



# Solar Photovoltaics Durability and Resilience – a win-win

**Innovations in Climate Resilience 2023**

**Columbus, OH**

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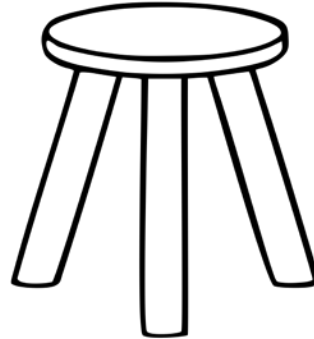
3/30/2023

# Photovoltaics has 45 years of reliability research



Caccivio et al.,  
WCPEC, 2022.

**Durable =  
long lifetime**

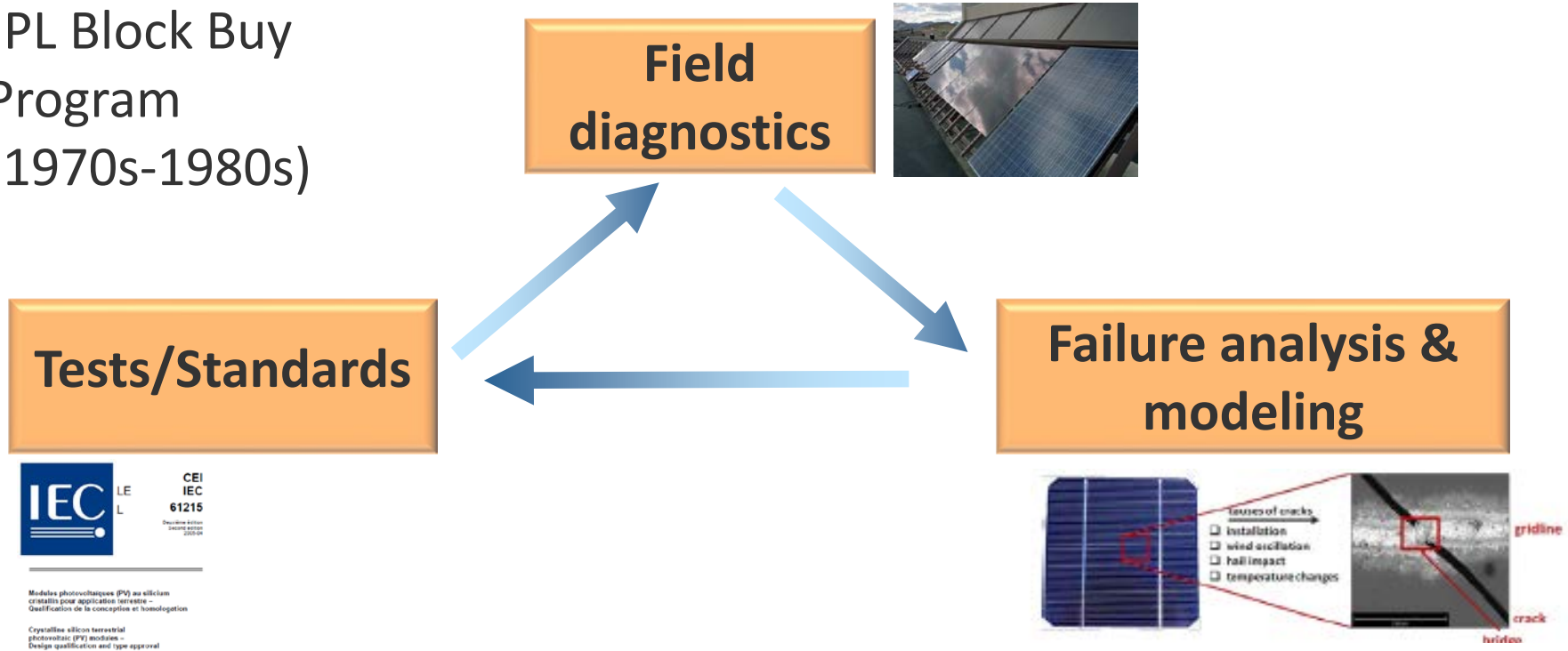


**Resilient =  
robust**

**Equitable =  
low cost**

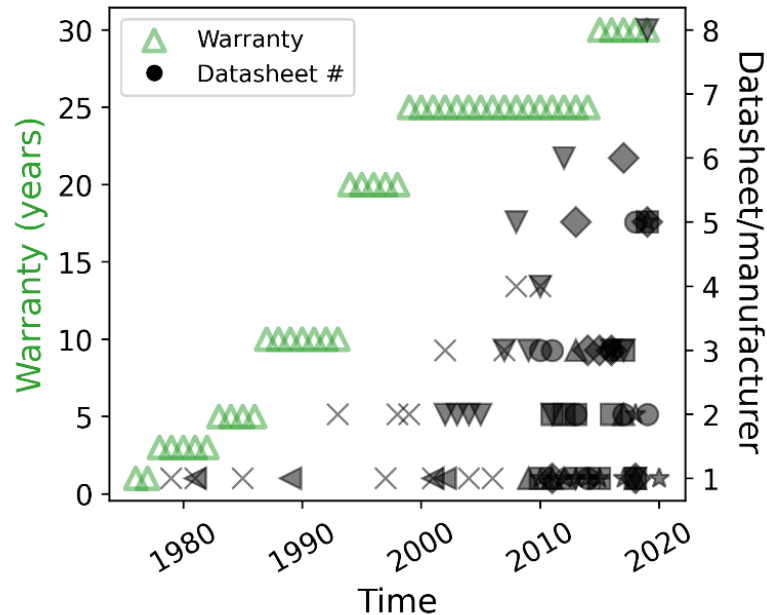
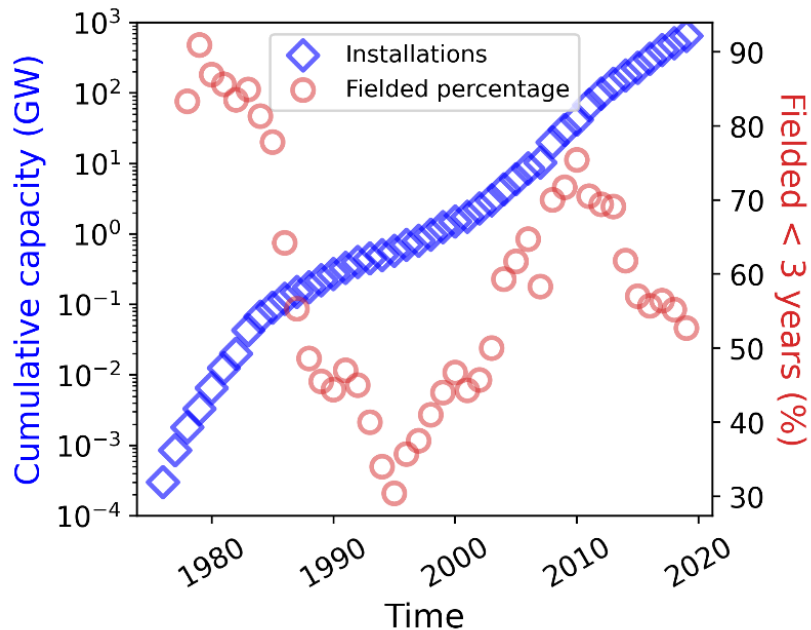
# Reliability learning cycle

JPL Block Buy Program  
(1970s-1980s)



