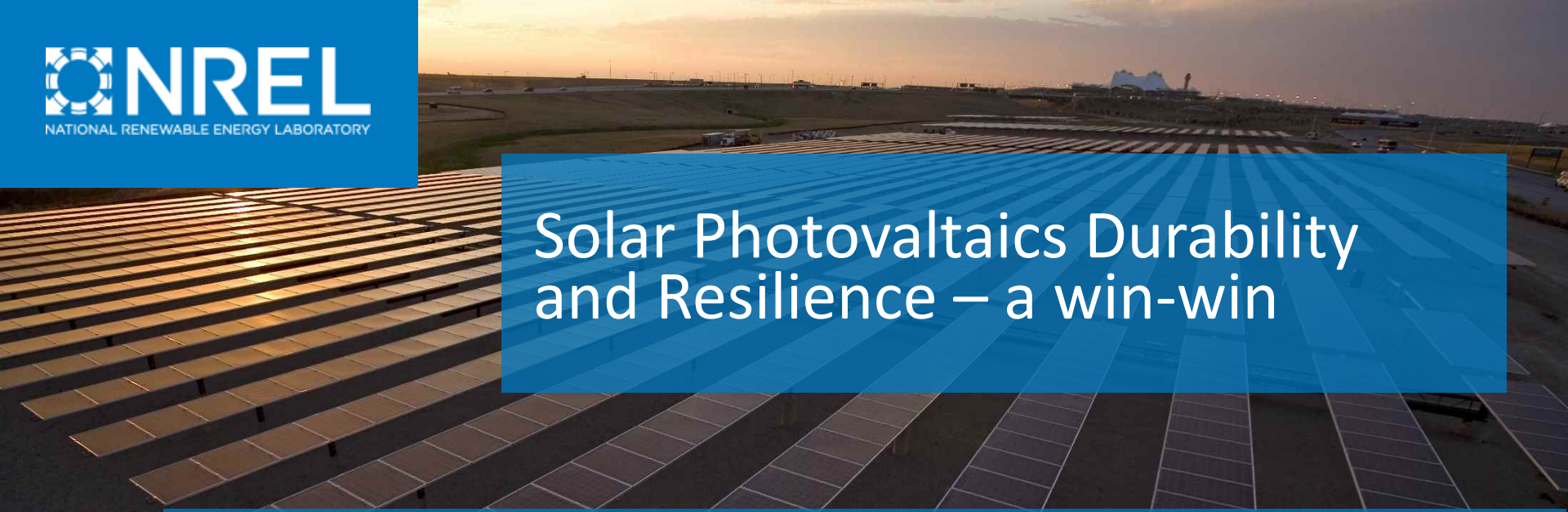


NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Solar Photovaltaics Durability and Resilience – a win-win

Innovations in Climate Resilience 2023

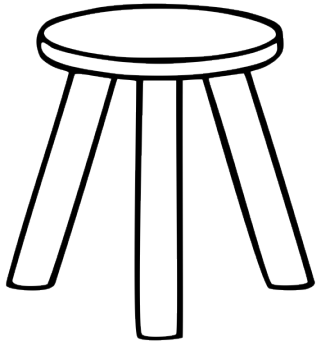
Columbus, OH

Dirk Jordan, Teresa Barnes, Chris Deline, Kirsten Perry, Nancy Haegel

3/30/2023

Photovoltaics has 45 years of reliability research

Caccivio et al., WCPEC, 2022.



Durable = long lifetime

Resilient = robust

Equitable = low cost

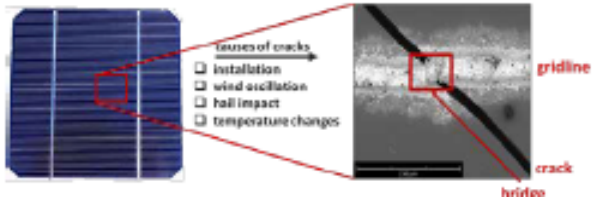
Reliability learning cycle

JPL Block Buy Program (1970s-1980s)

