TÜV Rheinland PTL

PERFORMANCE LOSSES AND RELIABILITY OF PHOTOVOLTAIC MODULES

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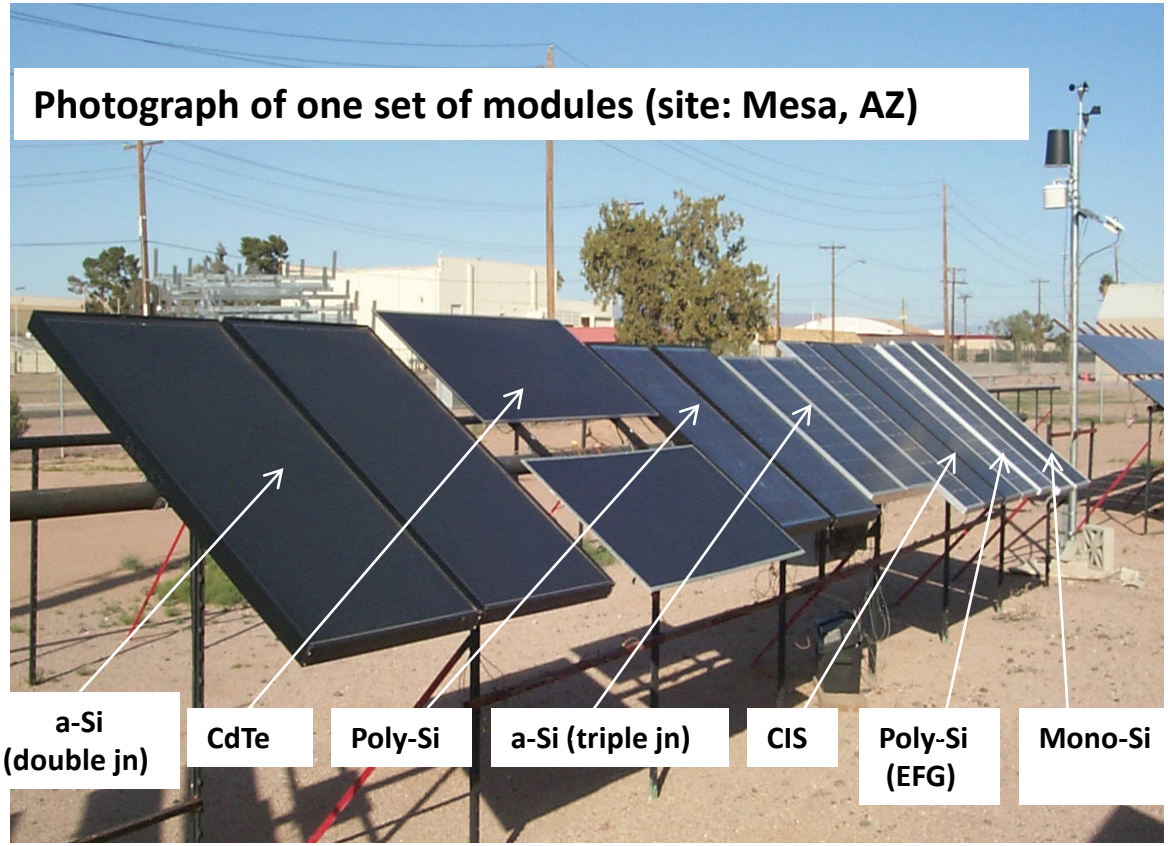
OUTLINE

- Performance issues
  - Higher operating temperature
  - Long term degradation
- Spectral issues - Outdoor
- Reliability issues

- **Performance issues**
  - **Higher operating temperature**

Module Temperature Prediction – Open Rack



Model developed based on the monitored data of two identical set of modules of varying technologies over 2 years at ASU (Arizona) and NREL (Colorado) locations.

$$T_{module}\ (^{o}C) = 0.964*T_{amb} + 0.028*Irradiance - 1.528*WindSpd + 4.3$$

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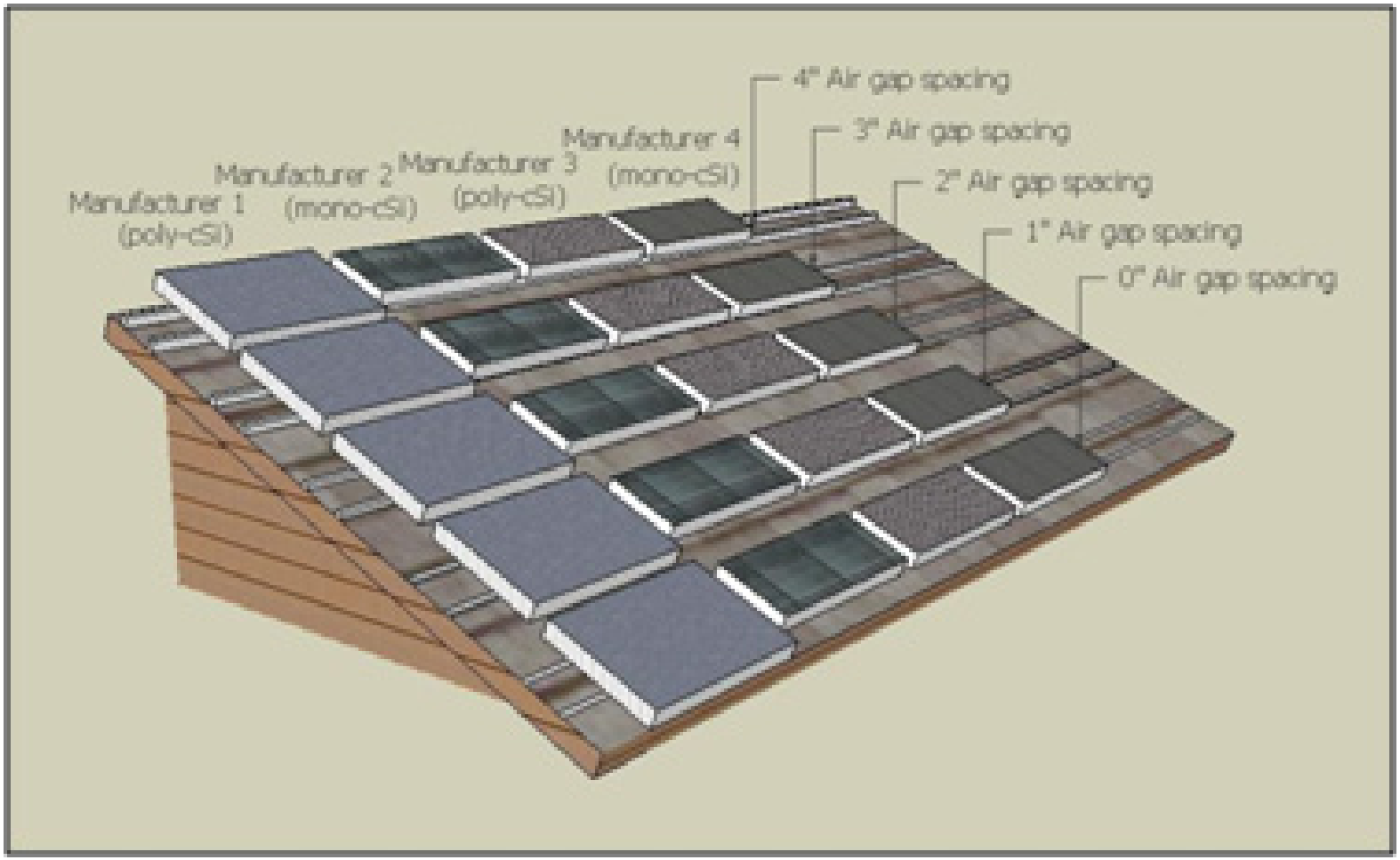
Module Temperature Prediction – Rooftop



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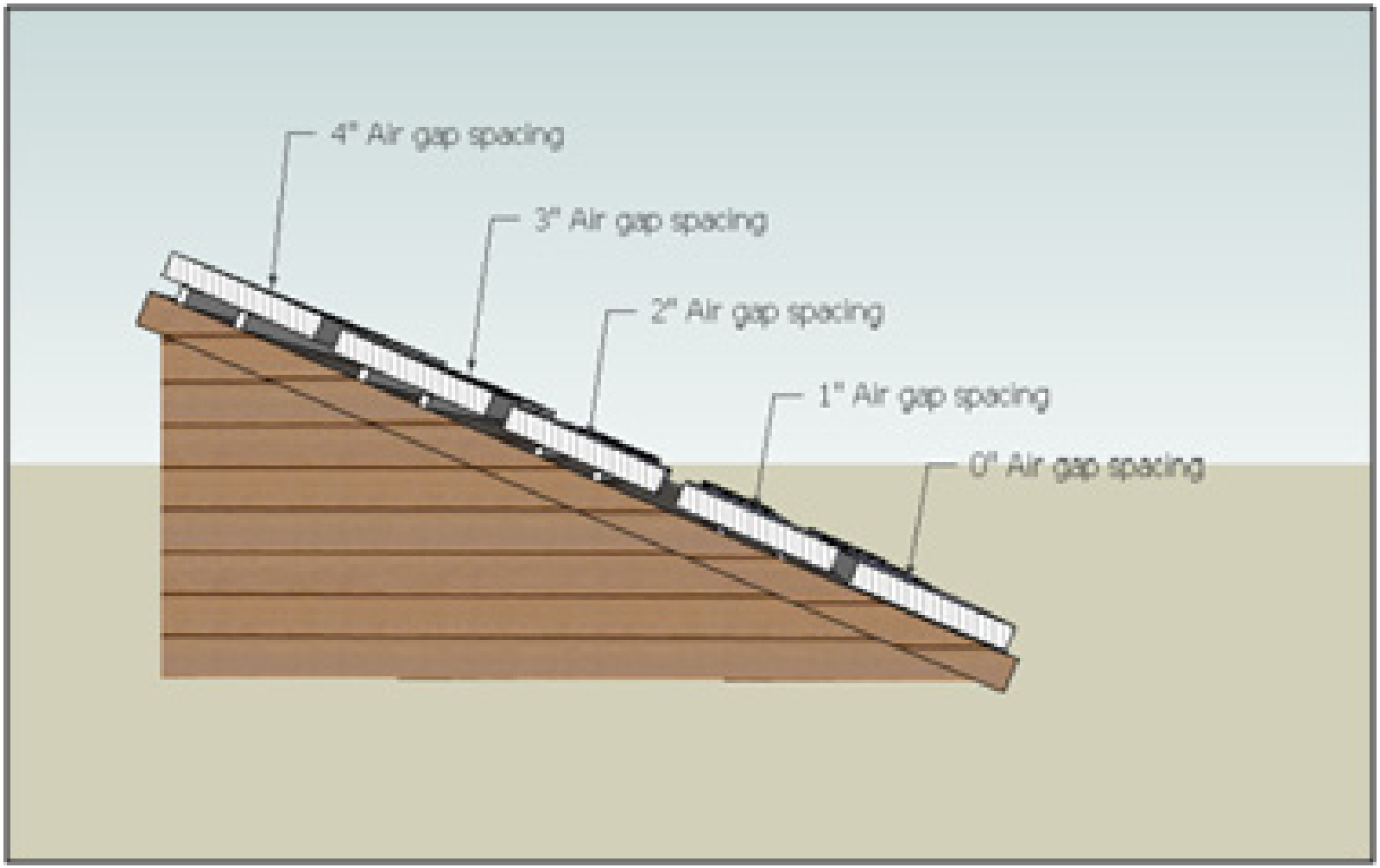
Module Temperature Prediction – Rooftop



