Materials Matter™
For Higher Returns

Innovating Photovoltaics: the Way Ahead
Solar Europe Industry Initiative
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The miracles of science™

DuPont PV Materials Impact Three Critical Areas

1. Efficiency	2. Lifetime	3. BoS Cost
Industry roadmap to 20+% c-Si cells, enabled by new materials	Robust materials enabling >30 year module lifetimes with high performance	Lower cost, light-weight polymers to replace glass and metals

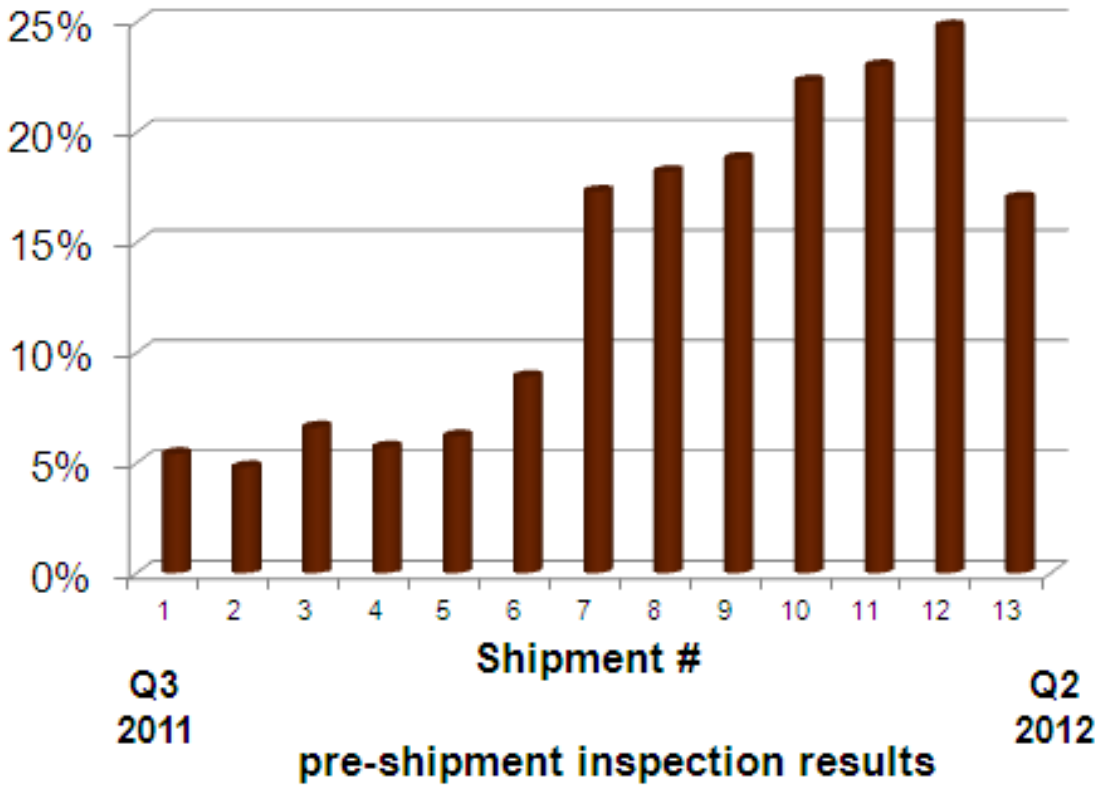
Drive lower PV LCOE to achieve grid parity and higher returns

Know What's In Your Module – Materials Matter™

Unproven and inferior materials are being substituted in modules – threatening durability and lifetime