Field diagnostics

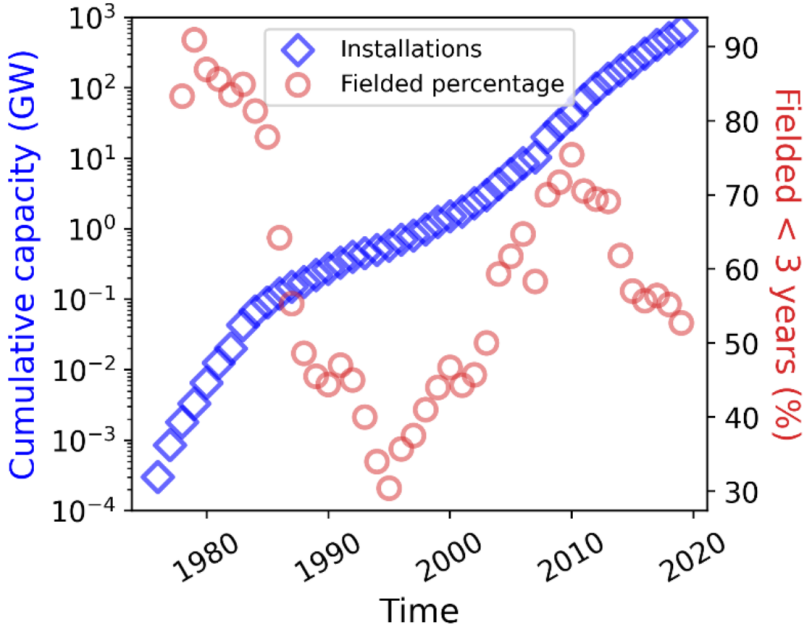
Tests/Standards

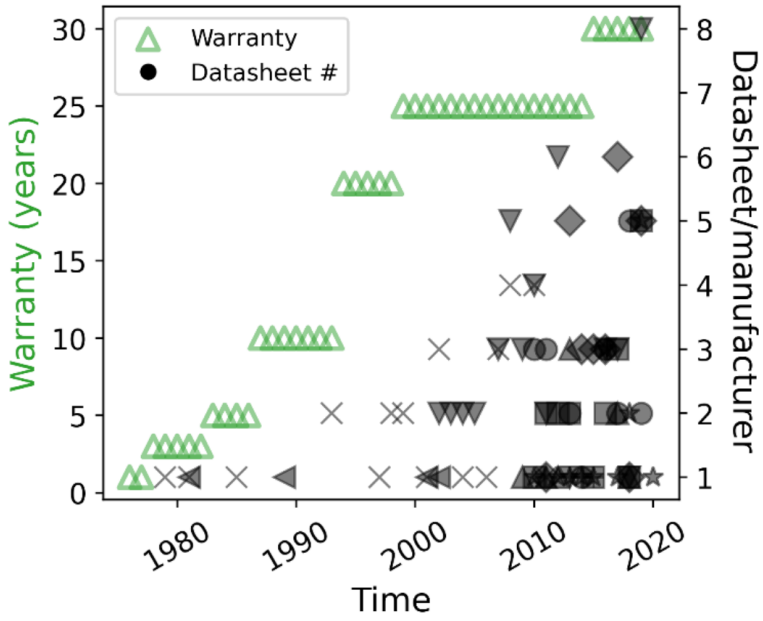
Failure analysis & modeling



The learning cycle can take several years

Rapid deployment & innovation





Most systems are new (< 3 years old)

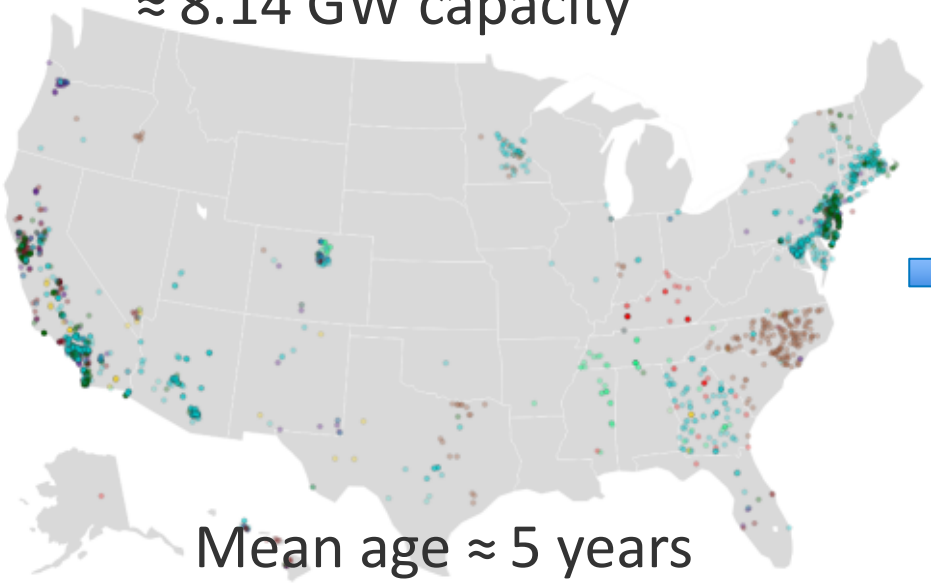
Warranties are decades long (20 – 40 years)

