DuPont Photovoltaic Solutions

Risk mitigation measures to help protect solar assets for the long-term

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For over 40 years

our material innovations have led the photovoltaics industry forward, and helped our clients transform the power of the Sun into power for us all. Today we offer a portfolio of solutions that deliver proven power and lasting value over the long term. Whatever your material needs, you can count on quality DuPont Photovoltaic Solutions to deliver the performance, efficiency and value you require, day after day after day…

DuPont Photovoltaic Materials Portfolio

DuPont™ Solamet®
Metallization Pastes

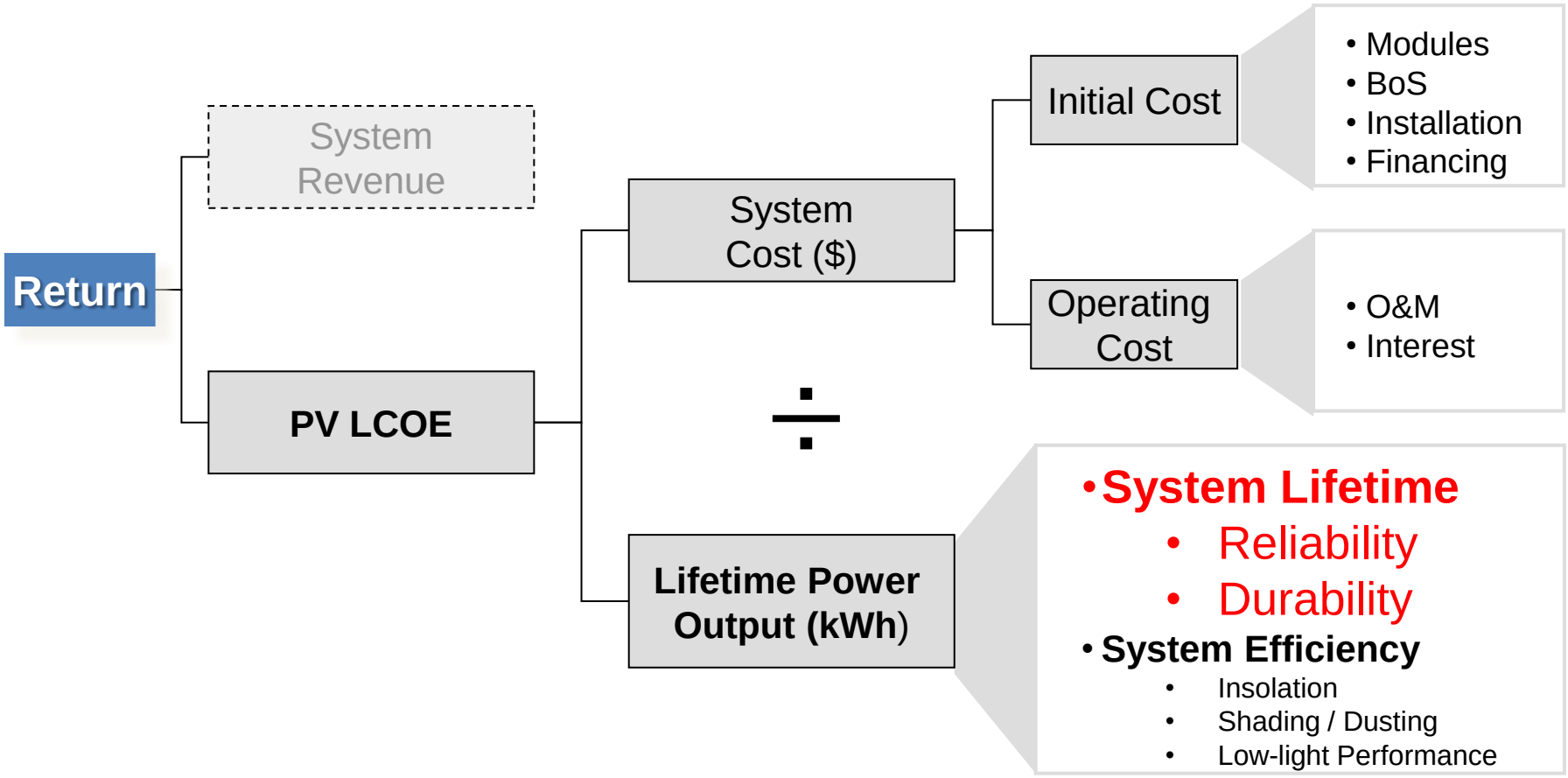
Driving higher energy conversion efficiency