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Module Temperature Prediction – Rooftop

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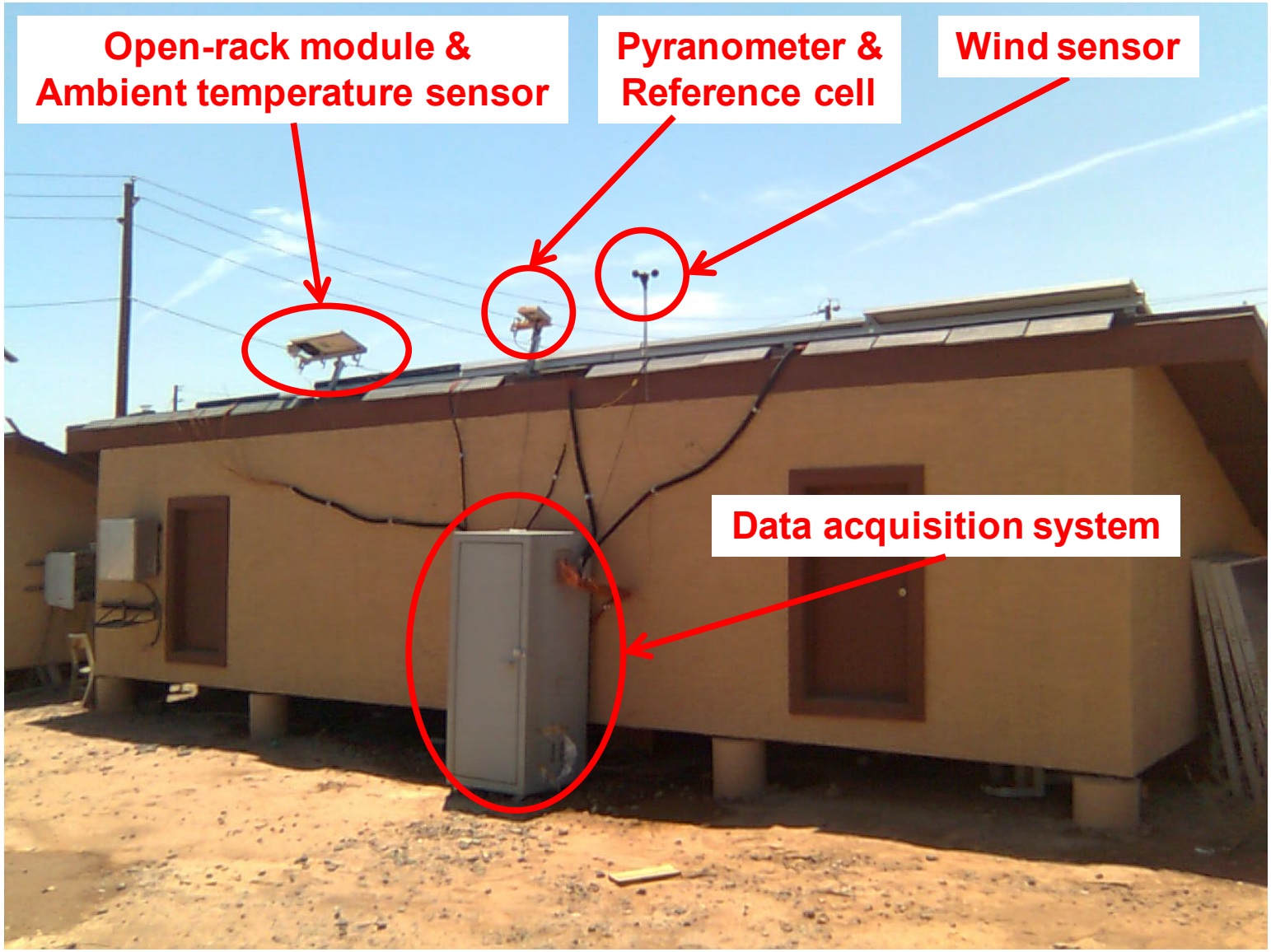
Module Temperature Prediction – Rooftop



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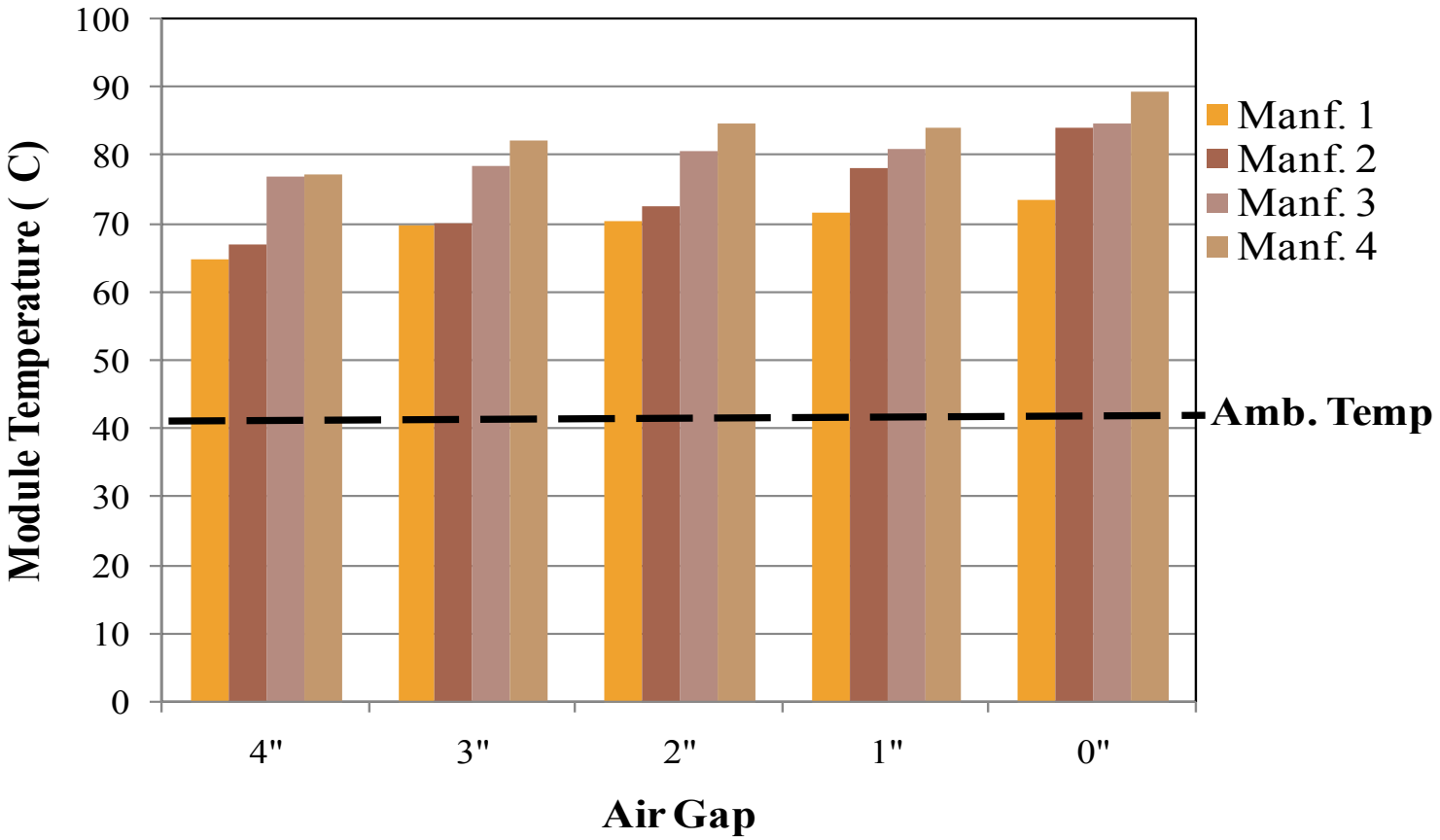
Module Temperature Prediction – Rooftop



Effect of air gap and wind direction on module temperature

(Ambient temperature 41.4°C; Irradiance 1063 W/m²; Wind speed 1.5 m/s; Wind direction west to east – left to right)

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Module Temperature Prediction – Rooftop

3-parameter model (based on May09 data)

$$T_{module} = w_1 * E + w_2 * T_{amb} + w_3 * WS + c \qquad (1)$$

Where:

T_{module}: module temperature (°C);

T_{amb}: ambient temperature (°C);

E: irradiance (W/m^2);

WS: wind speed (m/s);