New products come out every few months

PV Fleet Data Initiative

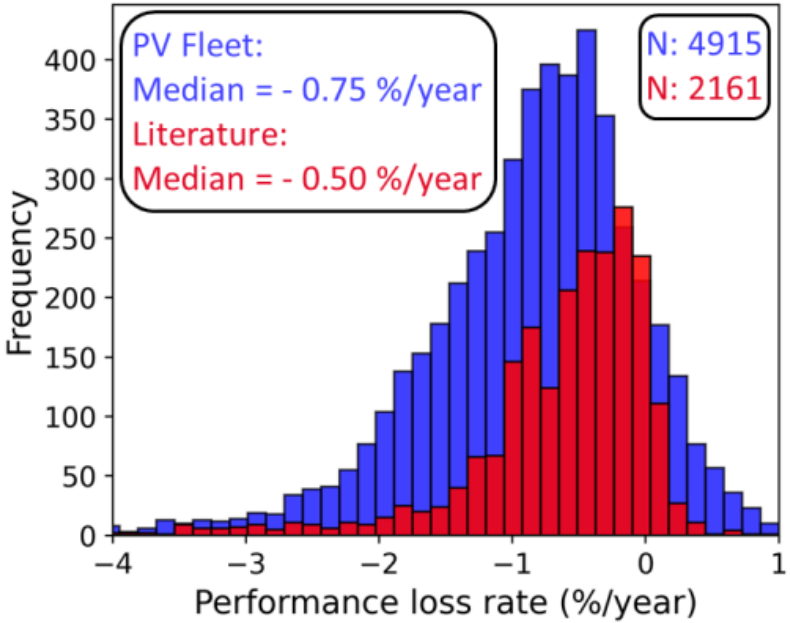
≈ 24,800 time series data,

≈ 8.14 GW capacity



Mean age ≈ 5 years

Long-term loss

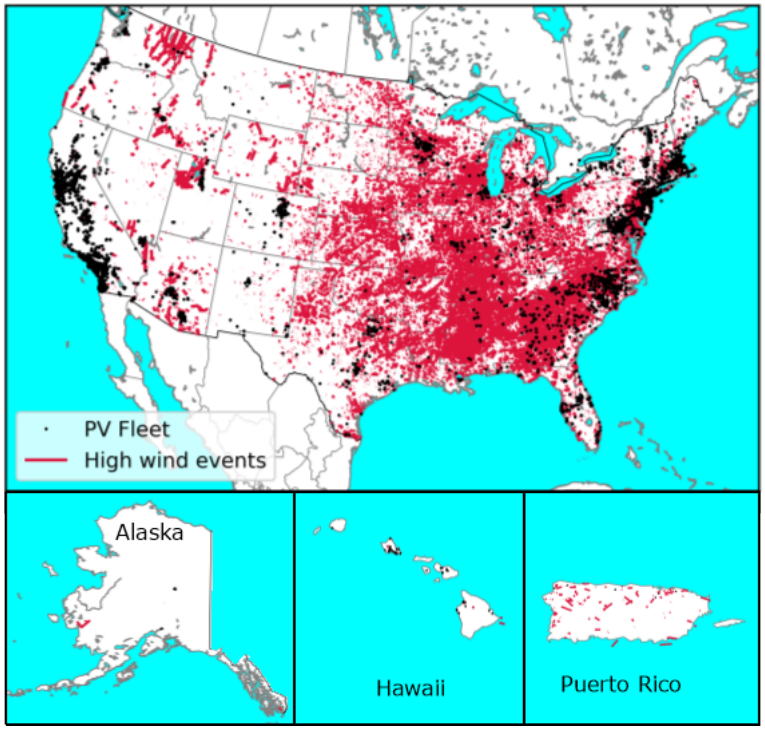


PV Fleet (blue): 100% systems

Literature (red) 80% modules

Jordan et al., Progress in PV, 2022.

