DuPont Photovoltaic Solutions

Risk mitigation strategies for solar assets by climate type and application sensitivity
Introducing innovation for bifacial c-Si panels

21 June 2018

Dr. Stephan Padlewski, Marketing Leader, EMEA
DuPont Photovoltaic Solutions
stephan.padlewski@dupont.com

DuPont Photovoltaic Materials Portfolio

DuPont™ Solamet®
Metallization Pastes

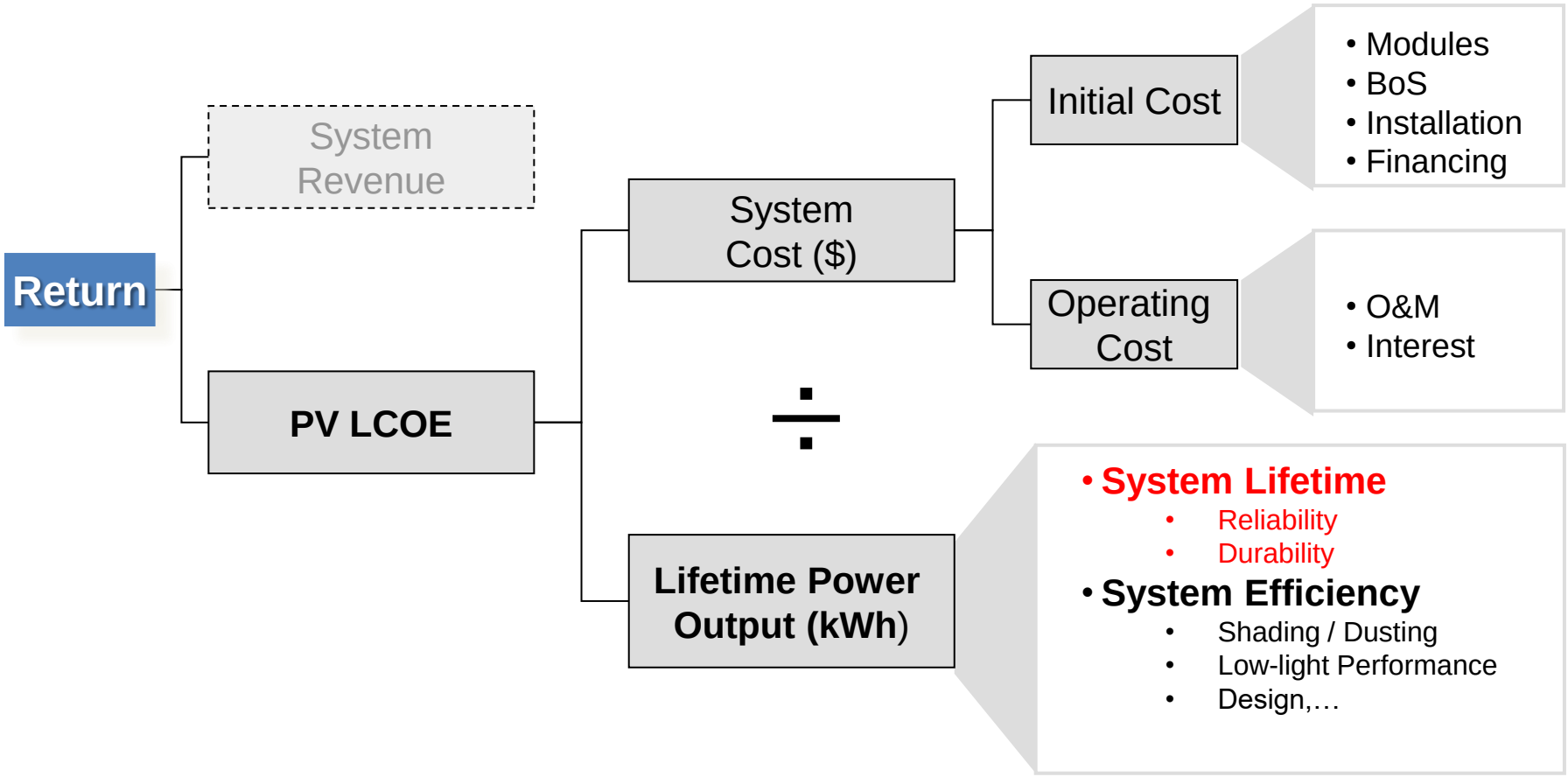
Driving higher energy conversion efficiency

DuPont™ Tedlar®
PVF Films for Backsheet

Protecting PV modules

Over 50% of panels installed in the field since 1975 contain DuPont materials

Levelized Cost of Energy (LCOE)



