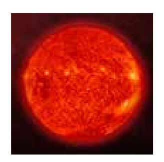
Adopting New Testing Standards to Avoid Backsheet Failures

Role of the Backsheet

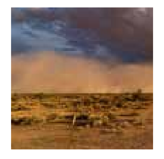


Ultraviolet (UV)
- Transmitted
- Reflected

Temperature
- Peak
- Cycling

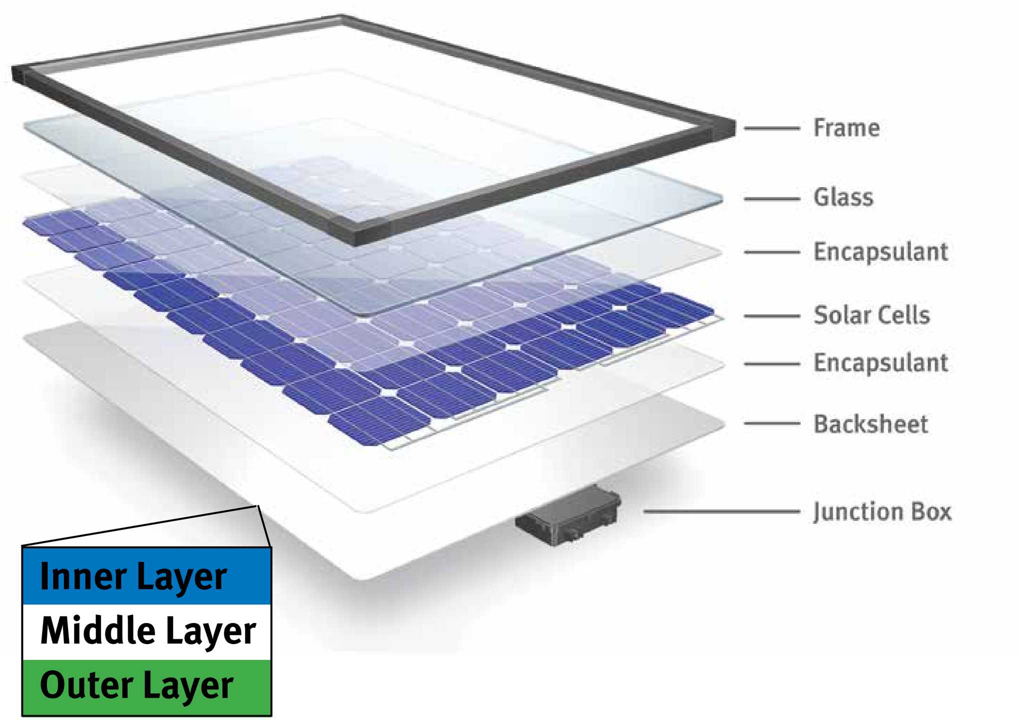
Moisture
- Humidity
- Precipitation
- Condensation

Corrosive Environment
- Atmospheric chemicals
- Ammonia
- Marine environment



Physical Protection
- Abrasion
- Impact

Backsheet structure

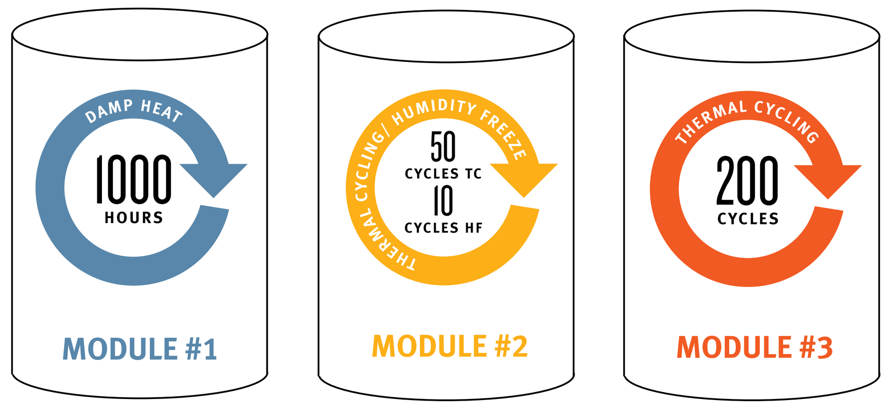


Backsheet must provide reliable electrical protection of module over the expected lifetime (and beyond).

