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NATIONAL RENEWABLE ENERGY LABORATORY

Recent Photovoltaic Performance Data in the USA

Photovoltaic Module Reliability Workshop (PVMRW)

Golden, CO

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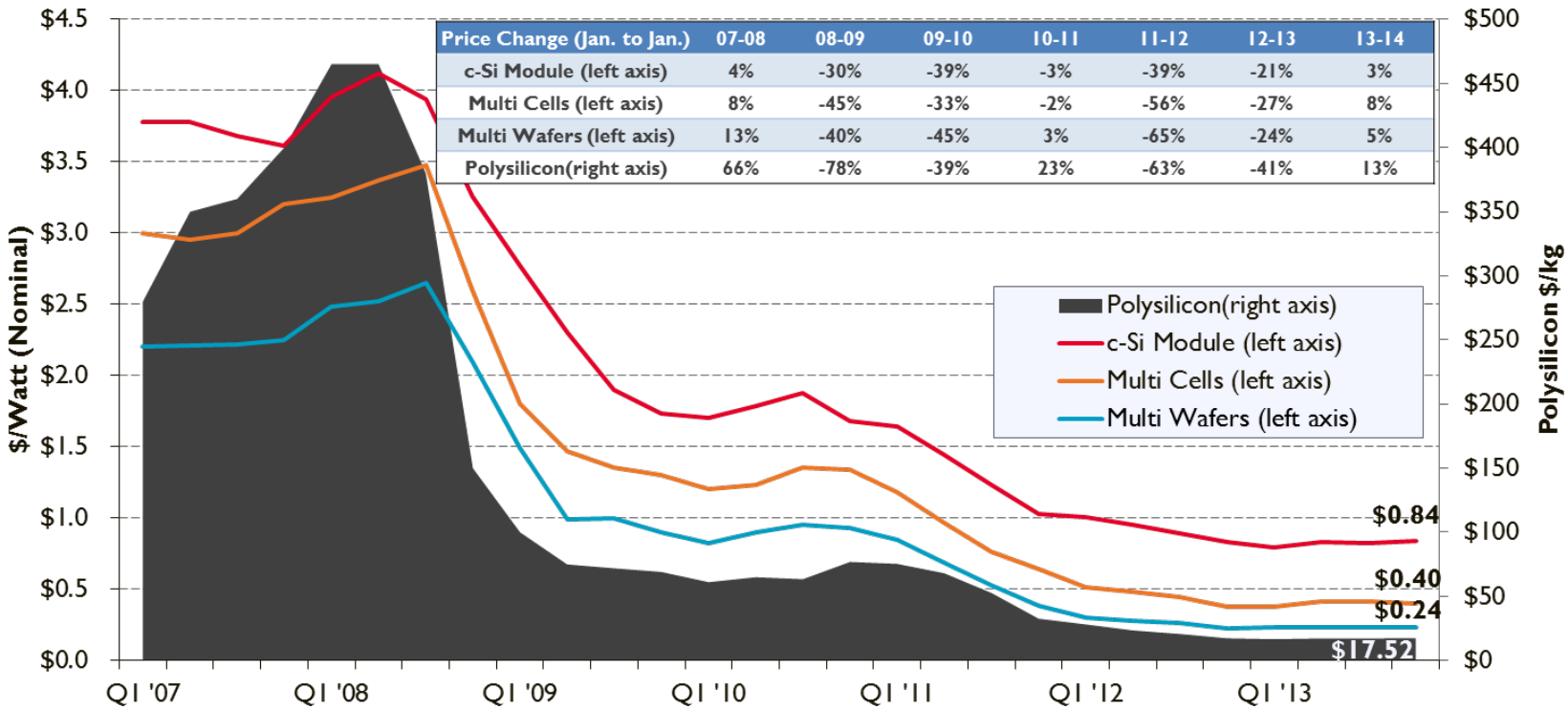
Outline

- Introduction
  - American Recovery & Reinvestment Act data
  - Performance relative to predicted
  - Reliability categories
  - First geographic trends
  - Impact of reliability categories
- Conclusion

Has the recent PV price decline led to reliability issues?



Price Change (Jan. to Jan.)	07-08	08-09	09-10	10-11	11-12	12-13	13-14
c-Si Module (left axis)	4%	-30%	-39%	-3%	-39%	-21%	3%
Multi Cells (left axis)	8%	-45%	-33%	-2%	-56%	-27%	8%
Multi Wafers (left axis)	13%	-40%	-45%	3%	-65%	-24%	5%
Polysilicon(right axis)	66%	-78%	-39%	23%	-63%	-41%	13%

D. Feldman et al., Q3 2013 /Q4 2013 Solar Industry Update, 2014 Edition

Recent Negative Headlines about Solar Industry

Quality issues threaten to give solar a black eye, PVTECH , F.Carus, 15 January 2013

