2023 PVPMC Blind Modeling Comparison Update

PRESENTED BY

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SAND2024-05652C

Participants

~ 35 participants from 15 countries and 34 organizations with 135 submissions

Lelia Deville, Marios Theristis, Kevin Anderson, Juergen Sutterlueti, Youri Blom, Mark Campanelli, Alejandro Gonzalez Carballo, Gregorio Olivares Casero, Arijit Chakroborty, Felix Perez Cicala, Andrei Cunha, Anton Driesse, A S M Jahid Hasan, Will Hobbs, Adam Rasmus Jensen, Sha Li, Javier Lopez Lorente, Ivan Diaz Martinez, Eduardo Mello Martins, Leonardo Micheli, Ricardo Motta, Marie-Joe Najm, Upama Nakarmi, Maitheli Nikam, Jeff Organ, Suveer Panditrao, Matthew Prilliman, Kurt Rhee, Rafael Pereira Santos, Martin Schneider, Branislav Schnierer, Ioannis Sifnaios, David Smith, Alvaro Fernandez Solas, Navin Vanderwert, Robert Williams, Bruno Wittmer, Changrui Zhao

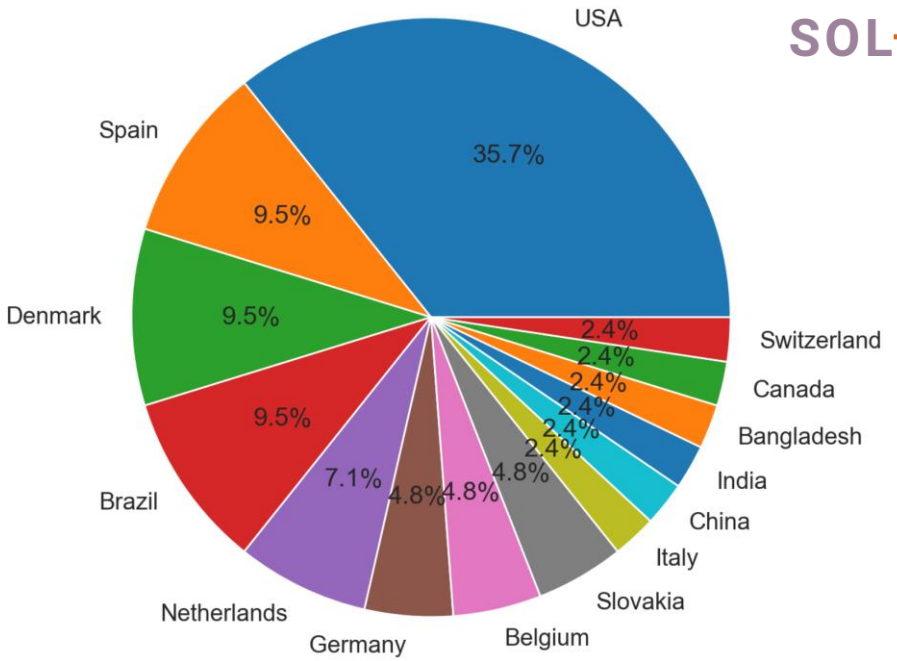
Special thanks to Juergen Sutterlueti and Gantner Instruments for data provision

Gantner instruments

Intelligent Measurement Systems LLC

Clean Power Research, greengo energy, CENER, DTU, PVSYST, NREL, STANDARD SOLAR, edp Renewables, LUMINATE, PV Performance Labs, ATKINS, DNV, SOLARGIS, Intersect Power, TU Delft, LEEWARD renewable energy, pvDesign a RatedPower app, NEO Virtus Engineering, Inc., CanadianSolar, SAPIENZA Università di Roma, EUROPEAN ENERGY, terabase, 3E, Universidad de Jaén, Universidade Federal de Santa Maria 1960, SOL-PHI ENGINEERING, Southern Company, inova energy, FOTOVOLTEC Solar Engineering, wood., Sandia National Laboratories

Country



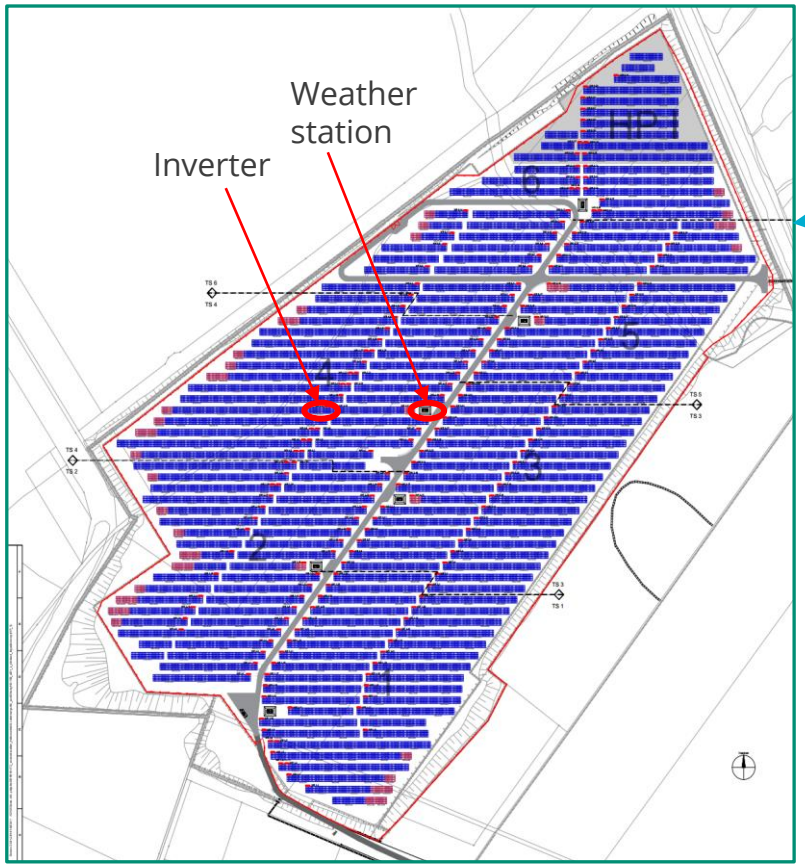
Motivation & Previous Blind Modeling Results

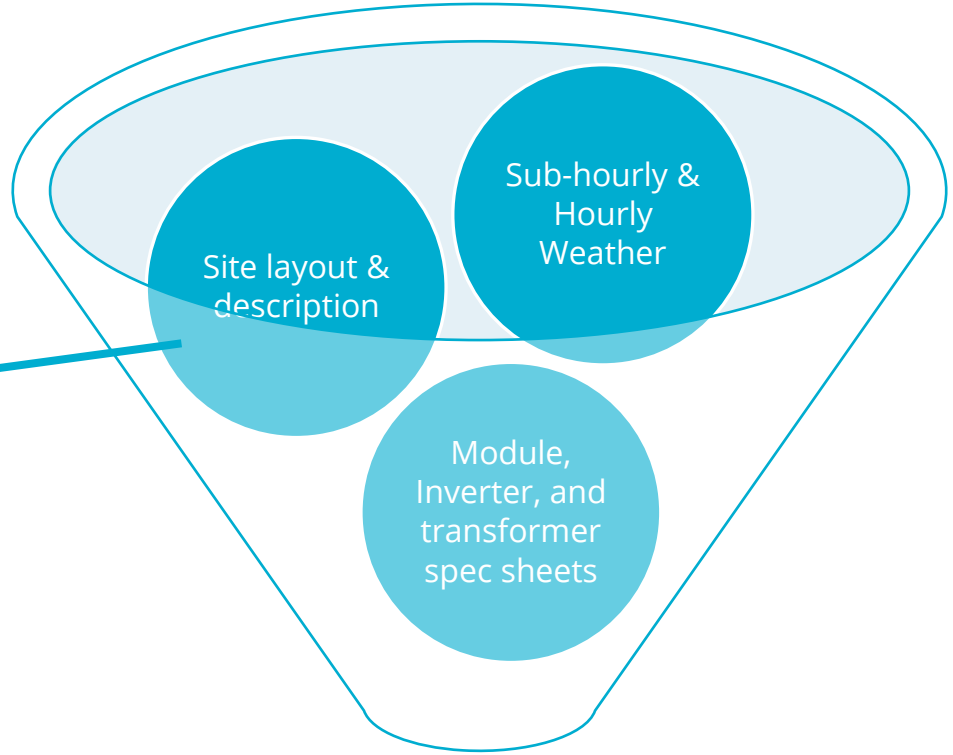
- Blind comparisons allow modelers to compare their models and skills to others from a wide variety of disciplines and skill levels without causing any bias from using known datasets

- This comparison:
  - Has a larger system size than considered in the previous comparison
  - Was done in stages to trace sources of uncertainty in each modeling step
  - Includes data at hourly and sub-hourly intervals
  - Software providers are separate to observe variations between them in greater detail
  - Is a work in progress