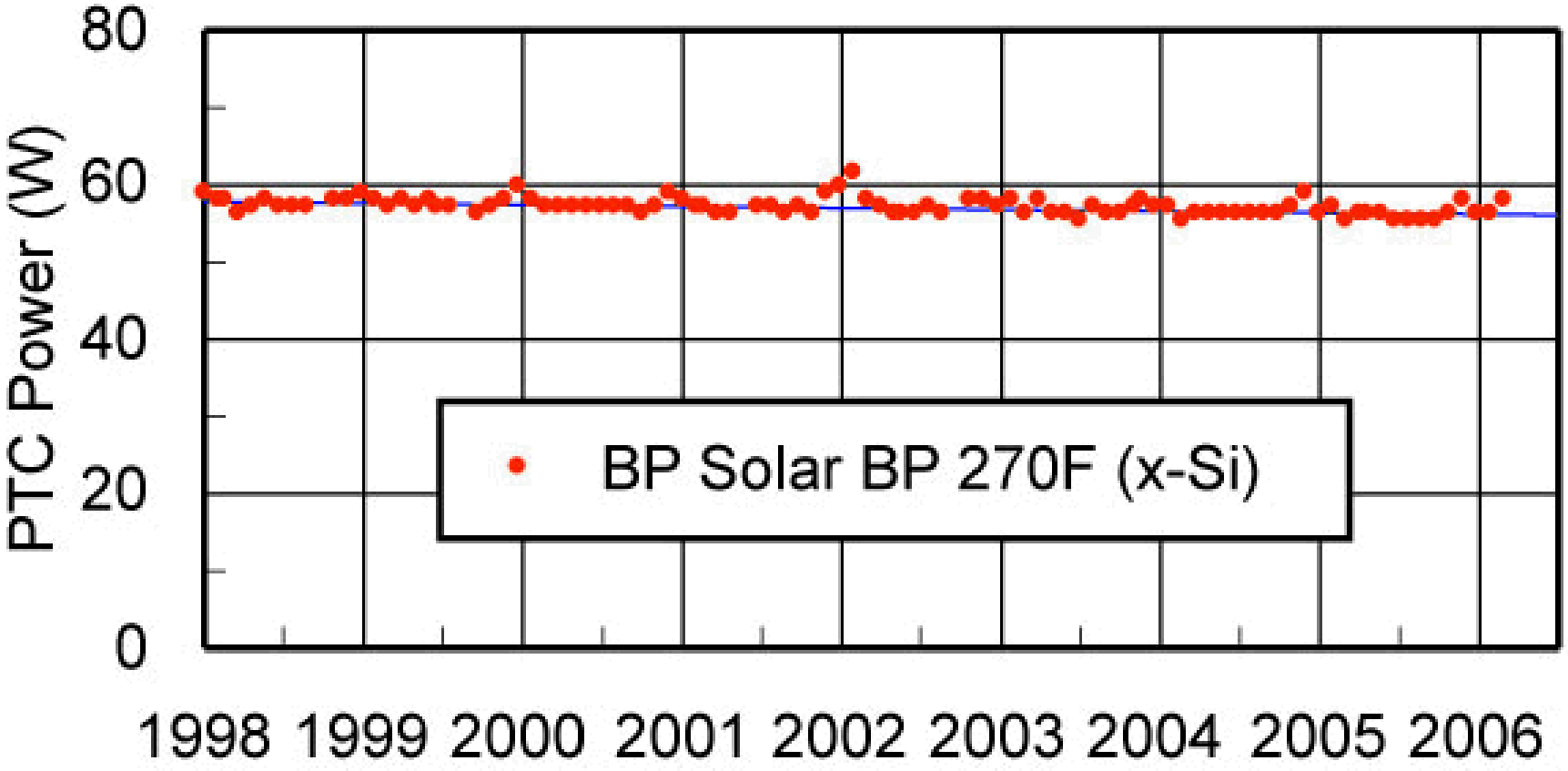
w1, w2 & w3 are coefficients and "c" is a constant

	Coefficients			
Air Gap	Irradiance (w1)	Amb. Temp (w2)	W.Speed (w3)	Const.
0"	0.040	1.27	-1.01	-6.38
1"	0.037	1.21	-0.98	-4.28
2"	0.036	1.10	-1.08	-3.88
3"	0.035	1.03	-1.41	-1.37
4"	0.031	1.09	-1.69	-2.18

An improved 4-parameter (ambient temperature, irradiance, wind speed and wind direction) thermal model is planned to be developed along with an extension of the data collection period from 1 month to at least 6 months.

- **Performance losses**
  - **Long term degradation**

FIELD DEGRADATION DATA (~8 years; Colorado)



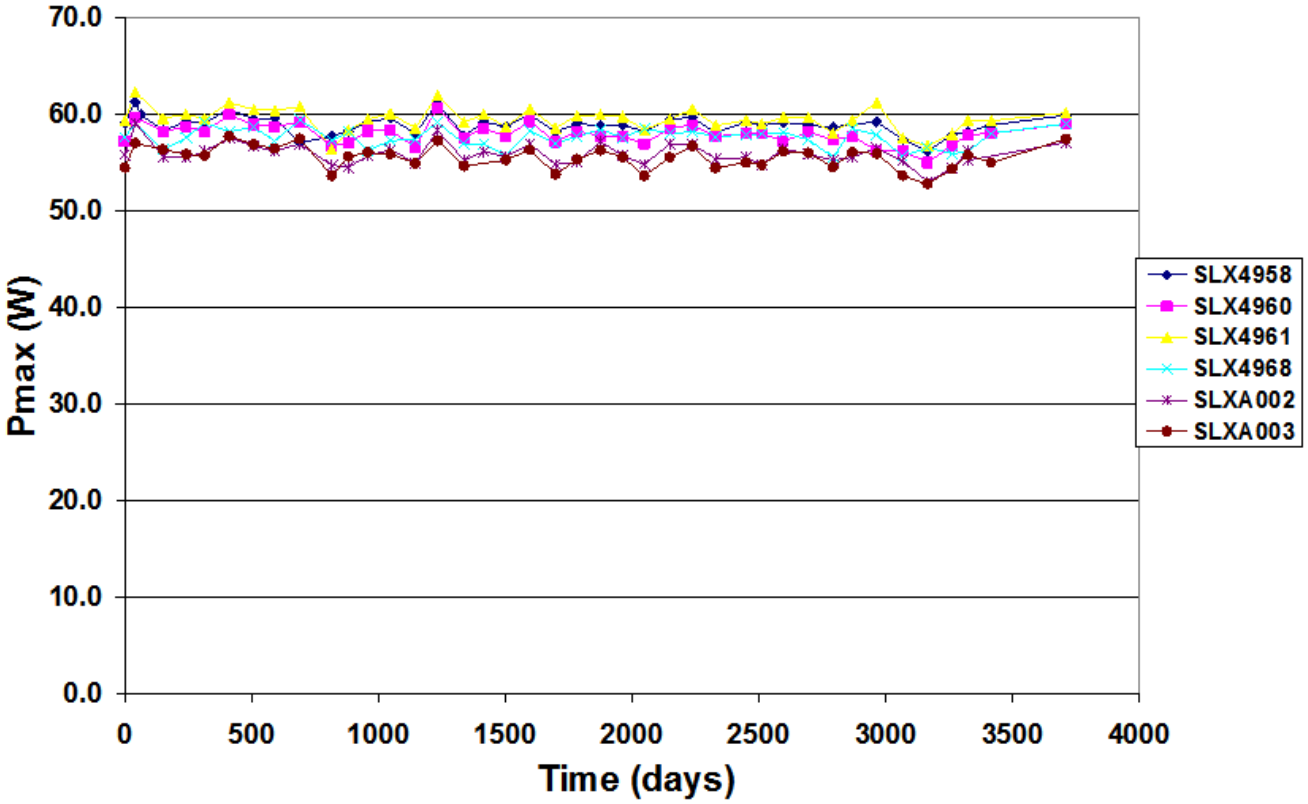
Degraded at 0.25%/year.

Courtesy: NREL

FIELD DEGRADATION DATA (~10 years; Arizona)

Change in Power for 6 modules at ASU

bp solar

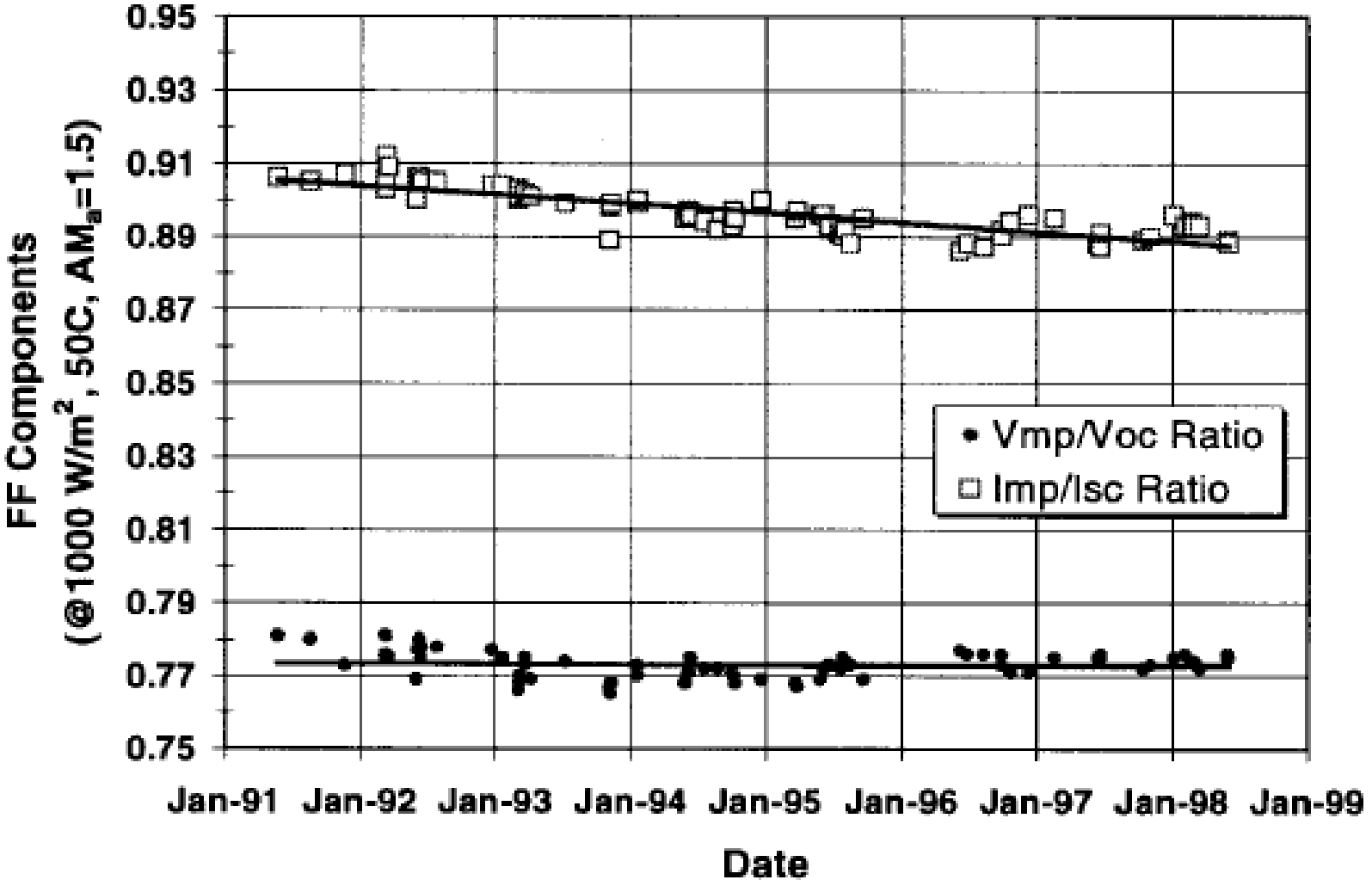


23rd European PVSEC Sept. 5, 2008

Degraded at less than 0.1%/year.