How Bad Is PV Panel Performance?, IEEE Spectrum, B. Sweet, 30 May 2013

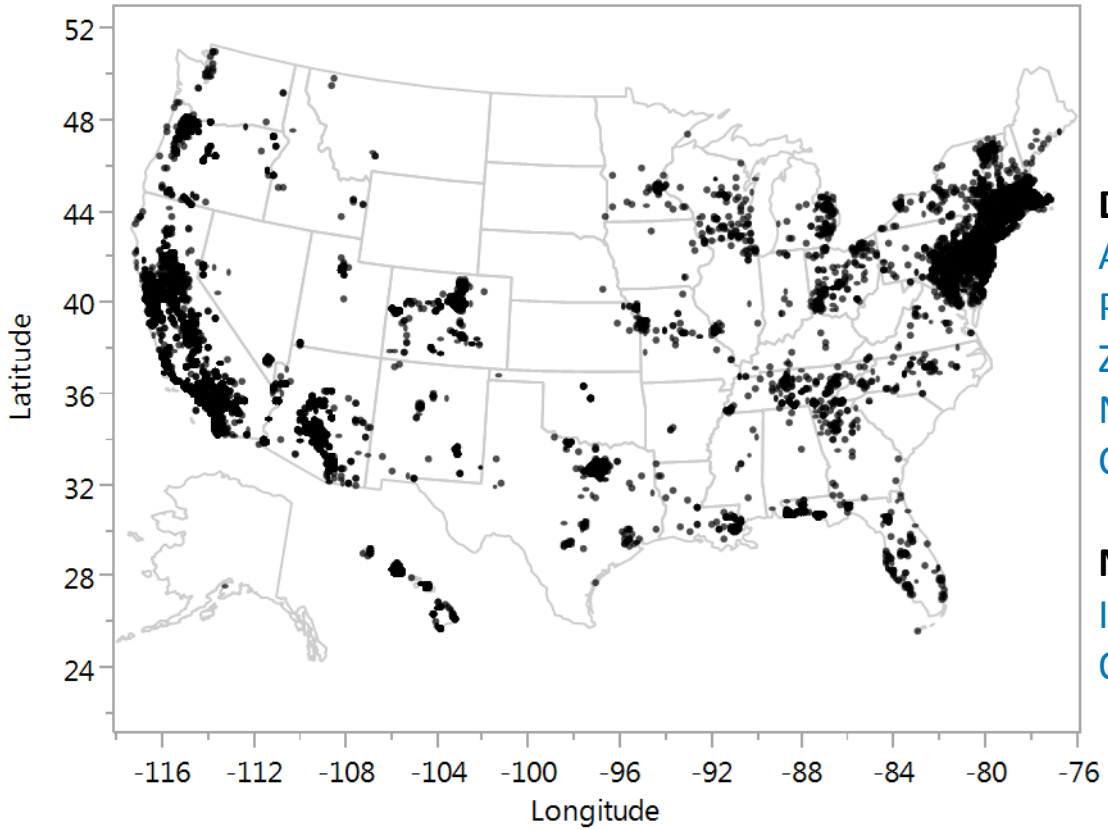
Solar Industry Anxious Over Defective Panels, New York Times, T. Woody, May 28, 2013

→ Documenting field performance data, especially on a large scale

Geographic Distribution of Systems

American Recovery & Reinvestment Act, Section 1603

50,000 Systems
1.7 Gwatts capacity
Up to 4 years of data



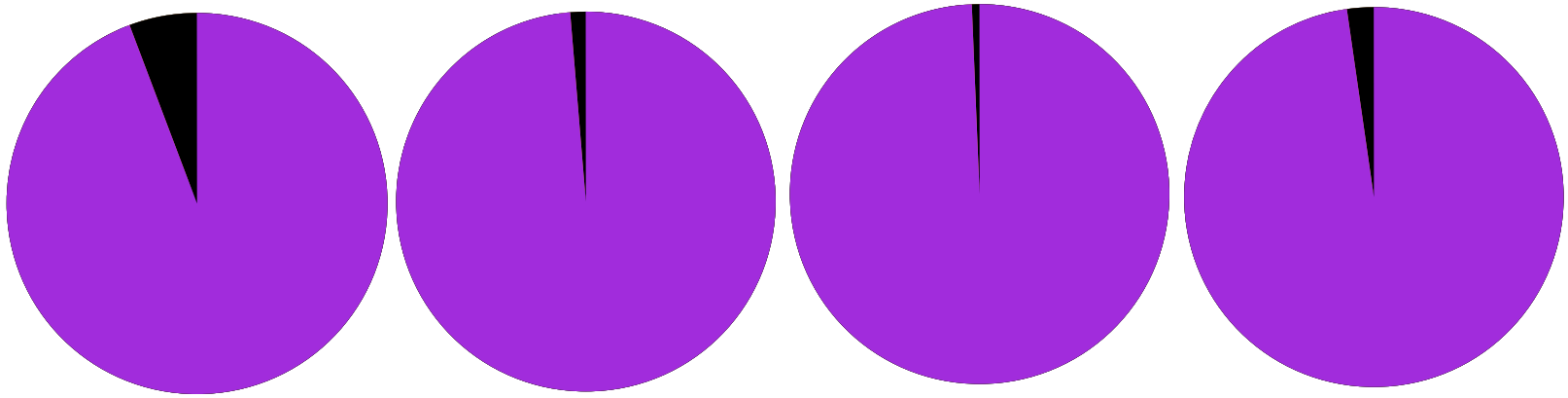
Data available:
AC production,
Predicted AC production
Zip code location
Nameplate
Comments

Not available:
Insolation
Orientation

Data filtering rules:

- Nameplate=production year1,2,3,4 → reject production years
- Predicted capacity factor: Predicted AC energy/(24*365*DC rating)*100= 3-40%
- Year1 production = Year2 production → reject year2 entry
- Annual production = predicted production → reject