System Introduction

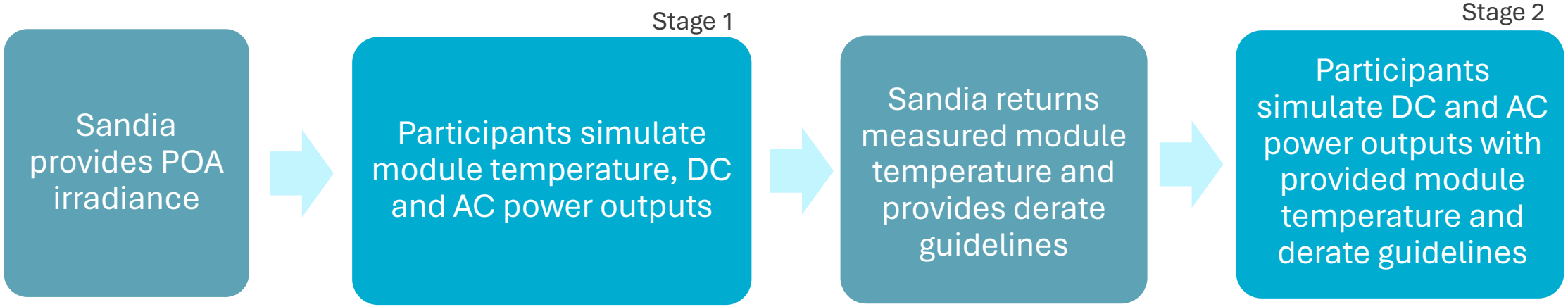
14.5 MW fixed-tilt power plant in Germany





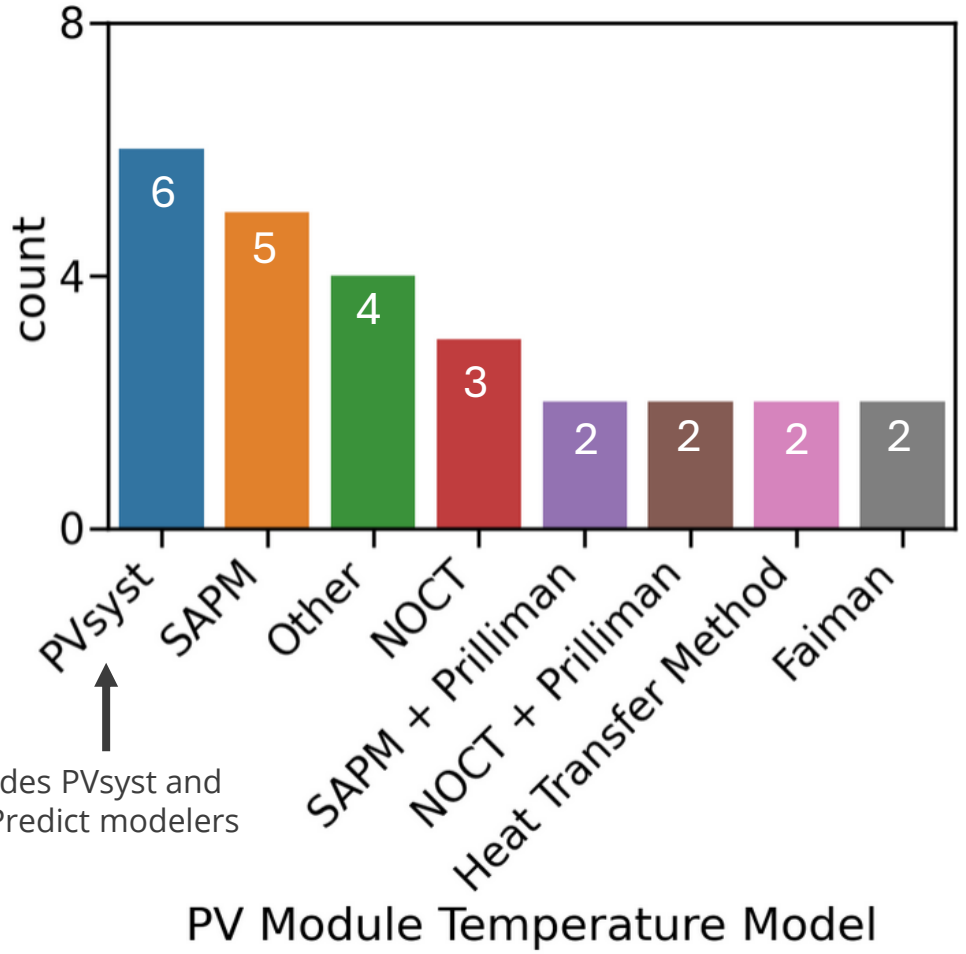
Modeled module temperature, inverter and site power at DC & AC levels

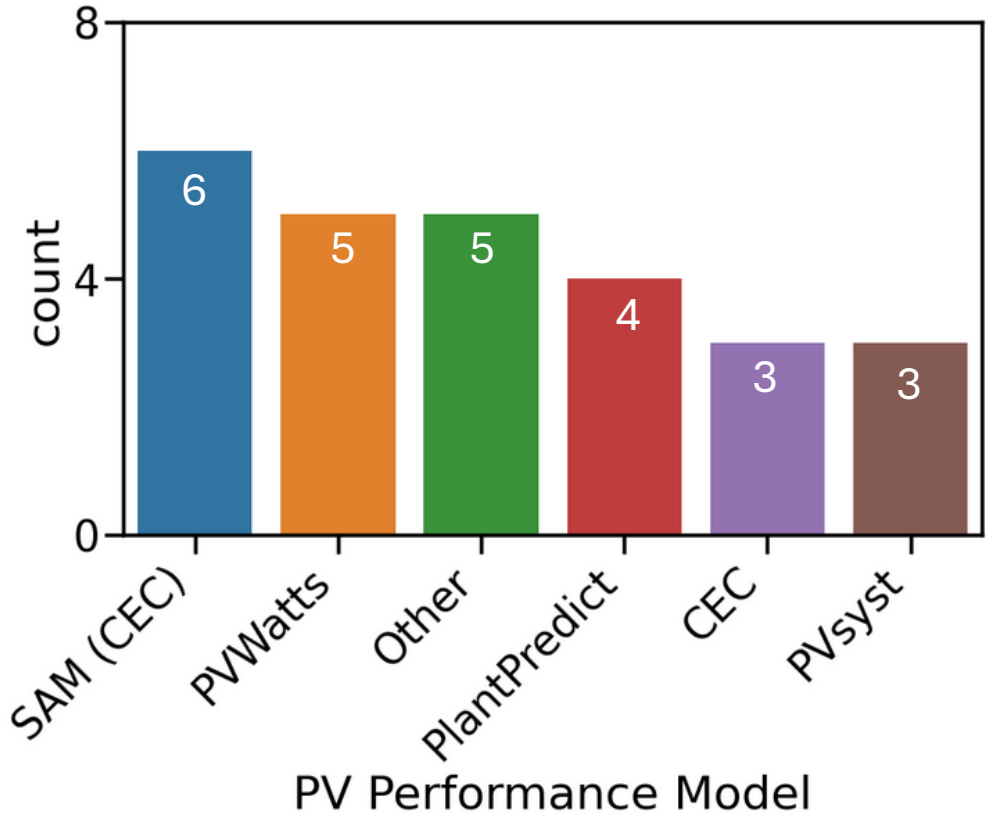
Iterative Process



Modeling Statistics

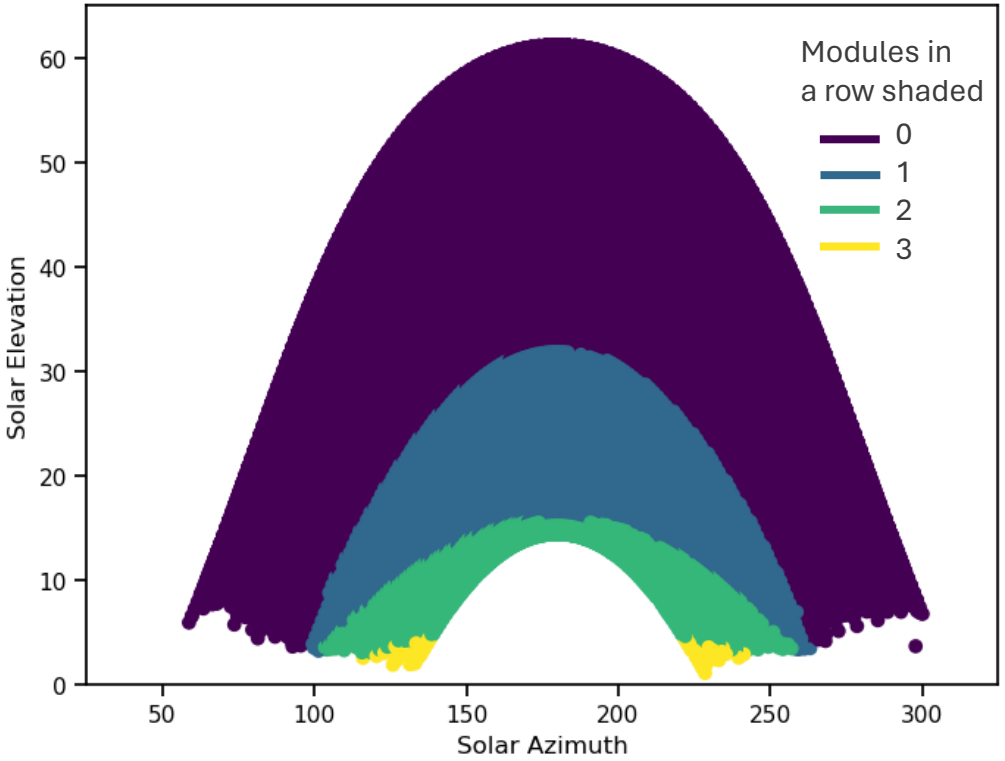
- ‘Other’ category includes users with custom & in-house models