System Issues and Failures are Real and Recent

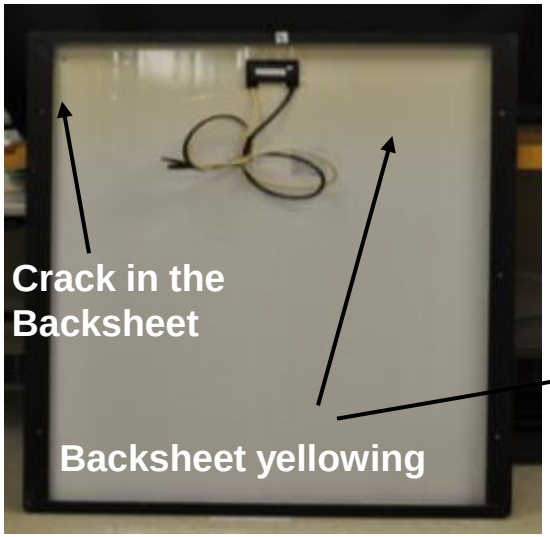
Rate of defective modules at the factory gate



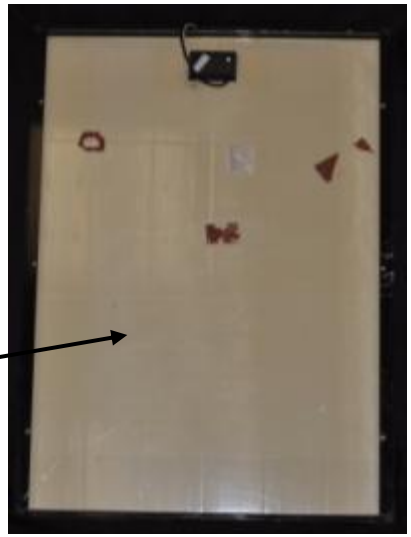
SolarBuyer - 2012

Material Choices Drive Real Differences in Lifetime Power Output and Failure

Module 1



Module 2

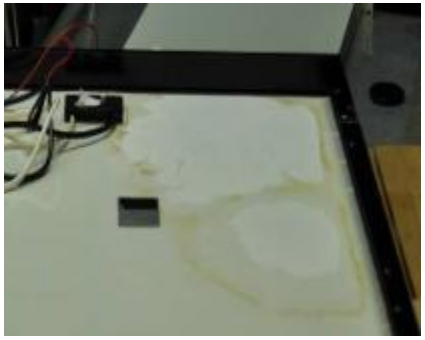


Module 3

	Duration in Service	Nameplate Rating Cell Type	Wet Leakage	IV Measurement % Degradation % Degradation/Yr	b* (Yellowing of backsheet)
Module 1	**10 Yrs**	**143 W mono-Si**	**Pass**	**77W 46% 4.6%**	**9.0**
Module 2	**12 Yrs**	**125 W poly-Si**	**Fail**	**105 W 16% 1.3%**	**14.2**
Module 3	**11 Yrs**	**100 W mono-Si**	**Pass**	**91 W 9 % 0.8%**	**2.7**

Failure Modes of Backsheets in the Field

Japanese
Tier-1 Module Maker

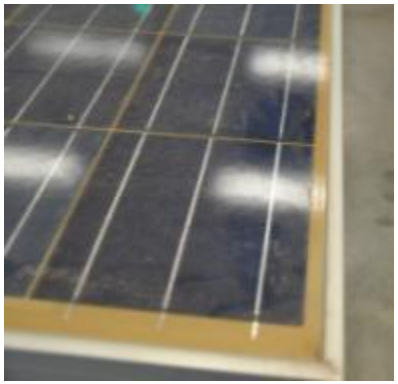


- 12 Year-old Modules
- 46% Power Loss

U.S.
Tier-1 Module Maker

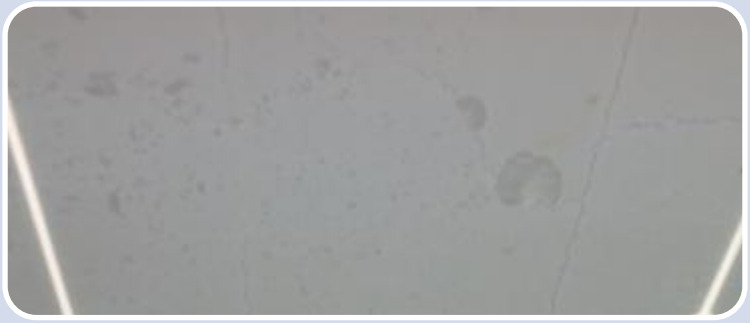
- 4 Year-old Modules
- $265MM Warranty Claims & Reparation Payments