Courtesy: BP Solar

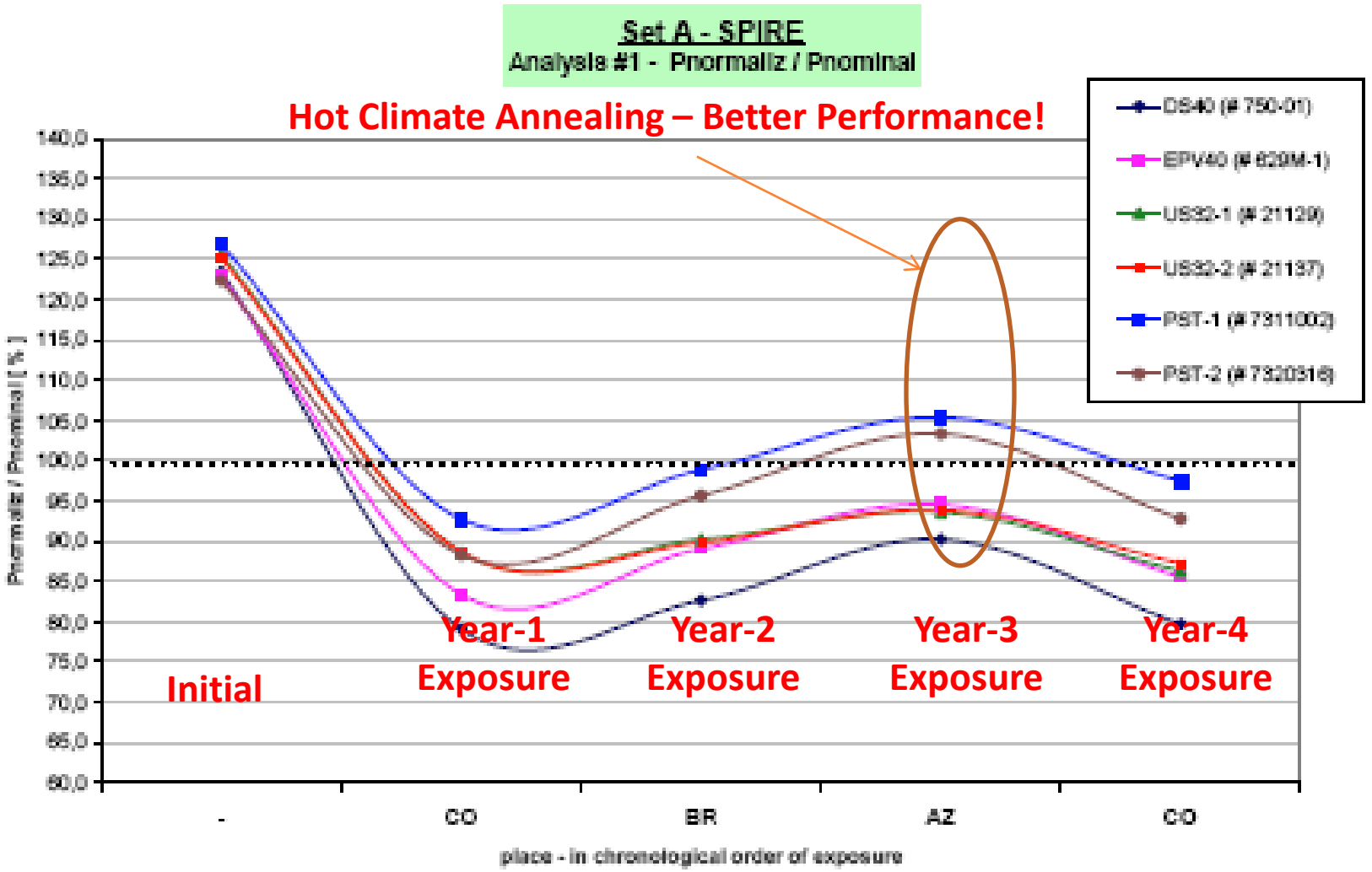
FIELD DEGRADATION DATA (~8 years; New Mexico)



Degraded at ~0.4%/year

Courtesy: Sandia

FIELD DEGRADATION DATA (4 years – Round Robin Testing Brazil-Colorado-Arizona)

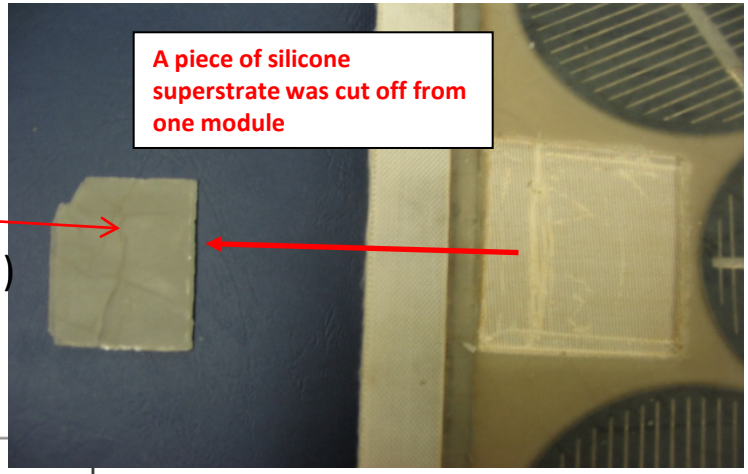


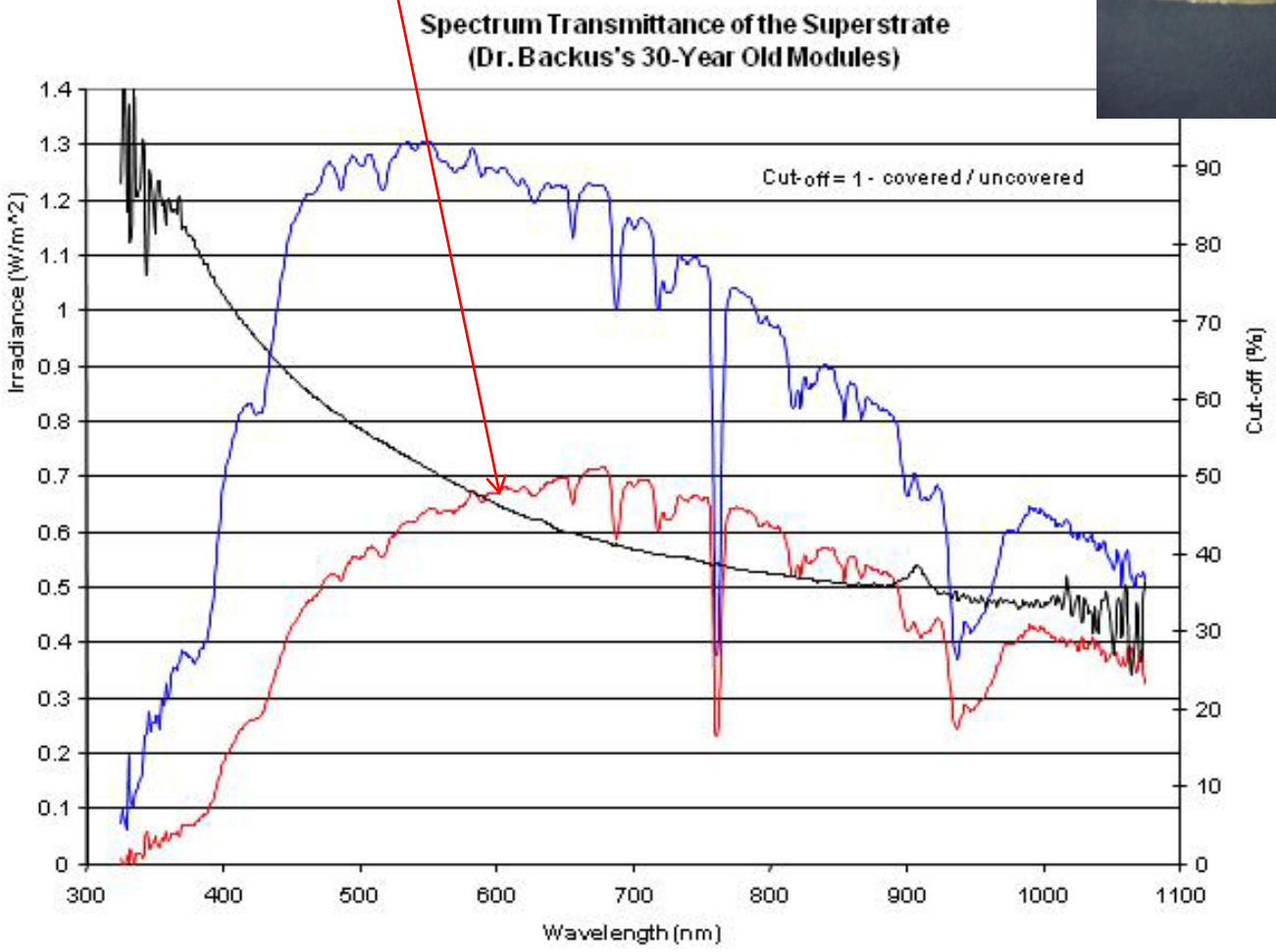
Microcracks and spectral transmittance of SILICONE superstrate of a PV module (~27 years in the field; AZ)

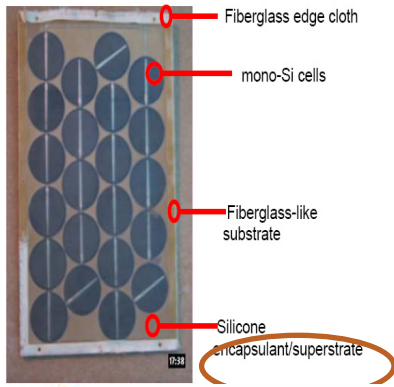
Silicone superstrate after ~27 years of exposure:

Microcracks (unsafe under wet conditions)

Transmittance (> 40% transmittance loss at > 600nm)