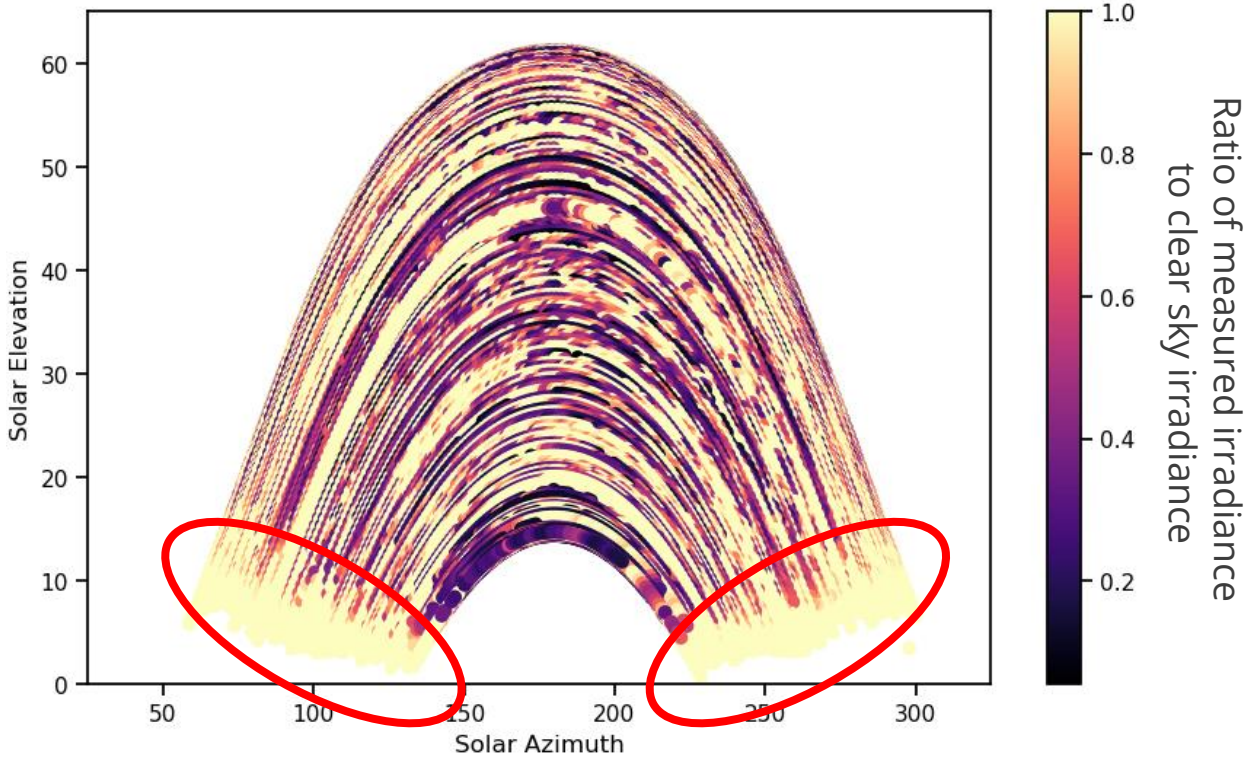
Data Quality Verification – System Shading

- Calculated shaded fraction with pvlib.bifacial.infinite_sheds._shaded_fraction



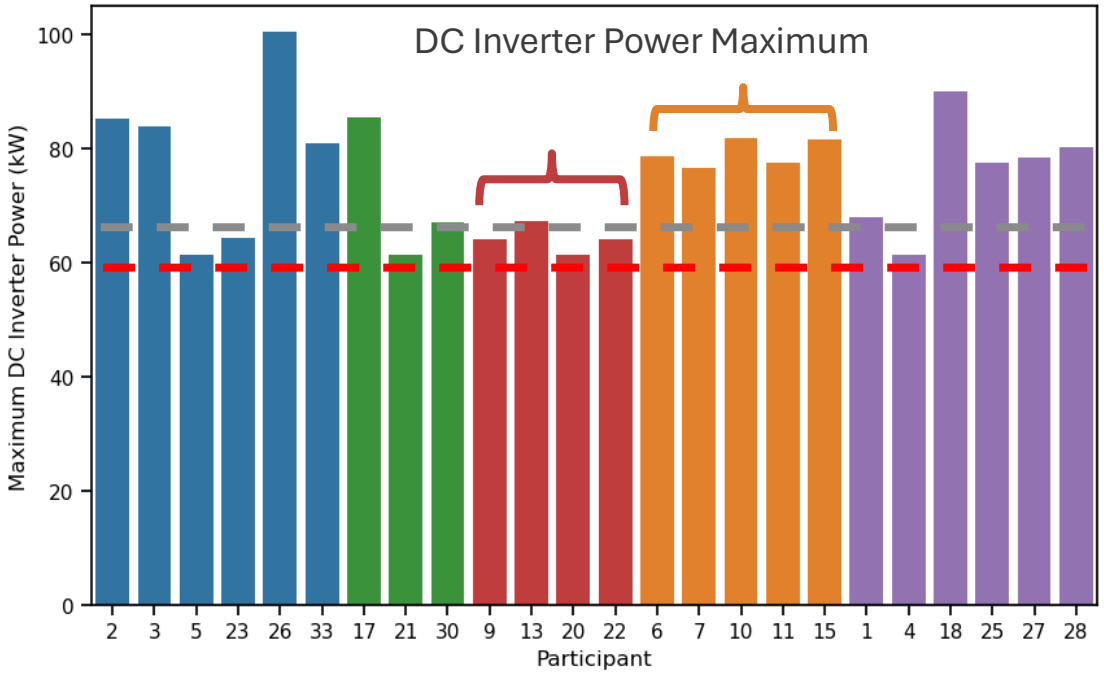
*Not used in any calculations but as a data exploration tool

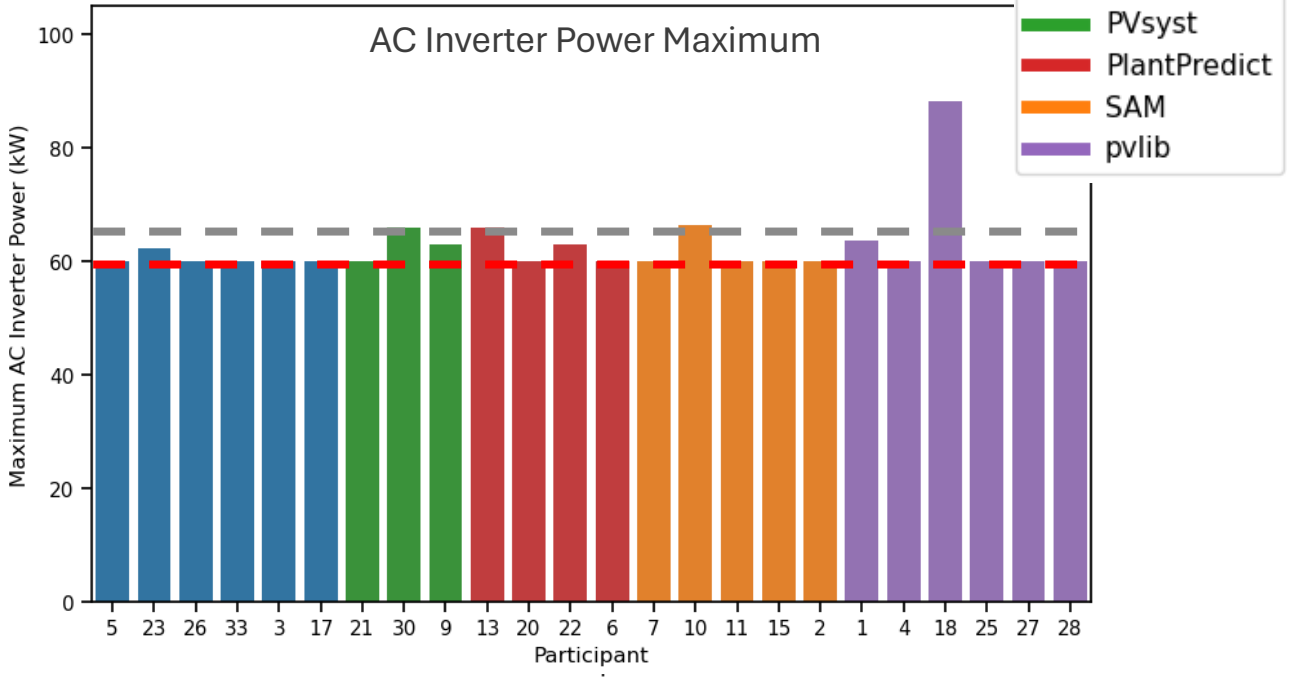
- Checked there is no sensor shading by comparing ratio of measured irradiance to clear sky values



System Clipping

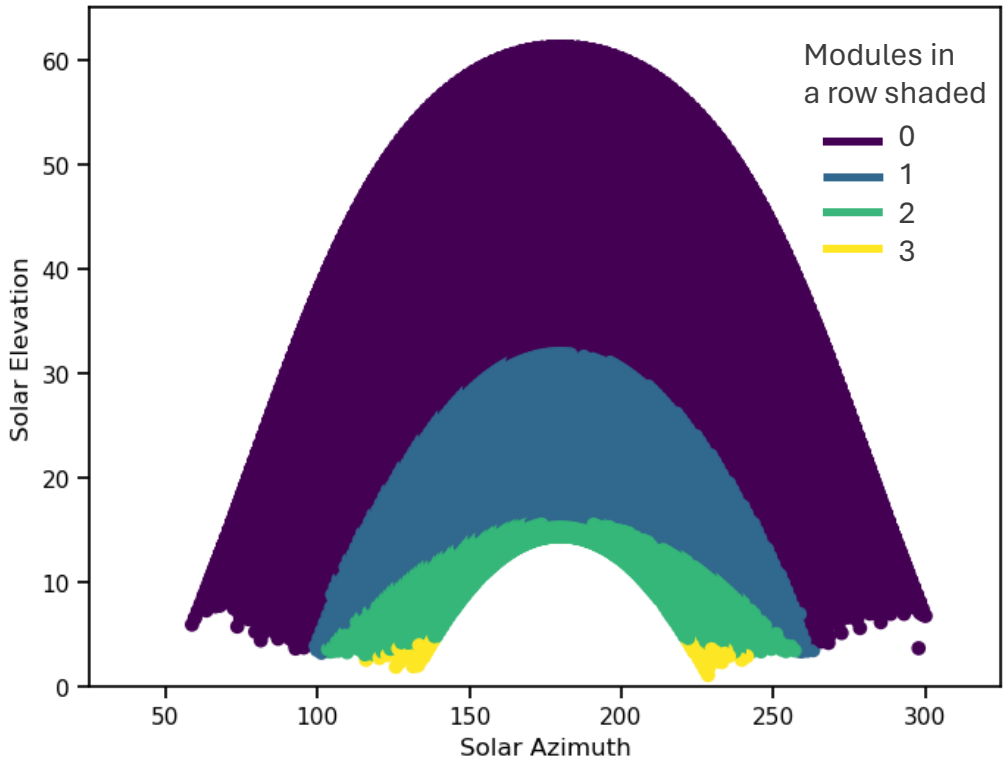
- Clipping was applied differently among software users
- Clipping only occurs in 5% of the dataset so in the worst case, incorrect clipping increased annual energy yield error by up to **3.4%**