No Evidence of Massive failure

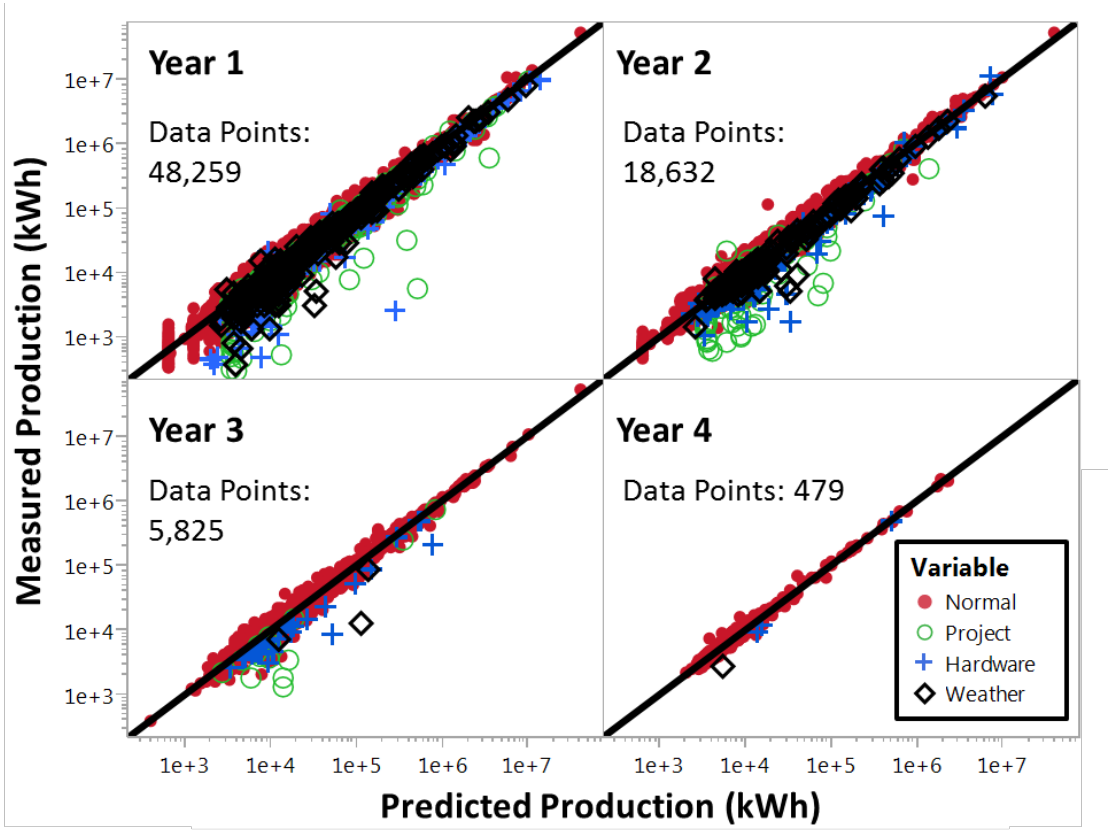


Year of Operation:	Year 1	Year 2	Year 3	Year 4
Data Points:	48,259	18,632	5,825	479
Normal	91.5	95.3	97.6	95.8
Hardware	0.7	0.6	0.5	0
Project	0.8	1.0	0.1	0.2
Weather	5.8	1.3	0.7	2.3
Data Collection	0.9	0.9	0.6	0.8
Hardware	0.2	0.9	0.7	0.8
No information				

Project/Site: Delay, grid interconnection, construction etc.
Weather: Snow, soiling, lightning, hurricanes etc.
Data Collection: Data acquisition, less than a year of data, etc. (not performance related)
Hardware: Inverter, module, breaker, fuses etc.

Most systems produce as expected

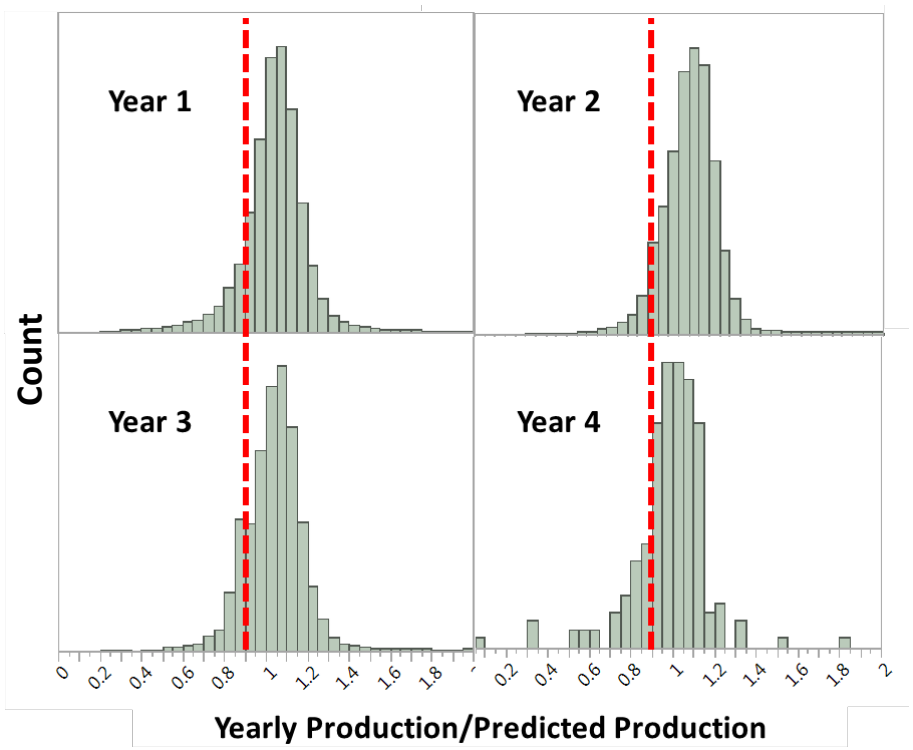
Measured vs. predicted production for all operation years



Project issues data points tend to be farther away from unity line →
They don't occur that often (previous slide) but if they do they tend to have larger impact