The Backsheet is Critical for Protecting the PV Panel

Stress Environment

Ultra Violet (UV)

- Transmitted
- Reflected

Temperature

- Peak
- Cycling

Moisture

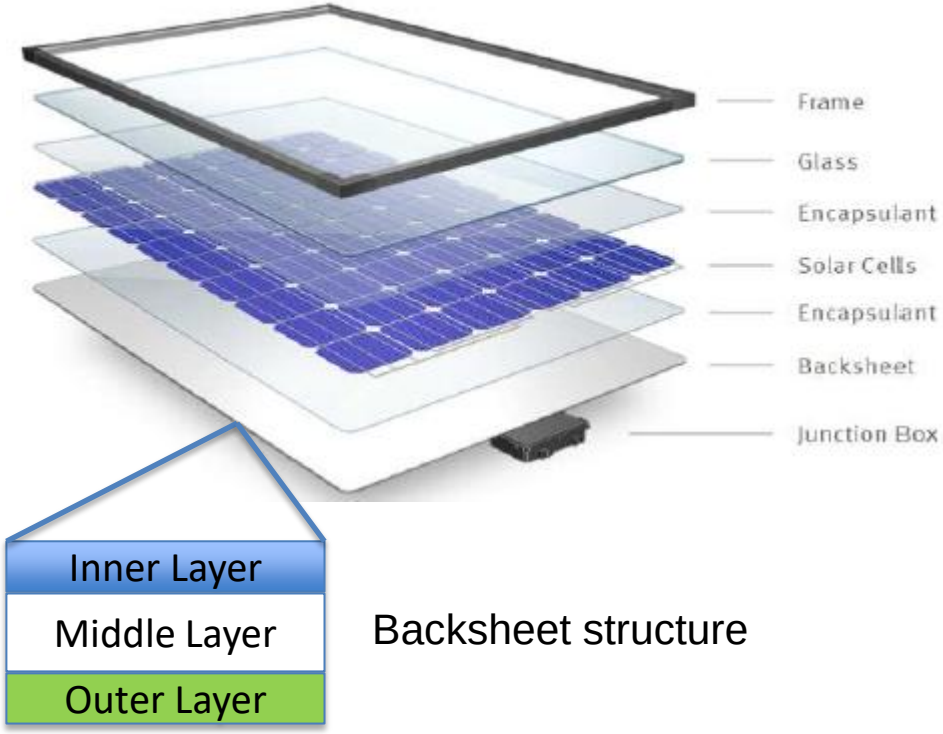
- Humidity
- Precipitation
- Condensation

Corrosive Environment

- Atmospheric chemicals
- Ammonia
- Marine environment

Physical Protection

- Abrasion
- Impact

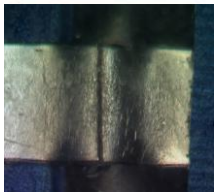


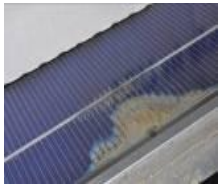
Backsheet structure

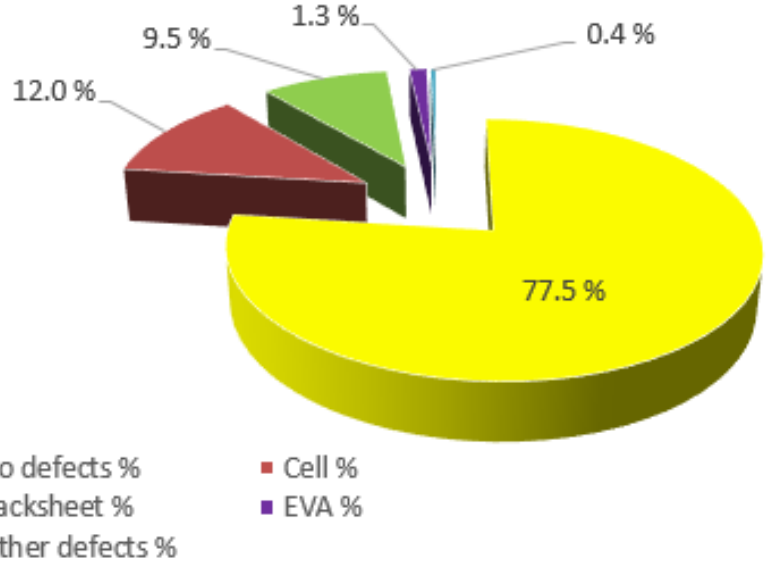
Backsheet must provide reliable electrical protection of module over the expected lifetime (and beyond)