Current IEC Testing Method—Single Aging Stress Tests

Current industry testing standards are insufficient to accurately determine the reliability and durability of components over time.

Single stress tests on individual modules do not mimic real-world conditions.



The Root of the Cause

Most historic and current lab testing standards are **not** rigorous enough to predict the durability of protective materials due to harsh, real-world stresses and long-term aging. Stresses include:

Current lab test shortcomings:

- Opting for single stress tests, insufficient UV doses and insufficient thermal cycles to test mechanical strength of materials

Materials such as **PET, PA** and **PVDF** may have passed IEC standards in testing—but it is evident now that **those requirements were insufficient to predict field performance.**

Change is needed. Current lab testing standards are insufficient and not rigorous enough.

Global Field Failures of Backsheets

Defects of PV modules in the field are not uncommon, with most of these defective modules using non field-proven materials. Defects are seen even among systems in use less than five years. Field studies have reported:

- 41% of global modules have shown visual defects, according to DuPont global survey[1]
- PV module defects increased from 19% in 2013 to 48% in 2015, according to research conducted by TUV[2]

In addition to potential induced degradation (PID) and glass breakage, defective backsheets are contributing to serious defects of solar modules.

It is time to focus on PV system quality, starting with quality materials.

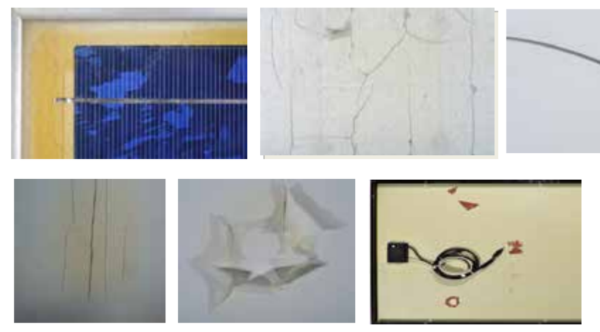
[1] From a global field-module survey including more than 70 global installations, (700,000+ modules at 150+ MW) in NA, EU and AP. Survey available upon request.

[2] TUV Rheinland Intersolar 2015, Roundtable Solarpraxis.

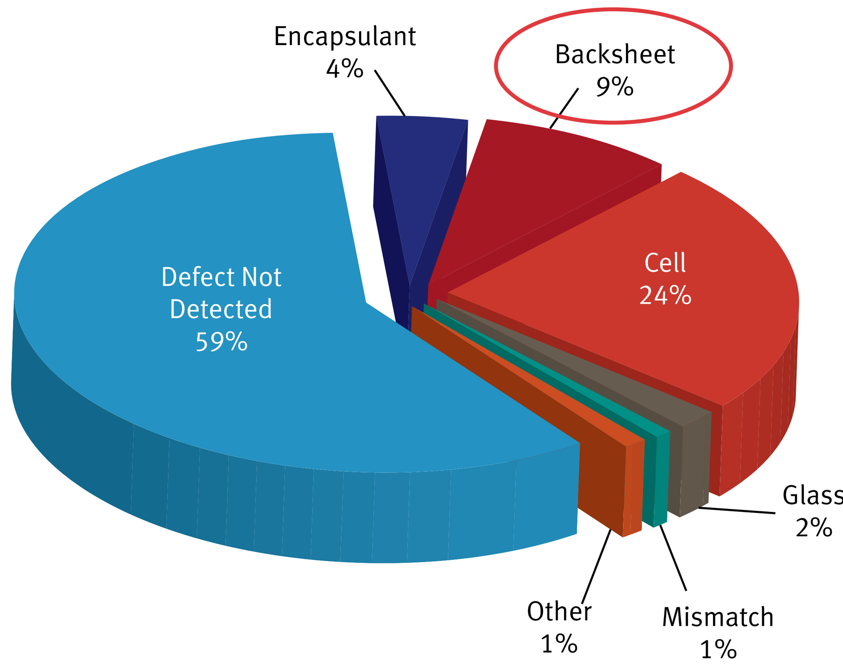
DuPont Field Surveys: Visual Degradation Observations

- Surveyed: >60 installations in North America, Europe & Asia Pacific
- Figures reported below: 45 module manufacturers, >200 MW, > 0.9 MM modules
- Range of exposure: from newly commissioned modules to 30 years in the service environment
- From hot to cold climates

Backsheet is one of the main components affected.



Defects observed: front and backsheet yellowing, micro-cracking, deep cracking and delamination.