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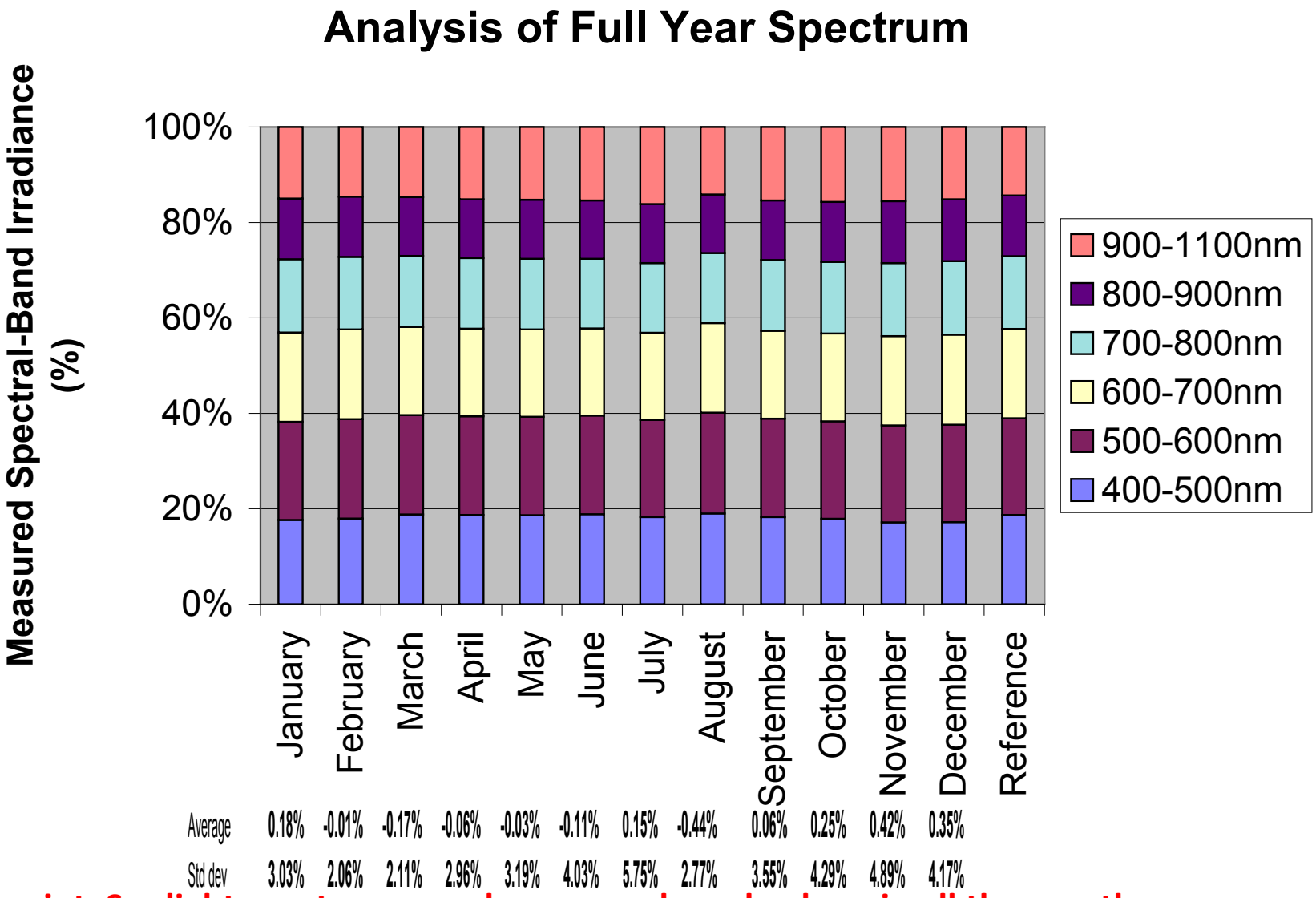
➢ Spectral issues - Outdoor

SPECTRAL QUALITY (OUTDOOR)

Site: Mesa, Arizona
(~21st day of month; ~12 noon)



<u>Key point:</u> Sunlight spectra, around noon on clear sky days, in all the months are nearly / practically identical for this test site!

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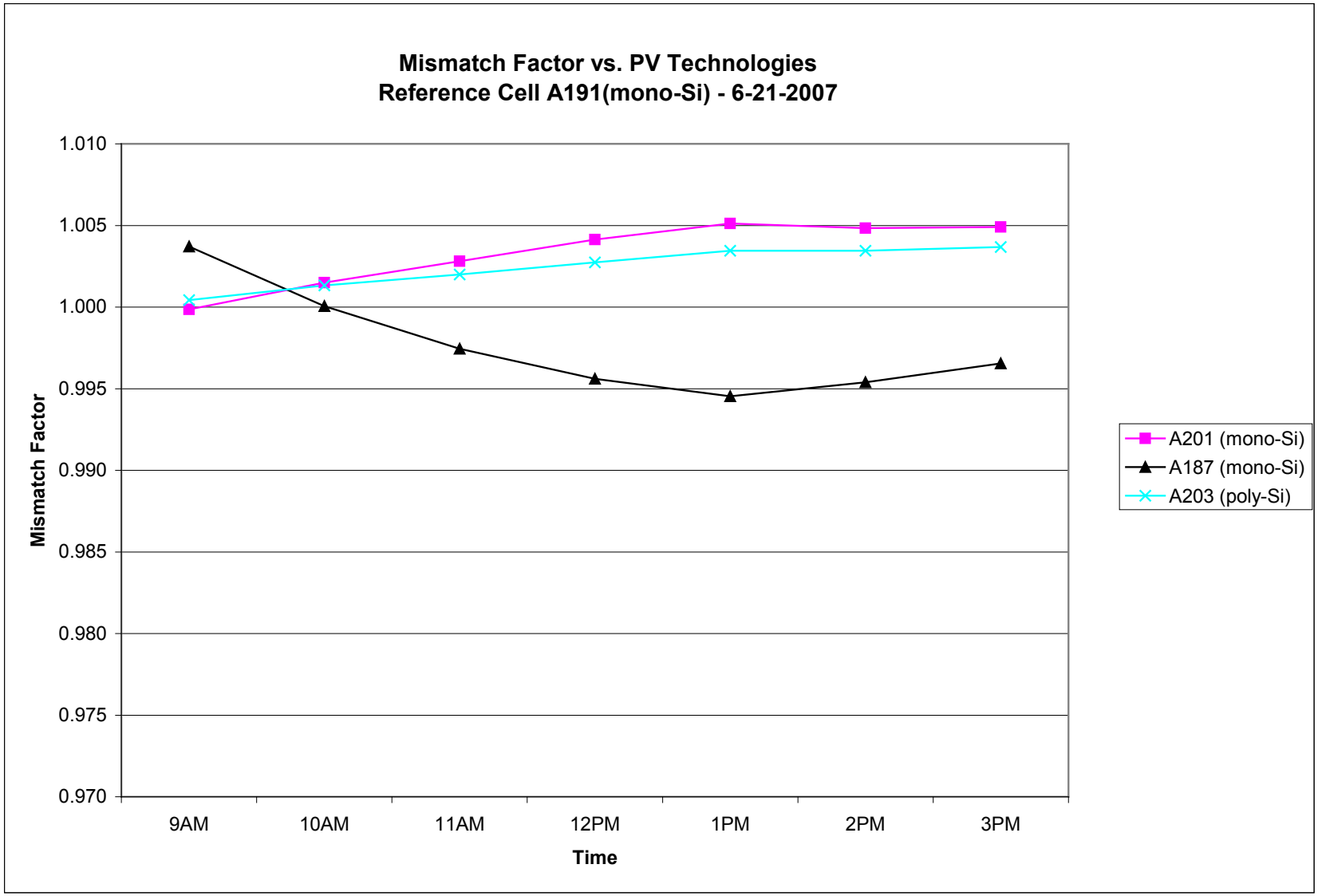
SPECTRAL CORRECTION (OUTDOOR)

Site: Mesa, Arizona

Hourly Spectral Mismatch Error



Site: Mesa, Arizona

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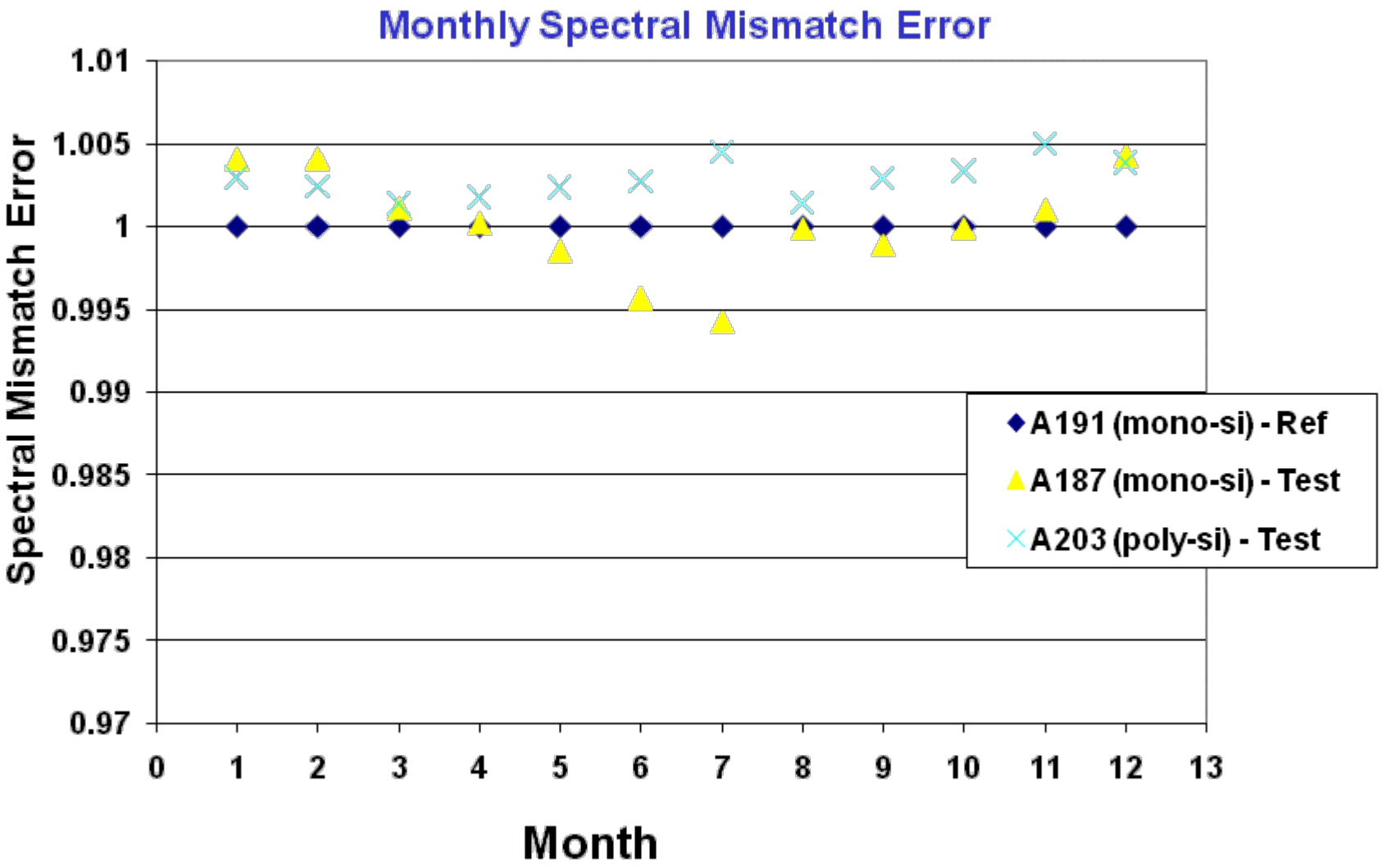