Global DuPont Field Surveys (2017)

- Surveyed: **286** Installations in North America, Europe & Asia Pacific
- Figures reported below: 45 module manufacturers, 1,047 MW > 4.2 MM modules
- Range of exposure: from newly commissioned modules to 30 years in service
- From multiple climates

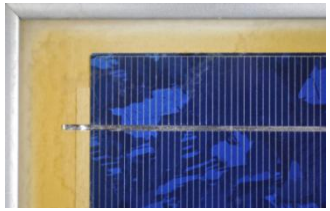






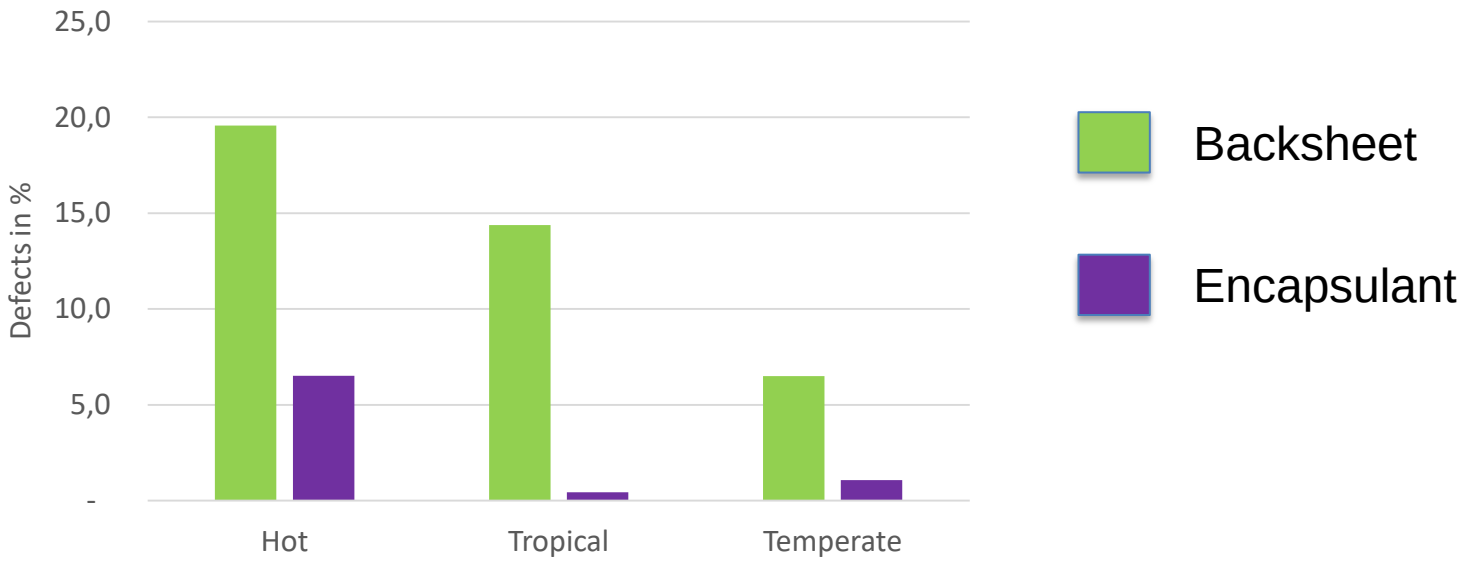
22.5% of panels affected

Backsheet is one of the main components affected



Source: DuPont Field Module Program 2017 analysis
Note: All percentage numbers are based on MW

Climatic Sensitivity vs. Polymer Degradation



$$k = Ae^{-\frac{E_a}{RT}}$$

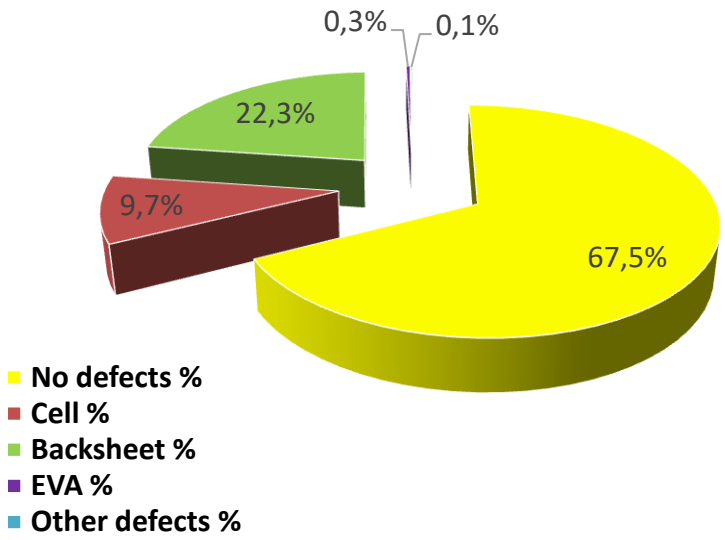
Temperature

Higher temperature seems to accelerate degradation rates of the encapsulant and backsheet