Ca. 90% of normal data produce at least 90% of predicted

Normal data



Ratio: measured production/predicted production

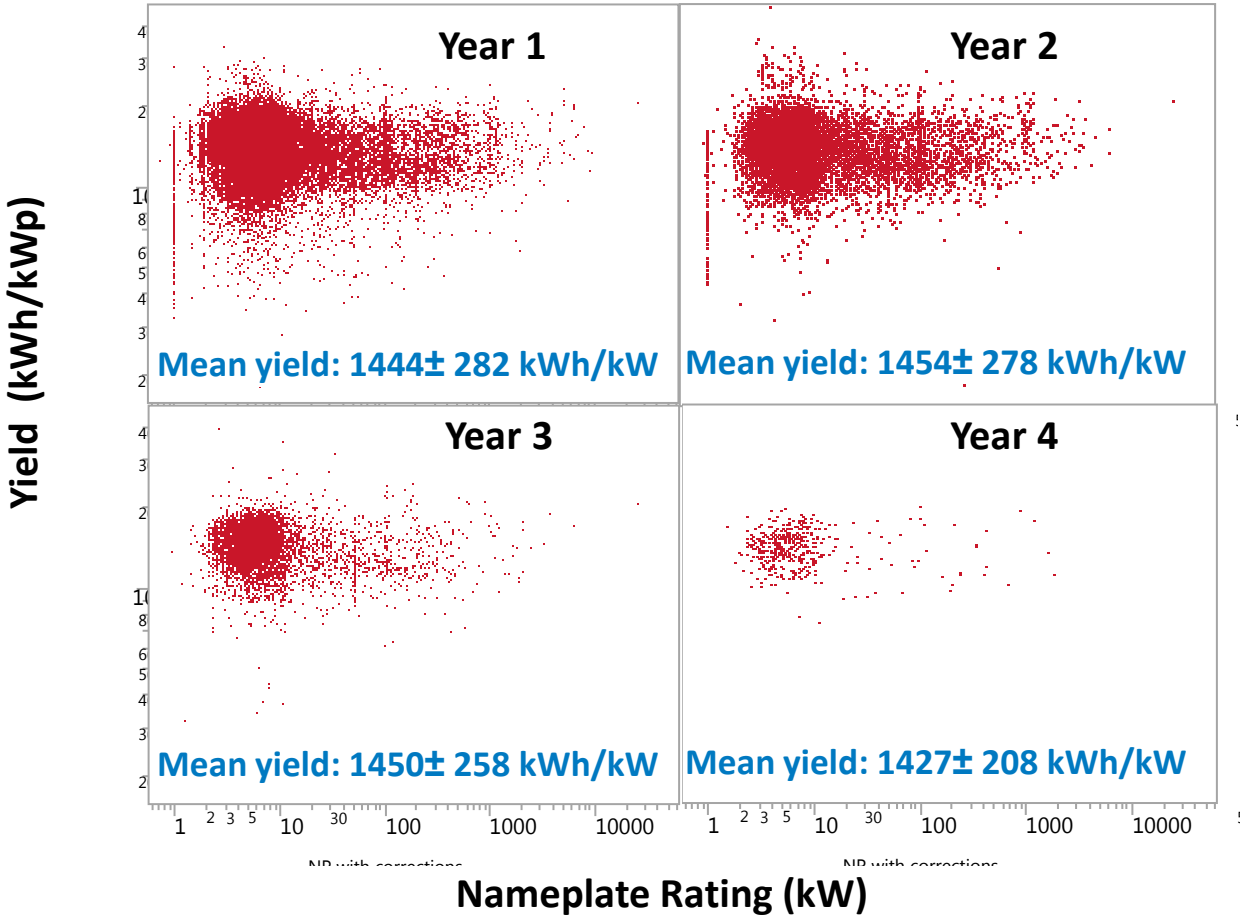
Median / Stdev	Year1	Year2	Year3	Year4
Normal	1.05 ± 0.14	1.06 ± 0.14	1.04 ± 0.14	1.03 ± 0.13
Project	0.84 ± 0.24	0.61 ± 0.37	0.29 ± 0.36	-
Data Collection	0.90 ± 0.41	0.76 ± 0.35	0.71 ± 0.21	0.65 ± 0.19*
Hardware	0.86 ± 0.23	0.77 ± 0.24	0.74 ± 0.18	0.74 ± 0.42*
Weather	0.87 ± 0.22	0.78 ± 0.20	0.45 ± 0.29*	-
No information	0.25 ± 0.37	0.48 ± 0.47	0.50 ± 0.16	0.54 ± 0.12*

* Indicates less than 10 data points

Normal data produce a few percent more than expected
→ may have significant impact on performance based incentive programs

No trend with nameplate rating

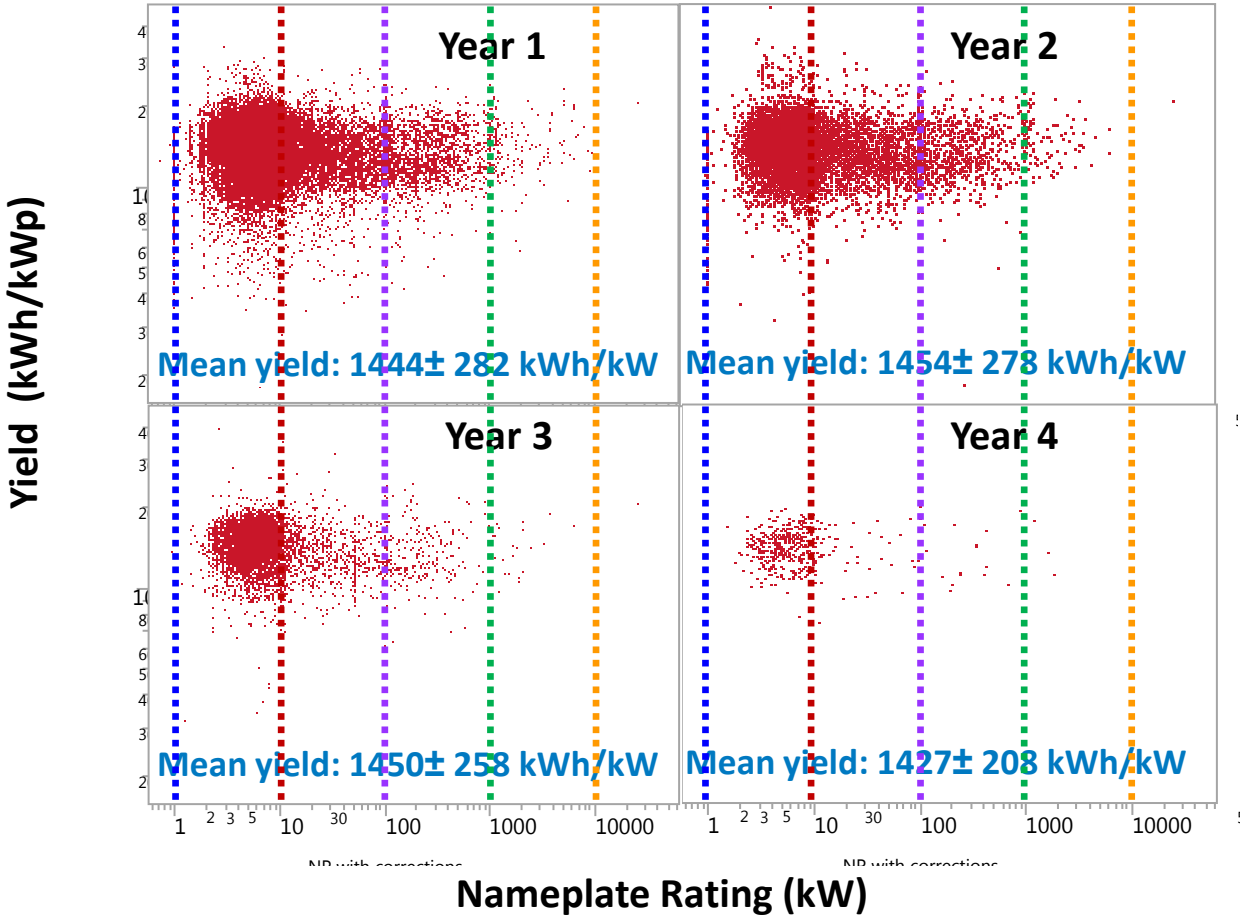
Yield (AC energy/nameplate rating) vs. nameplate & year