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

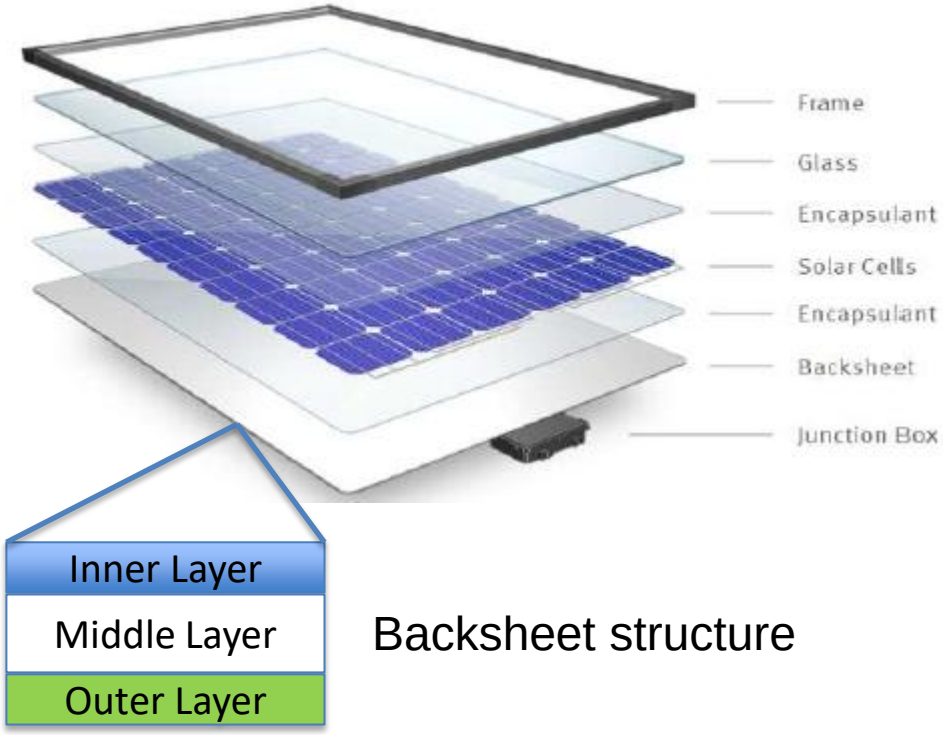
- Humidity
- Precipitation
- Condensation

