DUPONT GLOBAL PV RELIABILITY

2018 Field Analysis

Executive Summary

Since 2011, in collaboration with field partners, customers, downstream developers, universities and national labs, DuPont has conducted worldwide field surveys to inspect, assess and understand the state of degradation of fielded PV modules.

We have looked at PV modules of varying ages and with different bills of materials in a variety of geographies and climates—from North America and Europe to the Middle East and Asia. To date we have surveyed more than 4.2 million panels from 275 solar fields and 79 module manufacturers, accounting for over 1.04 GW of potential power production.

4.2M PANELS SURVEYED FROM **275** SOLAR FIELDS AND **79** MODULE MANUFACTURERS EQUALS **1.04GW** POTENTIAL POWER PRODUCTION

The program is one of the most thorough of its kind. It is guided by a multistep inspection protocol, and resulting data are analyzed using a variety of criteria, including component, material, mounting, time in service and climate.

A key learning from the program has been that high temperature and UV exposure are critical environmental factors affecting the performance of polymeric materials in panels.

Field studies conducted by DuPont clearly demonstrate that modules with different materials behave differently in the field. Low-quality, unproven materials degrade quickly when exposed to environmental stresses, which can negatively impact the modules' safety and power generation performance.

A large percentage of installations less than five years old exhibited material-level defects, highlighting compromises made by module suppliers in recent years.

2018 Study

Installation ages of the modules surveyed ranged from newly commissioned to 35 years; the average age of modules surveyed was 3.3 years.

Compared to the field survey published in 2016:

- Backsheet defects increased by 27%, although the overall module defect rate remained unchanged.
- Polyvinylidene difluoride (PVDF) and polyamide (PA) backsheet defects increased by 51% and 18%, respectively.

Backsheets made with DuPont™ Tedlar® maintained the lowest overall defect rate despite their use in the oldest installations surveyed and their longest time in the field.

Defect Categories

Defects observed in the 2018 study were organized into the following categories:

1. Cell/interconnect defects

Corrosion, hot spots, snail trails, broken interconnects, cracks, burn marks, delamination

