PV System Performance and Reliability - Quo Vadis?

Mitigating risks of premature solar panel failure in the field

September 17th, 2015 – EU PVSEC

Dr. Lucie Garreau-iles

EMEA Technical Manager, DuPont Photovoltaic Solutions

DuPont: the Leading Material Supplier in PV

Solamet® Metallization Pastes

Driving higher energy conversion efficiency

Tedlar® PVF Films for Backsheet

Protecting PV modules

Elvax® and Ionomer Encapsulants

Delivering long term protection of cells

+110

Over the last 7 years, DuPont has introduced more than 110 new Solamet® pastes designed to boost solar panel power output.

+30 YEARS

Tedlar® film is the only backsheet material proven to protect solar panels for 30+ years in all weather conditions.

+50%

More than half of the world's 700 million solar panels installed since 1975 have DuPont materials in them.

+11 TRILLION

DuPont materials have been time-tested in >11 trillion panel-hours of solar installations across the globe since 1975.

Industry Standards not Reflecting Long-term Performance

IEC testing protocols do not adequately simulate the performance in the environment

Qualification Tests

- **1 to 2 stresses in series**
- 15 kWh per m2 of UV radiation (front) – no irradiation on the back
- **200 thermal cycles**
- **No solar load (not in operation) in testing chambers**

25 Years In-Field

- **Multiple environmental and mechanical stresses**
- 171 kWh per m2 rear side of UV radiation (temperate) *
- **1000s of thermal cycles**
- **Higher operating temperature**
- **Stresses endured with solar load (in operation)**

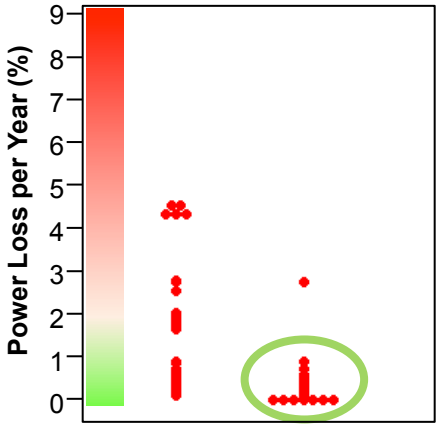
"Long-term outdoor exposure is the ultimate test for all module components, material quality and manufacturing quality."*

* Artur Skoczek, Tony Sample, and Ewan D. Dunlop, *The Results of Performance Measurements of Field-aged Crystalline Silicon Photovoltaic Modules,* Wiley InterScience, 2008

Independent Testing Validates Performance Advantage of Tedlar®PVF: Long Module Life, with Low & Tightly Distributed Power Loss

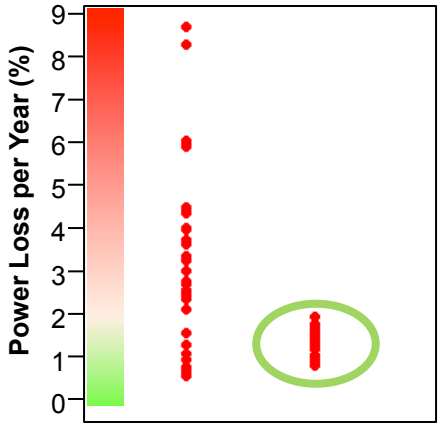
PV Module Power Loss After Years of Outdoor Operation

Glass vs. Tedlar®*



Backsheet →	Glass	Tedlar®-based
Age of tested modules (years in field) →	20-23	19-23

PET vs. Tedlar®**



	PET-based	Tedlar® TPT-based
	5-14	11-19

PVDF vs. Tedlar®

No PVDF data available

Not used in PV 10+ years ago

Variable PVDF film characteristics from 5+ film providers

Tedlar® is the only backsheet material proven to deliver superior outdoor PV performance for decades