Yield appears wider for smaller systems → caused by higher point density

No trend with nameplate rating

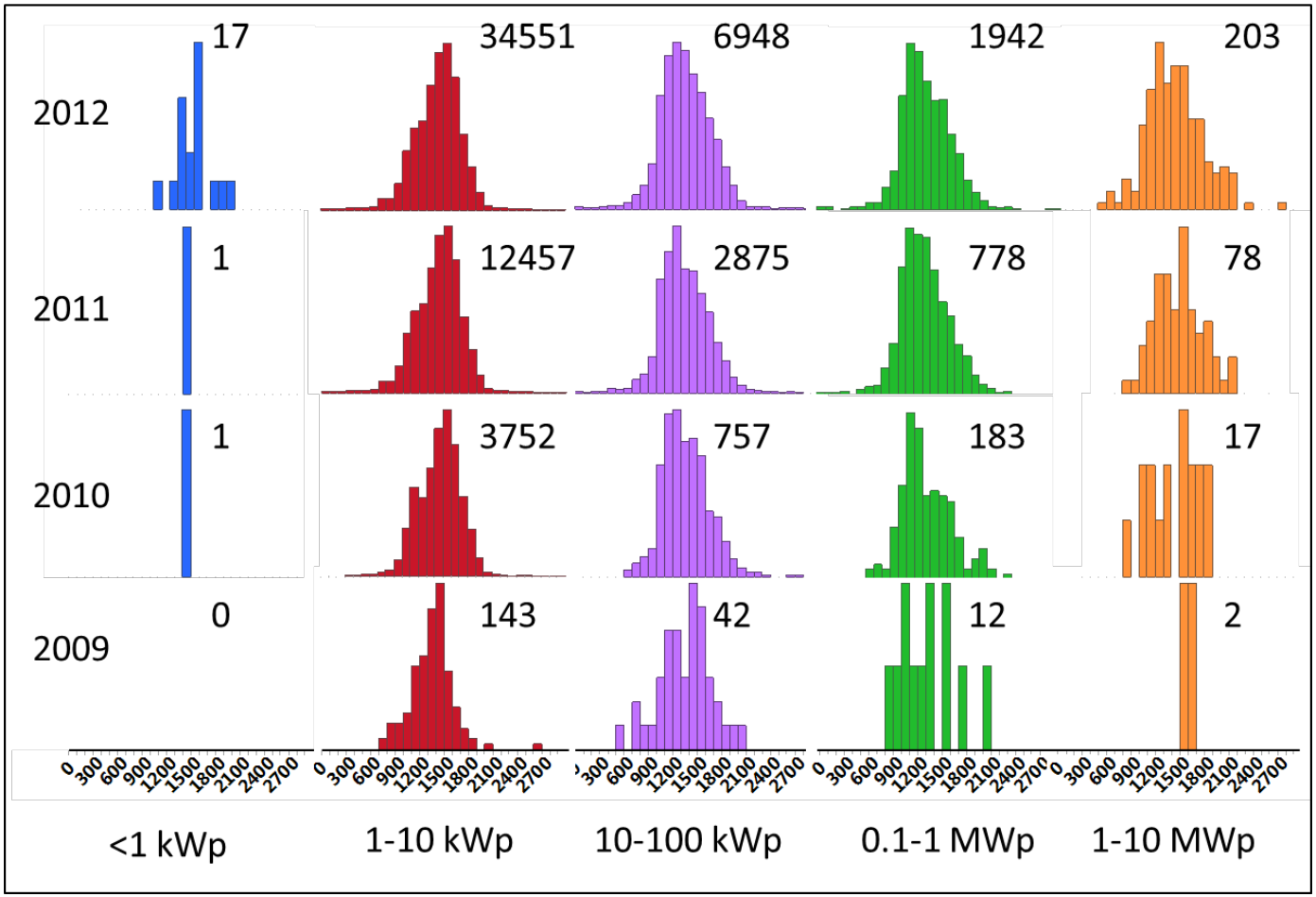
Yield (AC energy/nameplate rating) vs. nameplate & year



Yield appears wider for smaller systems → caused by higher point density

Yield distributions similar for different system size

Note: individual histograms have different count scales



AC yield

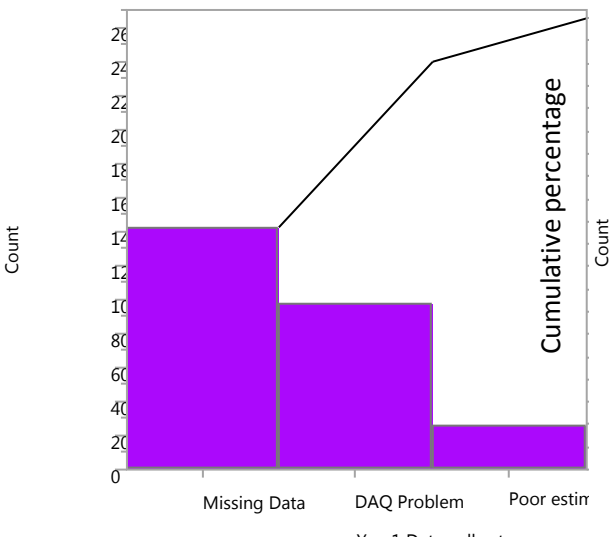
Nameplate rating

Distribution shapes for the AC yield for different rating bins as a function of year

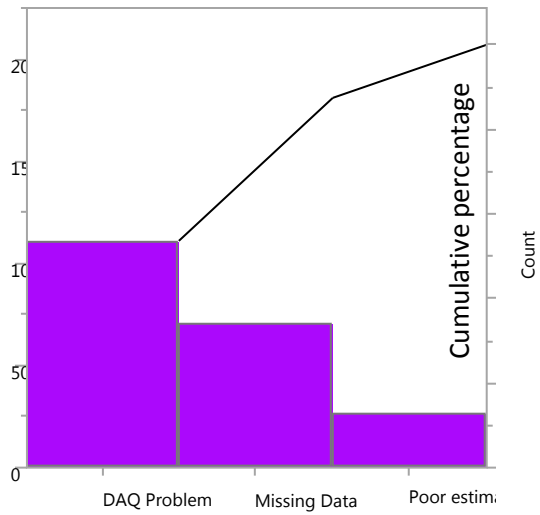
Data collection issues fall by order magnitude