Corrosive Environment

- Atmospheric chemicals
- Ammonia
- Marine environment

Physical Protection

- Abrasion
- Impact

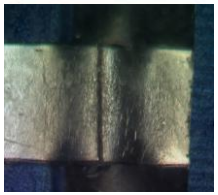


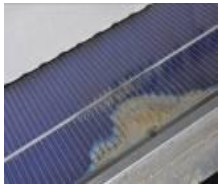
Backsheet structure

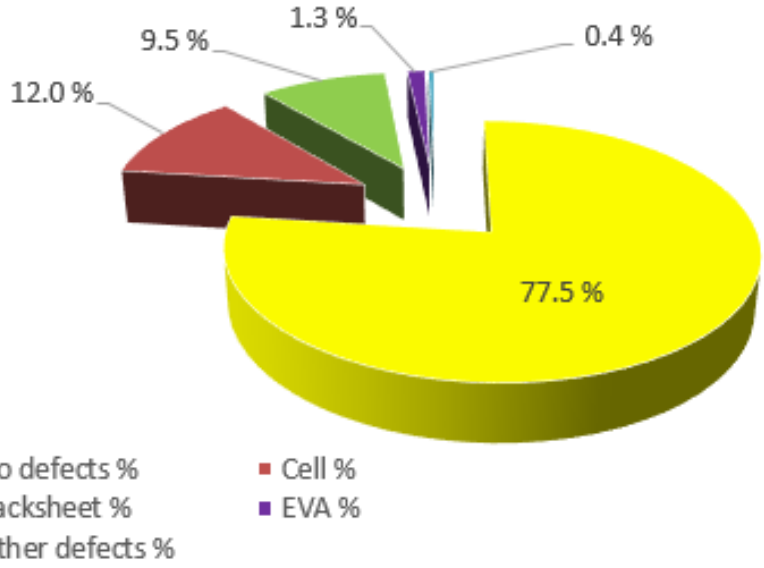
Backsheet must provide reliable electrical protection of module over the expected lifetime (and beyond)