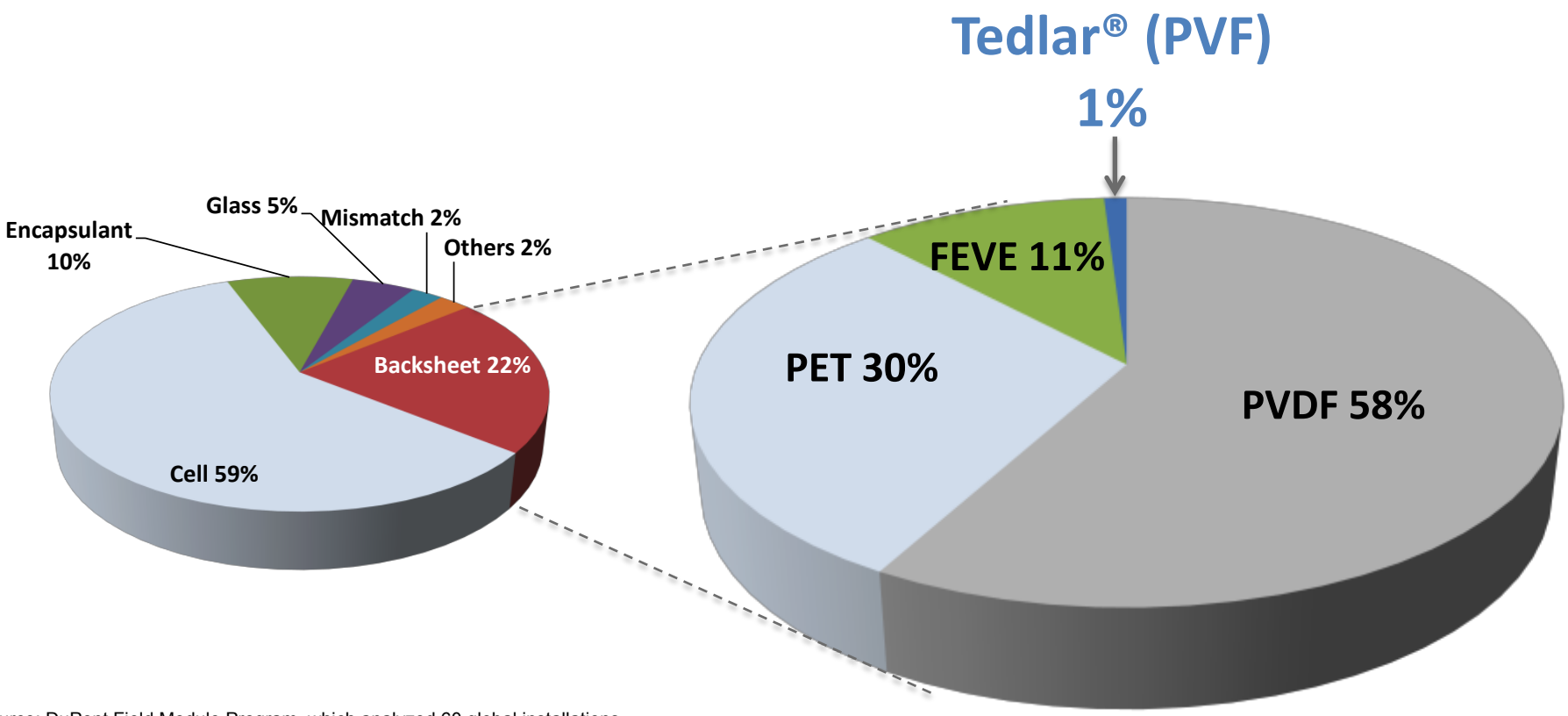
Source: * Joint Research Centre (Italy)