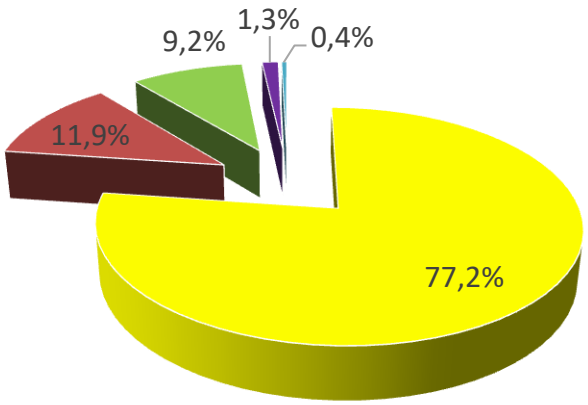
Source: DuPont Field Module Program 2017
Note: All percentage numbers are based on MW

Application Sensitivity

Rooftop Mounted



Ground Mounted



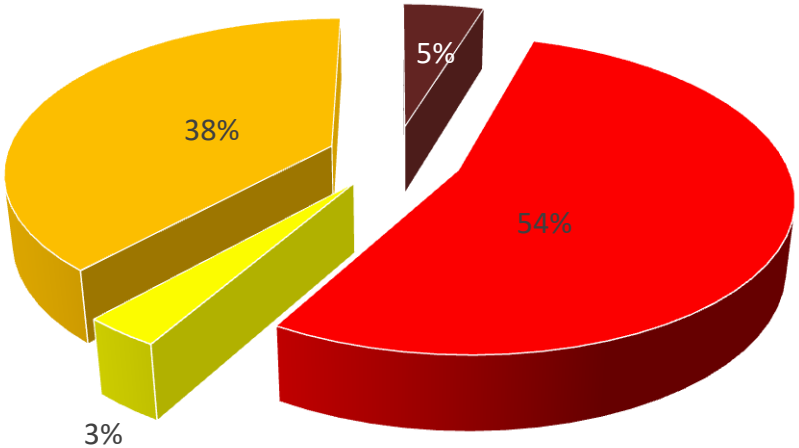
$$k = Ae^{-\frac{E_a}{RT}}$$

Temperature

Higher defect rates for rooftop vs ground installations. Differences are likely due to higher temperatures for rooftop systems