Data collection-related issues

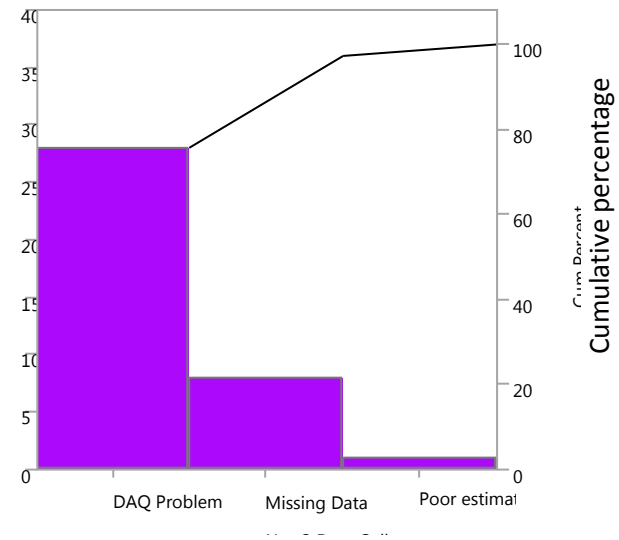
Year 1



Year 2



Year 3

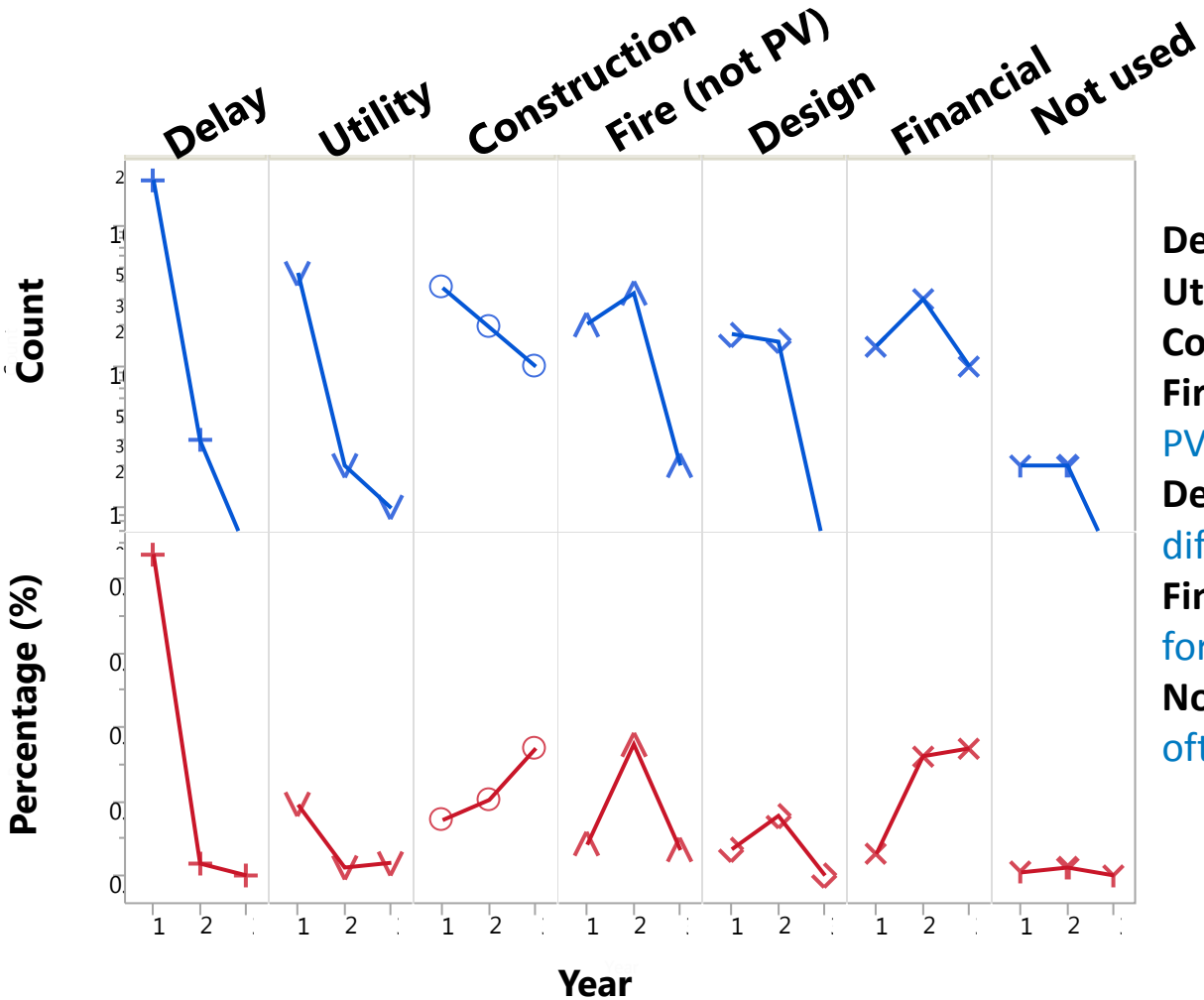


DAQ: data acquisition problem such as data transmission problem, internet outage etc.
Missing data: Less than a year before data were entered

Mean missed time (months)

Less than 1 year:	2.1	Less than 1 year:	2.2	Less than 1 year:	2.1
DAQ Problem:	3.5	DAQ Problem:	4.5	DAQ Problem:	5

