PVcase

Validation of PVcase Yield – A yield simulation software based on 3D PV plant digital twins

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We are PVcase

Our focus is on **automation** and **accuracy** from the earliest stages of planning, incorporating **3D topographical data** points to simulate the actual location of the solar plant. This allows our customers to be able to compete for and **win more projects** by delivering greater yields. Our products are AutoCAD and Cloud based tools allowing seamless integration into our customer's design process.

PVcase GROUND MOUNT

PVcase ROOF MOUNT

PVcase YIELD

500 GW+
Projects designed per quarter

800+
Customers

60+
Countries

12
Employee locations

AGENDA

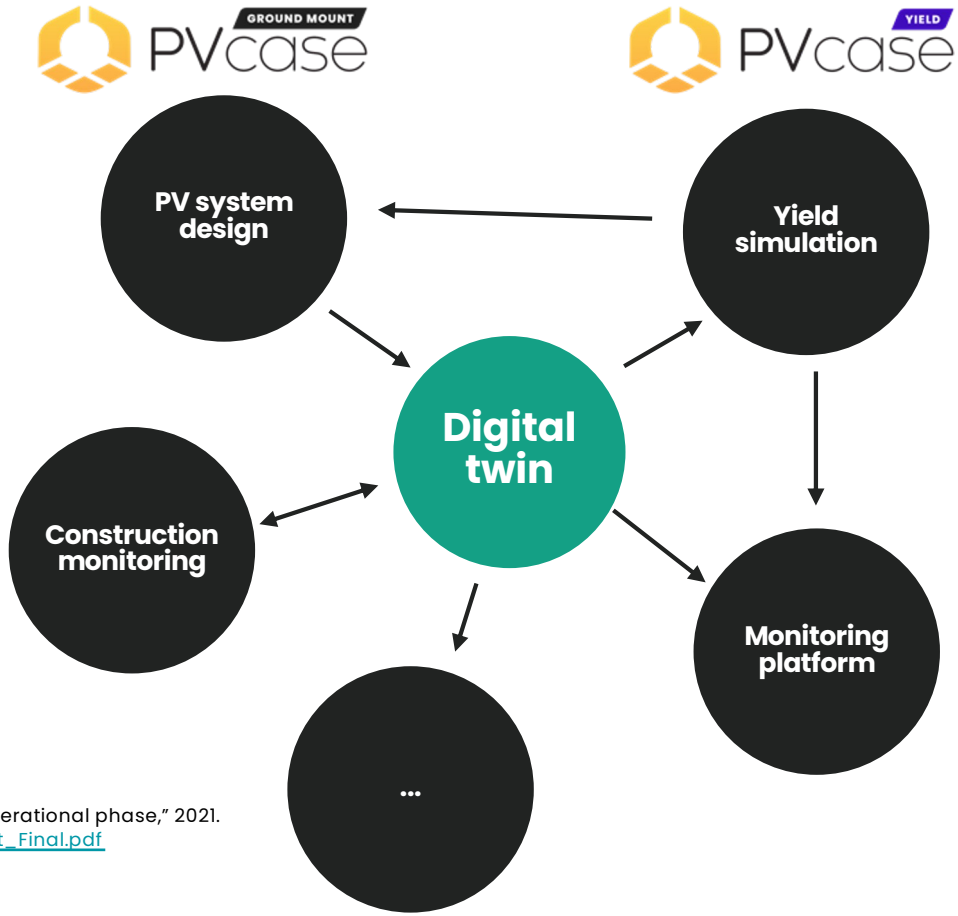
01 Digital twin-based software ecosystem

