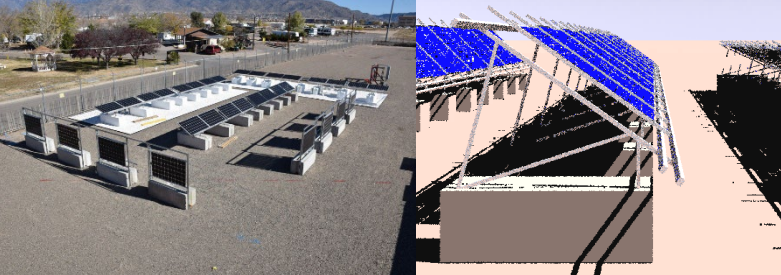


# Sandia's PV Performance Modeling Project Priorities for FY25-27

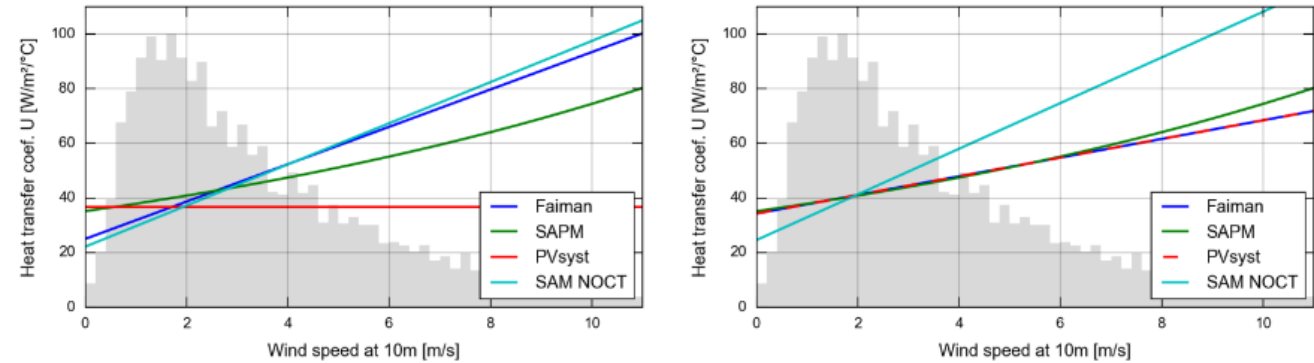


*PRESENTED BY*

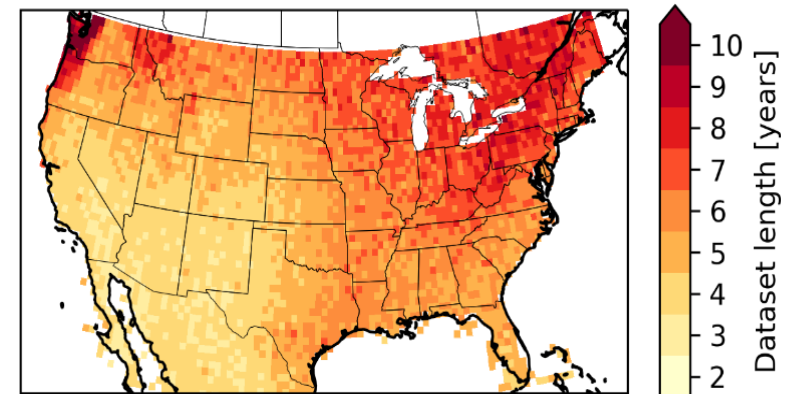
Marios Theristis



- Bifacial modeling functions
- Module parameter toolkit
- Modeling PV performance derates
- PV Atlas



Example of the parameter translation toolkit showing the heat transfer coefficients calculated by 4 models before translation (left) and after (right). The NOCT SAM model has only one degree of freedom and cannot fully match the others.