Source: DuPont Field Survey 2017

Types of Degradation Affecting the Backsheet



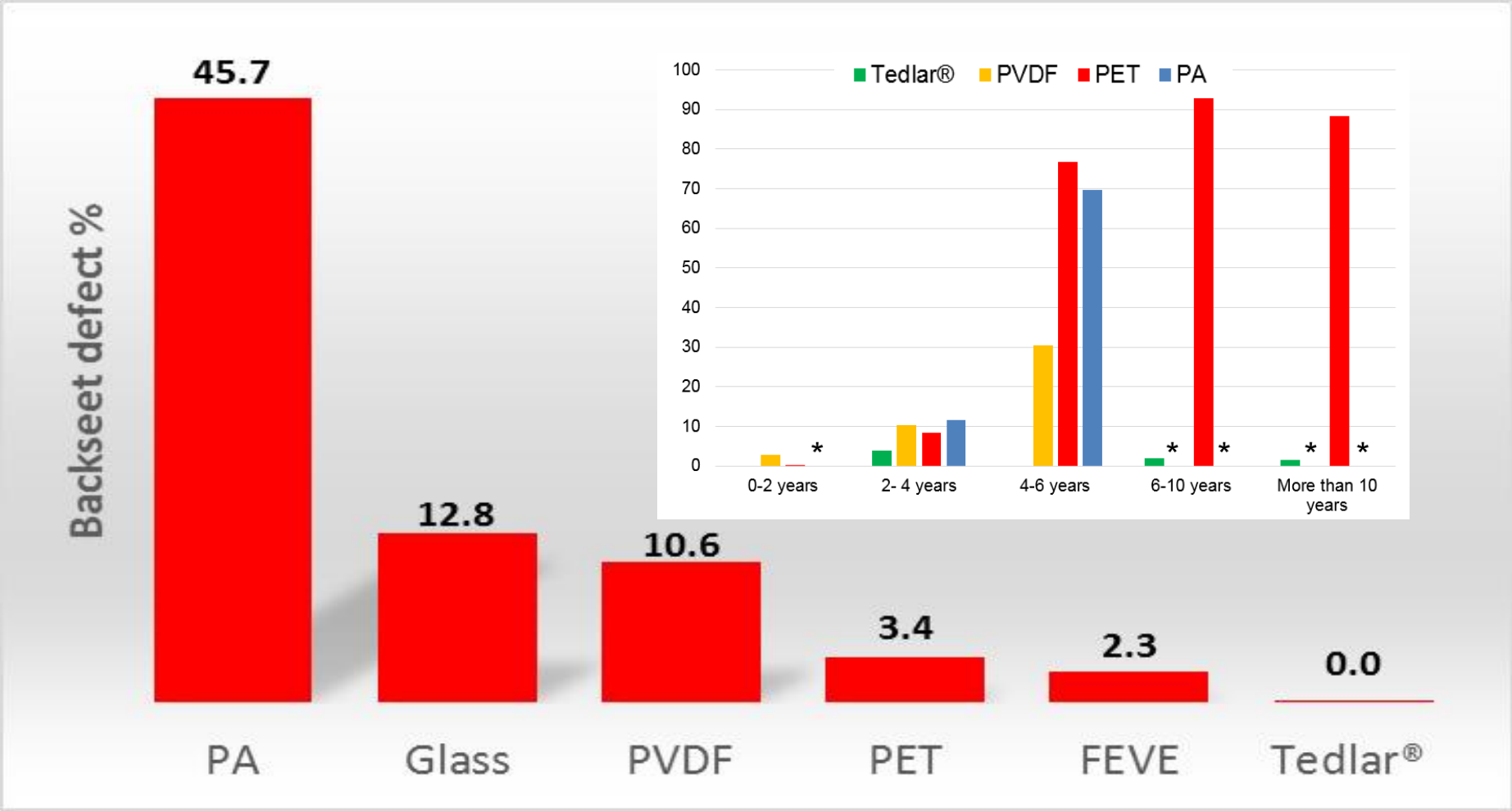
- Delamination
- Cracking
- Air side yellowing
- Front side Yellowing

Cracking and delamination represent serious threats to the electrical protection of the panel (59% of defects).
Yellowing is an indicator that the polymer has started to degrade

Source: DuPont Field Survey 2016

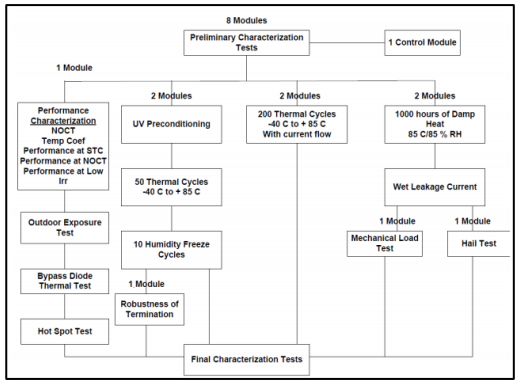
Material Sensitivity vs. Backsheet Defect Rates