China
Tier-1 Module Maker



- 1 Year-old Modules
- Severe Backsheet Yellowing
- Module Hot Spots

Premature Degradation in Fielded Modules

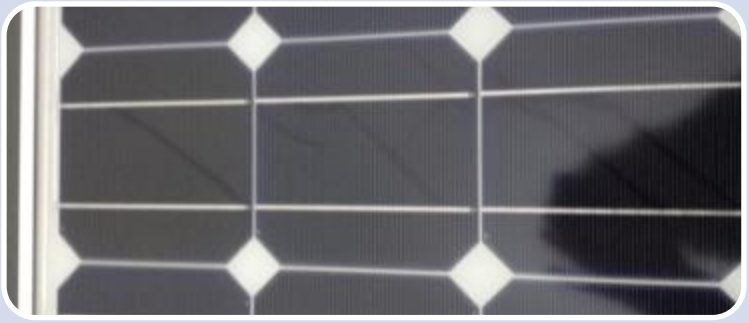


Module 4 - type B

Cracked backsheet

Safety concern

All of the type B modules affected



Module 4 - type A

Snail trails

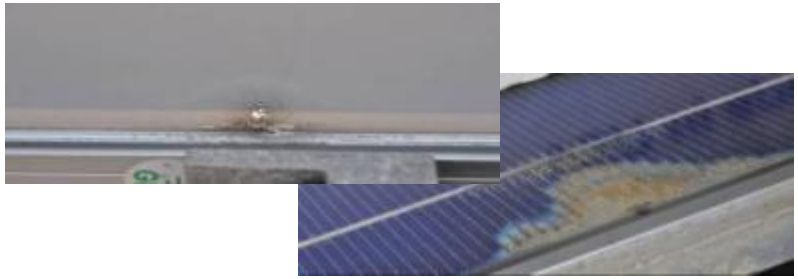
Frequent occurrence, ca. 30% of type A modules affected

Valencia, Spain, ground mounted system, 4 years old

Warranties and “Bankability Status” Are No Longer Effective in Mitigating Risk

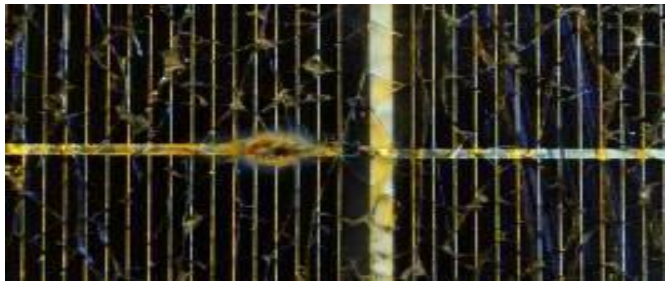
Example 1
Ground Mounted; c-Si modules
4 years old at time of discovery

- Installation error
  - Backsheet puncture
  - Frontside cell and metallization corrosion
- Form factor no longer available–no recourse



Example 2
Rooftop Mounted; c-Si modules
4 years old at time of discovery

- Shattered glass – 3% of modules
  - Mechanical stress from installation
  - Interconnect breakage
- Cannibalized array
  - “Finger pointing” installer and module maker
  - Module maker subsequently out of business
  - 6 months downtime



Lifetime: Accelerated vs. Field Testing

IEC testing protocols do not adequately simulate field stress environment

Qualification Tests

- **1 to 2 stresses in series**
- **15 kWh per m2 of UV radiation**
- **200 thermal cycles**
- **No solar load (not in operation) in testing chambers**