02 Introduction to PVcase Yield

03 Accuracy evaluation study

A common information model integrates different services

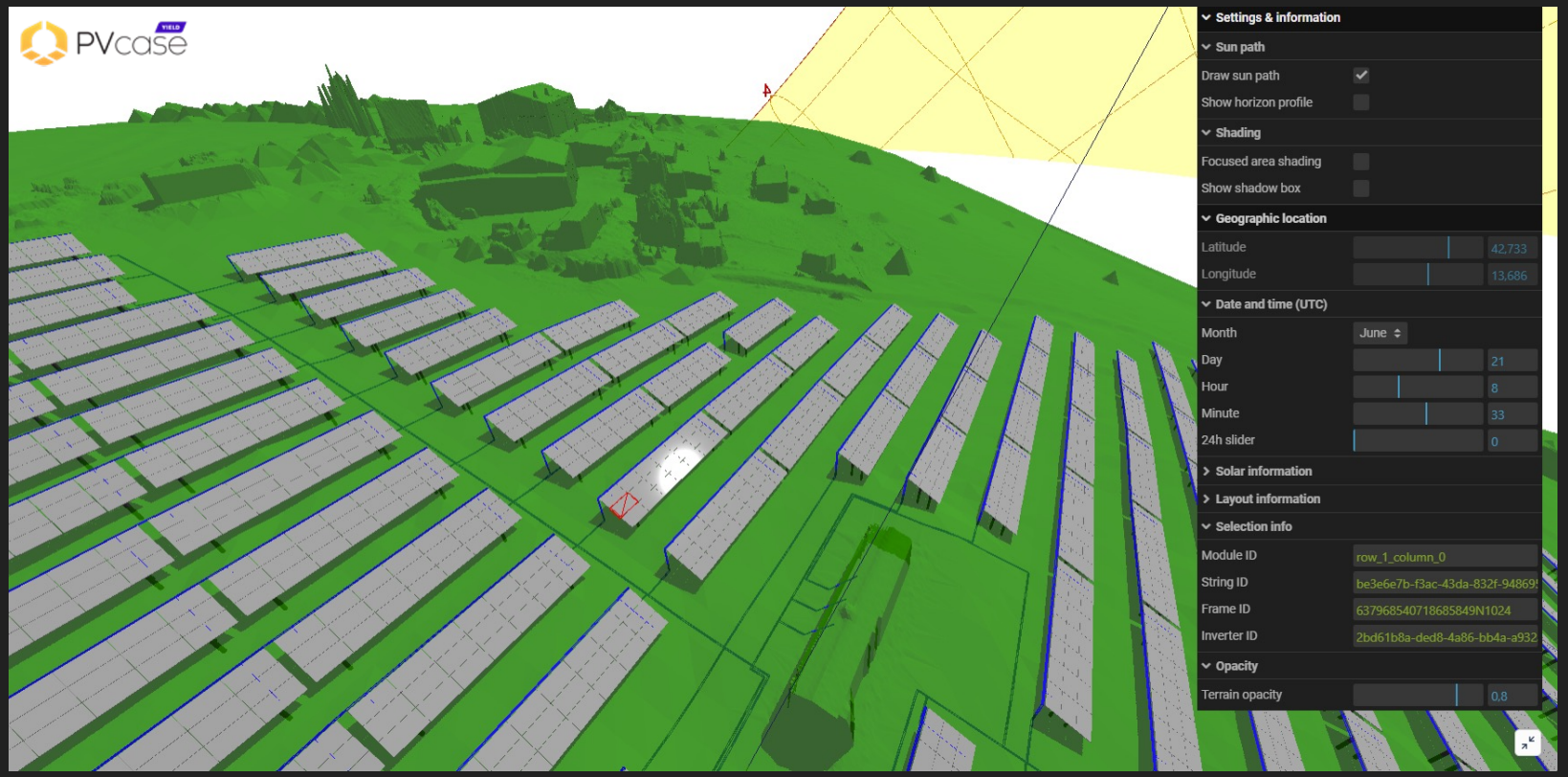
- Parametrized virtual model containing physical information of a real PV plant
- Integration interface between different platforms and processes
- Asset information is preserved, reused and updated in version control system



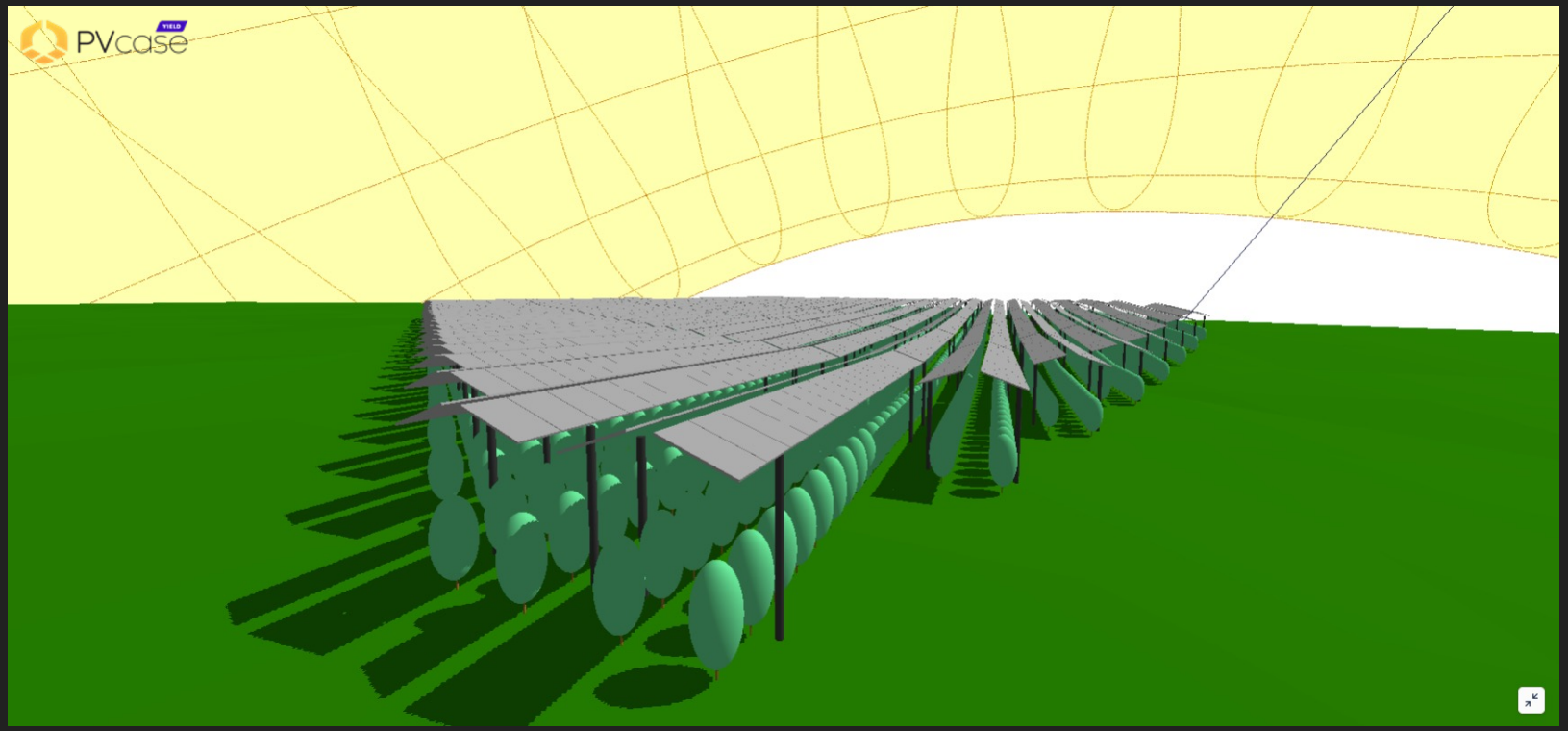
TRUST-PV consortium, "Building Information Model (BIM) requirements and design for the operational phase," 2021. [Online]. Available: https://trust-pv.eu/wp-content/uploads/2021/10/TRUST-PV_T3p4_report_Final.pdf

