead to underperformance.

Pre & Post Installation Checks

Pre and post-installation inspections are recommended to ensure that any defects that occurred during shipment are identified before installation, and any issues arising during installation are also caught. Having a record of the condition of the modules is crucial to monitor and address potential problems effectively.

For more information

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