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

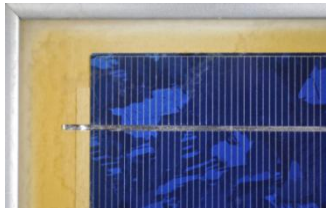






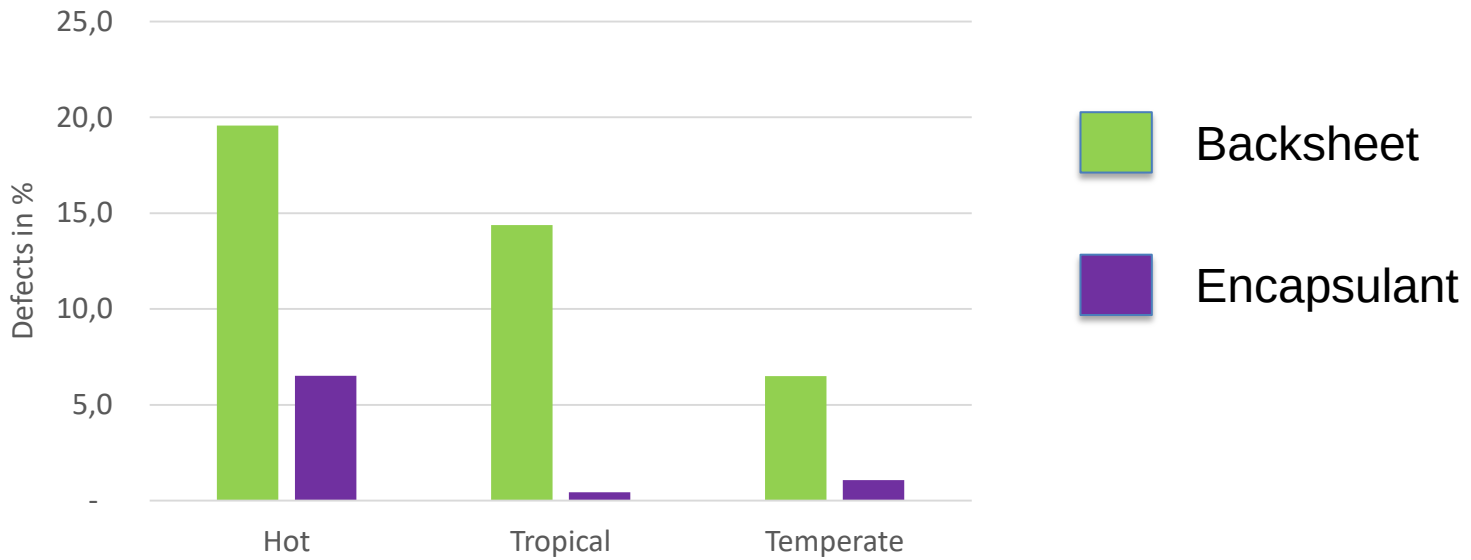
22.5% of panels affected

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



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

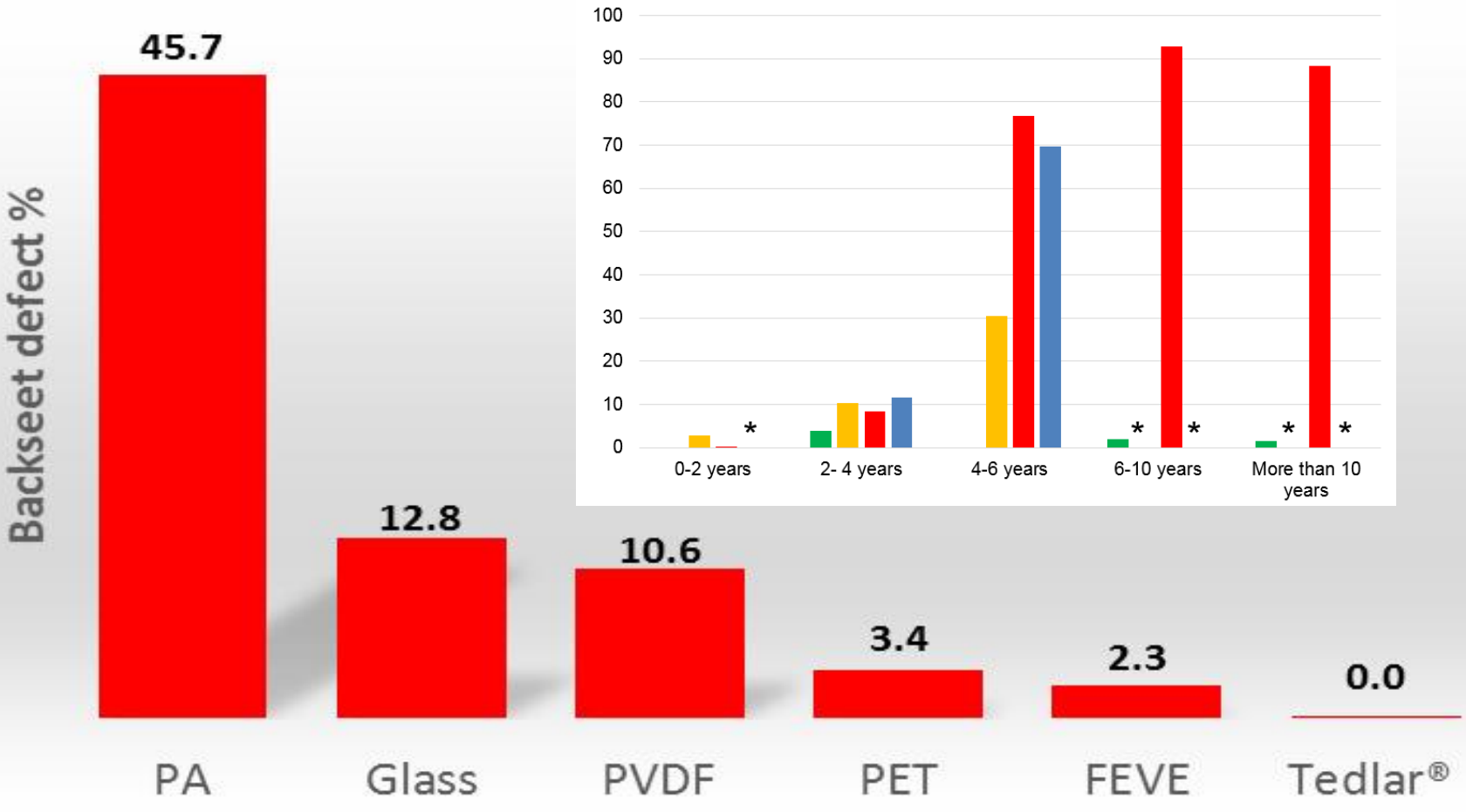
Temperature

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

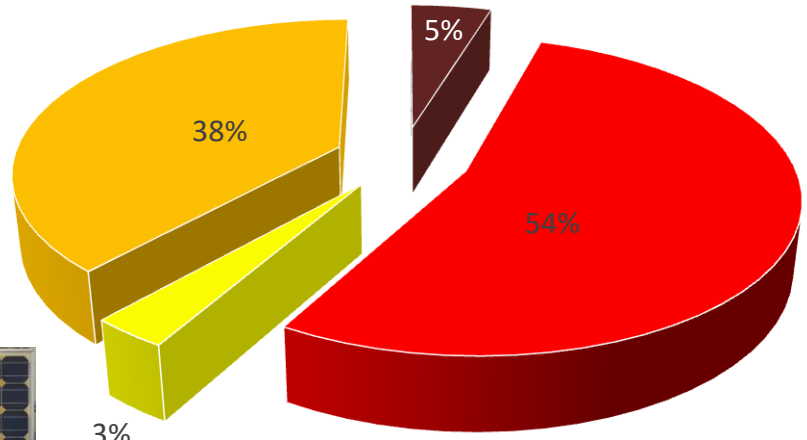