Defect rate as a function of backsheet used

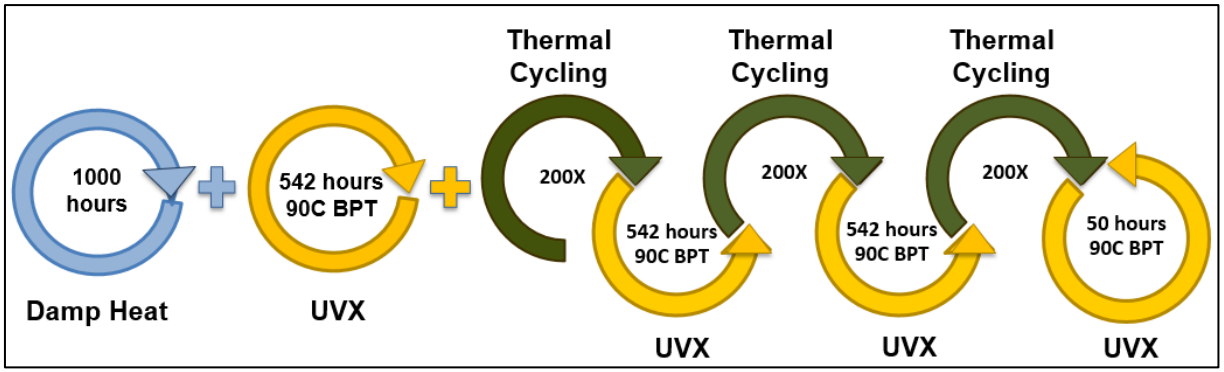


PA = Polyamide
PVDF = Polyvinylidene Difluoride
PET = Polyethylene Terephthalate
FEVE – Fluoroethylene Vinylether
* No field data available

DuPont Sequential Stress Test (MAST) vs. Field



IEC 6125



MAST (DuPont)

Stress	PET	PVDF	PA	Tedlar®	Comment
Field	Yellowing Mech Prop Loss Cracking	Cracking Front Side Yellowing	Yellowing Mech Prop Loss Cracking	Low defects	Effects of simultaneous and sequential stresses
Damp Heat (1000 hrs)	Slight Yellowing	No Change	Mech Prop Loss	No Change	Misses UV degradation
UV (4000 hrs)	Yellowing Mech Prop Loss	No Change	Mech Prop Loss	No Change	Misses hydrolysis and moisture
DH/UV/TC (MAST Sequential Test)	Yellowing Mech Prop Loss Cracking	Cracking Front Side Yellowing	Yellowing Mech Prop Loss Cracking	No Change	Combines key stresses Gives best correlation

Sequential tests correlate better with degradation seen in the field

- Combine most important stress factors
- Use stress levels / dosages that match field exposures
- Accelerate with highest temperature but
- Do NOT produce degradation not found in the field

Bifacial: An Opportunity to Lower LCOE

For ground installations operating in high albedo environments

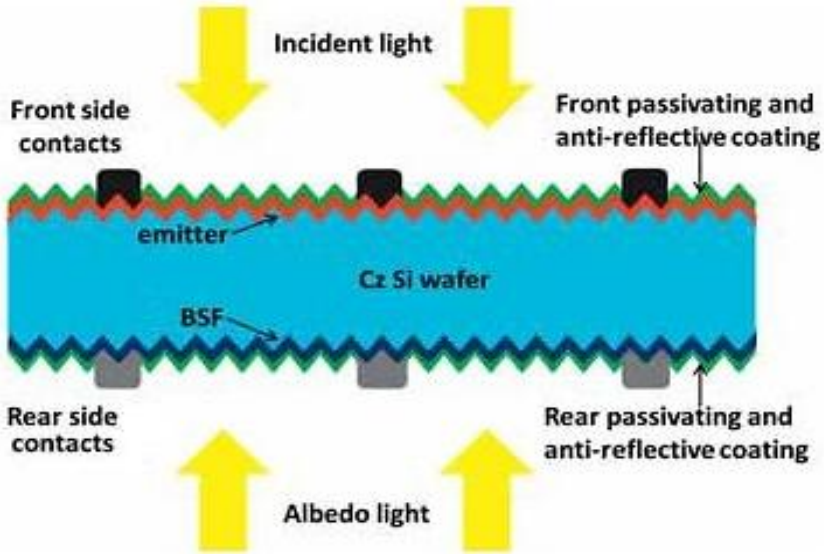
Benefits

- Can boost power output by 8-30%
  - System design, e.g. tracker, pitched
  - Ground characteristics, e.g. albedo
  - Cell technology
- Can use existing cell PV manufacturing infrastructure