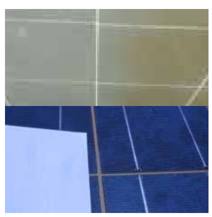
Snail trails

Ribbon corrosion

ARC delamination

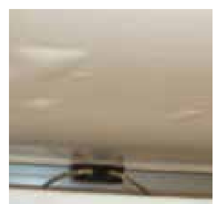
2. Backsheet defects

Cracking, delamination, yellowing, inner-layer cracking



Airside yellowing/ Frontside yellowing

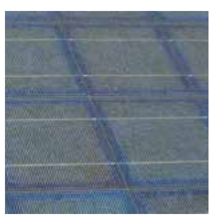
Cracking



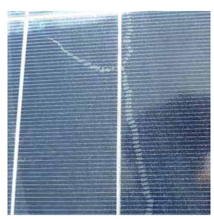
Delamination

3. Encapsulant defects

Discoloration, yellowing, delamination



Yellowing



Delamination from cell

Delamination from glass

4. Other defects

Glass defects, loss of AR coating, junction box defects

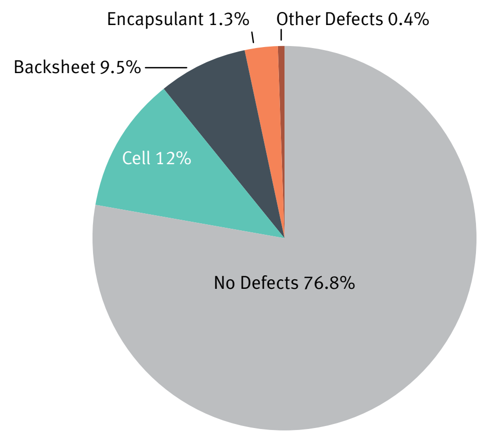
Junction box melting

Cable corrosion

Glass breakage

Defect Rates

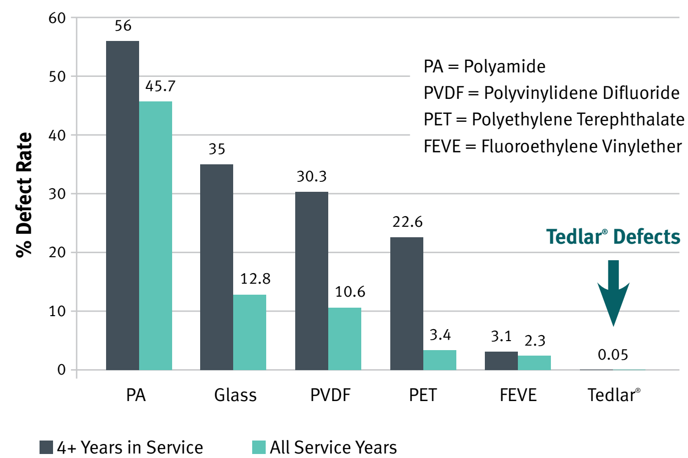
In 2018, the overall rate of module defects observed was 22.3%. The rate of backsheet defects, however, increased by 27%, from 7.5% to 9.5%.



Backsheet Defects by Material

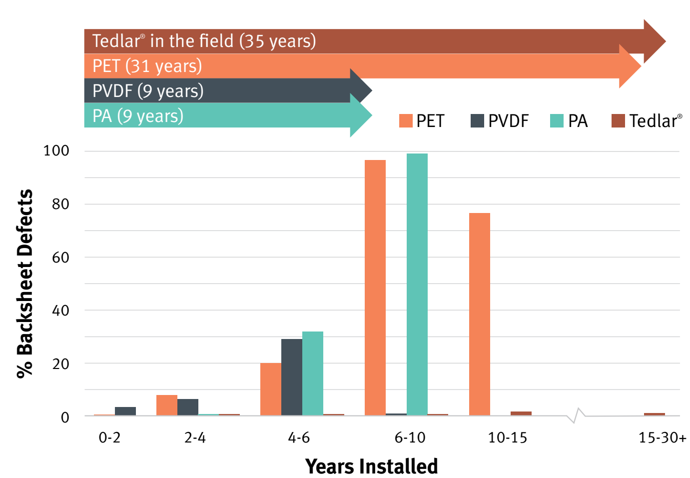
PET (av. panel age: 2.1 years) and PVDF (av. panel age: 2.8 years) had defect rates 70 and 200 times higher, respectively, than Tedlar® (av. panel age: 5.6 years), despite their lower average ages.

Significantly higher rates for PET, PVDF and glass for ages >4 years of service.



Backsheet Defects by Panel Age

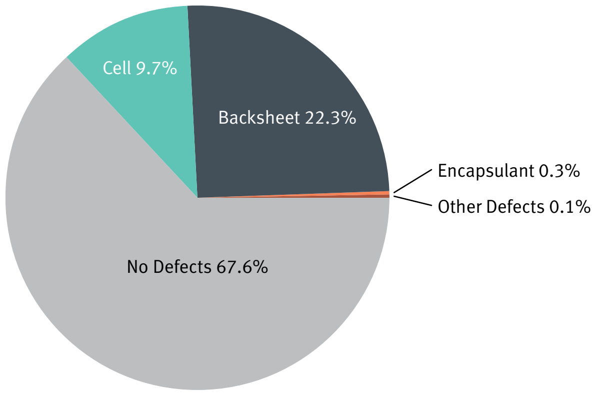
The study found that defect rates in PVDF, PET and PA backsheets increased with age. Tedlar® backsheets maintained low defect rates even after 30+ years in service.



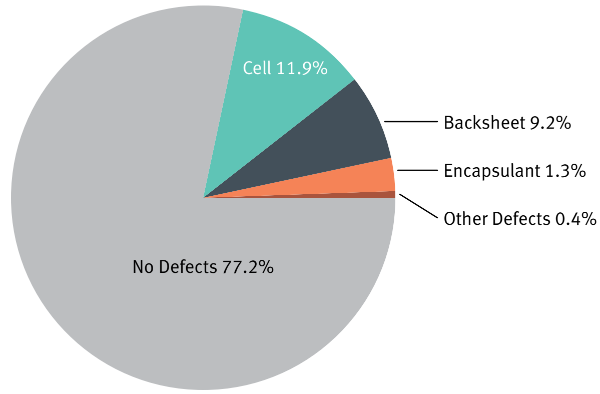
Backsheet Defects by Mounting Location

Roof-mounted systems evidenced an overall higher defect rate than ground installations. The rate of backsheet defects was more than 2.5 times higher on roof-mounted systems, likely due to higher operating temperatures accelerating degradation.