**The learning cycle can take several years**

# Rapid deployment & innovation



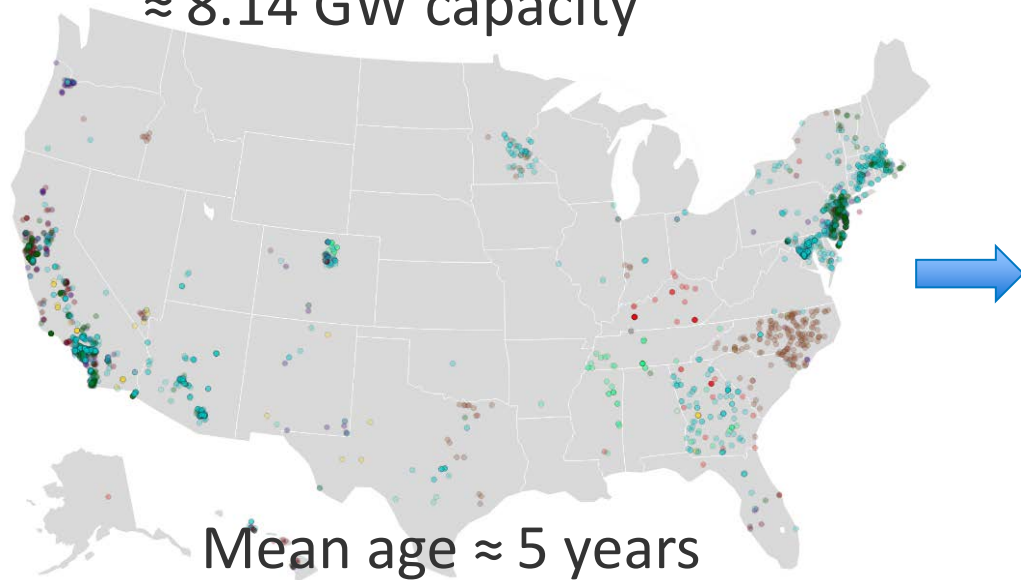
**Most systems are new (< 3 years old)**

**Warranties are decades long (20 – 40 years)**

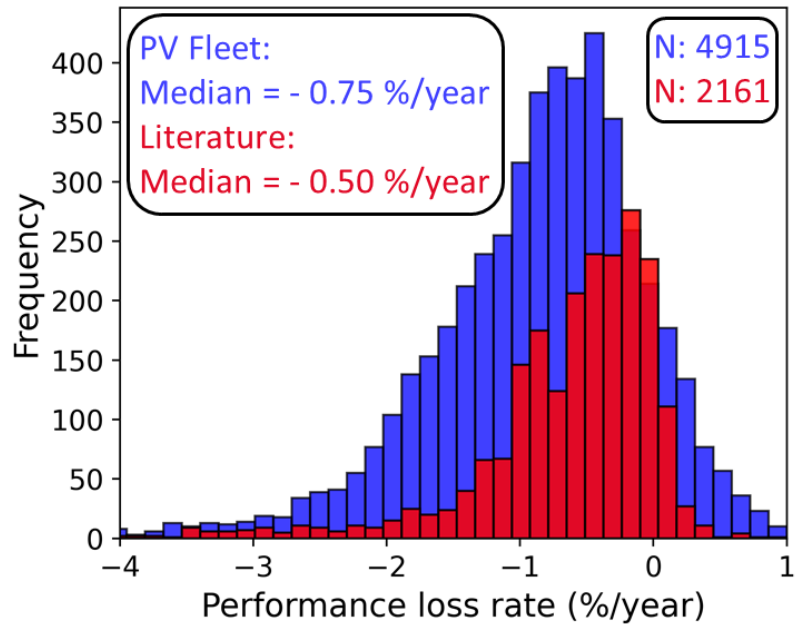
**New products come out every few months**