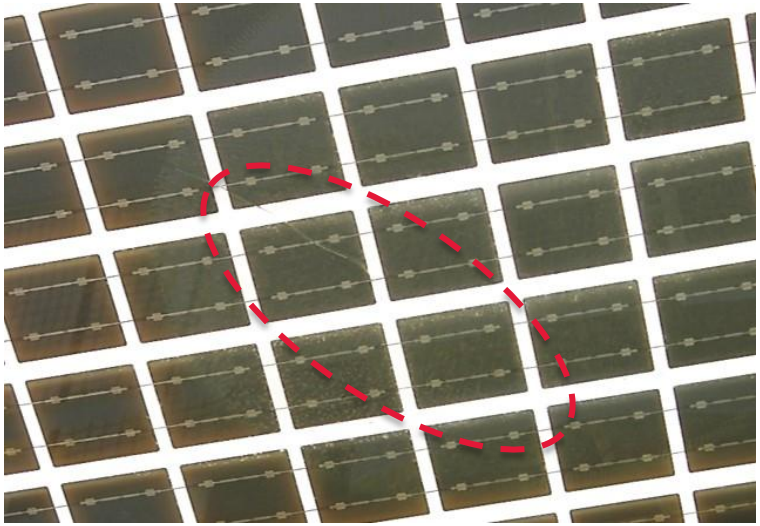
Concerns

- Glass-glass: weight, risk of cracking
- Frameless (usually), mounting
- Higher cost non-EVA encapsulant required
  - To prevent acetic acid entrapment
- Higher NOCT (by >3°C)
- Cost premium vs standard
- Lack of long track record in the field, bankability