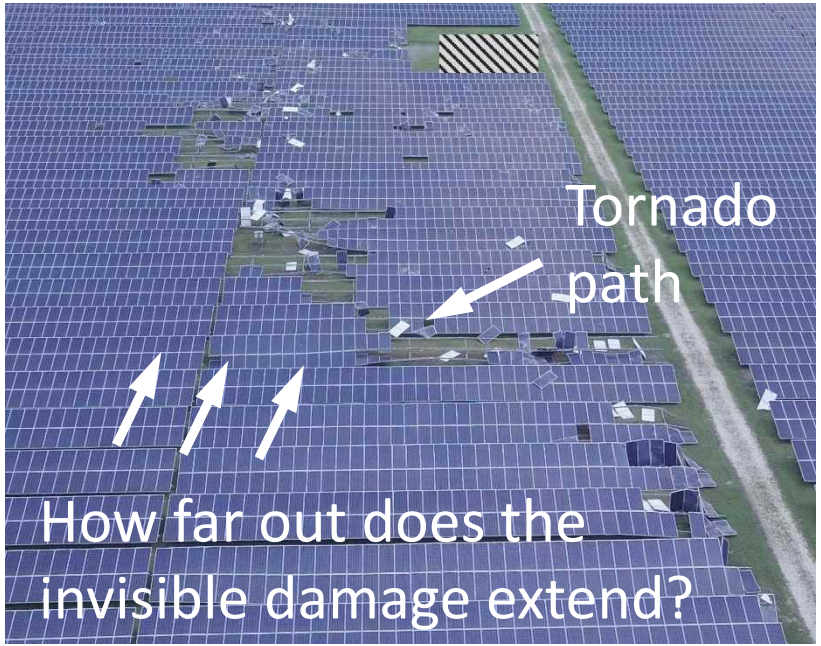
Extreme weather & PV systems



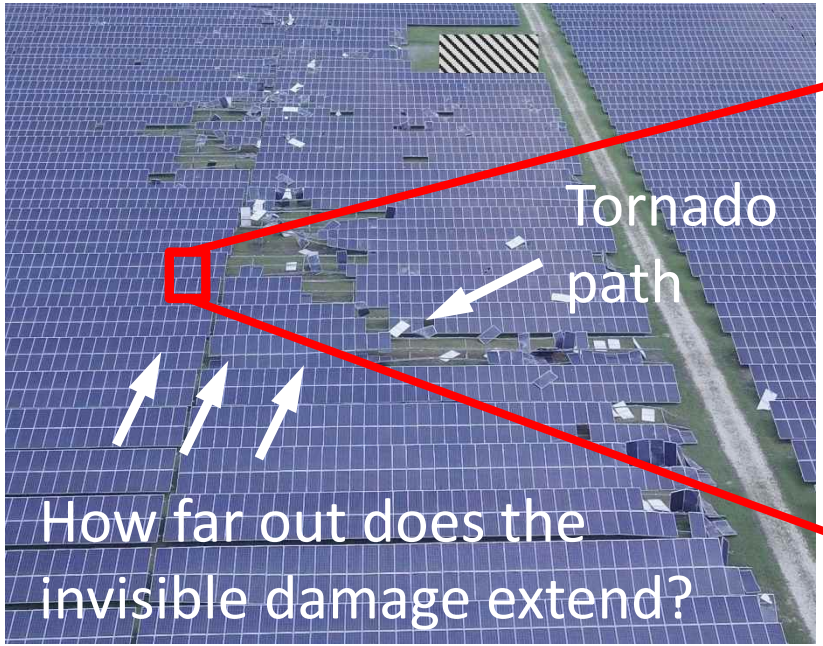
NOAA database on extreme weather PV Fleet timeseries