** AIST (Japan)

DuPont™ Tedlar® PVF Film-Based Backsheet Demonstrates Outstanding Reliability

Visual Defects by Component*

% of Backsheet with Visual Issues

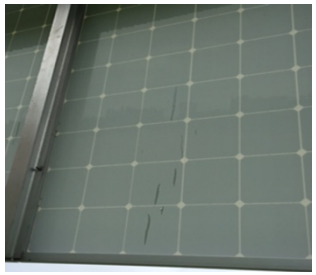


Source: DuPont Field Module Program, which analyzed 60 global installations
Note: All percentage numbers are based on MW
* PVF (Polyvinyl Fluoride), PVDF (Polyvinylidene Fluoride)
PET (Polyethylene Terephthalate), FEVE (Fluorinated Ethylene Vinyl Ether)

Fielded Module Program Summary

- **Surveyed: >60 global solar installations in NA, EU & AP**
- **45 module manufacturers, > 150 MW, > 700,000 modules**
- **Range of Exposure: Newly commissioned modules to 30 years in the service environment**

Backsheet Based:	Tedlar®	PVDF	PET	FEVE
Profile of Sample Size	30 Installations 20 MW 122K Modules	24 Installations 104 MW 403K Modules	15 Installations 23 MW 112K Modules	4 Installations 21 MW 102K Modules
Avg System Age **Avg Range**	10.5 years 2 - 27 years	3.2 years 2 - 5 years	6.5 years 2 - 15 years	3.75 years 3 - 5 years
Fields with Identified Defects	**3/30 (10%)**	**12/24 (50%)**	**11/15 (73%)**	**2/4 (50%)**
Percentage Defects on MW Basis	**0.1%** (15kW / 20MW)	**43%** (44/104 MW)	**39%** (9/23 MW)	**29%** (6/21 MW)
Types of Defects Observed	Delamination Cracking* * Only in 4 mil single layer	Frontside Yellowing Cracking	Frontside or Backside Yellowing Delamination / Cracking	Backside Yellowing Delamination / Cracking



Two very different outcomes

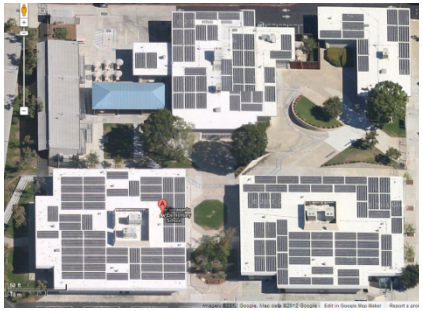
6 Years Later: "Faulty solar panels pulled from 24 schools"*

Stated Expectations (2006, 2007; PPA):

- "Wanted on-site generation at predictable rates but we didn't want any upfront costs."
- "Expected to provide the lion's share of our peak power needs"

Results – after 6 years:

- Defect discovered that created potential safety hazard
- SDCS lost future savings from the PV (now purchasing power from the grid)



*Source: San Diego Union Tribune: Sept 13, 2012

28 Years Later: "SMUD forges a new path in Photovoltaics Generation "*

Stated Objectives

- "PV is an excellent match for our generating needs"
- "The Utility specified the type and level of quality assurance it would expect"
- "We laid down the basic criteria for the design and manufacture of the PV modules"

Results – 28 Years with Tedlar® PVF Backsheet

- First large scale (1 MW) utility PV generation facility in the world
- Expected power provided for 28 years

*Source: Electric Light & Power, August 1984

Minimal Cost Difference Between Tedlar® PVF Film-Based Backsheet and "Non-Proven" Backsheets

Cost difference between Tedlar® PVF film-based backsheet and specialty PET-based backsheet	Days of operation needed to cover the cost difference
$0.003~0.015/W*	**Only 5~25 days**** **operation out of entire lifetime**

* Difference derived from TPT (Tedlar®/Polyester/Tedlar® backsheet) and TPE
** DuPont calculation based on following assumptions
*** Financial calculation varies by location
Location: California, U.S.
Panel output: 270W
Efficiency rate: 18%
Performance ratio: 78%
Source of electricity price data: U.S. EIA