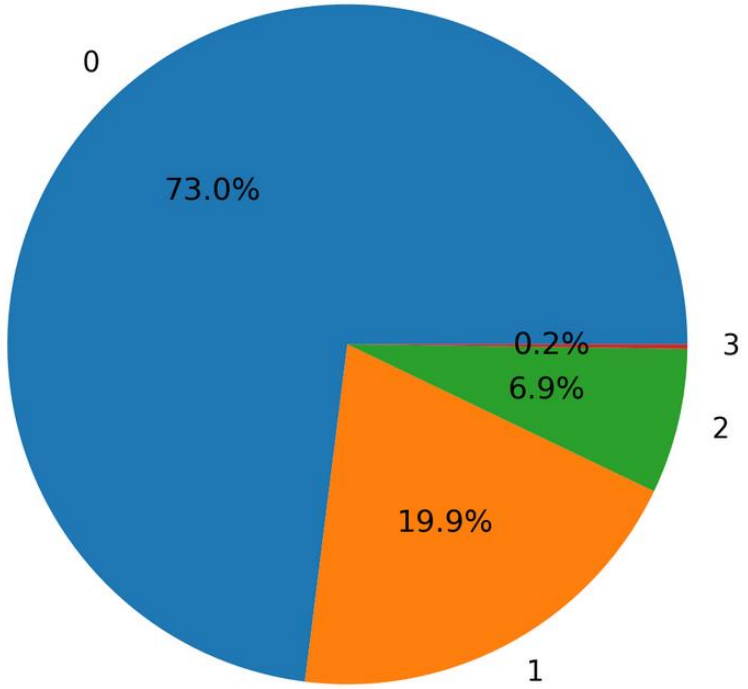




Sandia provides POA irradiance → **Participants simulate module temperature, DC and AC power outputs** → Sandia returns optimum modeled module temperature and provides derate guidelines → Participants simulate DC and AC power outputs with provided module temperature and derate guidelines

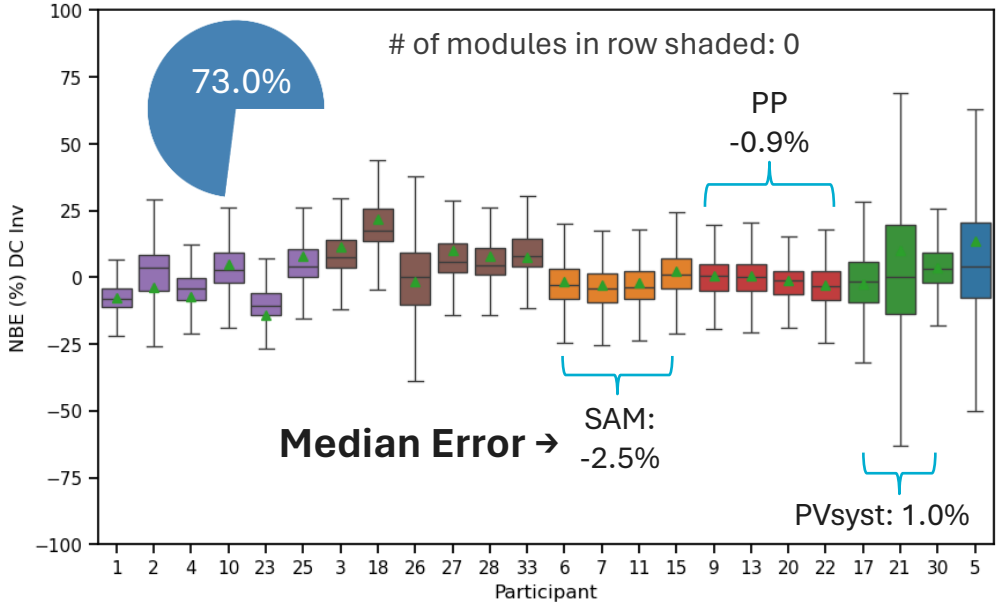
System Shading

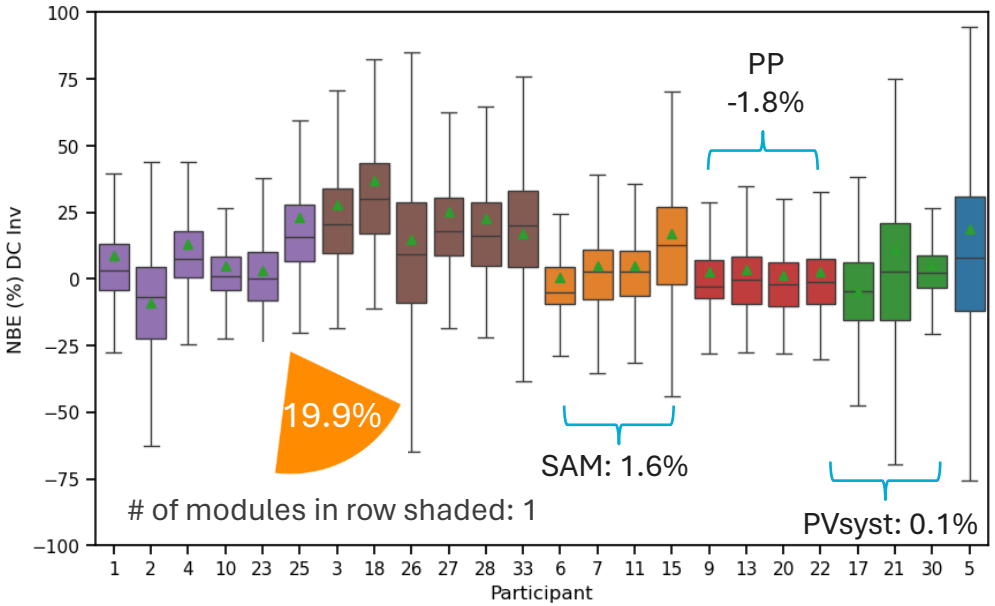


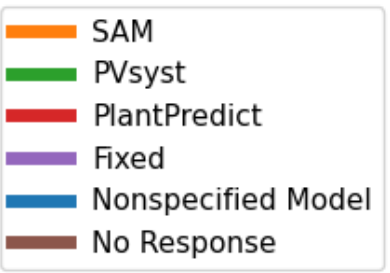


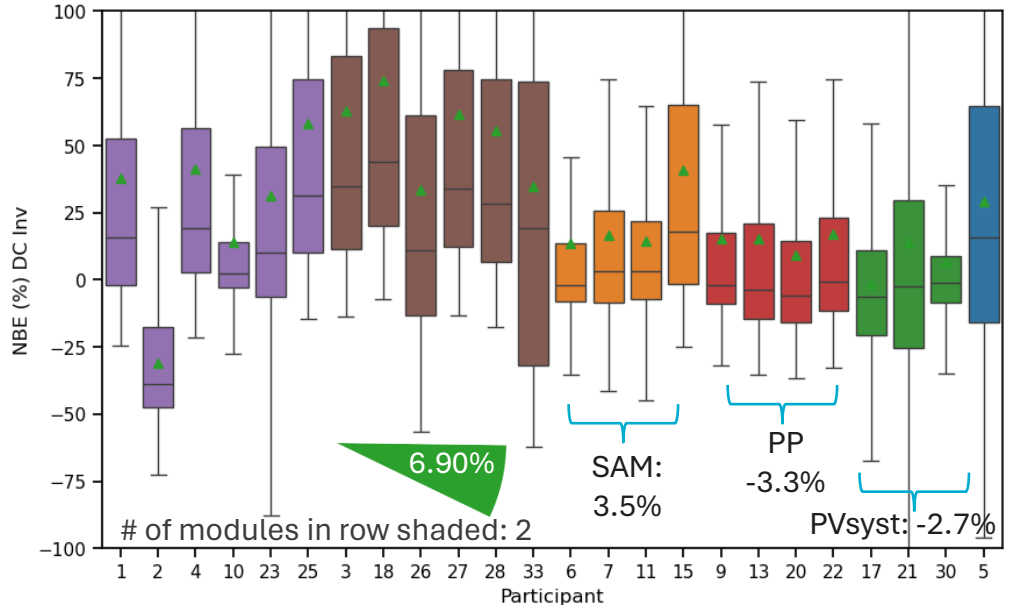
Sandia provides POA irradiance → **Participants simulate module temperature, DC and AC power outputs** → Sandia returns optimum modeled module temperature and provides derate guidelines → Participants simulate DC and AC power outputs with provided module temperature and derate guidelines