TRUST-PV consortium, " Automated PV digital twin-based yield simulation framework", 2022

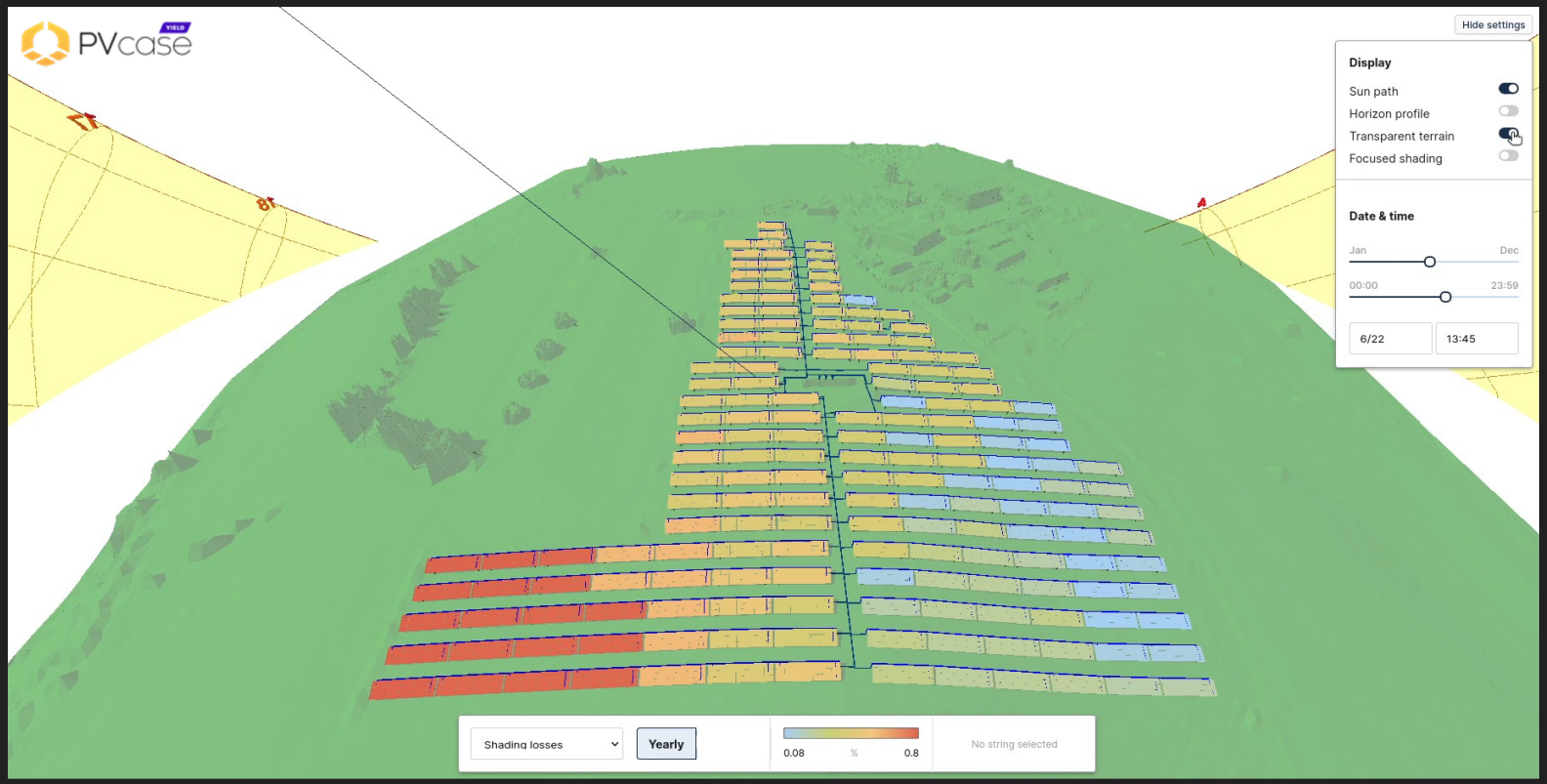
PVcase Yield: the next-gen yield simulation software