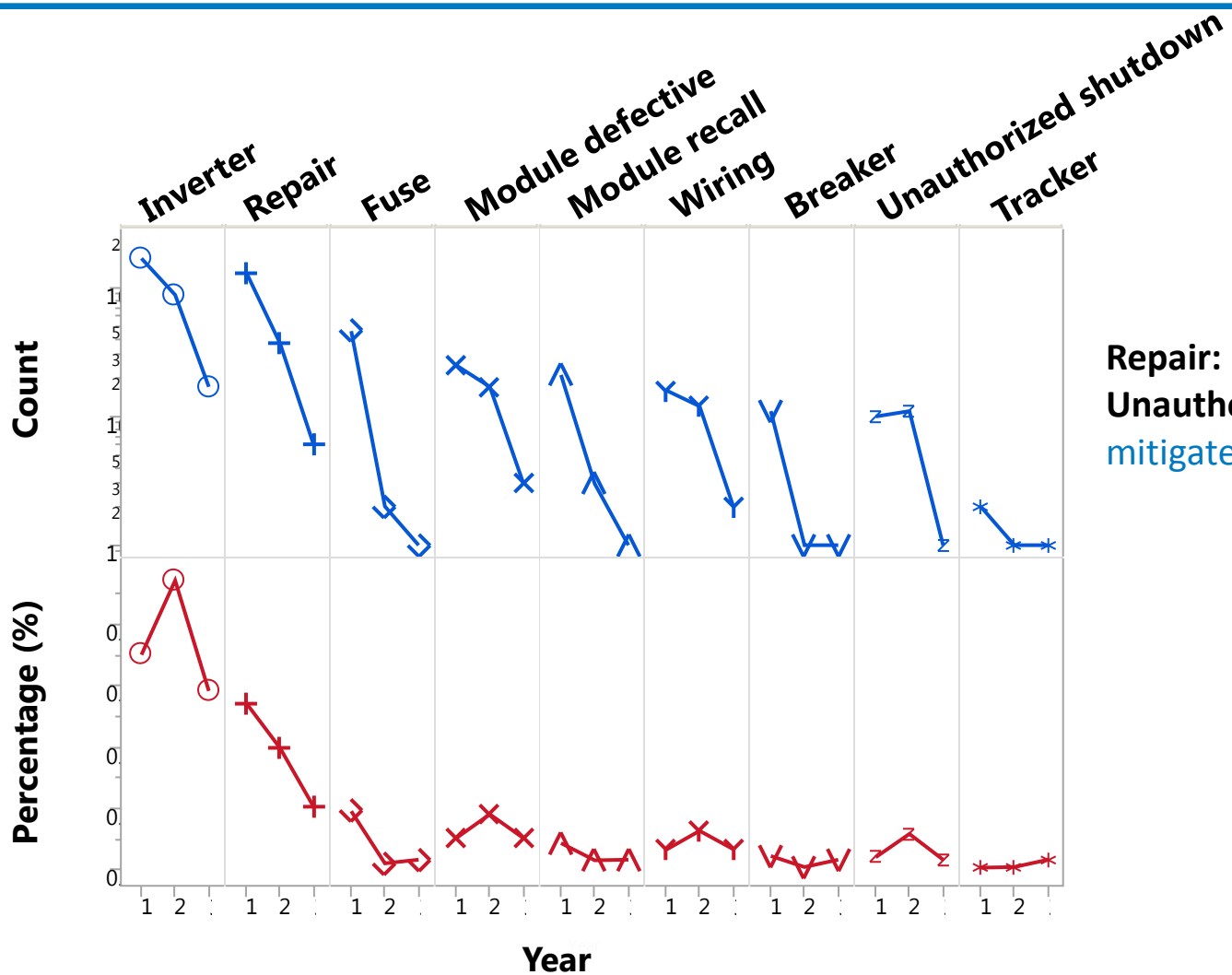
Project-related issues are dominated by delays



Delay: Permitting & construction
Utility: Grid interconnection
Construct.: Roof repair, remodeling…
Fire: fire at site not caused by PV → PV was turned off as precaution
Design: addition of new part-array @ different orientation
Financials: shutdown due to foreclosure
Not used: PV system not used as often

- Delay & grid interconnection dominates 1st year, rapidly declines in subsequent years
- Construction shows small percentage increase over years
- Fire can have broader impact due to precautionary PV system shutdown
- Financial reasons correlated to states with large housing price cycles

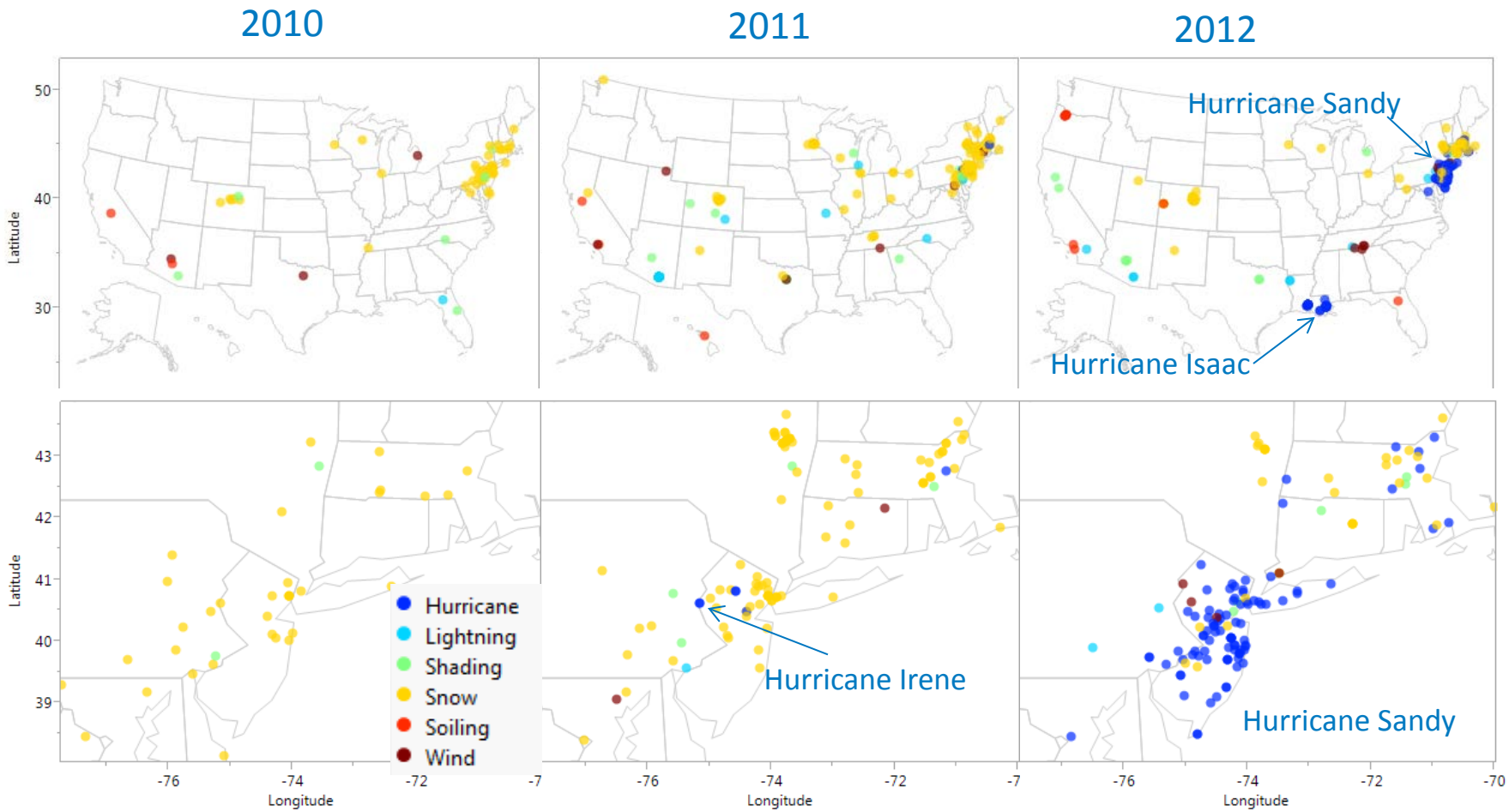
Hardware-related issues are dominated by inverter