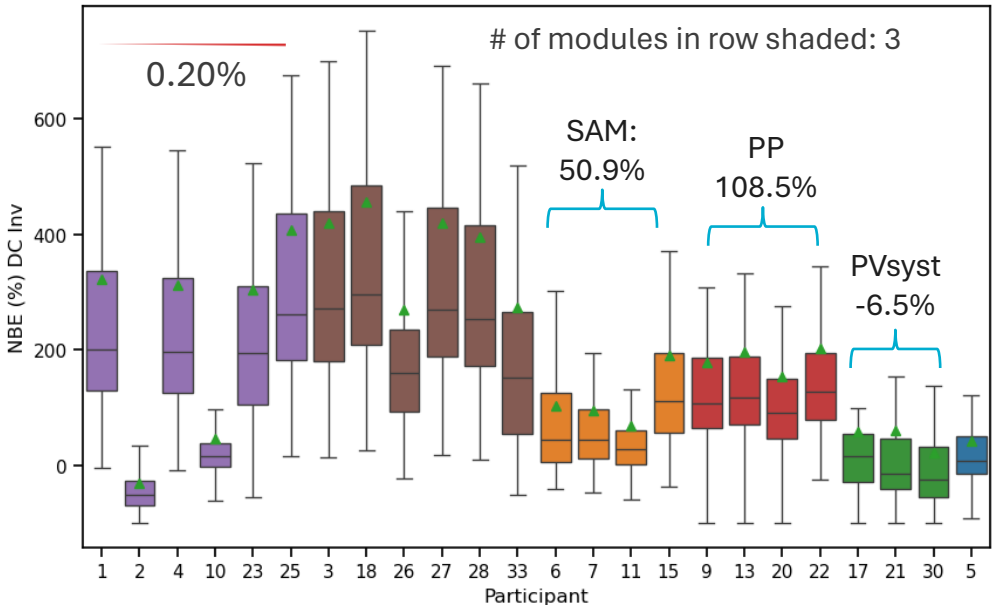
System shading by shaded fraction





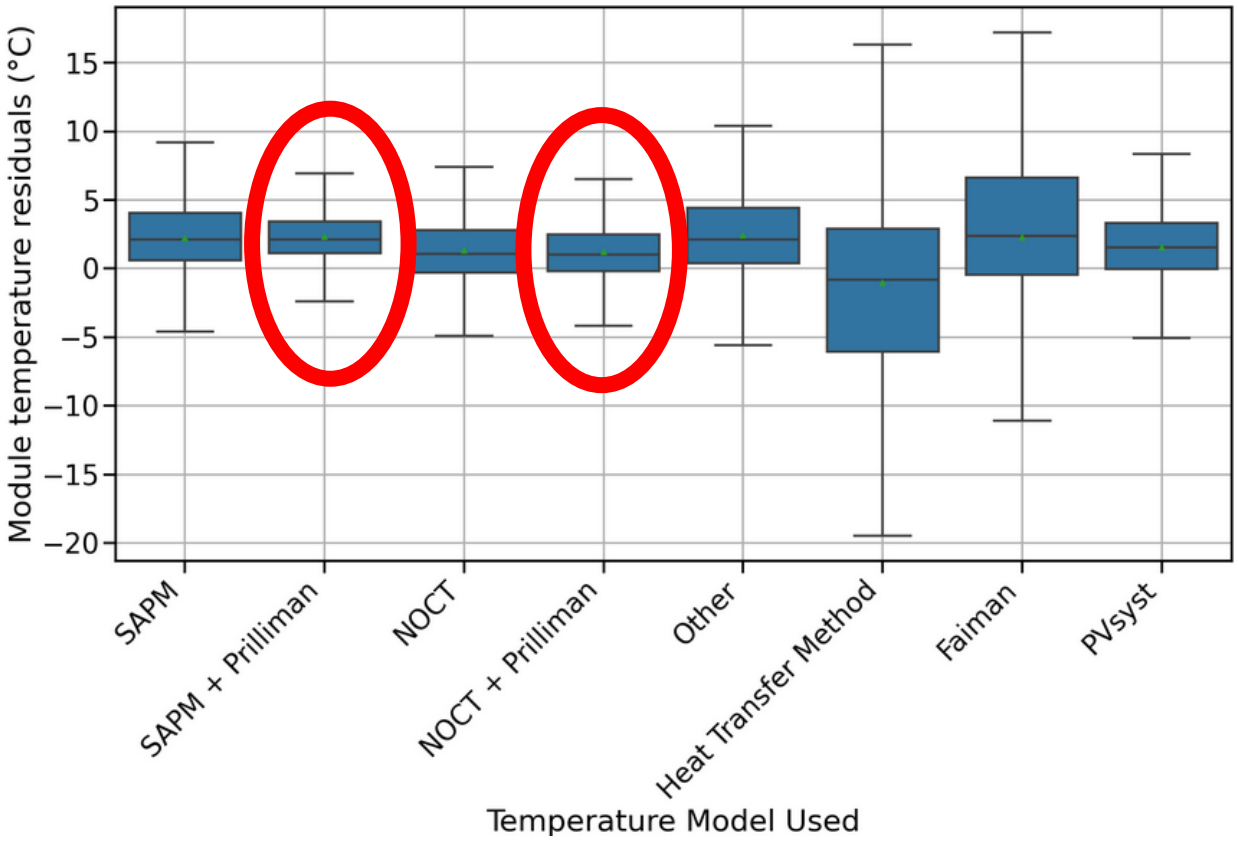






Participants who used SAM, PVsyst, or PlantPredict shading models had median errors within 3.5%, until all modules were shaded

Temperature Modeling



Base Model	Applied Prilliman?	Std Dev (°C)
SAPM	No	3.20
	Yes	**1.92**
NOCT	No	3.03
	Yes	**2.55**

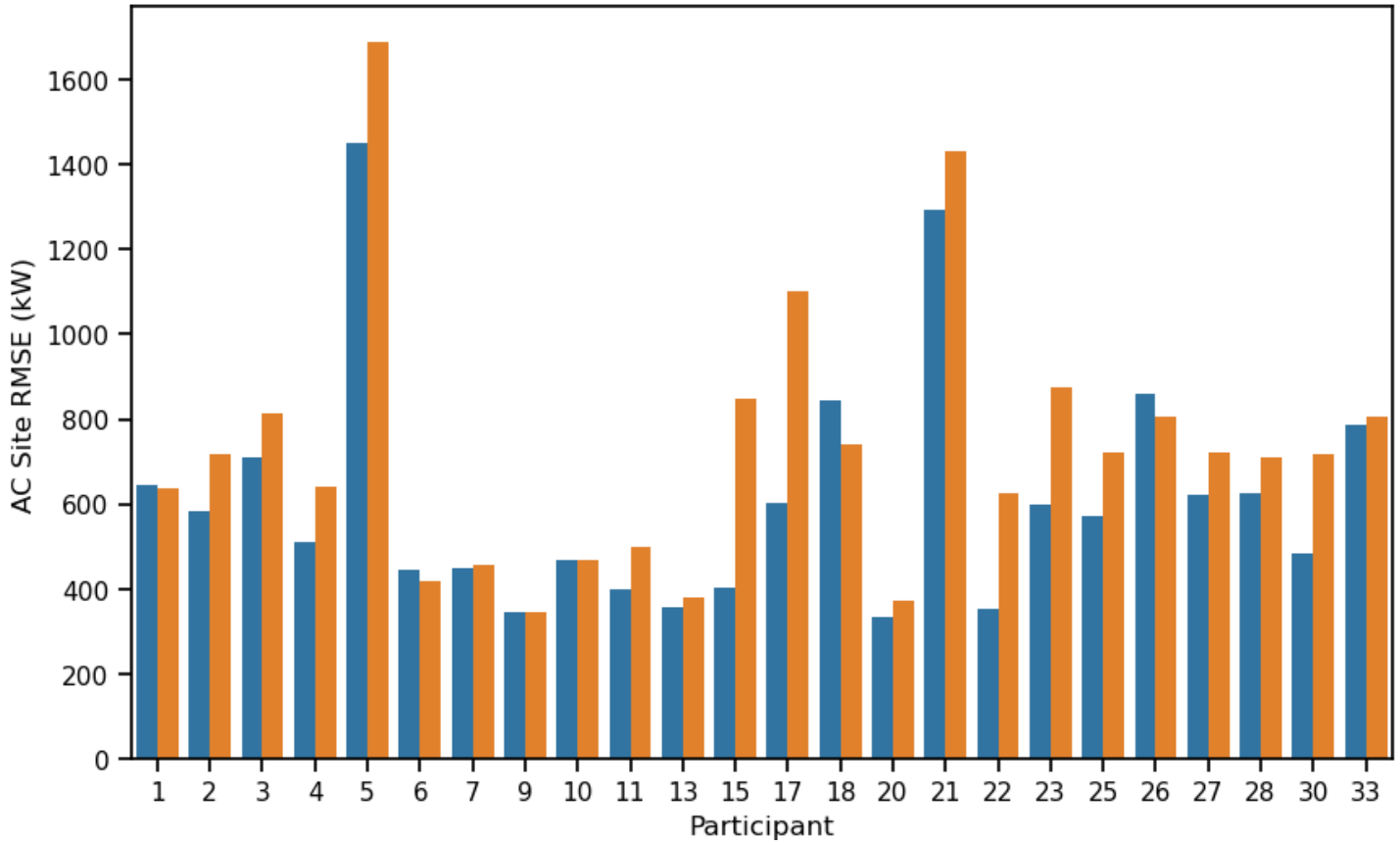
Participants who used a transient model had greater accuracy than their steady-state counterparts