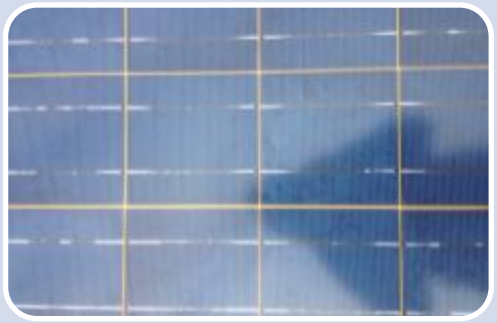
25 Years In-Field

- **Multiple environmental and mechanical stresses**
- **1.5 MWh of UV radiation***
- **1000s of thermal cycles**
- **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

Tier 1 Module Manufacturer, IEC Certified

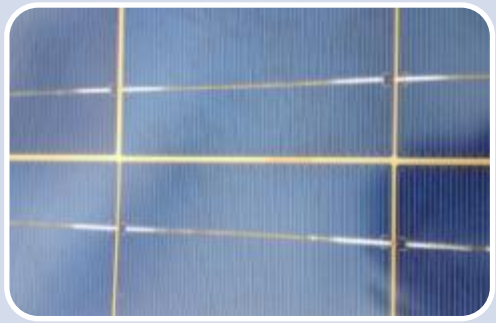


Module 3

4 Years Old / Valencia

Backsheet yellowing on the EVA side of the backsheet

100% occurrence in the park

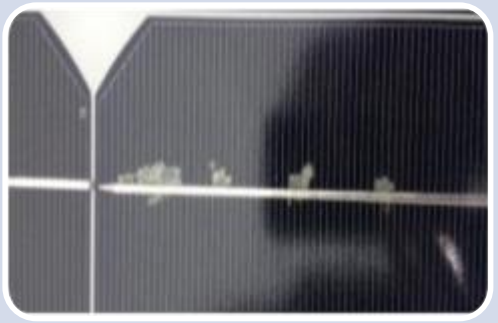


Module 3

4 Years Old / Valencia

Solder ribbon blackening (does not look like corrosion)

100% occurrence in the park



Module 3

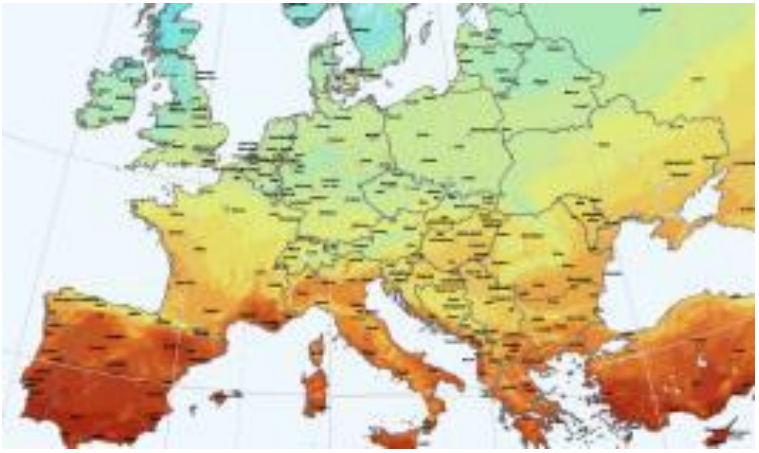
6 Years Old / Valencia

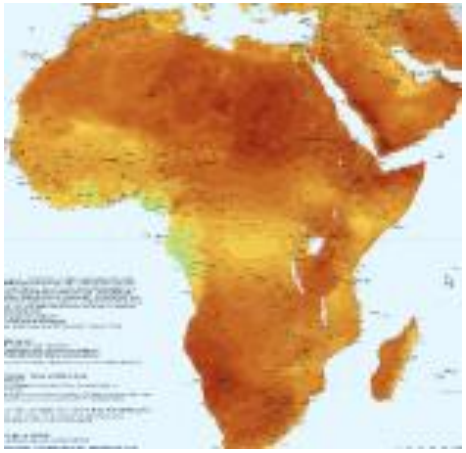
Silver trails

Close monitoring to detect potential for loss of power

20% of modules (at various degrees)