Repair: Unspecified repair & outages
Unauthorized shutdown: May be mitigated by interconnect locks

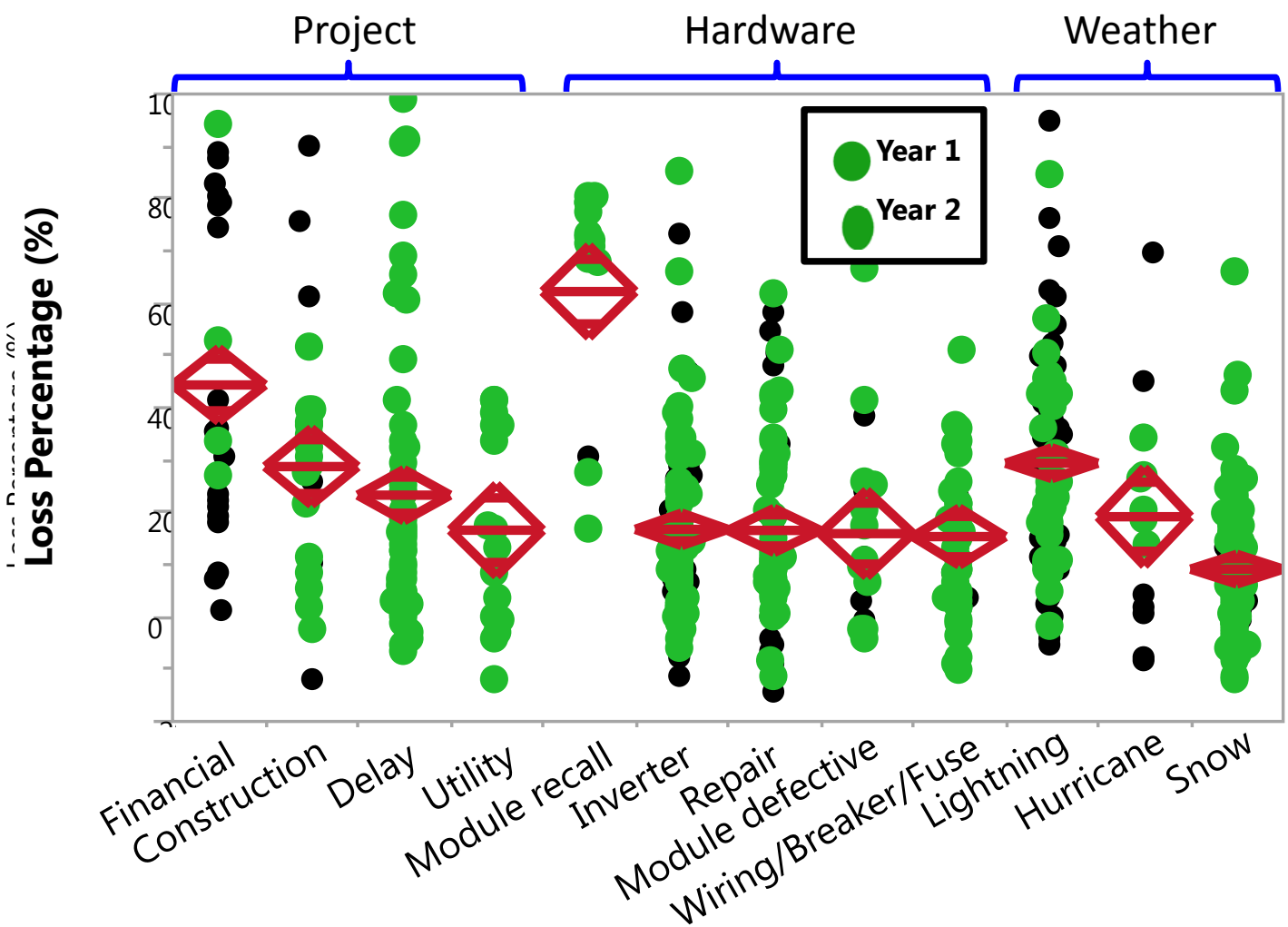
Less than 0.1% are due to defective modules

Weather-related issues dominated by snow & hurricanes



Hurricane: Typically, down time due to grid outage, not because of damage to system
Lightning: Not direct hits to PV system but transformer

Annual loss impact (%) of different categories



Performance in anomalous year compared to normal year → loss estimation due to cause of anomaly (assumes the same annual production)

Diamonds: 95% confidence interval
Crossbar: Mean

Module recalls do not occur often but if they do they can have large impact

Conclusion

- Analyzed field performance of 50,000 PV systems
- More than 90% of normal systems produce at least 90% of expected
- Project problems may not occur as often but have large impact
- Project-related problems are dominated by delays in the first year of operation, then rapidly declines in subsequent years.
- Hardware issues dominated by inverter, particularly in the first year of operation
- Less than 0.1% are due to defective or underperforming modules
- Module recalls can lead to significant annual production losses
- Weather-related issues are dominated by snow and hurricanes

Acknowledgments

Thank you for your attention

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