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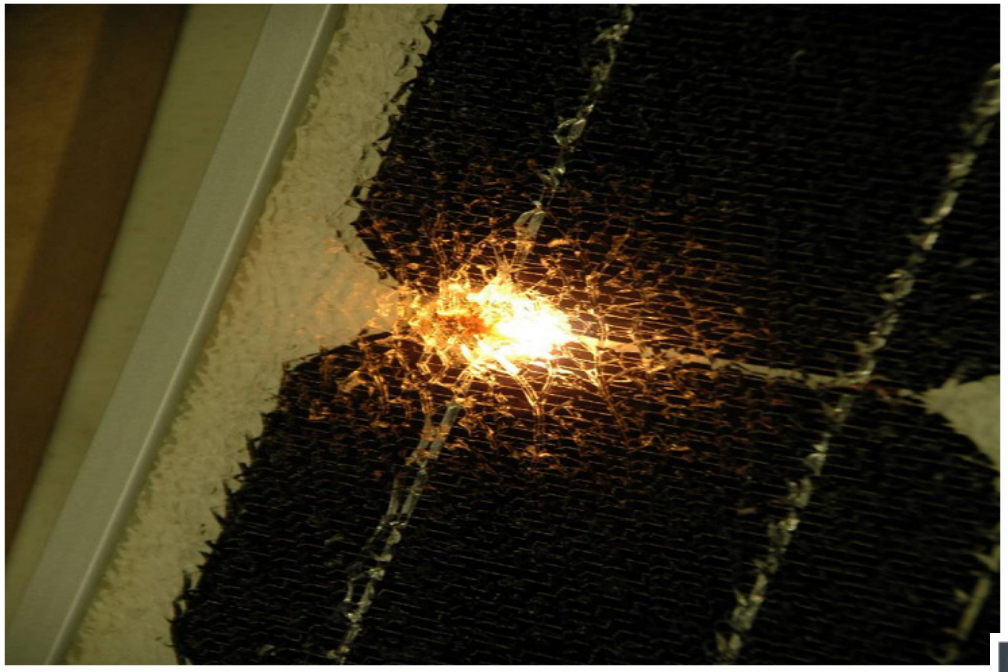
➢Reliability Issues

FIELD FAILURES

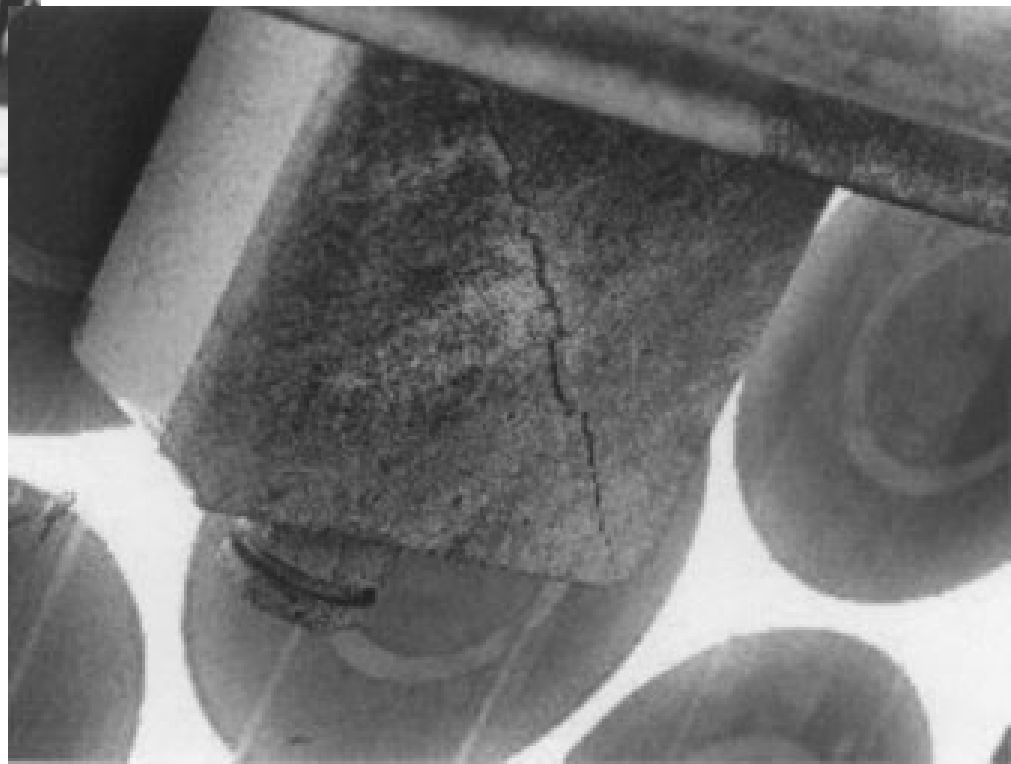


Arcing – Interconnect break

Arcing – Junction Box

FIELD FAILURES

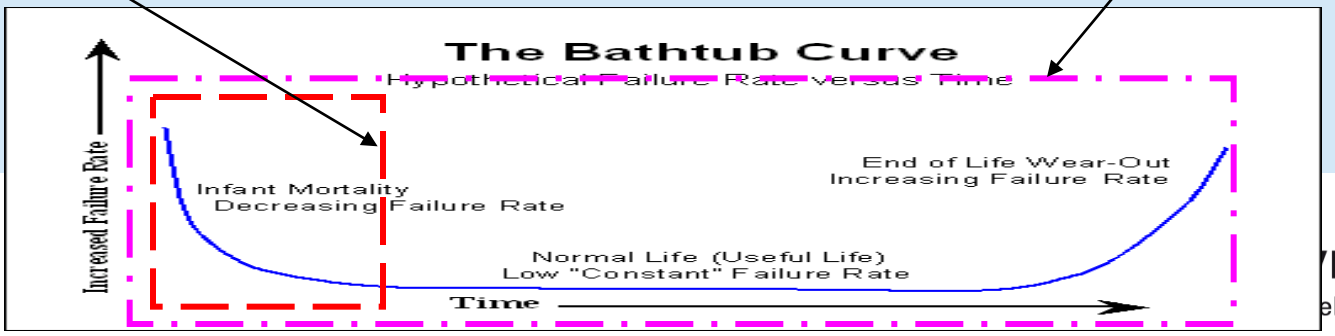
Backsheet crumbling (Italy; 22 years)



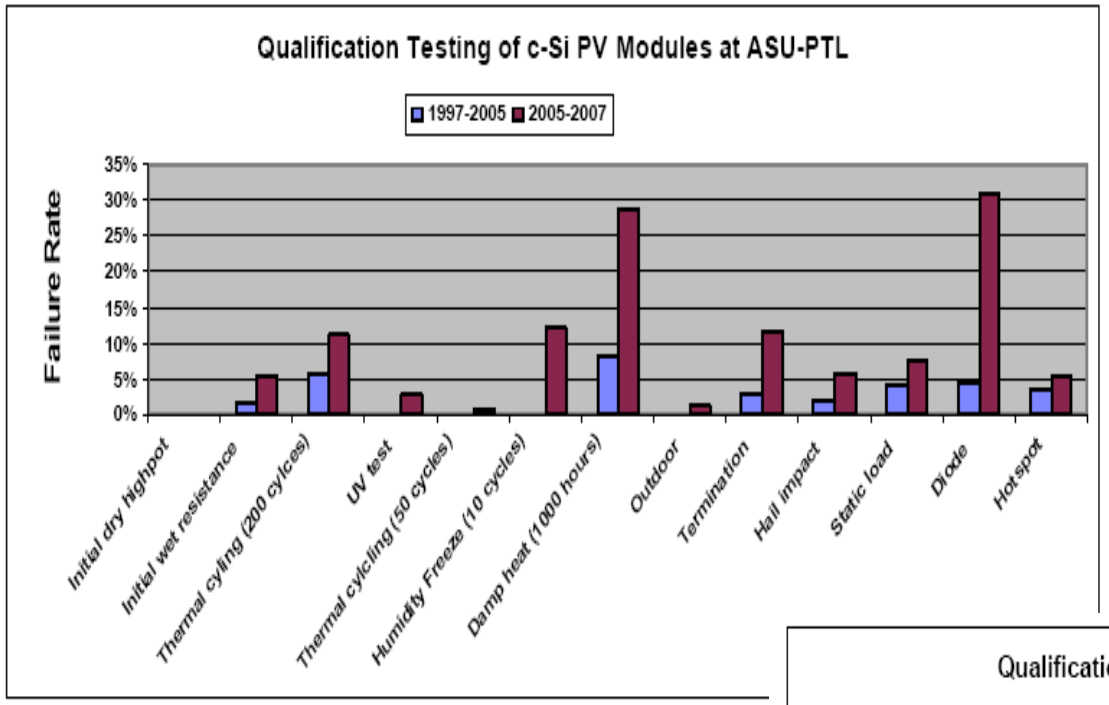
Junction Box Cracking (Italy; 22 years)

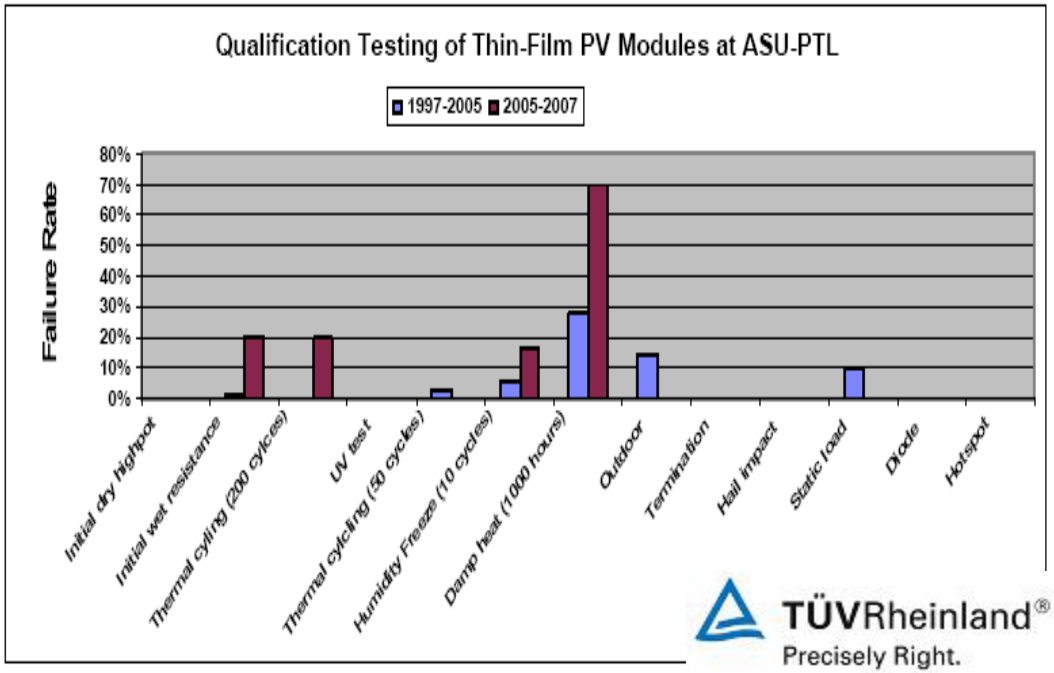
Photovoltaic Testing

Qualificaation Testing (Practically, a certification testing)	Reliability Testing (Practically, a warranty service testing)
Primary Goal: Market introduction	Primary Goal: Lifetime prediction
Test-to-Pass	Test-to-Fail
Primary Purpose: Intended to identify initial design failures (Intended to identify the typical design/ catestrophic quality issues; represents the first few years in the field; qualification testing eliminates the decreasing failure rate part of the bathtub curve)	Primary Purpose: Intended to identify initial design failures (Intended to identify the typical design quality issues; represents the first few years in the field; qualification testing eliminates the decreasing failure rate part of the bathtub curve) Intended to identify use/field failures (intended to identify all the field issues; represents a few decades in the field; represents the constant failure rate part of the bathtub curve) Intendend to identify aging/wear-out/fatique failures (represents the increasing failure rate part of the bathtub curve)
Test Protocol: National and international standards (the test protocol is designed for typical environmental and use conditions)	Test Protocol: Manufacturer specific extended/modified qualification/ stress testing and field testing protocol (the test protocol is designed for typical as well as specific environmental and use conditions)