Roof-Mounted Panel Defects



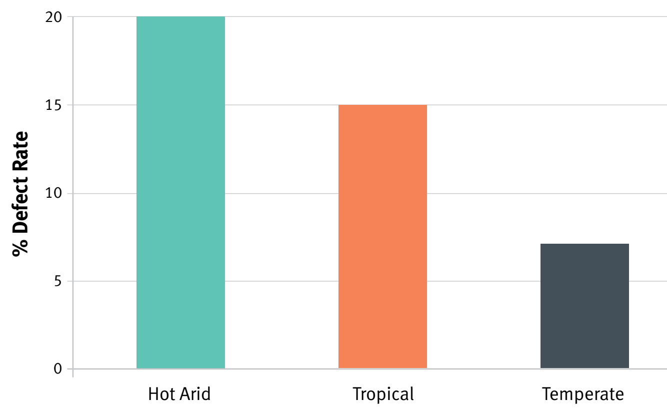
Ground-Mounted Panel Defects

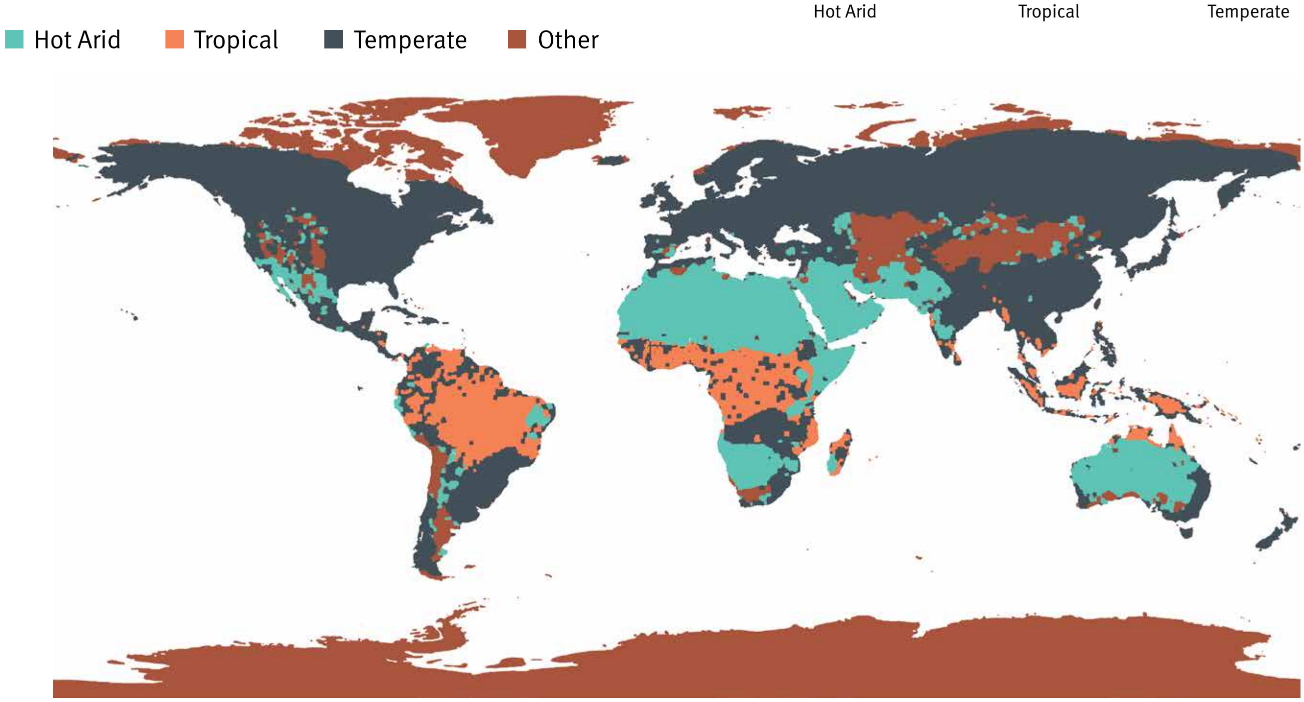


Backsheet Defects by Climate

The survey classified PV defect rates in three climate types: Hot Arid, Tropical, and Temperate. These climate types represented a simplification of the 29 climate zones identified in the Köppen Climate Classification System.

In general, backsheets were more affected by climate than cells and encapsulants. Backsheet defects were highest in Hot Arid climates.





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