# PV Fleet Data Initiative

≈ 24,800 time series data,  
≈ 8.14 GW capacity

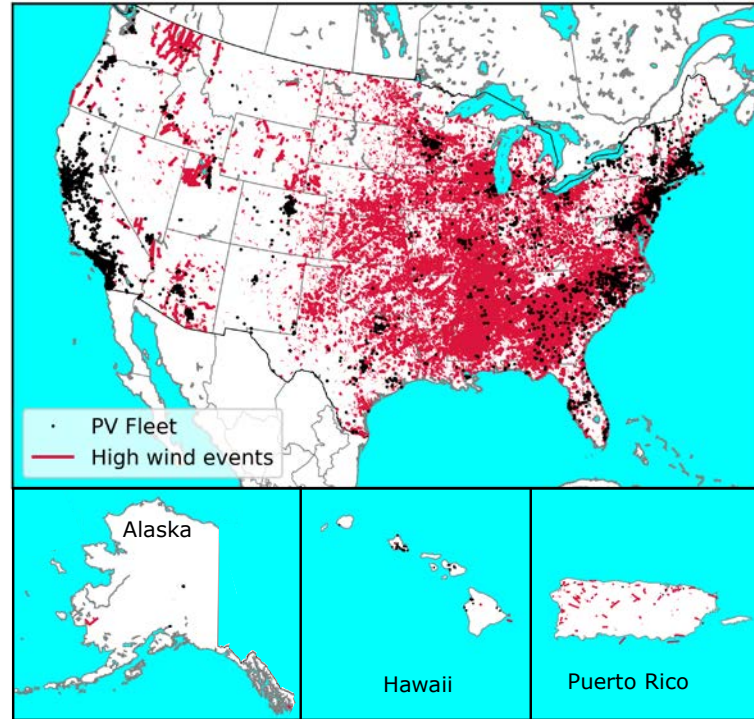


## Long-term loss



PV Fleet (blue): 100% systems  
Literature (red) 80% modules

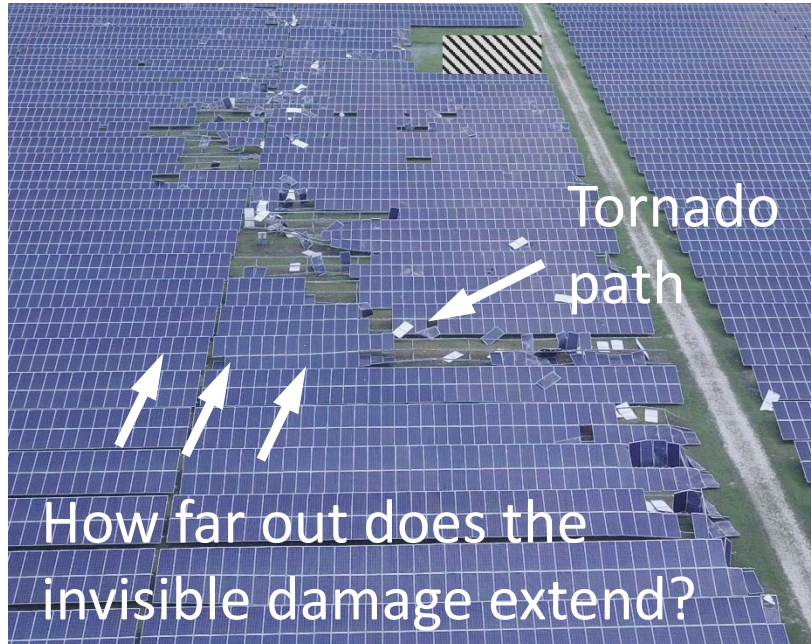
# Extreme weather & PV systems



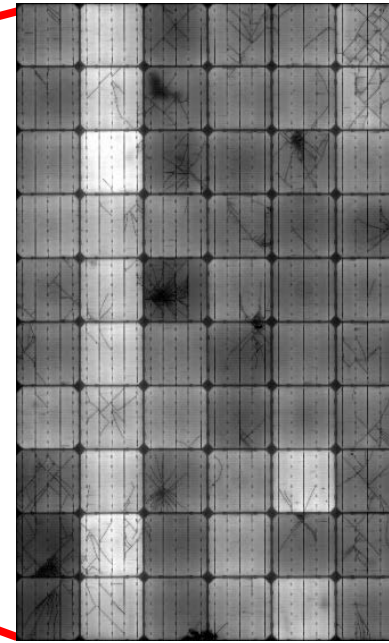
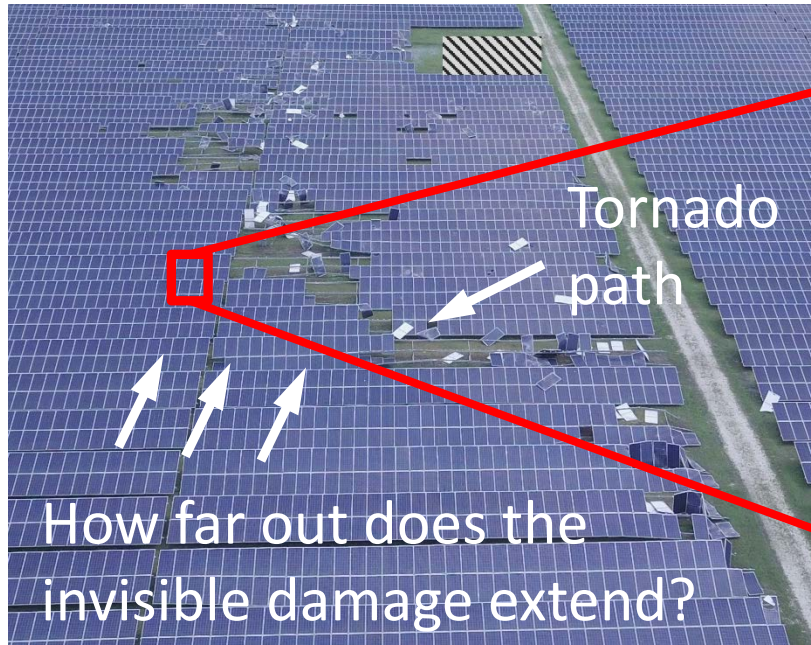
NOAA database on  
extreme weather  
PV Fleet timeseries