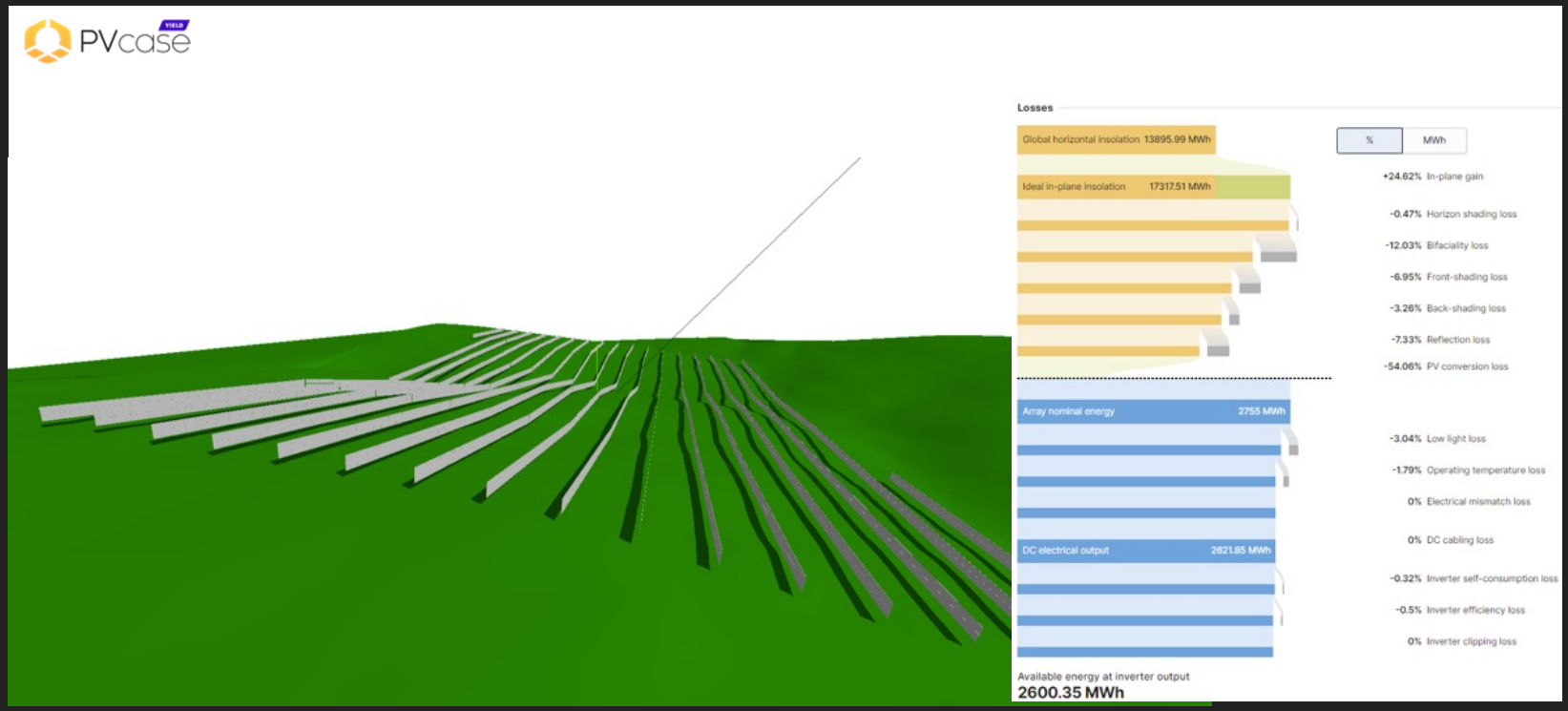
Develop and analyze layouts on arbitrary topography