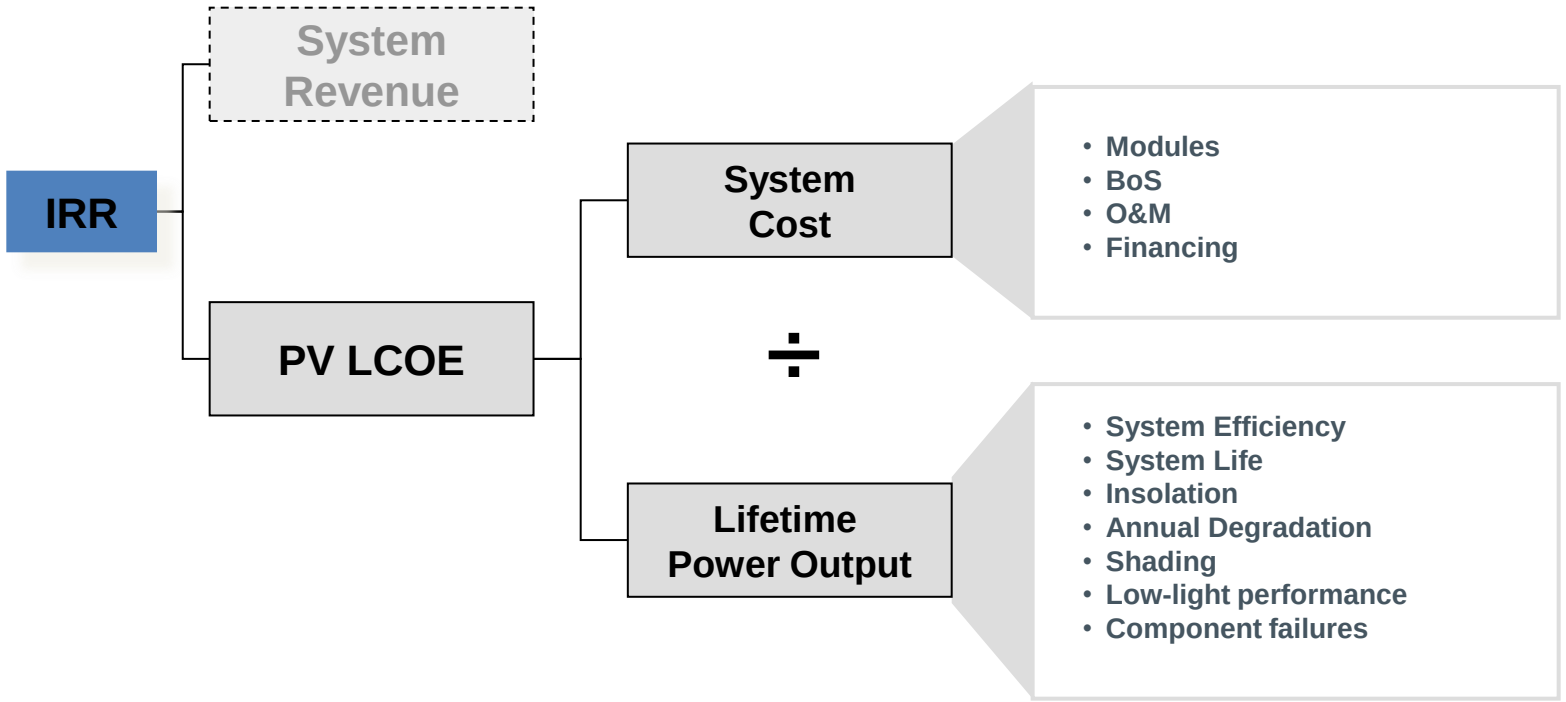
Recommended UV Exposures Based on Climate