**Determined events that came within 10 km of an existing PV system**

# Extreme weather impact is often not obvious



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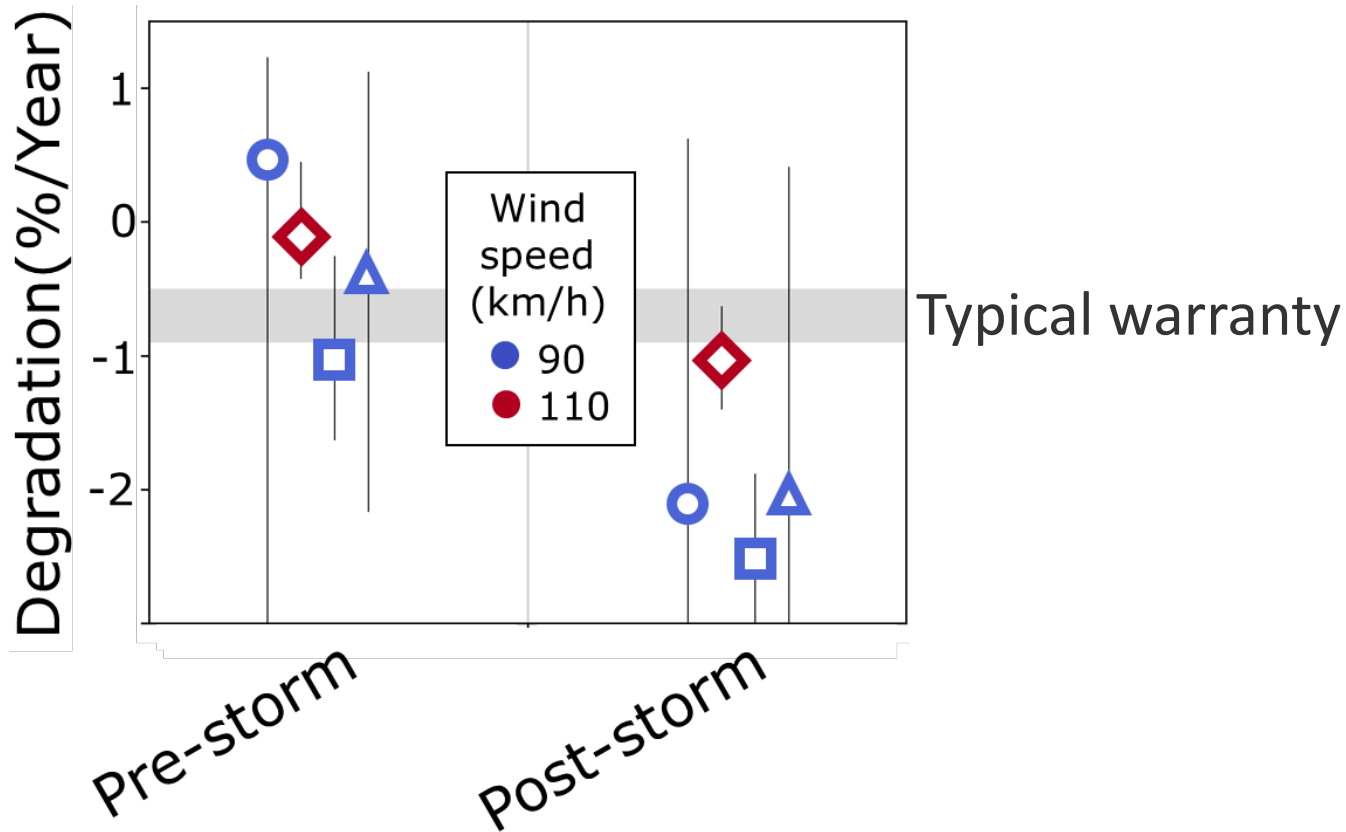