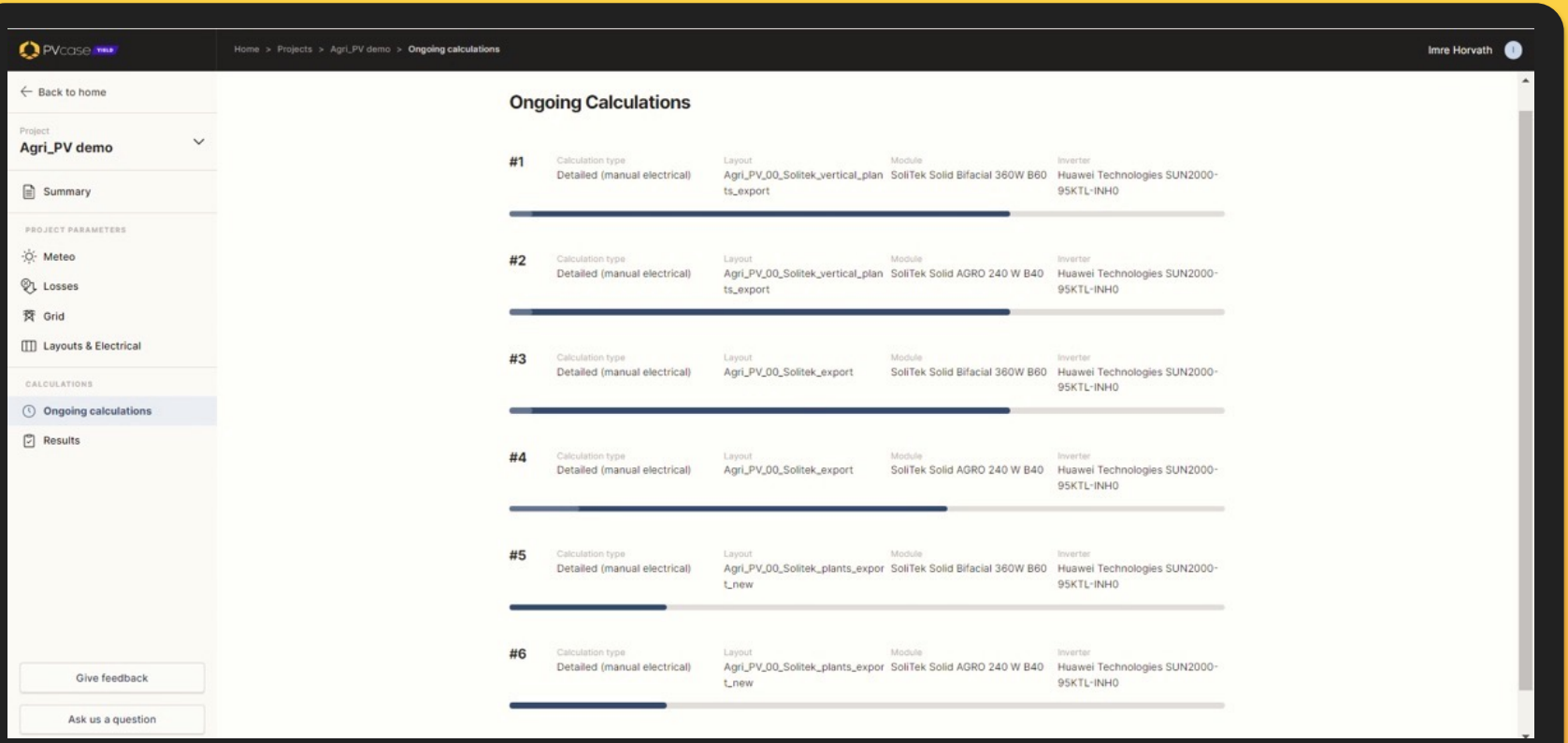
Simulate complex PV plants on arbitrary topography



Optimize PV system performance in space and time



Analyze losses of vertical bifacial PV plants on uneven terrain

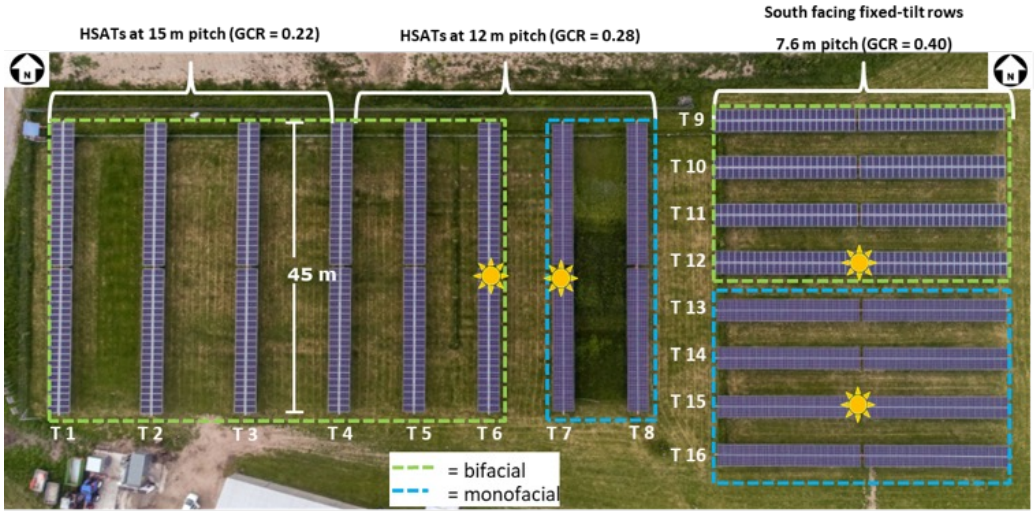


Run concurrent simulations in the Cloud while working on other tasks

How accurate is PVcase Yield?