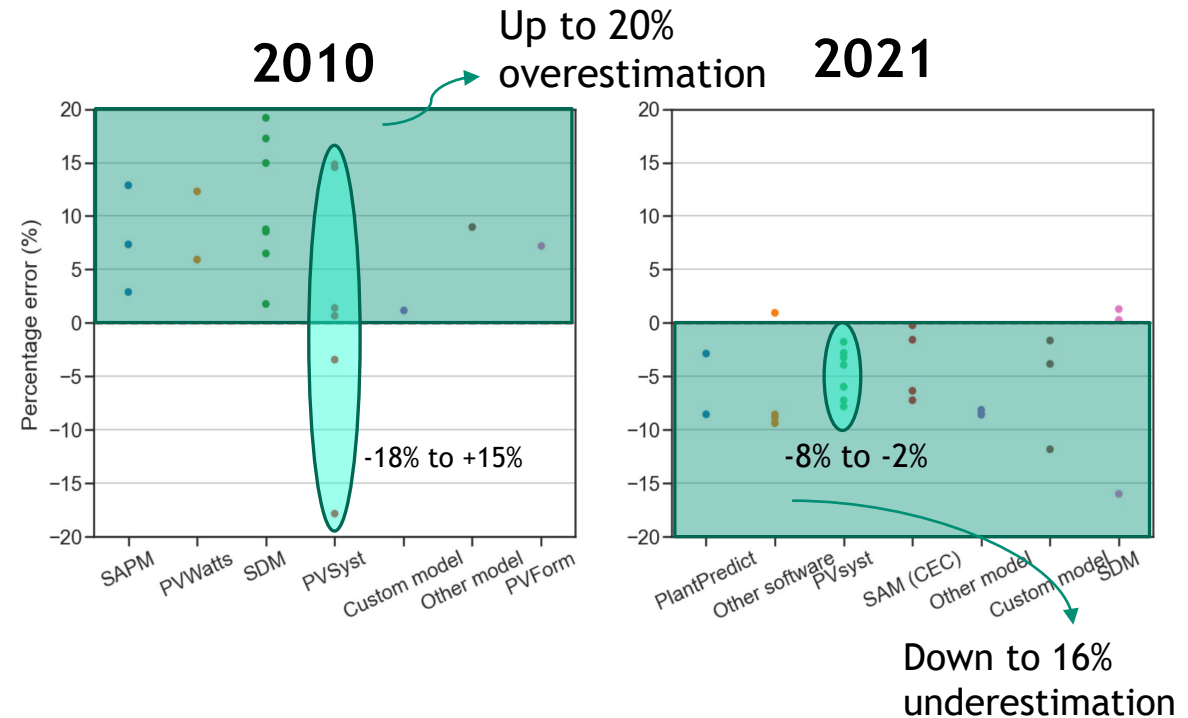


Example of PVPMC's PV Atlas Task demonstrating performance loss rate (PLR) uncertainty due to climatic variability and dataset length. The map shows the minimum number of years of data to achieve uncertainties within  $\pm 0.05\%$ /year. Attention is required when evaluating PV power plants in different climates, because the same assumptions do not apply everywhere.





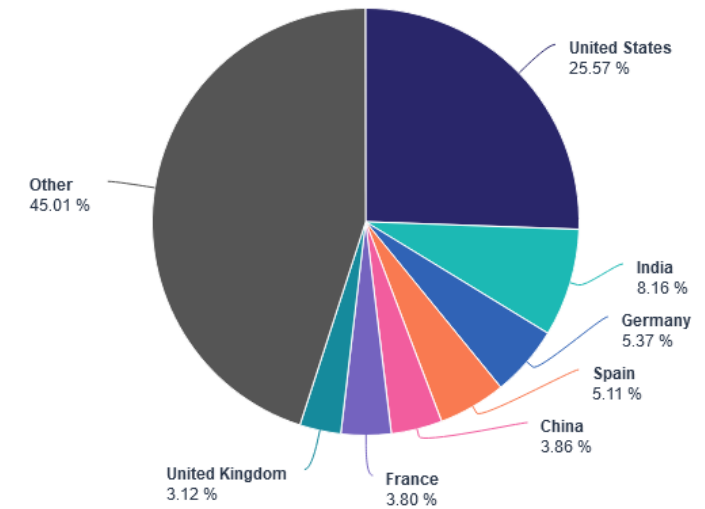
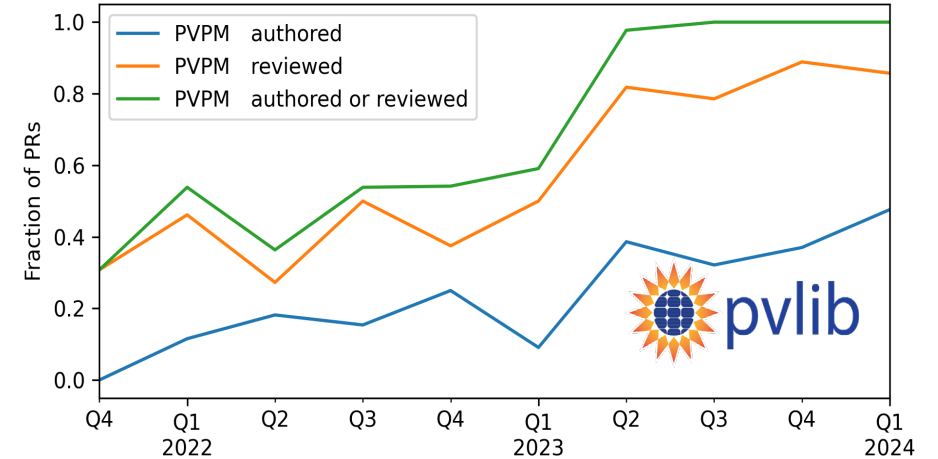
- Publish high-quality, well documented validation datasets
- Develop a protocol for PV performance validation
- Blind modeling comparisons
- Perform cross-comparison of PV performance software and libraries