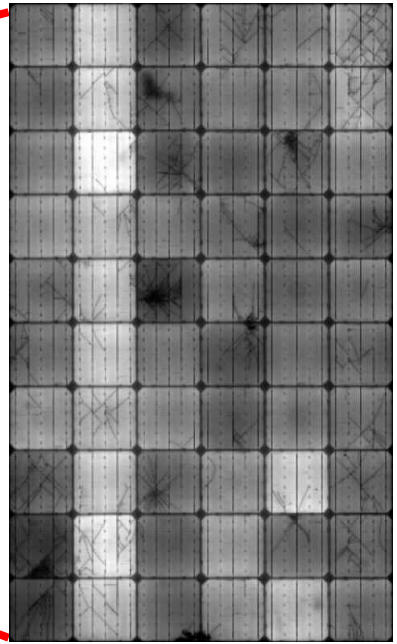
Determined events that came within 10 km of an existing PV system

Extreme weather impact is often not obvious



Extreme weather impact is often not obvious

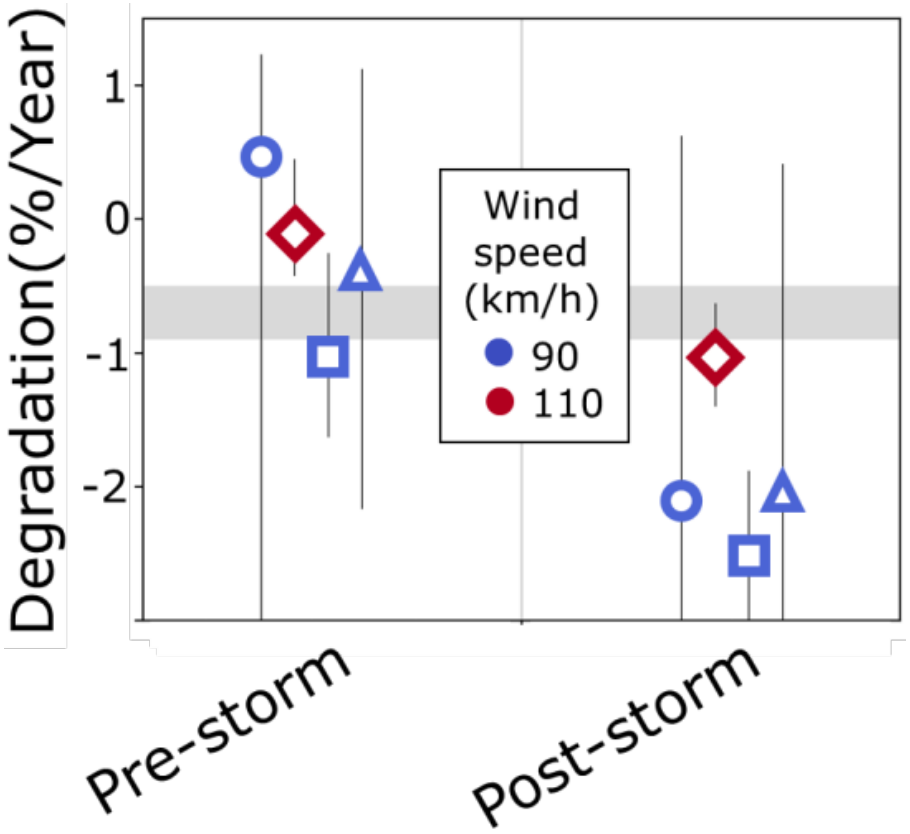




Cracked cells in module

Electroluminescence

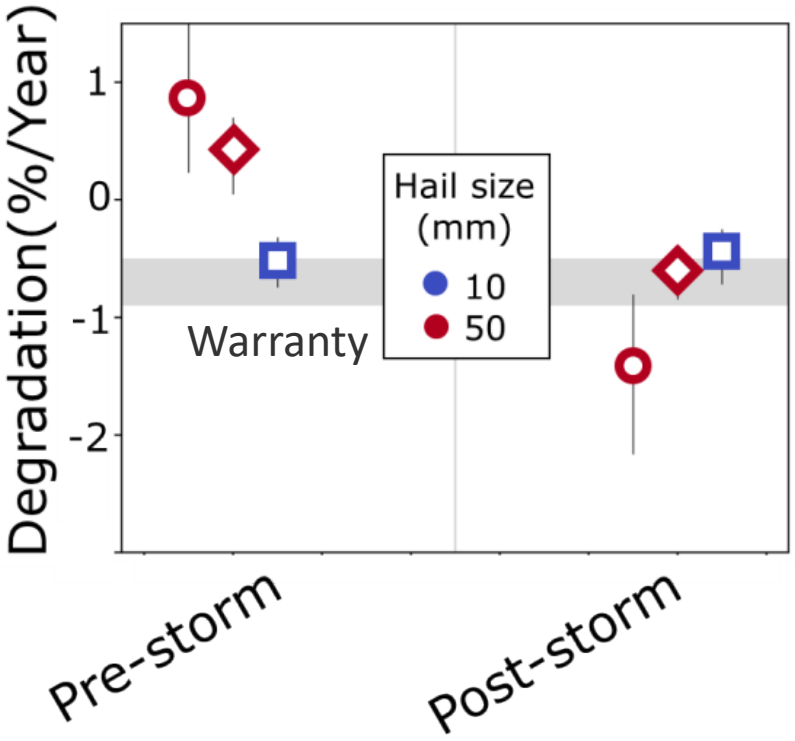