Source: DuPont Field Module Program 2015 analysis.

Note: All percentage numbers are based on MW.

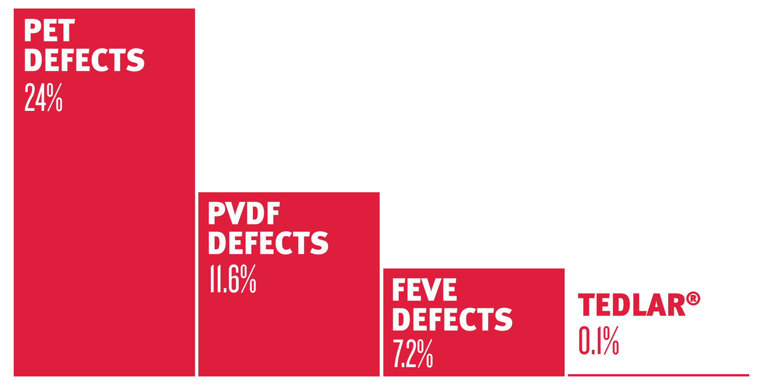
Defect Rate by Backsheet Type

Field observations paint a very different picture of how different types of backsheets actually perform. All backsheets passed the current IEC certification standards.

Only 0.1% of the DuPont™ Tedlar®-based backsheets showed defects.

From a global field-module survey of 71 installations (912,000 modules at 203 MW) in NA, EU and AP.

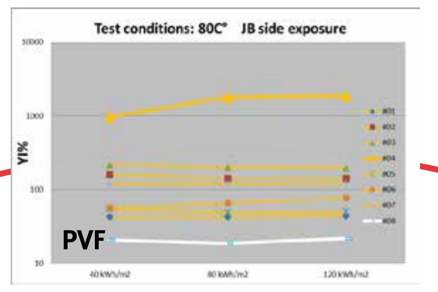
Survey available upon request.



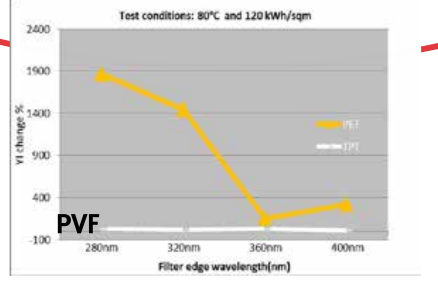
PET = Polyethylene terephthalate. PVDF = Polyvinylidene fluoride. FEVE = Fluoroethylene vinyl ether. Tedlar® PVF = Polyvinyl fluoride film.

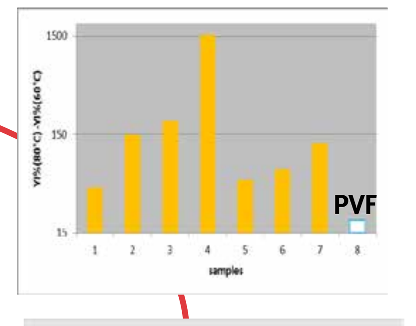
Materials Sensitivity to UV

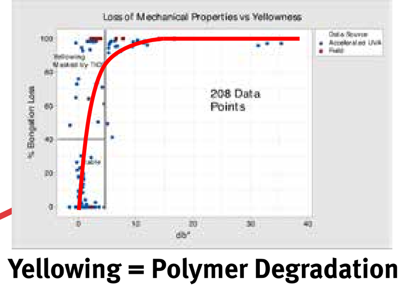
UV is a stressor and aging factor of solar panels. UV affects panels both from the front and the back (albedo). IEC standards do not test for albedo. The Fraunhofer ISE tests shown here demonstrate that most backsheet materials are sensitive to UV, causing them to yellow, become brittle and even crack. The data shows that the most robust materials to UV are Tedlar® PVF-based backsheets.