Cracked cells in module

Electroluminescence

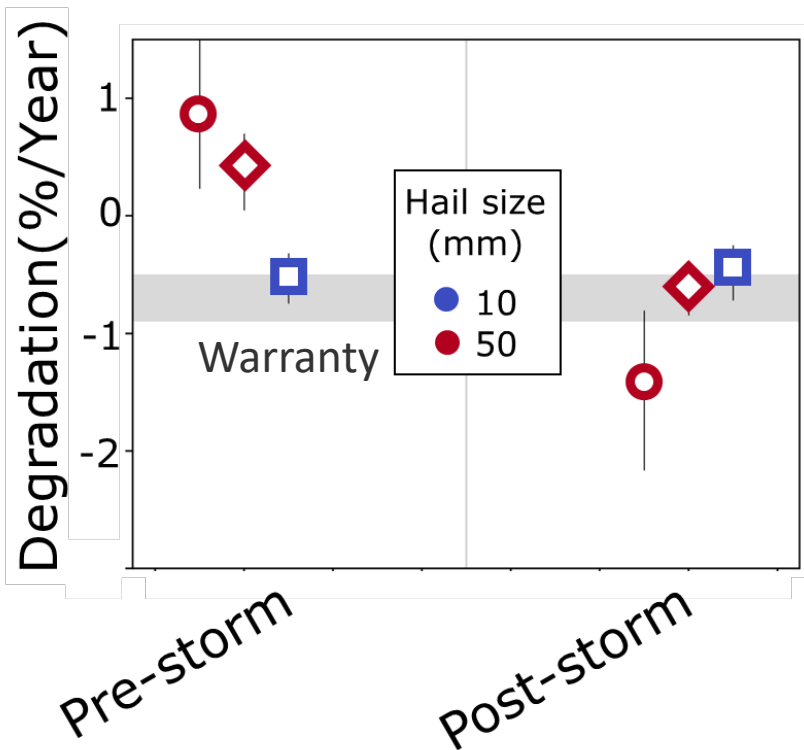
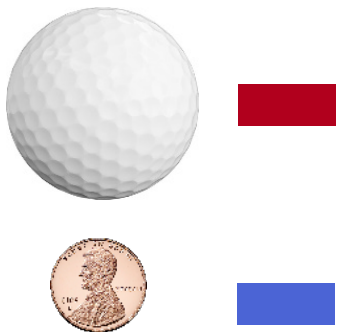