| Model Type               | Jupyter Notebook File                                                        | PDF                                                                        |
|--------------------------|------------------------------------------------------------------------------|----------------------------------------------------------------------------|
| Irradiance Decomposition | <a href="#">Irradiance Decomposition Validation (IPYNB) (1391 downloads)</a> | <a href="#">Irradiance Decomposition Validation (PDF) (1097 downloads)</a> |
| Irradiance Transposition | <a href="#">Irradiance Transposition Validation (IPYNB) (1390 downloads)</a> | <a href="#">Irradiance Transposition Validation (PDF) (1077 downloads)</a> |
| Incident Angle Modifier  | <a href="#">IAM Validation (IPYNB) (1379 downloads)</a>                      | <a href="#">IAM Validation (PDF) (1090 downloads)</a>                      |
| Cell/Module Temperature  | <a href="#">Temp Model Validation (IPYNB) (1336 downloads)</a>               | <a href="#">Temp Model Validation (PDF) (1063 downloads)</a>               |
| PV Module Performance    | <a href="#">PV Performance Validation (IPYNB) (1359 downloads)</a>           | <a href="#">PV Performance Validation (PDF) (1081 downloads)</a>           |

# Outreach

- PVPMC workshops (5 workshops with record numbers of participation)
- pvlib-python (> 20 functions)
- pvpmc.sandia.gov website (>250k visits per year; email list exceeds 6k)
- IEA Task 13 (contributing to 3 reports)



pvpmc.sandia.gov traffic statistics.

Kevin S. Anderson <sup>\*1</sup>, Clifford W. Hansen <sup>1</sup>, William F. Holmgren <sup>2</sup>, Adam R. Jensen <sup>3</sup>, Mark A. Mikofski <sup>2</sup>, and Anton Driesse <sup>4</sup>

## Blind photovoltaic modeling intercomparison: A multidimensional data analysis and lessons learned

Marios Theristis <sup>1</sup> | Nicholas Riedel-Lyngskær <sup>2</sup> | Joshua S. Stein <sup>1</sup> | Lelia Deville <sup>1</sup> | Leonardo Micheli <sup>3</sup> | Anton Driesse <sup>4</sup> | William B. Hobbs <sup>5</sup> | Silvana Ovaite <sup>6</sup> | Rajiv Daxini <sup>7</sup> | David Barrie <sup>8</sup> | Mark Campanelli <sup>9</sup> | Heather Hodges <sup>10</sup> | Javier R. Ledesma <sup>11</sup> | Ismael Lokhat <sup>12</sup> | Brendan McCormick <sup>13</sup> | Bin Meng <sup>14</sup> | Bill Miller <sup>10</sup> | Ricardo Motta <sup>15</sup> | Emma Noirault <sup>16</sup> | Megan Parker <sup>10</sup> | Jesús Polo <sup>17</sup> | Daniel Powell <sup>18</sup> | Rodrigo Moretón <sup>19</sup> | Matthew Prilliman <sup>6</sup> | Steve Ransome <sup>20</sup> | Martin Schneider <sup>21</sup> | Branislav Schnierer <sup>22</sup> | Bowen Tian <sup>14</sup> | Frederick Warner <sup>23</sup> | Robert Williams <sup>24</sup> | Bruno Wittmer <sup>25</sup> | Changrui Zhao <sup>26</sup>



RESEARCH ARTICLE |  Open Access | 

## Open-source photovoltaic model pipeline validation against well-characterized system data

Lelia Deville  Marios Theristis, Bruce H. King, Terrence L. Chambers, Joshua S. Stein

First published: 20 December 2023 | <https://doi.org/10.1002/pip.3763>



EU PVSEC PAPER |  Open Access | 

## Failure diagnosis and trend-based performance losses routines for the detection and classification of incidents in large-scale photovoltaic systems

Andreas Livera  Marios Theristis, Leonardo Micheli, Joshua S. Stein, George E. Georghiou