Long-term impact – high wind



Typical warranty

Performance outside warranty after storm

Long-term impact - hail



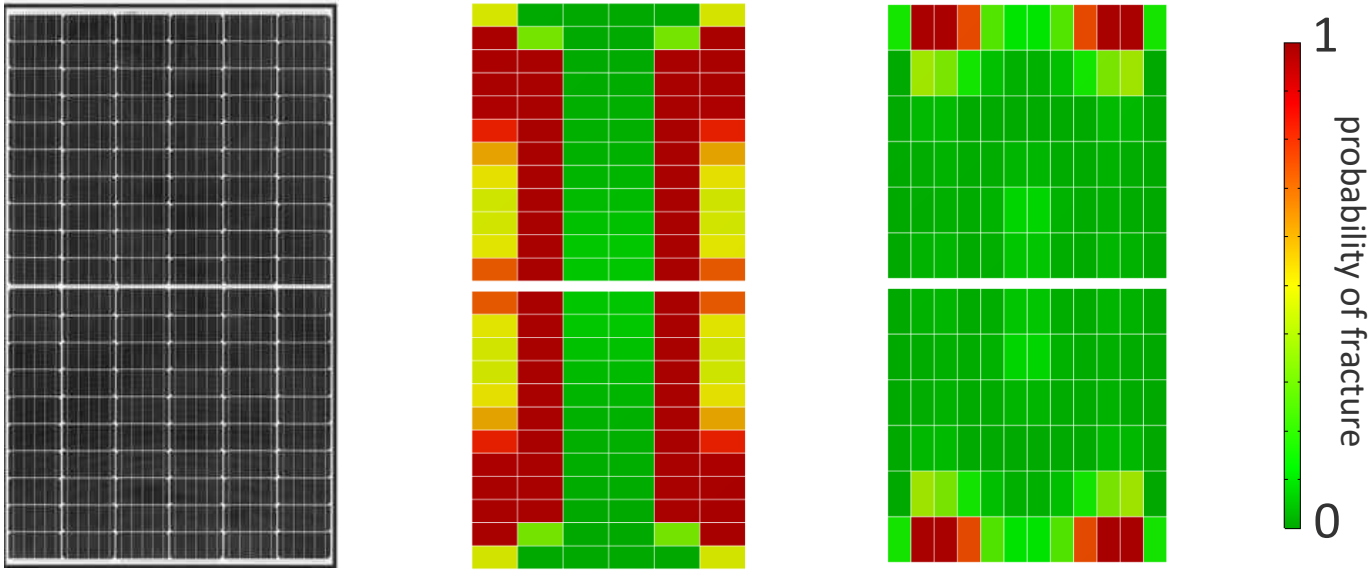
PV module are tested for hail

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

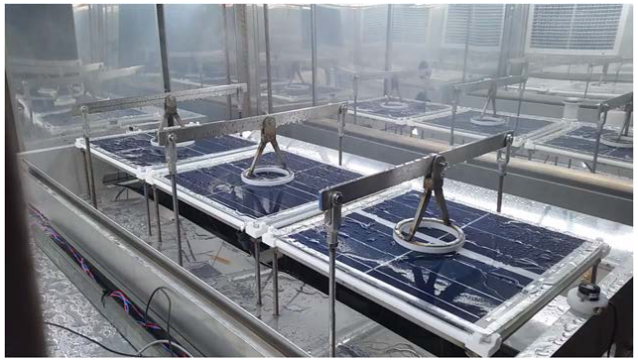
AAA polyamide module backsheets introduced

≈ 2020

Eder et al., 2019.