Failure: Qualification Testing & Certification at PTL





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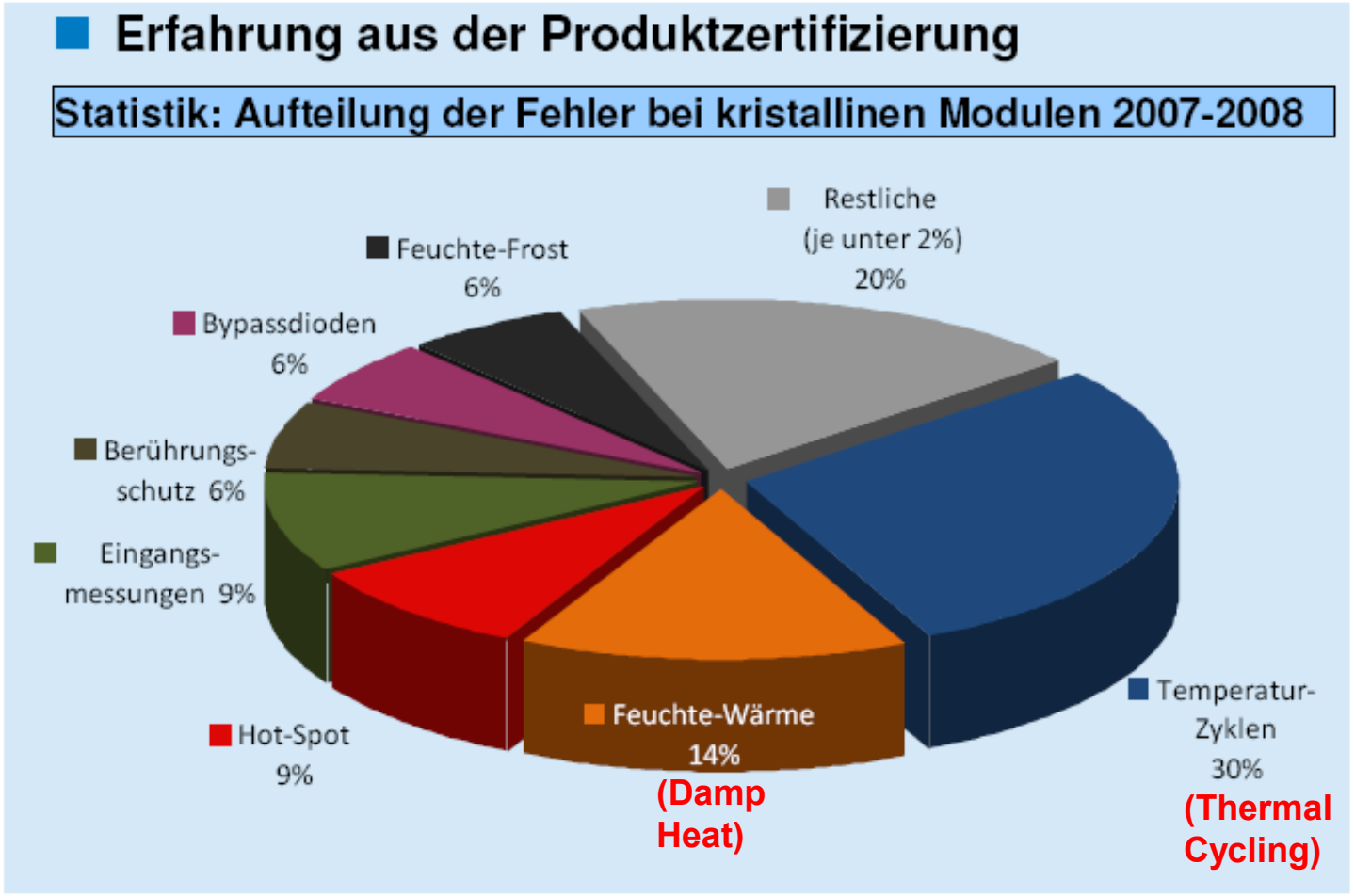
ACCELERATED TESTING

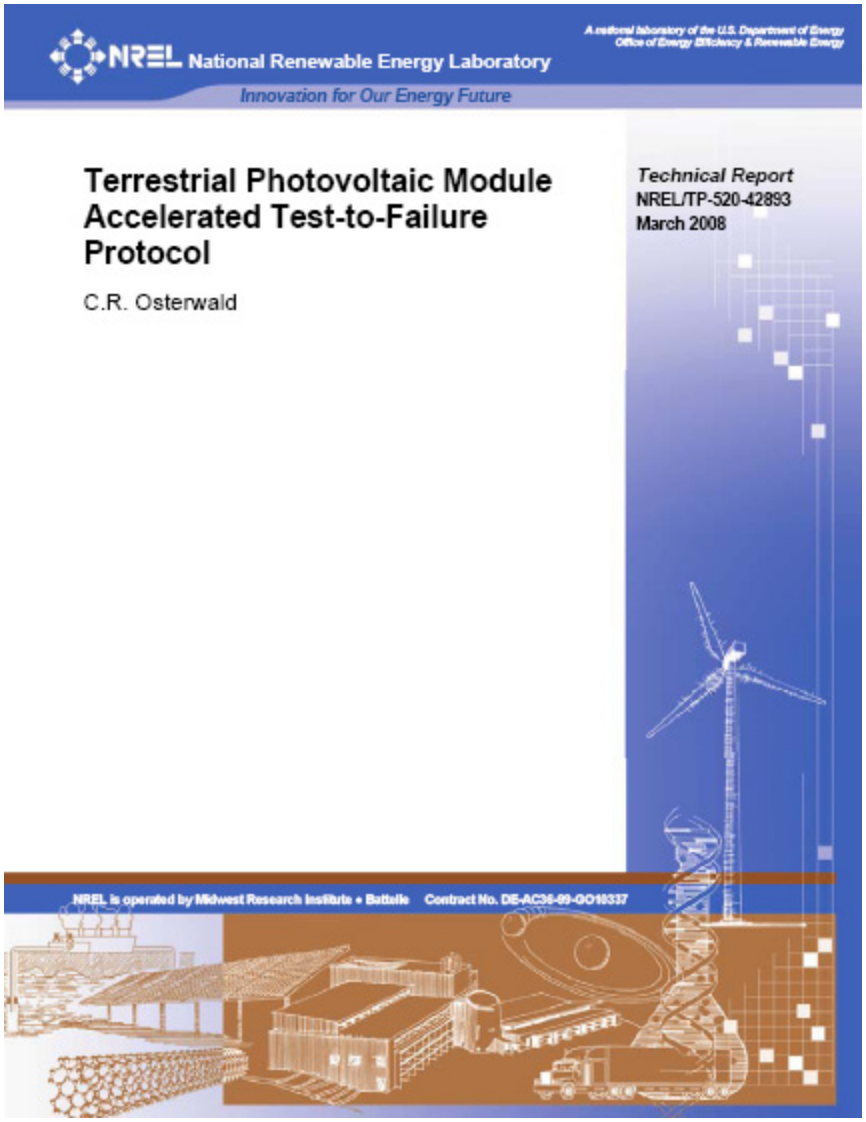
Qualification Testing (TUV Rheinland)

c-Si Failure Rate: 2007-2008



ACCELERATED TESTING

Test-to-Failure



The test protocol provided in this report can be seen as falling between qualification testing and true accelerated life testing.

The protocol can be used to compare the reliability of different modules on a quantitative basis.

Source: NREL

ACCELERATED TESTING

Test-to-failure

Determine if any modules have failed using the following criteria:

- **Power output less than 50% of the initial P_{max} (x-Si)**

- ***Power output less than 50% of the manufacturer's P_{min} rating following a recovery treatment (a-Si, CdTe, CIGS)***

- ***Arcing in module circuitry or junction box***

- ***Failure of dielectric withstand test as defined in Sec. 10.3.5 of IEC 61215***

- ***Failure of wet insulation resistance test as defined in Sec. 10.15.4 of IEC 61215***

- ***Leakage current greater than 50 μA during biased DH exposure***

- ***Open-circuit fault during forward biased TC***

- ***Development of major visual defects: - As defined in IEC 61215 sections 7a, 7b, 7d, and 7e - Corrosion of any active part of the electrical circuit greater than 50% in area of any cell.***