First published: 13 May 2022 | <https://doi.org/10.1002/pip.3578> | Citations: 7



Solar Energy  
Volume 266, December 2023, 112092



Data article

## pvlib iotools—Open-source Python functions for seamless access to solar irradiance data

Adam R. Jensen <sup>a</sup> , Kevin S. Anderson <sup>b</sup>, William F. Holmgren <sup>c</sup>, Mark A. Mikofski <sup>c</sup>, Clifford W. Hansen <sup>b</sup>, Leland J. Boeman <sup>d</sup>, Roel Loonen <sup>e</sup>

Journals & Magazines > IEEE Access > Volume: 10 

## Operation and Maintenance Decision Support System for Photovoltaic Systems

Publisher: IEEE

 Cite This

 PDF

Andreas Livera  Marios Theristis  Leonardo Micheli  Eduardo F. Fernández; Joshu... [All Authors](#)



Research Article |  Open Access | 

## How Climate and Data Quality Impact Photovoltaic Performance Loss Rate Estimations

Marios Theristis  Kevin Anderson, Julian Ascencio-Vasquez, Joshua S. Stein

First published: 29 November 2023 | <https://doi.org/10.1002/solr.202300815>

IOP Publishing

Prog. Energy 4 (2022) 022003

<https://doi.org/10.1088/2516-1083/ac655f>

## Progress in Energy



TOPICAL REVIEW

## Best practices for photovoltaic performance loss rate calculations

Sascha Lindig <sup>a</sup>, Marios Theristis <sup>c</sup> and David Moser <sup>1</sup>

<sup>1</sup> Institute for Renewable Energy, EURAC Research, Viale Druso 1, 39100 Bolzano, Italy

<sup>2</sup> Sandia National Laboratories, Albuquerque, NM 87185, United States of America

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E-mail: [sascha.lindig@eurac.edu](mailto:sascha.lindig@eurac.edu)

Keywords: photovoltaics, photovoltaic performance, degradation models, performance loss rate, photovoltaic ageing

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Volume 225, May 2024, 120317



## Quantifying the impact of inverter clipping on photovoltaic performance and soiling losses

Leonardo Micheli <sup>a</sup> , Matthew Muller <sup>b</sup>, Marios Theristis <sup>c</sup>, Greg P. Smestad <sup>d</sup>, Florencia Almonacid <sup>e</sup>, Eduardo F. Fernández <sup>e</sup>

> 45 technical publications and presentations in FY22-24

<https://pvpmc.sandia.gov/workshops-and-pubs/publications/>

# Try our PVPMC datasets

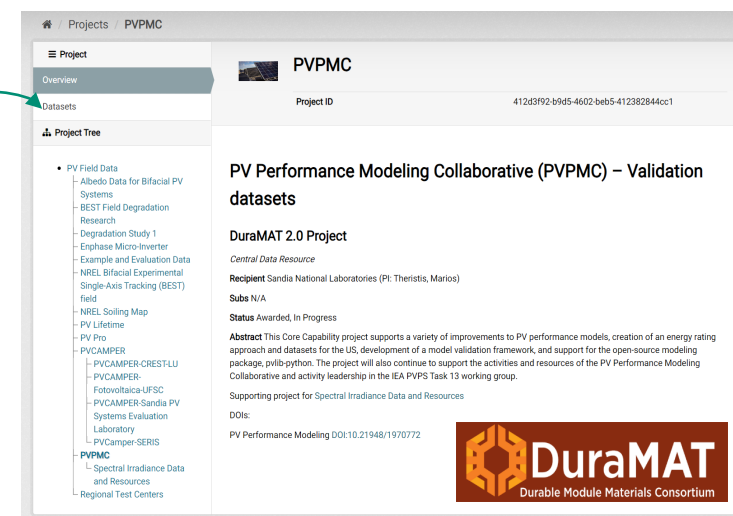
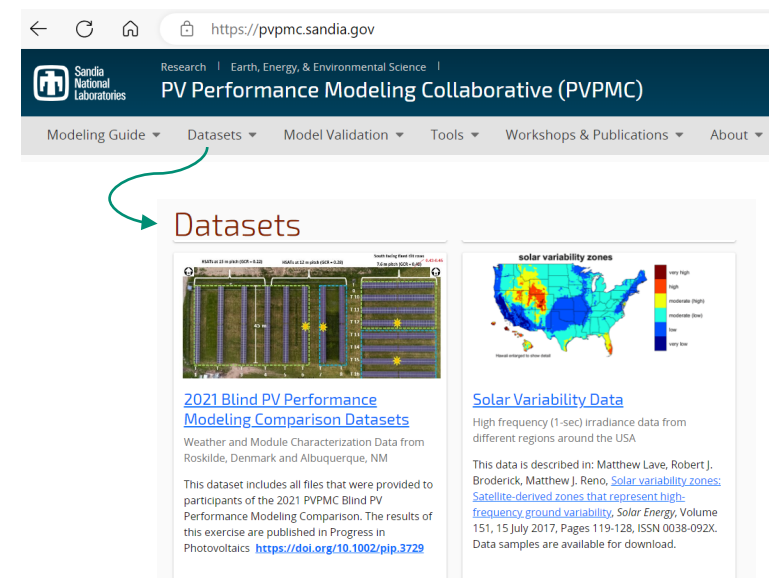
Well-documented PVPMC validation datasets can be downloaded at:

<https://pvpmc.sandia.gov>

<https://datahub.duramat.org/project/about/pvpmc>

- 1) PV module spectral response measurements – Data and Resources  
<https://www.osti.gov/biblio/2204677>
- 2) Global horizontal spectral irradiance in Albuquerque - Data and Resources  
<https://www.osti.gov/biblio/2204674>
- 3) PV Module Operating Temperature - Data and Resources  
<https://www.osti.gov/biblio/2204673>
- 4) PV Performance Modeling - Data and Resources  
<https://www.osti.gov/biblio/1970772>

Click here!





What is [might be] coming in FY25-27  
[pending funding]





**Inverter modeling** (e.g., off-unity power factor; MPPT voltage range; curtailment due to DC current or temperature limits). The goal is to account for inverter operating states that affect output power by > 1%.

**Transposition models** (e.g., vertical E-W, high-latitude). Gaps were found in available model chains for tilted-plane irradiance at high latitudes. We will 1) add the best-performing models to pvlib, and 2) assess pvlib irradiance models against real data.

**Bifacial/tracked system modeling** (extend view factor models; sloped terrain, edge effects; non-uniform albedo). Conduct studies to improve reproducibility in tracked bifacial PV modeling. Our IEA Task 13 exercise showed large variations among modelers.

**PV module modeling** (e.g., half-cut cells, thin-film, SHJ, TOPCon). Assess the extent to which existing models accurately predict the PV behaviour. For example, shading effects, or ensuring that existing models can predict TOPCon performance accurately.

Develop models for **tandem modules**. For example, silicon/perovskite tandem have made dramatic gains in efficiency and are being commercialized by several companies. Such PV performance models are not available in pvlib.

Improve pvlib's default **clear-sky model**. Depending on location, predicted annual insolation shows up to 18% difference from more sophisticated clear-sky models. The goal is to improve the climatology bundled with pvlib to reduce this discrepancy.

**Generate model parameters from system monitoring data** (e.g., field -> IEC61853 -> PAN/CEC). The goal is to generate model parameters that represent a built system in its current state.

Please scan the QR code to provide feedback and/or in person during this workshop!

**slido**

Select four of the proposed PVPMC model developments based on importance/impact.



- Establish the PVPMC Academy to create instructional material for PV performance modeling
- Engage with academic and vocational institutions to identify curriculum needs
- Engage with industry stakeholders to understand the skillsets they are looking for when filling PV modeling positions
- A textbook with emphasis on “How to model” a PV system and “How to analyze” data from a PV system using open-source code as examples
- Run training workshops for educators and instructors, using the train-the-trainers model

Stakeholder  
engagement

Develop  
curriculum for  
PV modeling

Develop  
curriculum for  
PV performance  
analysis

Training schools

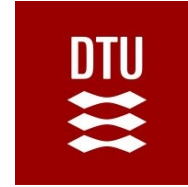


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Clean Power Research

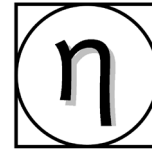
CFV Labs



CENER



QualifyingPhotoVoltaics



PV Performance Labs



Intersect  
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# Emphasizing **C** on the PVPMC



How to get involved?

- Join our email list
- Provide us with your feedback
- Contribute with data
- Contribute information on the PVPMC website
- Participate in the blind modeling comparisons
- Become a PVPMC workshop sponsor
- Participate in our workshops



# Sandia's PV Performance Modeling Team



Marios Theristis



Josh Stein



Cliff Hansen



Kevin Anderson



Lelia Deville



Please join the PVPVC at <https://pvpmc.sandia.gov/>  
Contribute, and help increase confidence in PV system performance

Solar Energy Technologies Office Award Number 38267