# Long-term impact – high wind



**Performance outside warranty after storm**

# Long-term impact - hail



PV module are tested for hail

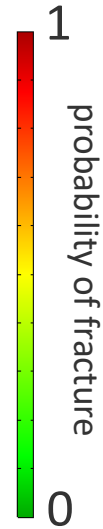
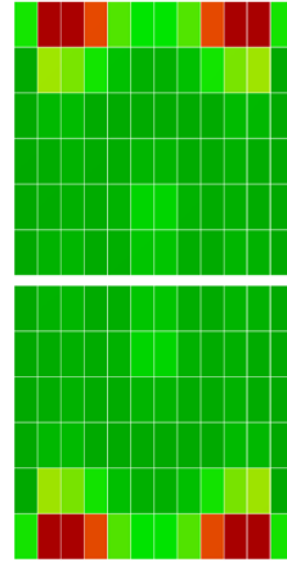
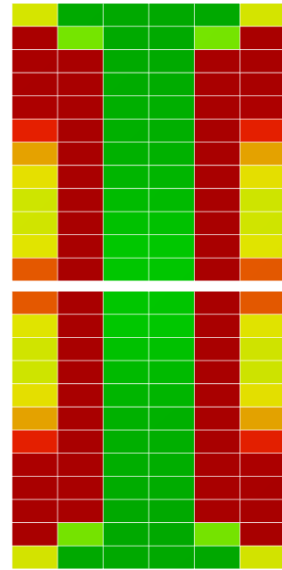
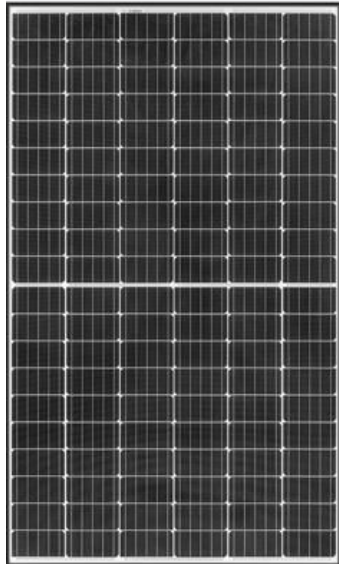
Module qualification standard

IEC 61215 (25mm)

**Supports more stringent hail testing standards**

# What can we do?

Same mechanical load: 5,400 Pa



Bosco, J.  
PV, 2022.

Rectangular cell orientation relative to bracketing-- resilience to static load

**PV module design can easily improve reliability**

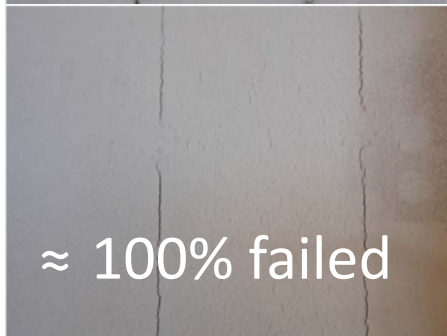
# The AAA backsheet learnings

2010-2015

AAA  
polyamide  
module  
backsheets  
introduced

Eder et al., 2019.