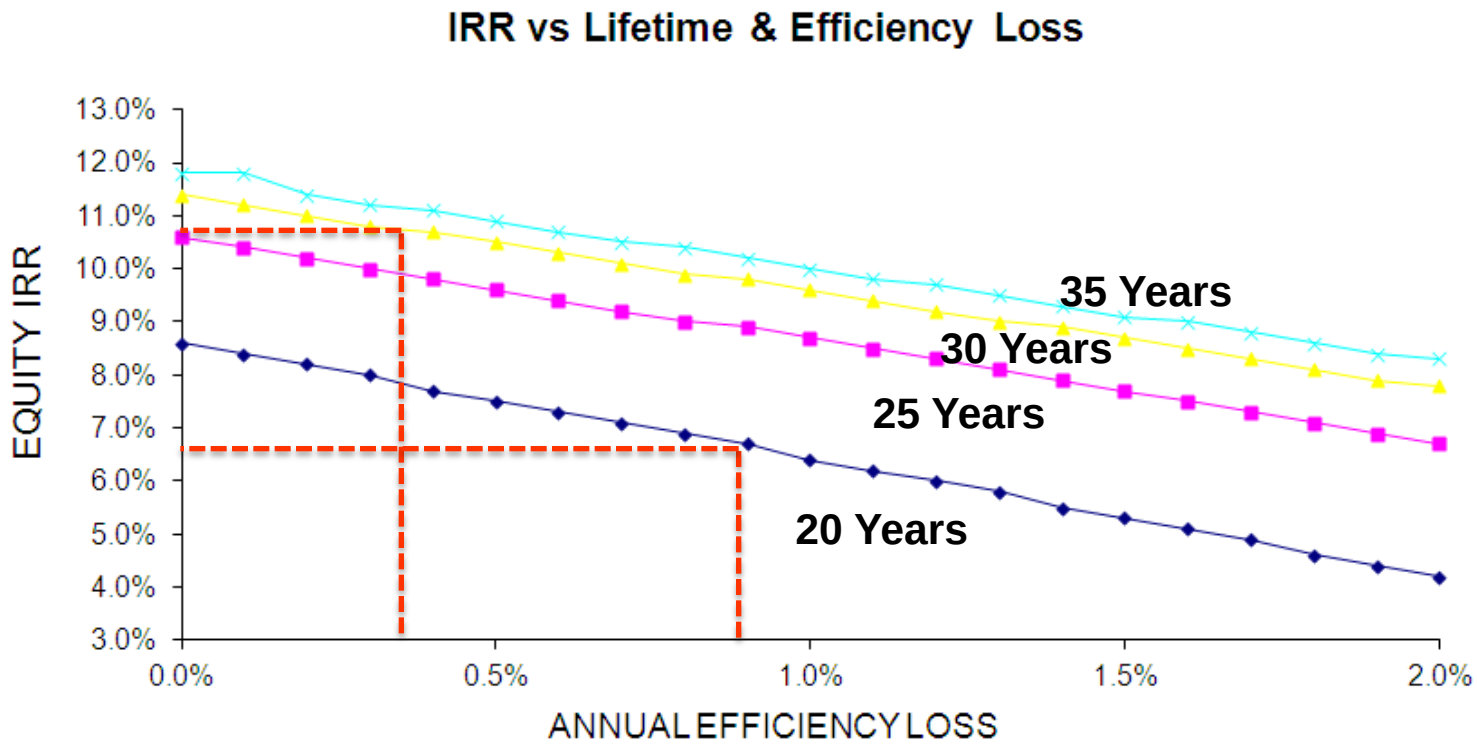


	Desert	Tropical	Temperate
Annual UV (kWh/m2) **(source Atlas)**	**92**	**79**	**57**
25 year UV Exposure to Back of Module @12% albedo (kWh/m^2)	**275**	**235**	**171**
IEC	**15kWh/m2** pre-conditioning		
UV Exposure Level to Simulate 25 years (hrs)	**4230**	**3630**	**2630**