Public, high quality PV performance datasets (input + output)

- Denmark Technical University (DTU)*
  - Denmark
  - 4 systems combining: Fixed tilt, HSAT, Monofacial, and Bifacial
  - Hourly data for 1 year: In-plane irradiance (front & back), module temperature, DC power
  - Additional system losses fairly objectively determined

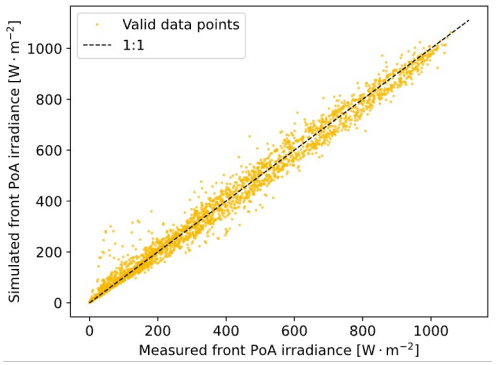


*Riedel-Lyngskær, Nicholas et al., *Appl. Sci.*, ***2022*** *10*(23); DOI: 10.11583/DTU.13580759.v3

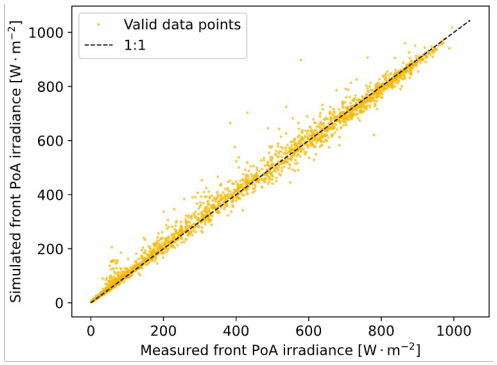
DTU: irradiance and temperature simulations closely match measurements

- Compare to **in-plane pyranometer** measurements: switch off angular reflection model
  - Front-side: very high accuracy
  - Back-side: 5 – 7 W/m² overestimation
    - Higher relative uncertainty for back-side pyranometer measurements