Sandia provides POA irradiance → **Participants simulate module temperature, DC and AC power outputs** → Sandia returns optimum modeled module temperature and provides derate guidelines → Participants simulate DC and AC power outputs with provided module temperature and derate guidelines

RMSE across stages

Stage 1 → Participants used measured POA

Stage 2 → Participants used measured POA, measured module temp, & limited derates



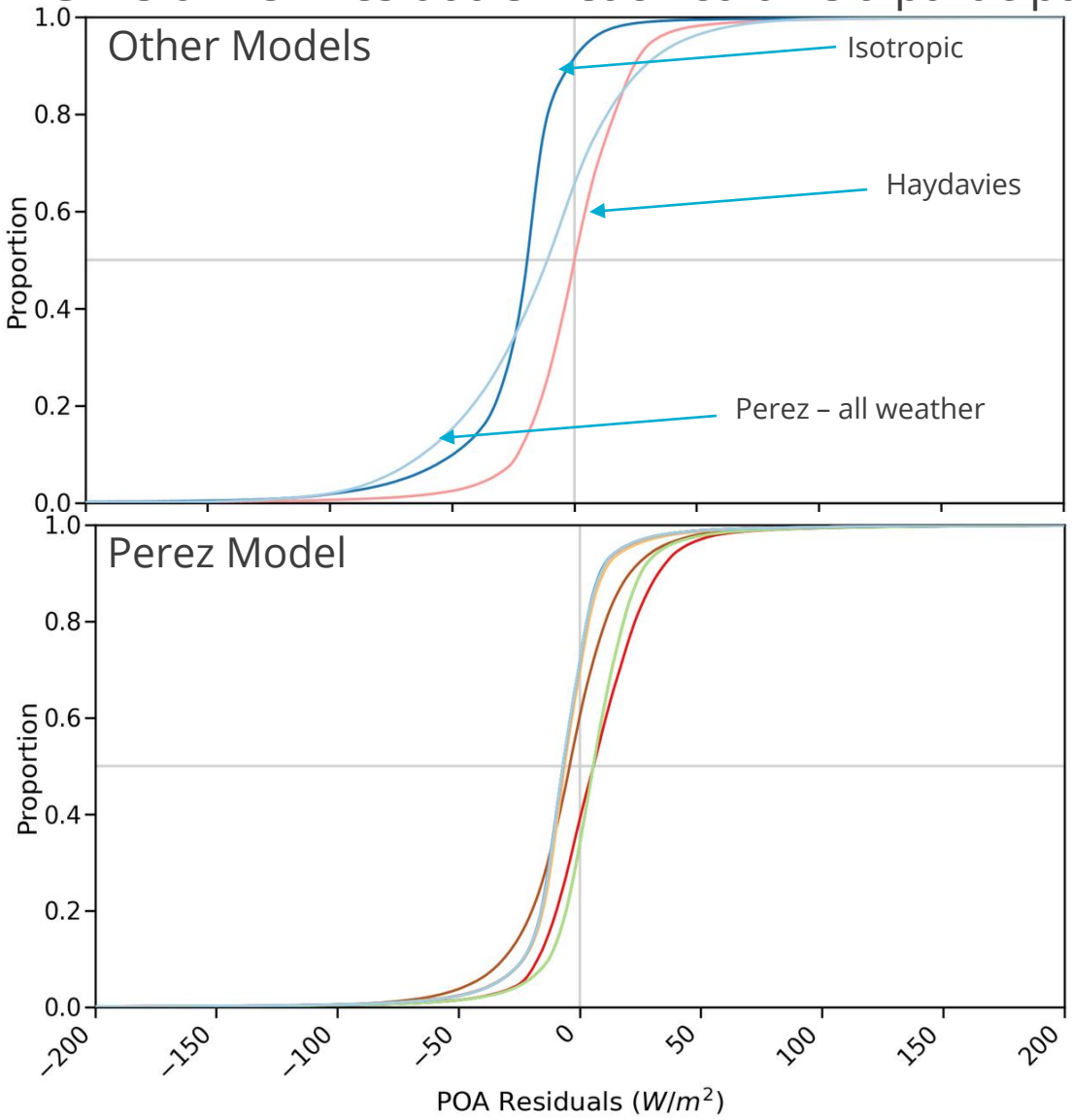
Removing all major derates increased RMSE by as much as 496 kW

Sandia provides POA irradiance → Participants simulate module temperature, DC and AC power outputs → Sandia returns optimum modeled module temperature and provides derate guidelines → **Participants simulate DC and AC power outputs with provided module temperature and derate guidelines**

Phase 2 – Albuquerque
15.4 kW System Preview

POA Residuals - Albuquerque

ECDFs of POA residuals – each color is a participant



- Almost all participants used Perez transposition model except 3.
  - Perez – all weather considers sky luminance & is used with ray-tracing software, typically
- Perez model medians range from -8.5 to 6.2 W/m^2
  - Even though all reported allsitescomposite1990 coefficients

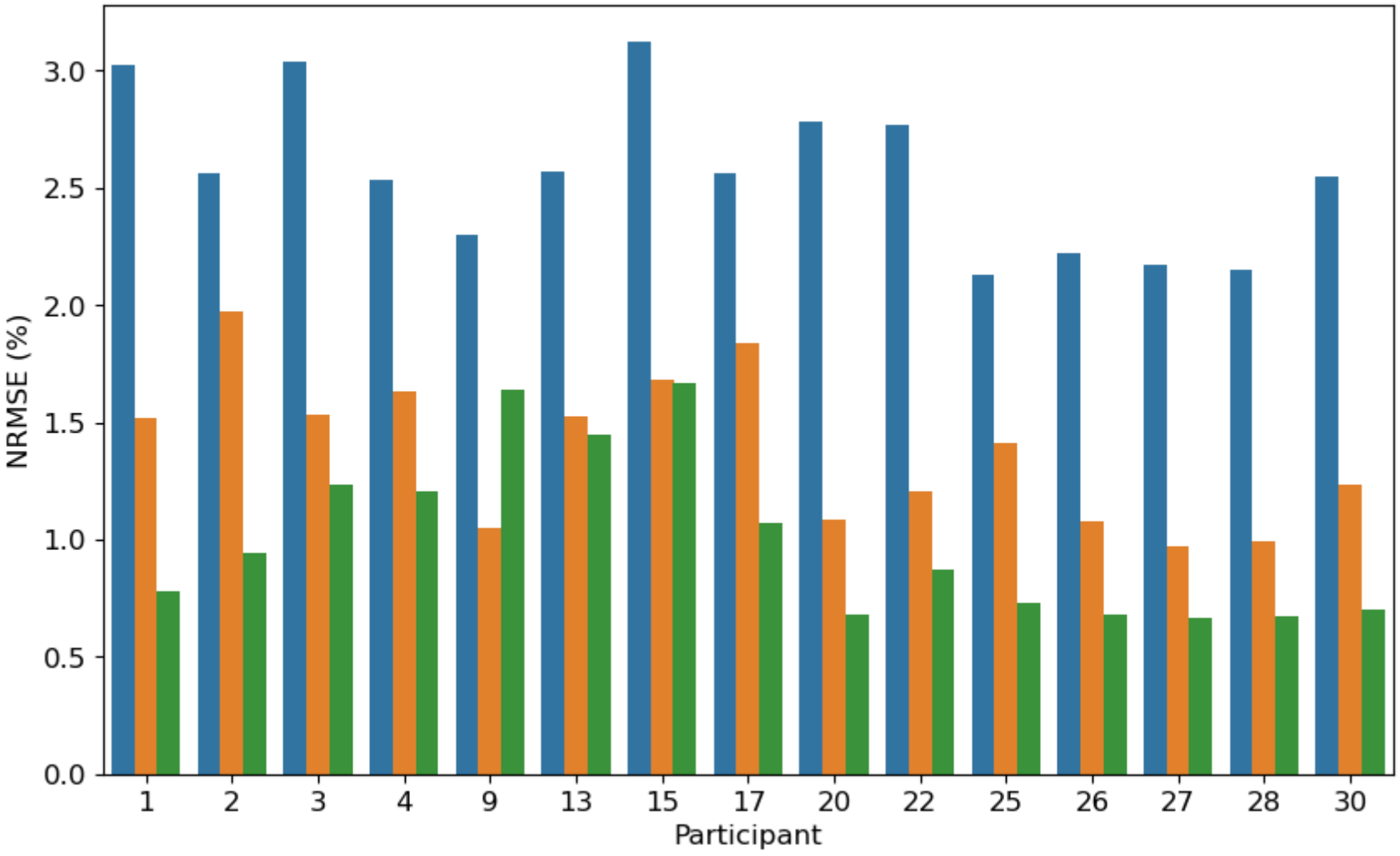
The same Perez model is not being implemented the same way by all software

NRMSE (%) across stages

Stage 1 → Participants used modeled POA, modeled module temp

Stage 2 → Participants used measured POA, modeled module temp

Stage 3 → Participants used measured POA, measured module temp, & limited derates