Source: LONGi Solar

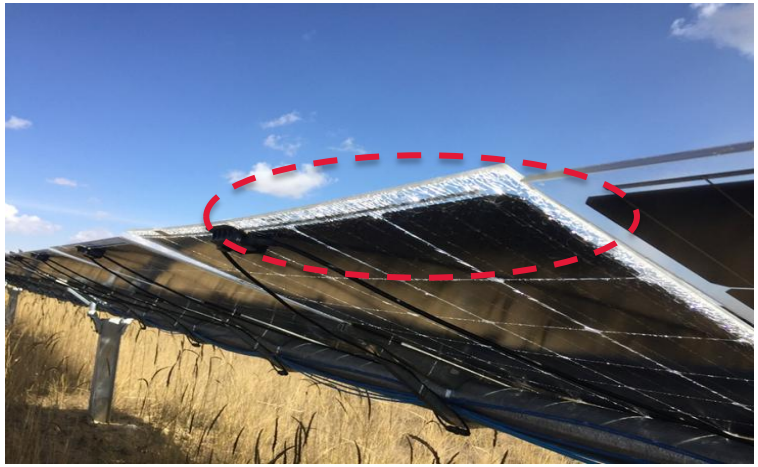


Glass-Glass Panels in the Field

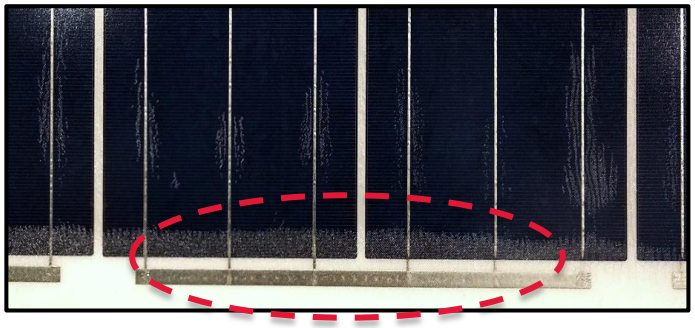


2008: Cracking glass

2016: Bending



2016: Edge cracking, bending

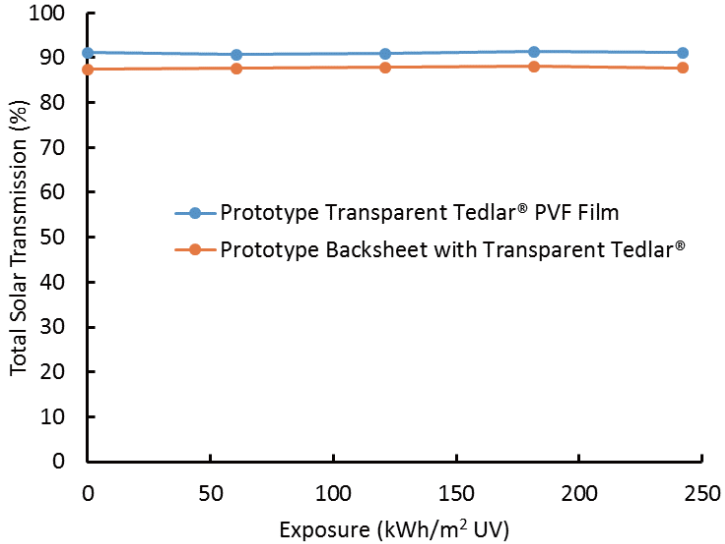


2016: Delamination

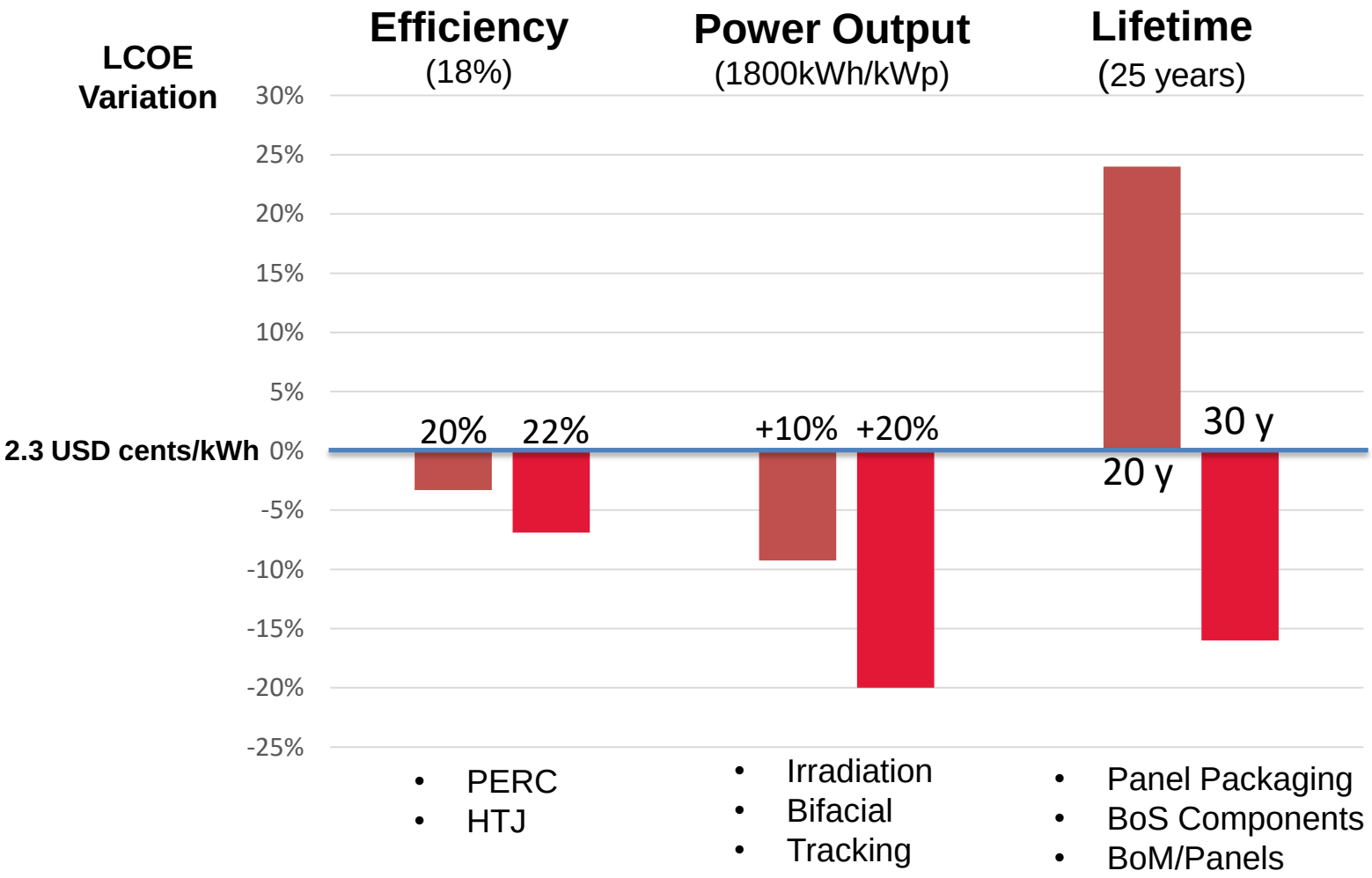
Durable Clear Tedlar® for Transparent Backsheets

Key Properties

- Field-proven, 20+ years
- High transparency
- Compatible with incumbent production assembly
- Blocks UV durably
- Compatible with EVA (breathable)
- Lighter weight
- Easier mounting, framed panels



LCOE Sensitivity



Summary

- Think in terms of USD/kWh rather than USD/Wp - reliability & durability are key
- IEC certification is not designed to predict the long-term performance of the panels, consider sequential testing approach, as more representative of field observations
- Consider field-proven BoM, select the most UV and thermally resistant backsheet materials, if panels are expected to operate in harsh environments
- Bifacial system designs have the potential to significantly improve power output. But the use of glass-glass may impact panel durability
- PV cell innovation can significantly lower LCOE; preserving/extending panel lifetime is also critical
- Mitigate risks through panel and BoM selection, and EPC and O&M best practices.

photovoltaics.dupont.com