Material Sensitivity vs. Backsheet Defect Rates

Defect rate as a function of backsheet used



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

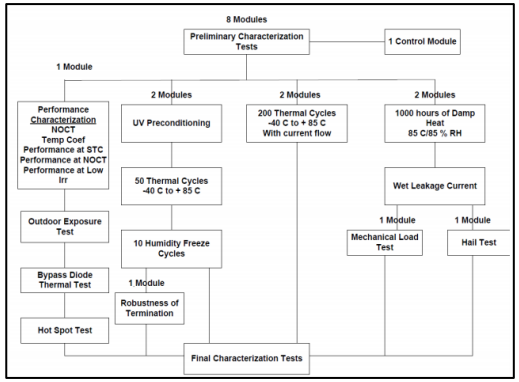
Types of Degradation Affecting the Backsheet



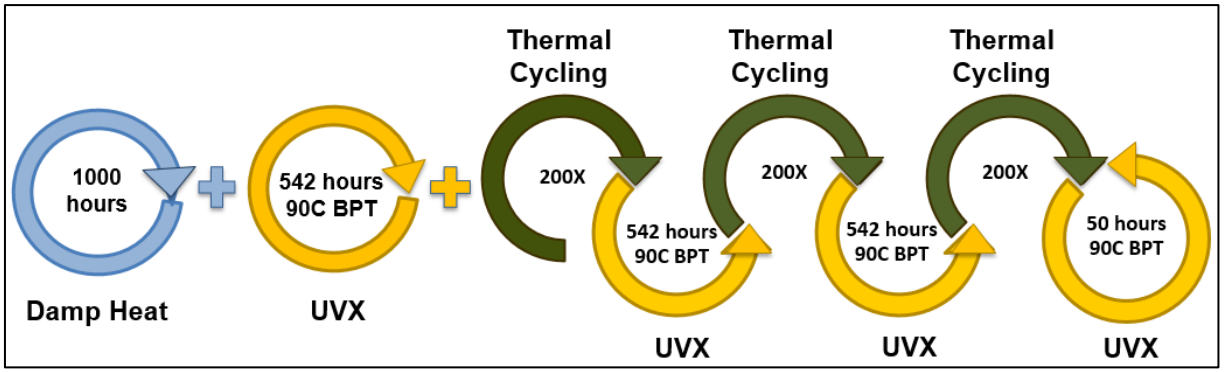
Cracking and delamination represent serious threats to the electrical protection of the panel (59% of defects). Yellowing is an indicator that the polymer has started to degrade