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

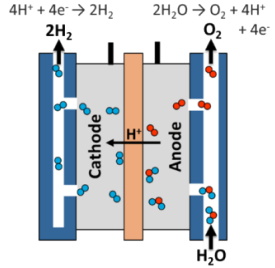
Wind

Catalysis

PV

Storage

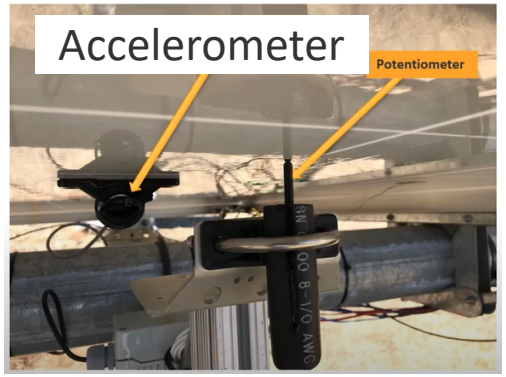
Electrolysis

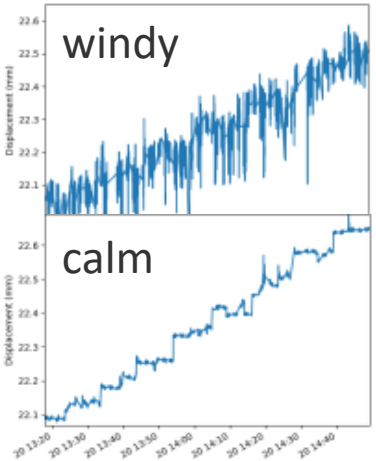


- Reliability data
- Characterization methods & tools
- Testing & standards

Rapid Degradation: convergent research area

Sensors & methods





Data from more sensors enables faster reaction to extreme weather

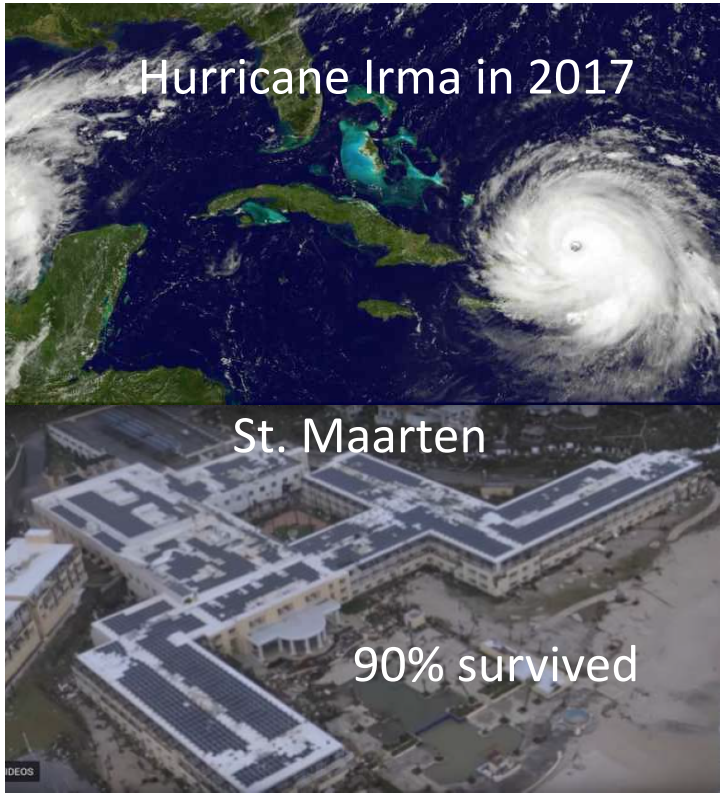
Opportunity for machine learning algorithm for detection

Conclusion

Building durable, resilient & equitable PV is possible

Systems engineering approach required

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



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Thank you

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PV reliability group,
Katherine Jordan

National Renewable Energy Laboratory
15013 Denver West Parkway, MS 3411
Golden, CO 80401, USA
dirk.jordan@nrel.gov

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