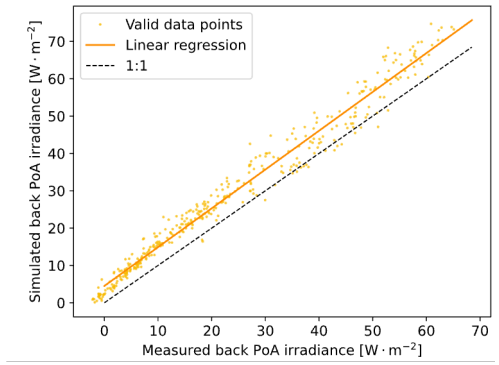
Fixed-tilt, front-side



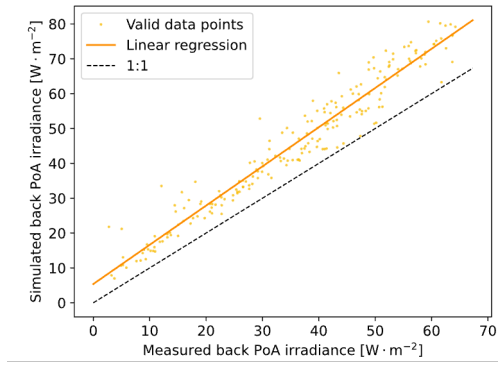
Tracker, front-side



Fixed-tilt, back-side

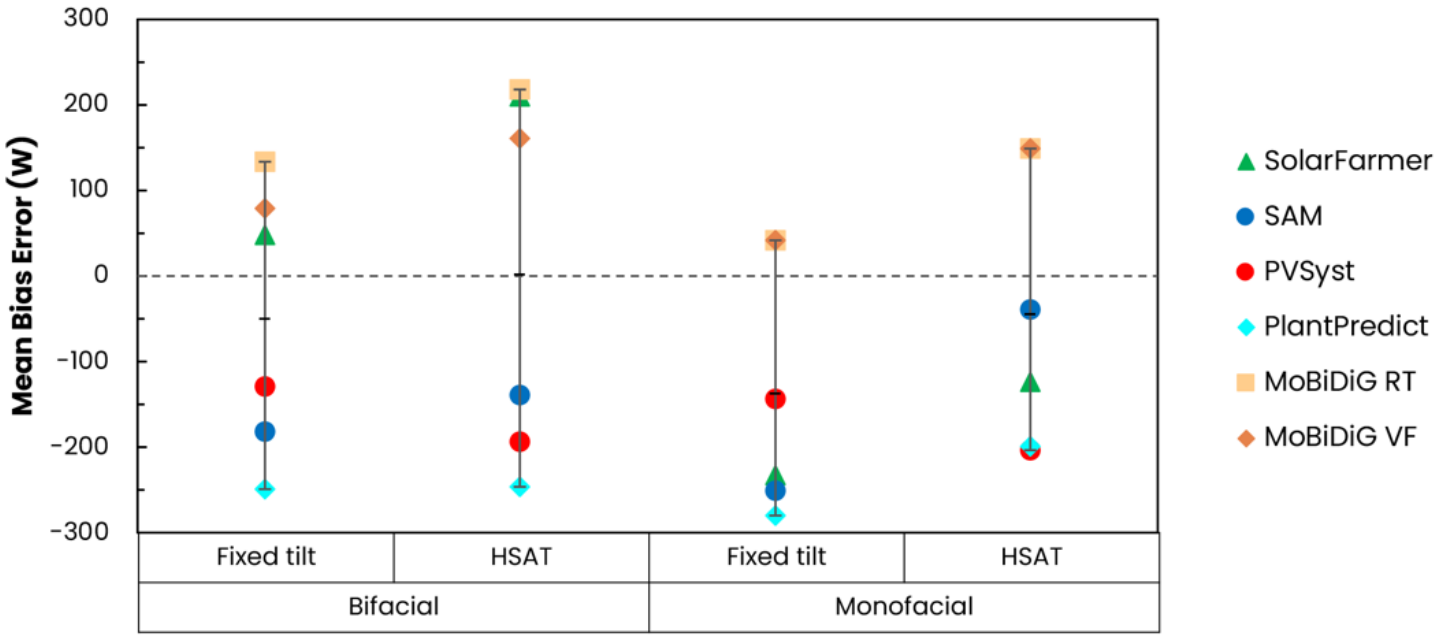


Tracker, back-side



- On average, **module temperature** is underestimated by 2.7°C (monofacial tracker data)

DTU: yield estimations are comparable to other software

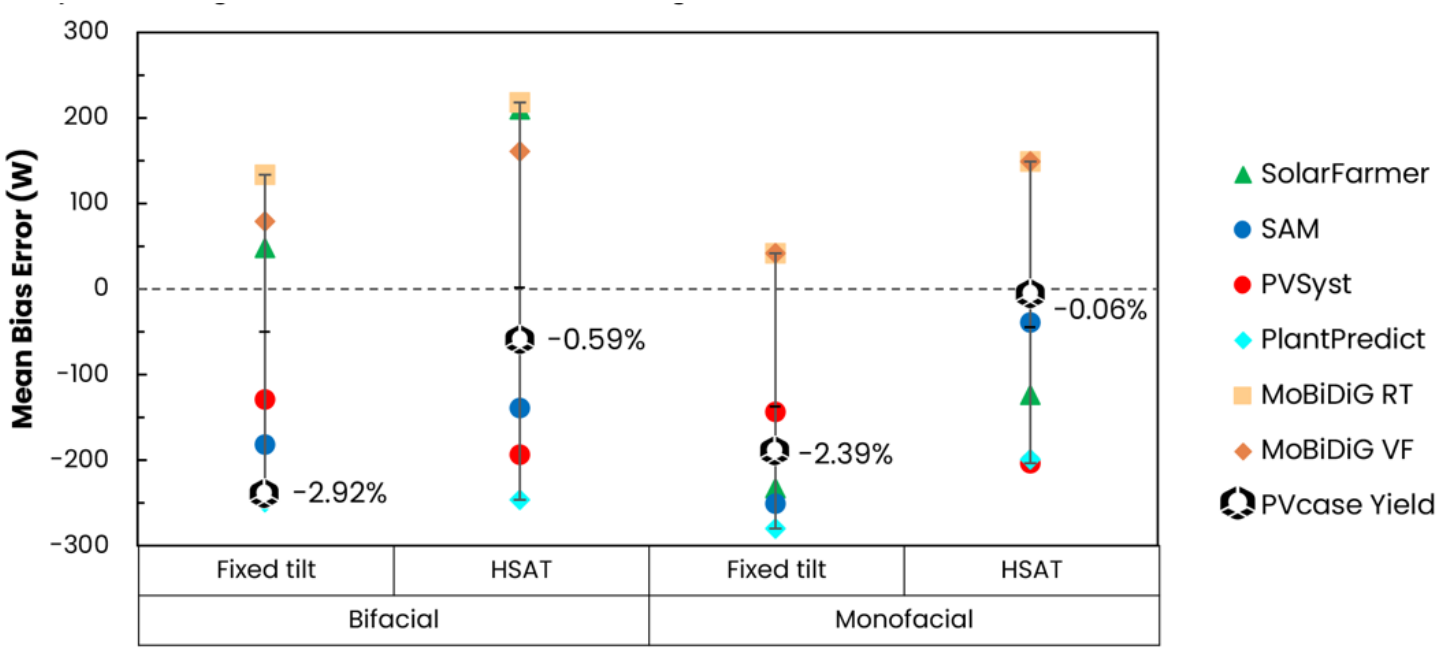


Based on Figure 10 in **[1]**

[1] Riedel-Lyngskær, Nicholas, et al, *Appl. Sci.*, ***2020*** *10*(23); https://doi.org/10.3390/app10238487

DTU: yield estimations are comparable to other software

- PVcase Yield
  - Tendency of being conservative, within range of other software tested in **[1]**