LCOE – the Better Measure of Overall Cost of Ownership



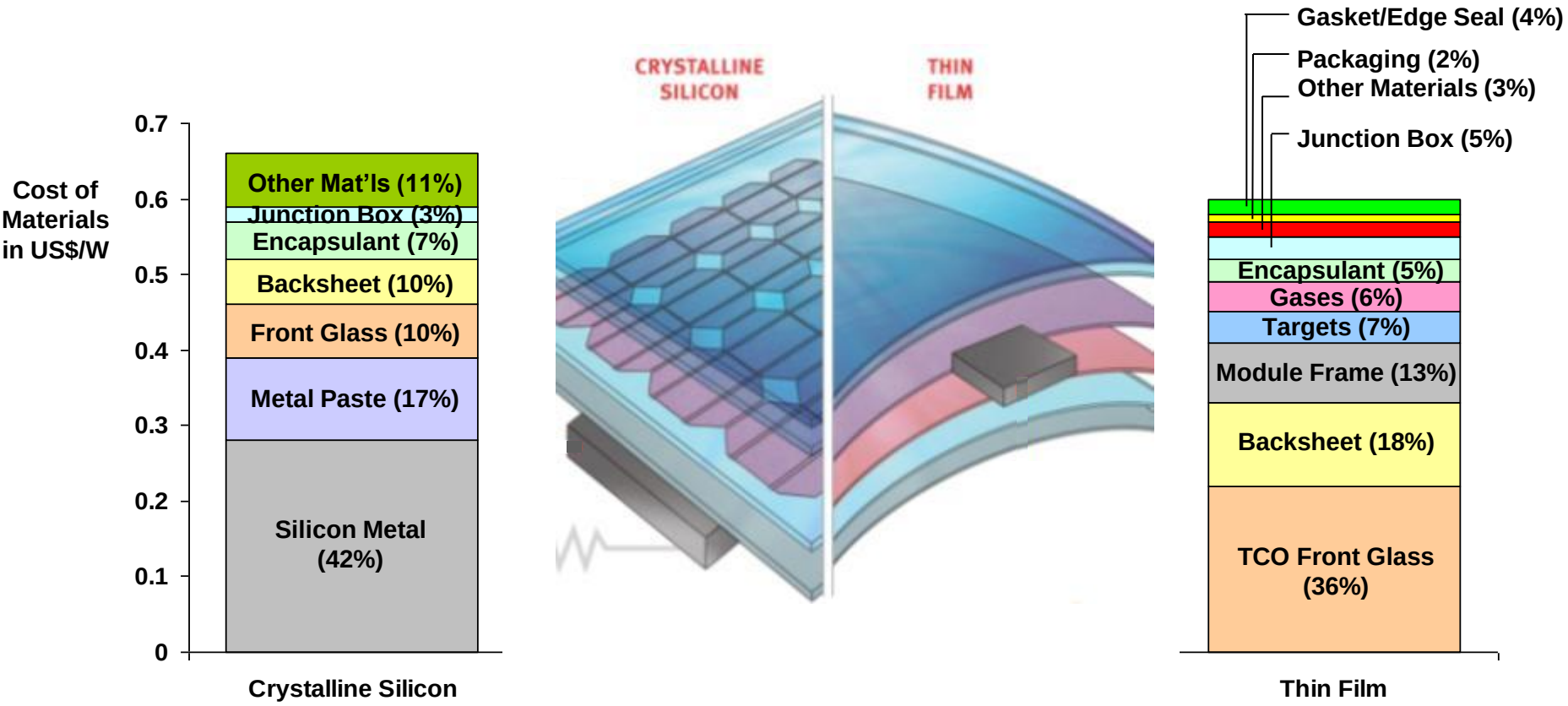
Reliability & Durability Impact IRR



Modules that can improve expected power output and lifetime. Premium cost can translate into lower LCOE and higher IRR!!