≈ 2020



≈ 100% failed

2-step failure  
mechanism

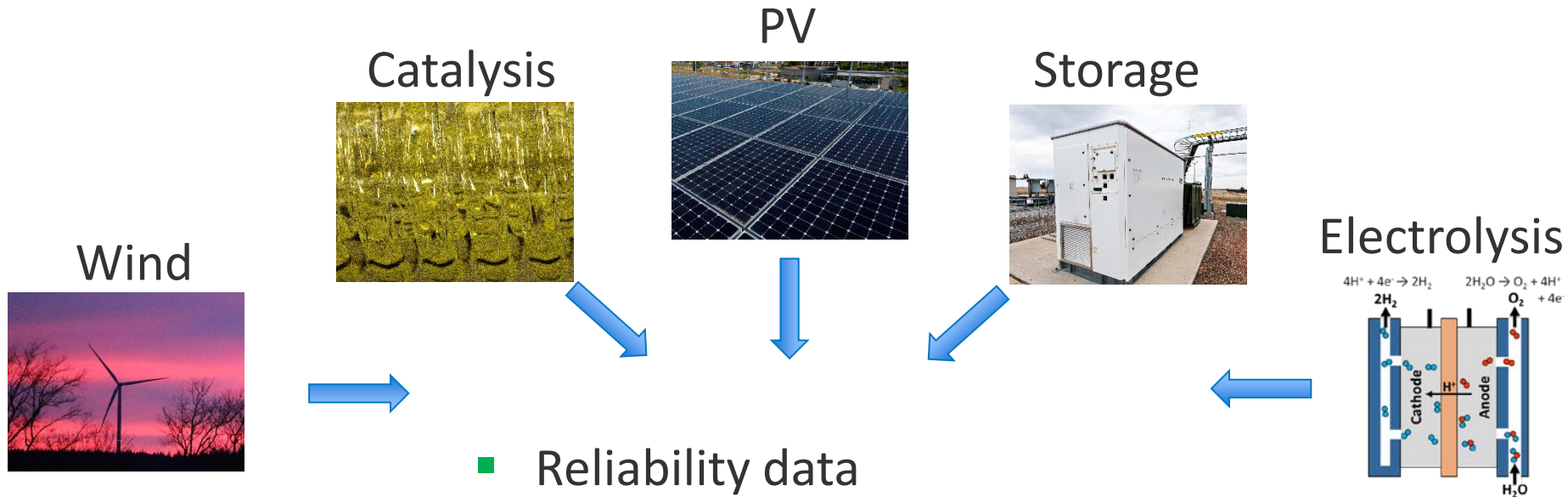
Today



Combined/sequential  
accelerated testing

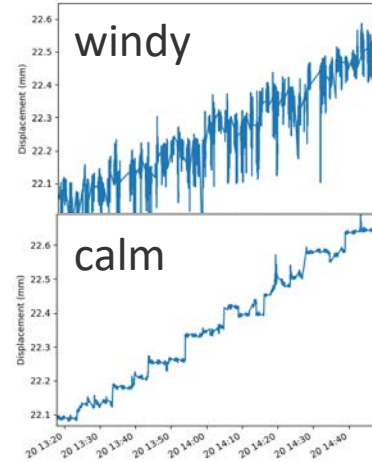
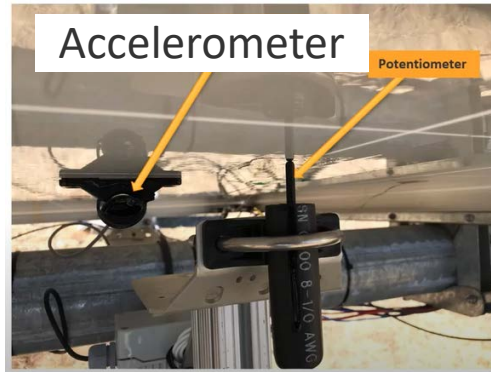
**Combining stressors can test materials interactions  
--More combined test apparatus needed--**

# Renewable energy degradation science workshop



**Rapid Degradation: convergent research area**

# Sensors & methods



**Data from more sensors enables faster reaction to extreme weather**

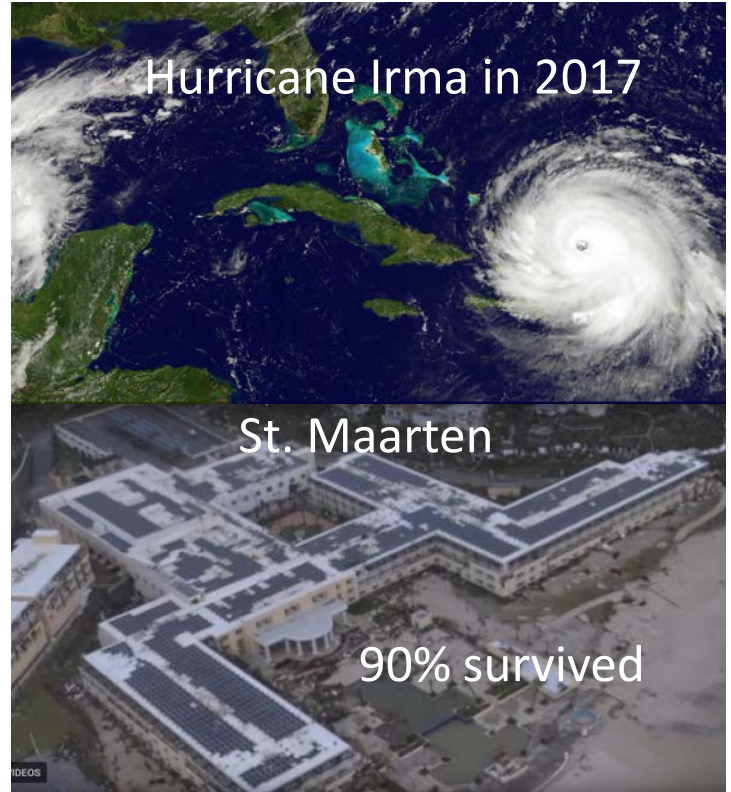
**Opportunity for machine learning algorithm for detection**

# Conclusion

Building durable, resilient & equitable PV is possible

Systems engineering approach required

- Atomic interfaces
- Module design
- Testing & standards
- Installation & deployment
- System monitoring



# Acknowledgments

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