Source: DuPont Field Survey 2016

DuPont Sequential Stress Test (MAST) vs. Field



IEC 6125



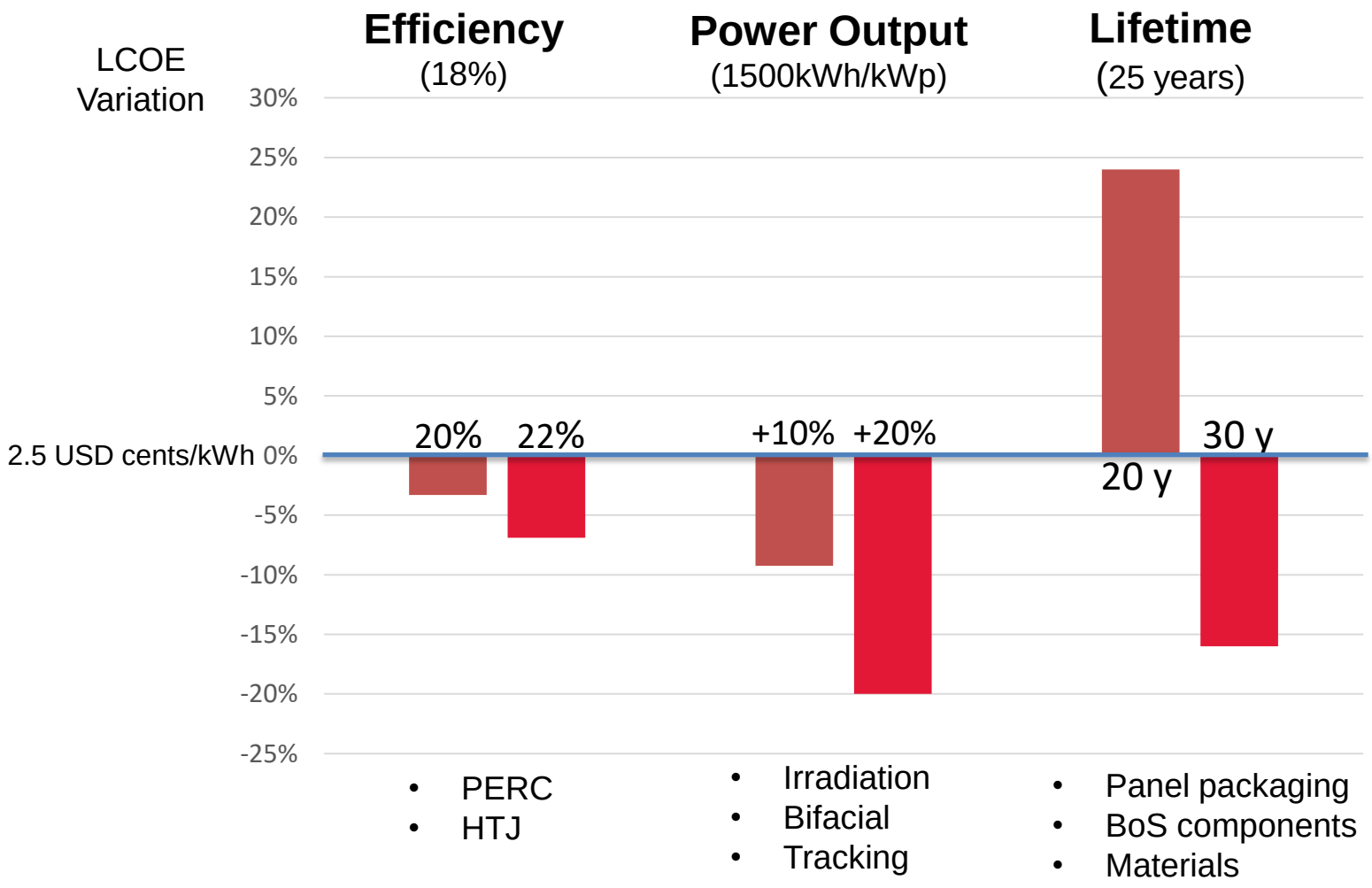
MAST (DuPont)

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

LCOE Sensitivity



Summary

- Think in terms of EUR/kWh rather than EUR/Wp - reliability & durability are key
- IEC certification is not designed to predict the long-term performance of the panels
- Consider alternative sequential testing approach (MAST) to better simulate the field stress conditions and mimic actual defects observed
- Consider field-proven materials and panel construction, UV and thermal resistant – especially in harsh climatic and temperature-sensitive environments
- Work with trusted partners up and down the value chain who have a proven field track record.

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