- **UV + Temperature ⟶ Yellowing**
- **Sensitivity:**
  - UV < 360μm
  - Limited with UV intensity
  - Strong dependence with temperature
- **Tedlar® PVF demonstrated strongest stability**







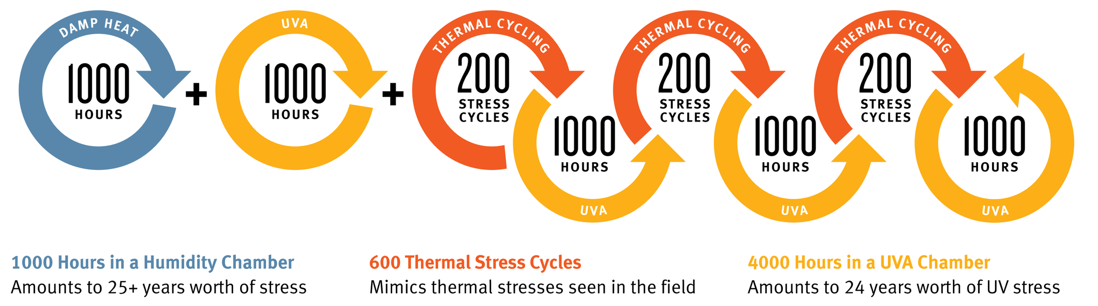
Yellowing = Polymer Degradation

Source: EU-Project SOPHIA—Fraunhofer Institute for Solar Energy Systems: Round Robin on UV-Testing with different radiation sources (started 2012). Ten backsheets tested; DuPont loss of mechanical strength study.

Module Accelerated Sequential Testing (MAST)

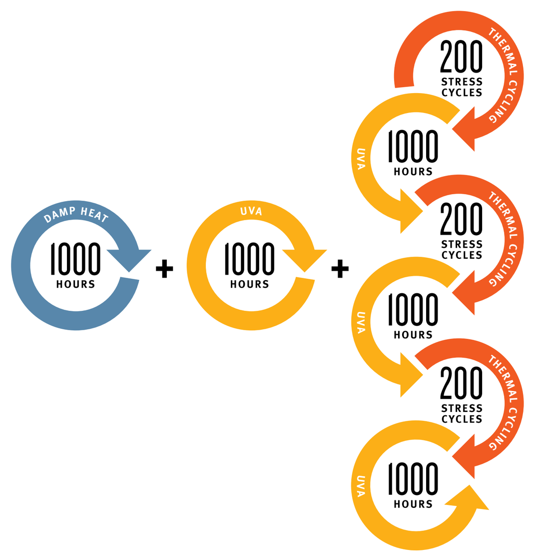
Broad adoption and use of the DuPont Module Accelerated Sequential Testing (MAST) as the **new standard in accurate, predictive backsheet field-testing:**

- Combines the most important stress factors in the field
- Most predictive single test for field performance
- Appropriate for component, minimodule, or full-size module testing



MAST is the best predictor of long-term reliability, simulating real-world conditions by repeating multiple field-aging stresses (UV, heat, humidity, thermal cycling).

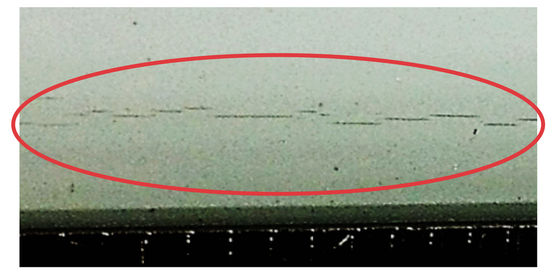
DuPont Materials Deliver Proven Performance



DuPont Module Accelerated Sequential Test (MAST)

	Double-Sided Fluoro		Single-Sided Fluoro		Non-Fluoro		
Measurement	Tedlar® PVF	PVDF	Tedlar® PVF	PVDF	PA (Polyamide)	HPET (Hydro-stabilized)	PET
Yellowing	● (Excellent)	● (Excellent)	● (Excellent)	● (Excellent)	● (Excellent)	● (Fair/Yellowing)	● (Poor/Cracking)
Mechanical Loss - Cracking	● (Excellent)	● (Poor/Cracking)	● (Excellent)	● (Poor/Cracking)	● (Poor/Cracking)	● (Poor/Cracking)	● (Poor/Cracking)

● Excellent ● Fair/Yellowing ● Poor/Cracking



PVDF/PET/FEVE Backsheet
Cracks of PVDF film found along ribbon after one thermal cycle.

PVDF backsheet shows cracking in sequential accelerated test after one thermal cycle.

Tedlar® PVF film-based backsheets demonstrate the best balance of properties across the tests required for long module lifetimes.

Summary of Recommendations

- Use proven materials that have been performing well in the field for many years.
- Adopt DuPont Module Accelerated Sequential Testing (MAST).
- Avoid materials and backsheets that show degradation and failures in sequential test protocols.