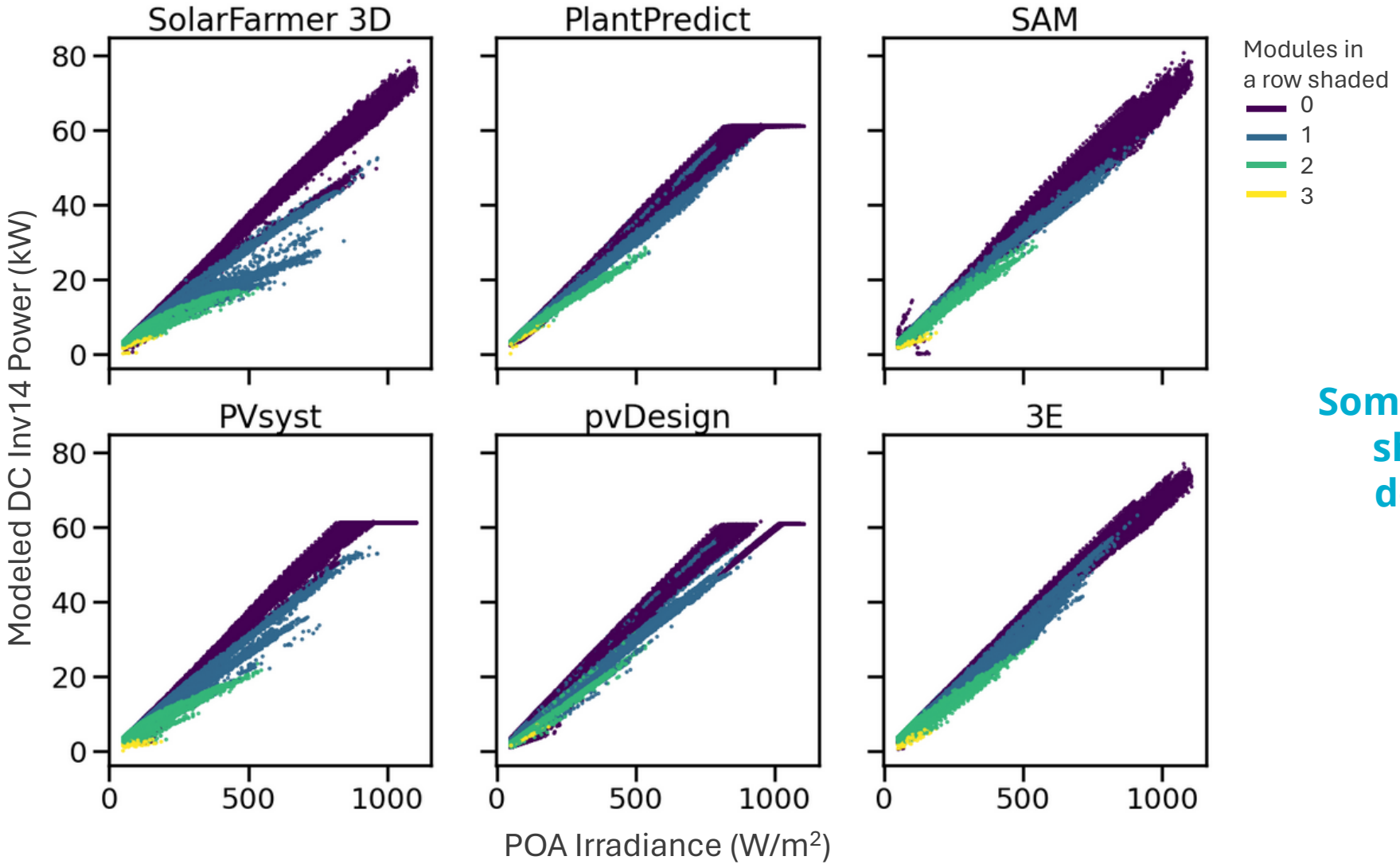
NRMSE decreased as more measured information was used in the modeling, even when removing major derates

Modeling Software Comparison

7 unique companies
with 11 total submissions
NOTE: Software comparison did not involve iterative stages

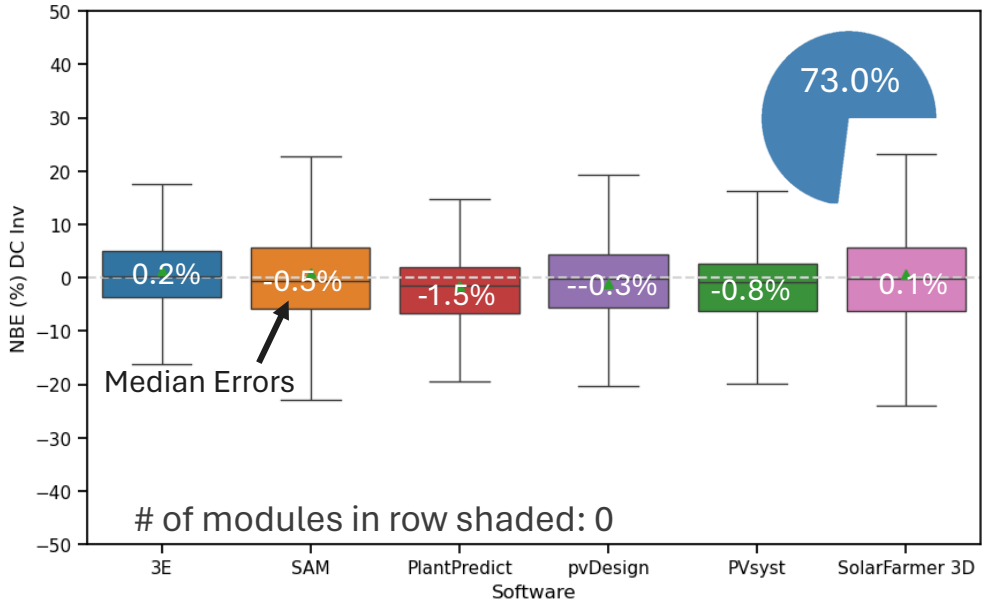
System Advisor Model
3E
SOLARGIS
pvDesign
a RatedPower app
PVSYST
PHOTOVOLTAIC SOFTWARE
PLANTPREDICT
SOLARFARMER