Source: NREL

ACCELERATED TESTING

Test-to-Failure

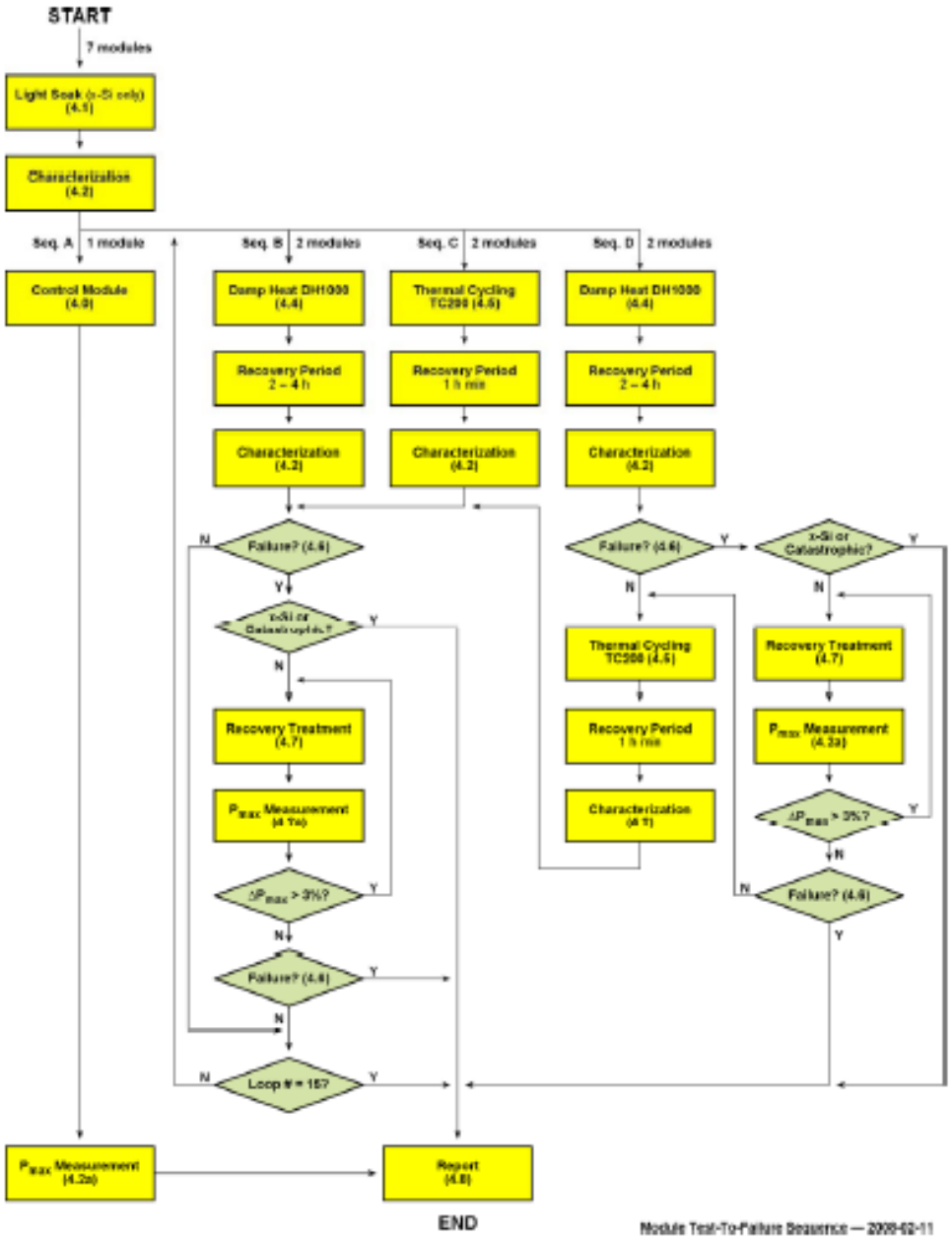
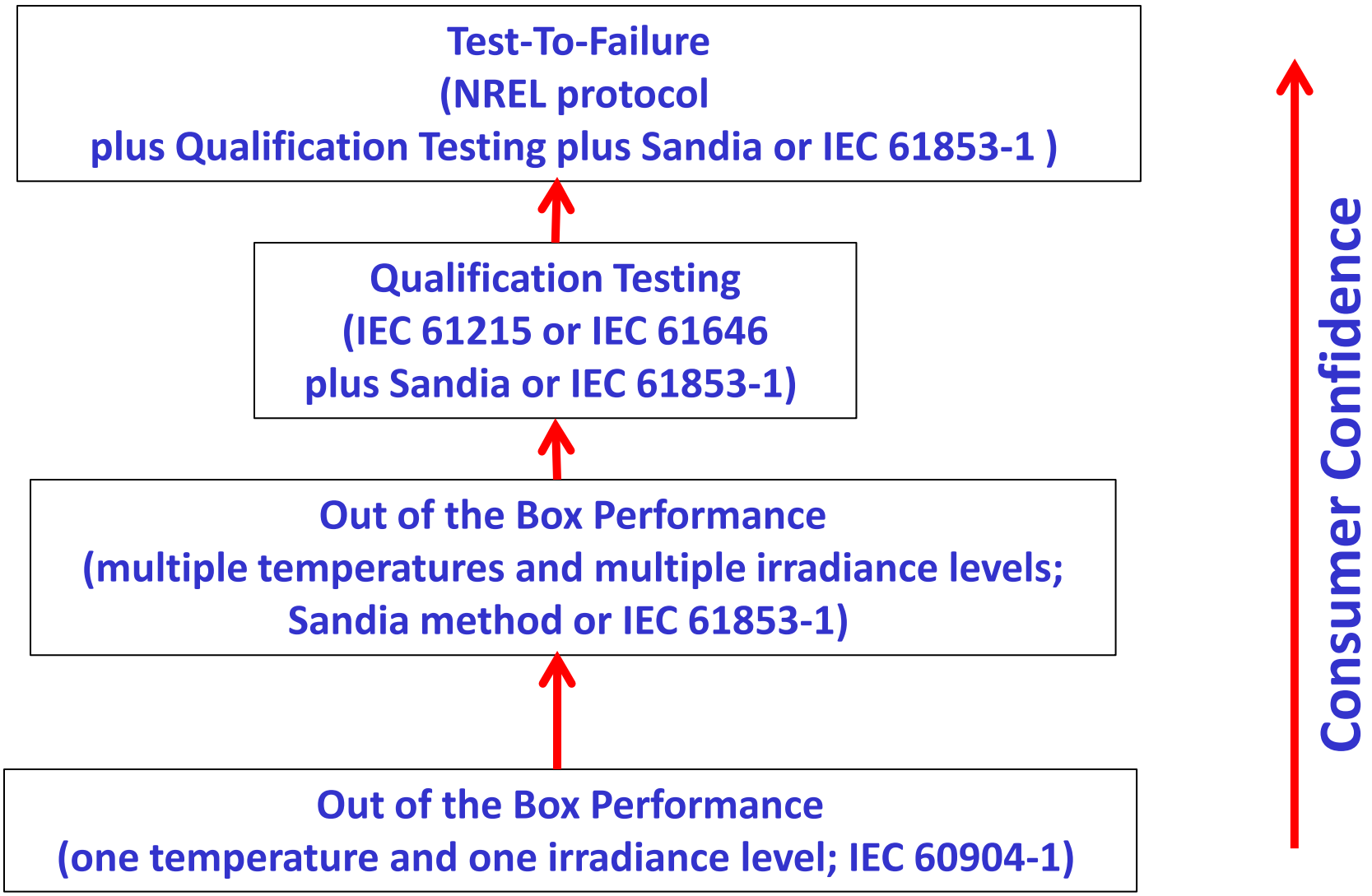


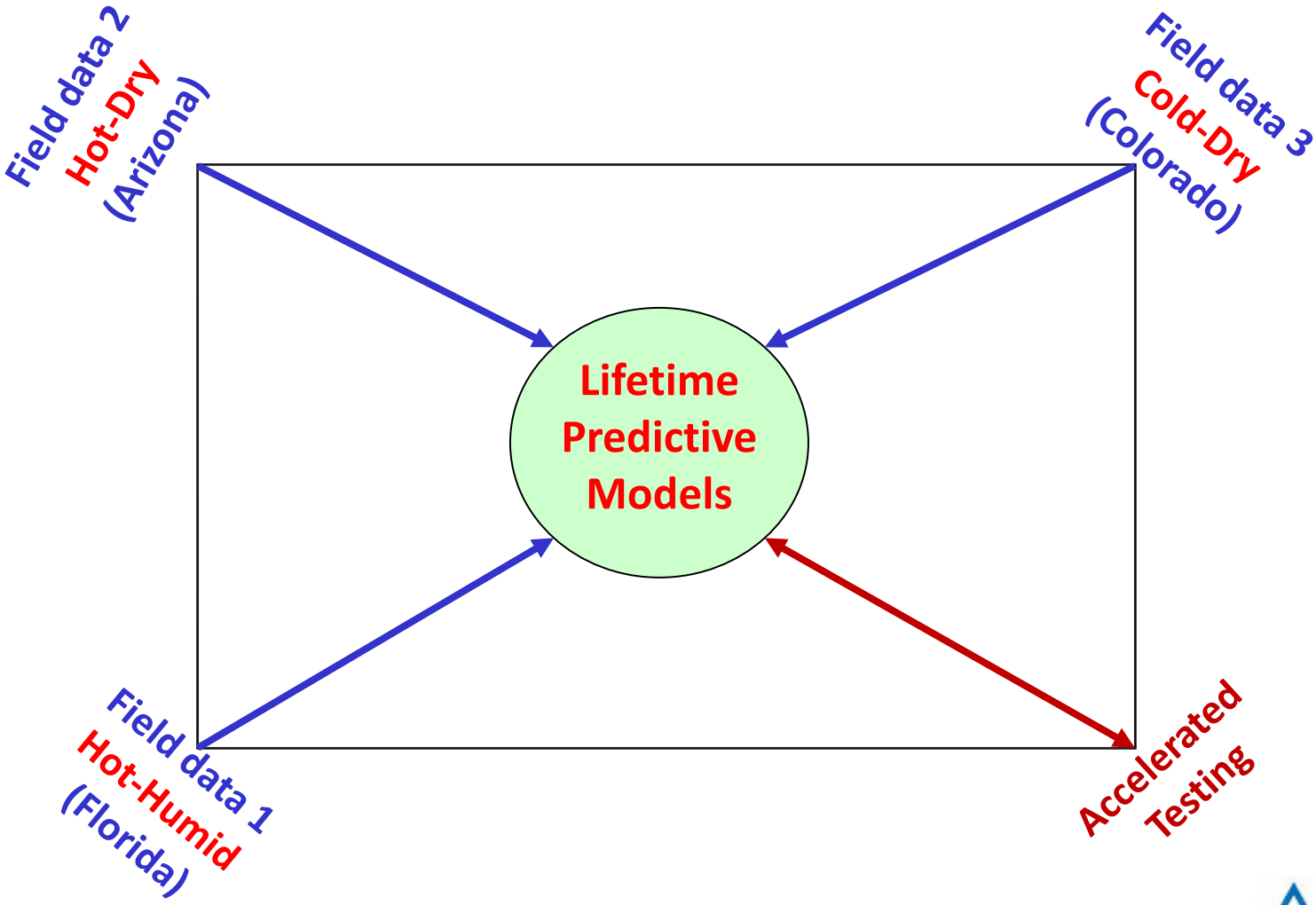
Figure 3. Flow sequence of the module test-to-failure protocol.

Source: NREL

Module Procurement: Possible Choices



Lifetime Prediction: A Potential Approach



Thanks for your attention!

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