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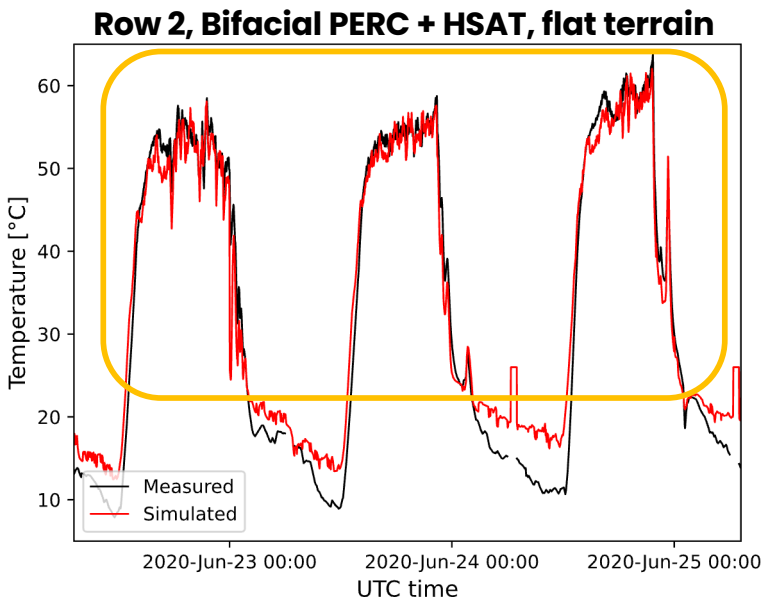
Public, high quality PV performance datasets (input + output)

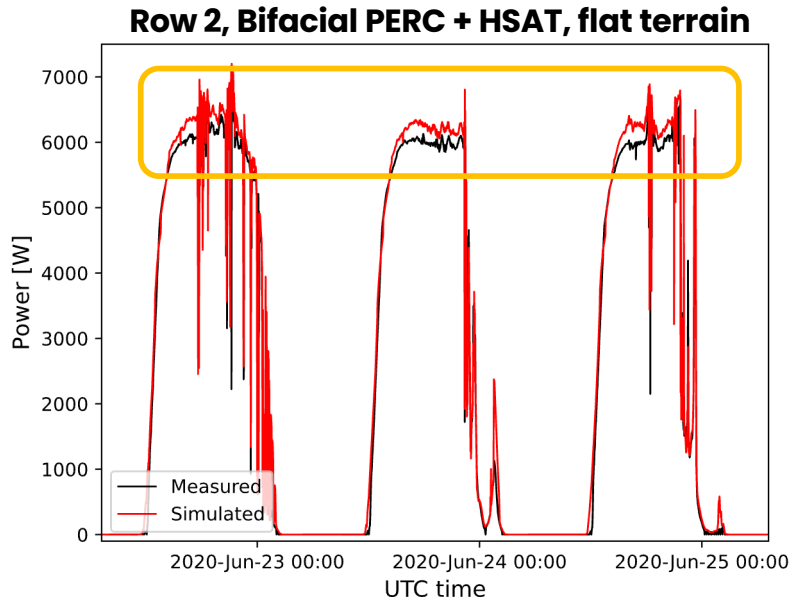
- National Renewable Energy Laboratory (NREL)**
  - Golden, CO, USA
  - B.E.S.T. field: Bifacial and Monofacial on HSAT
  - **Minutely** data for 2 years: In-plane irradiance (front & back), module temperature, DC power
  - Additional **system losses**. Roughly estimated in 5% but **excluded from the results.**

Ovaitt, S. and Deline, C. ***2022*, Available: https://datahub.duramat.org/dataset/best-field-data

NREL: 1-minute resolution temperature and power time series

- High temperature estimation accuracy during daylight hours





- Power **overestimation** in the order of magnitude of the expected system losses.

NREL: irradiance and temperature simulations closely match measurements

- At 1 minute resolution, **irradiance** estimation accuracy remains within measurement uncertainty on both front- and back sides

HSAT, front-side

Row	Technology	Year	NMBE (%)
2	Bifacial PERC	2020	**-2.2**
		2021	**-2.4**
4	Monofacial PERC	2021	**1.1**
9	Bifacial HJT	2020	**1.1**
		2021	**-0.5**

Pyranometer measurement: reflection model OFF

HSAT, back-side

Row	Technology	Year	NMBE (%)
2	Bifacial PERC	2020	**-2.0**
		2021	**3.6**
9	Bifacial HJT	2020	**-9.0**
		2021	**-3.7**

Average of 4 reference cells: reflection model ON

- **Module temperature** estimation
  - Minor bias is observed: -0.9 … 2.8°C.

NREL: yield accuracy is within the uncertainty range of system losses

- When **excluding additional system losses** a tendency towards overestimation is observed

Row	Technology	Year	NMBE (%)
2	Bifacial PERC	2020	**5.5**
		2021	**6.9**
4	Monofacial PERC	2021	**-1.7**
9	Bifacial HJT	2020	**4.7**
		2021	**7.2**

Conclusions

Conclusions

- **3D digital twin-based** software ecosystem has the potential to
  - Solve many of today's PV simulation challenges through enabling 3D **ray tracing**
  - Reduce the cost and increase the value of digital PV services across the lifecycle

- PVcase Ground Mount + Yield: flexibly model various, complex PV systems with **efficiency**, **accuracy** and **ease**

- Metrics on analysed datasets, combining **monofacial**, **bifacial**, **tracker** and **fixed-tilt**
  - **Irradiance** simulation error is -2.4% … +1.1% (front) and -9% … +3.6% (back)
  - **Module temperature** simulation error is -2.9°C … +2.8°C
  - When additional system losses are objectively determined (DTU dataset), **DC Yield** simulation error is -3.5% … -1.4%

- Going forward: the **availability** of **high-quality datasets** will be crucial
  - Measured on **large ground- and roof-mounted installations**

PVcase

Thank you!

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