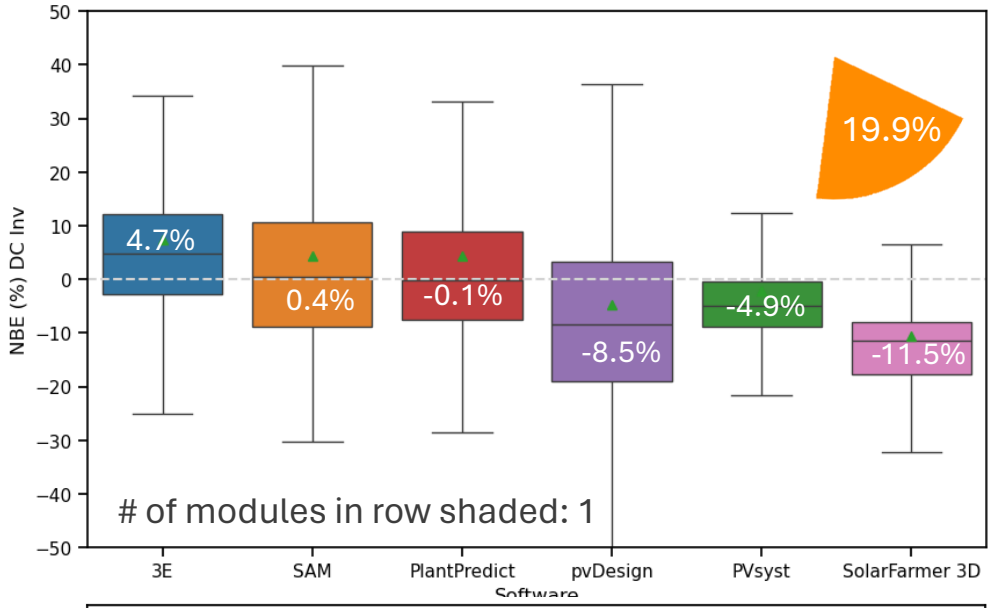
System Shading

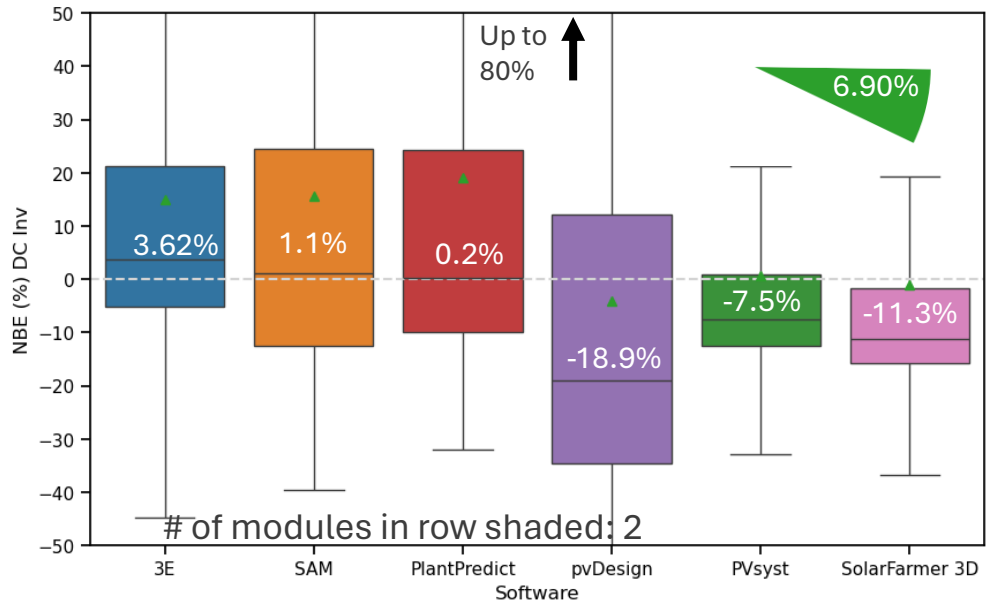


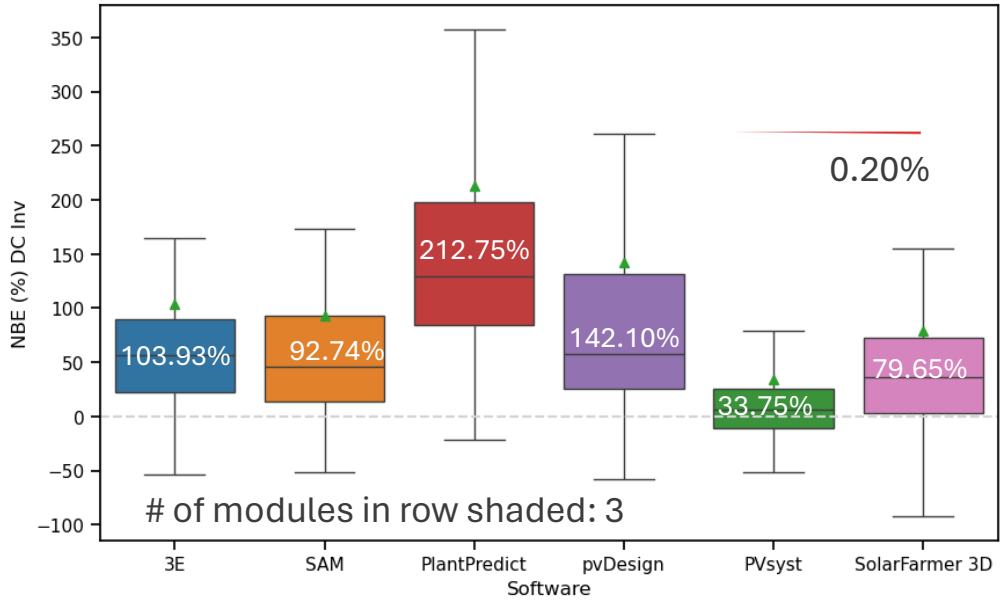
Some software consider shading in greater detail than others

System Shading by Shaded Fraction

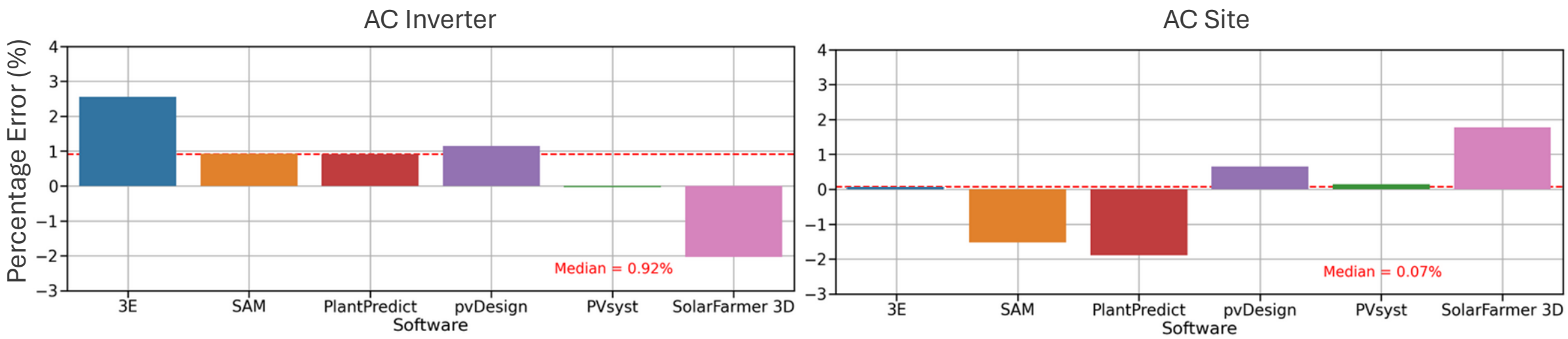






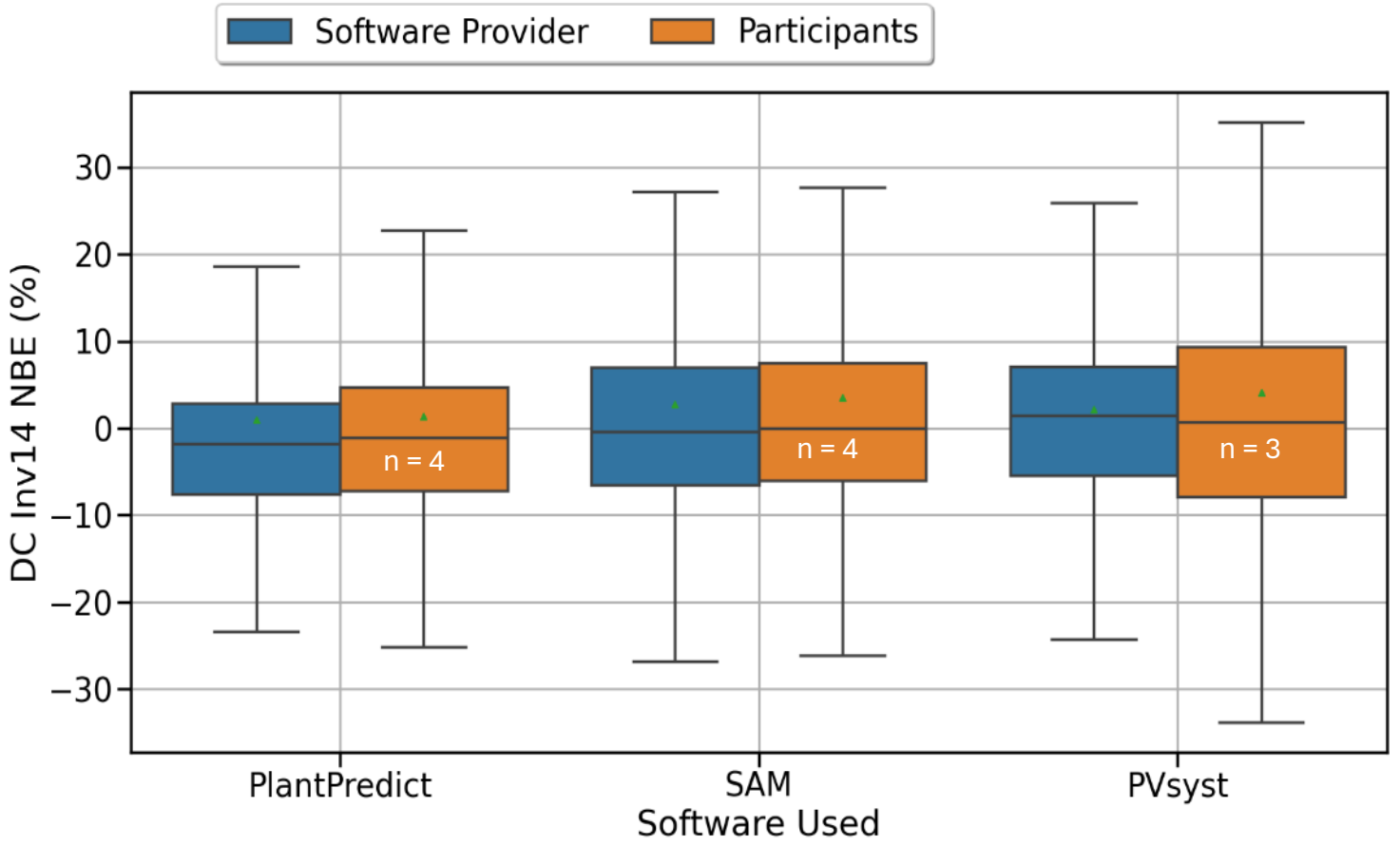


AC Annual Energy Yield



All software were within ±2.5% for AC inverter & site level annual energy yield

Software Providers vs Their Participants



Software Provider Comparison Table

Software	SolarFarmer	PlantPredict	SAM	PVsyst	pvDesign	3E	Solargis
API/SDK	API	API	SDK	No	No	No	No
System Mounting Types	Fixed & SAT Terrain Following	Fixed & SAT	Fixed, SAT, & DAT	Fixed, SAT*, & DAT Terrain Following*	Fixed & SAT	Fixed, SAT, & DAT	Fixed & SAT
Module Temp. Model	PVsyst	PVsyst	NOCT or Heat Transfer	PVsyst	PVsyst	SAPM Cell	NOCT
Considers Temp. Transience?	No	No	Yes	No	No	No	No
3D / Shade Scenes Accepted	PVC	PVC or PVJ	PVsyst scenes, Suneye, Solar Pathfinder	PVC, H2P, DAE	None	None	KML
Soiling Loss Default	0% - Fixed	2% - Fixed	5% - Fixed	0% - Fixed	2% - Fixed	1% - Fixed	Varies by Month

- 50+ questions compiled into table about weather & irradiance calculations, AC & DC system calculations, default derate values, etc.

Conclusions & Future Analysis

- While clipping only occurred in 5% of the Germany dataset, incorrect clipping caused up to a 3.4% difference in annual energy yield estimation
- Shading models' median normalized bias error did not exceed 10% for most participants until all modules in a row were shaded
- Transient assumptions resulted in greater accuracy in temperature modeling
- Perez models were not the same amongst participants, even when using same coefficients with median residuals ranging from -8.5 to 6.2 W/m^2
- All software providers were within 2.5% for AC annual yield in Germany
- Journal article(s) will give greater detail on:
  - Method for determining power plant derates using measured data
  - Did using PAN files made from measured data improve errors in the Germany or Albuquerque system?
  - How do sub-hourly vs hourly results vary? Do the models' accuracy change?
  - In-depth comparison of each software, including tables on models, derates, and more!

Thank You!

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Sandia National Laboratories

PVPerformance MODELING COLLABORATIVE

SOLAR ENERGY TECHNOLOGIES OFFICE
U.S. Department Of Energy

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