Materials Cost Impact on PV Cells & Modules

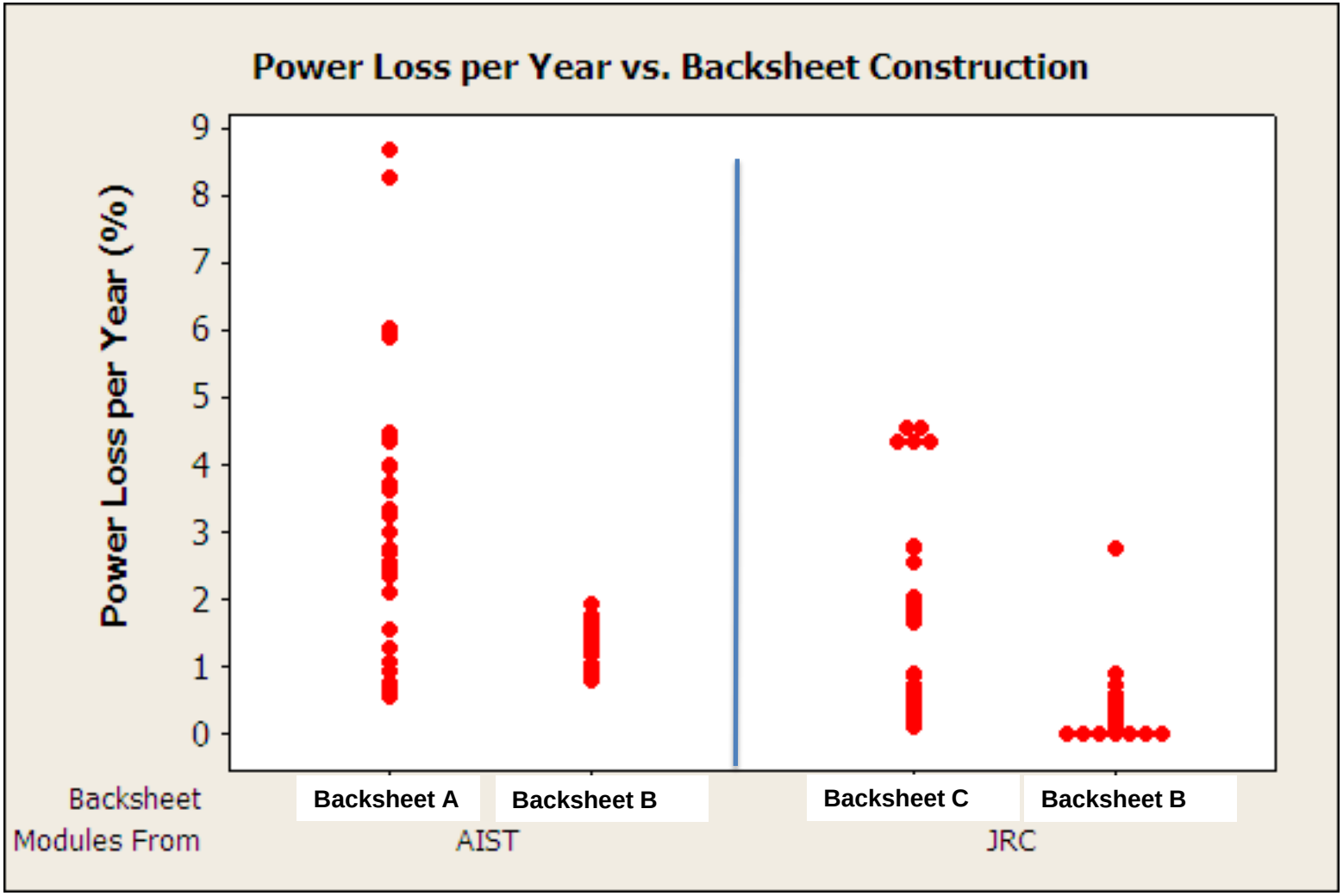
Bill of Materials



Backsheet represents a tiny portion of the total cost.
But it plays a critical role in module durability & reliability.

Source: DuPont

Power Degradation in the Field



What Can You Do Today – Four Ways to Mitigate Your Risk

1. Think in terms of LCOE

2. Ensure your system utilizes proven bill of materials, system design and manufacturing practices.

3. Know what materials are in your module–because all modules are not created equal.

4. Work with well-established industry leaders—up and down the value chain—who will prevail long-term.

DUPONT®

The miracles of science™

Reality: System Issues and Failures are Real and Recent