

Validation with PV plant data and updates of the 3D energy yield calculation model for the RatedPower software

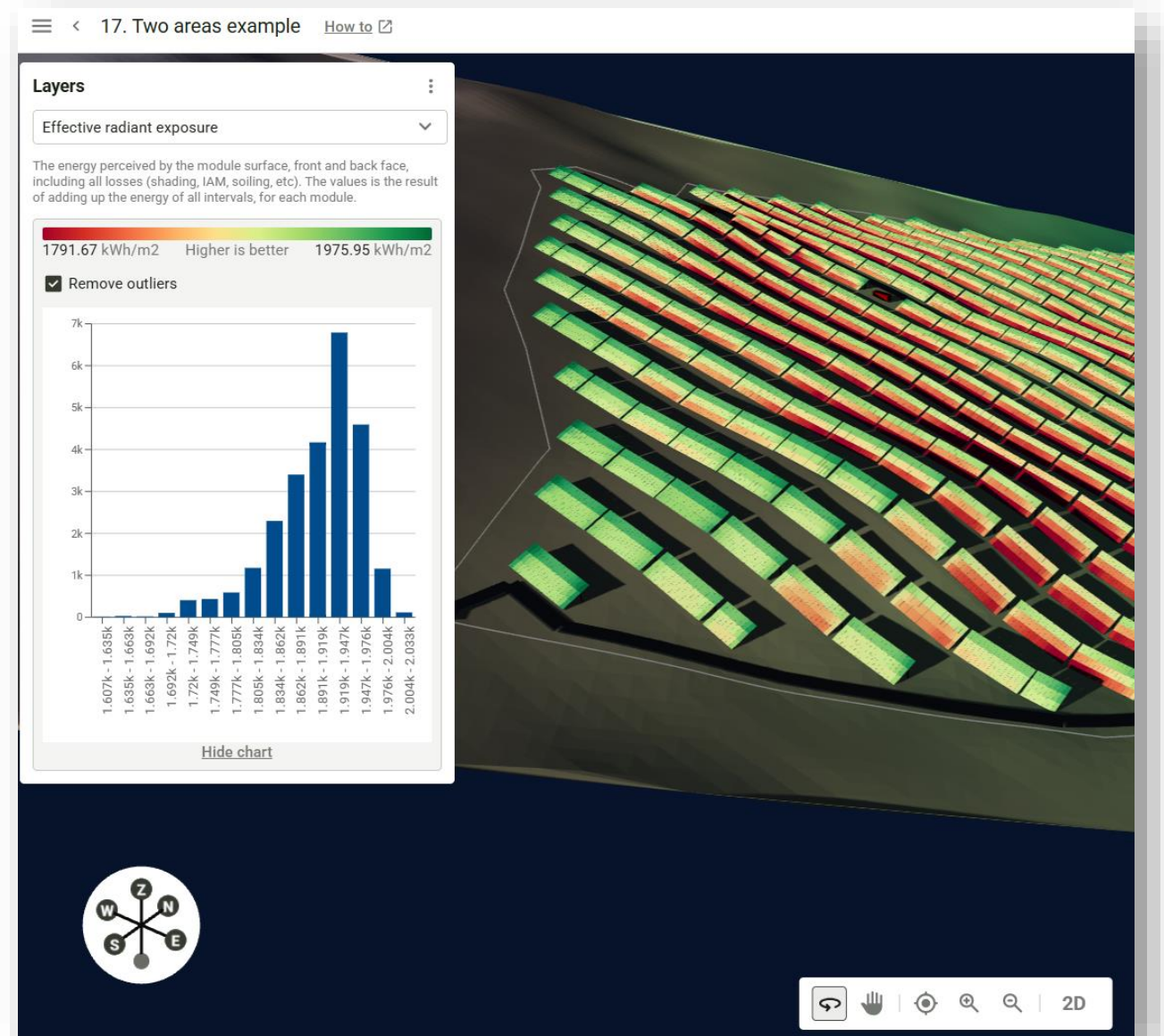
PVPMC 2026 Albuquerque



3D energy released October 2025

The 3D energy project in RatedPower:

- 3D energy is an energy yield calculation model which leverages ray tracing and an advanced electrical model. It also includes a terrain aware backtracking algorithm.
- Simulations have been available to customers since October 2025.
- Validation of the model using real PV plant data started a few months before release, and the preliminary validation report was published at the same time as the feature.
- So far, results from 2 plants have been published.
- More plants are in study.



Validation

Validation methodology

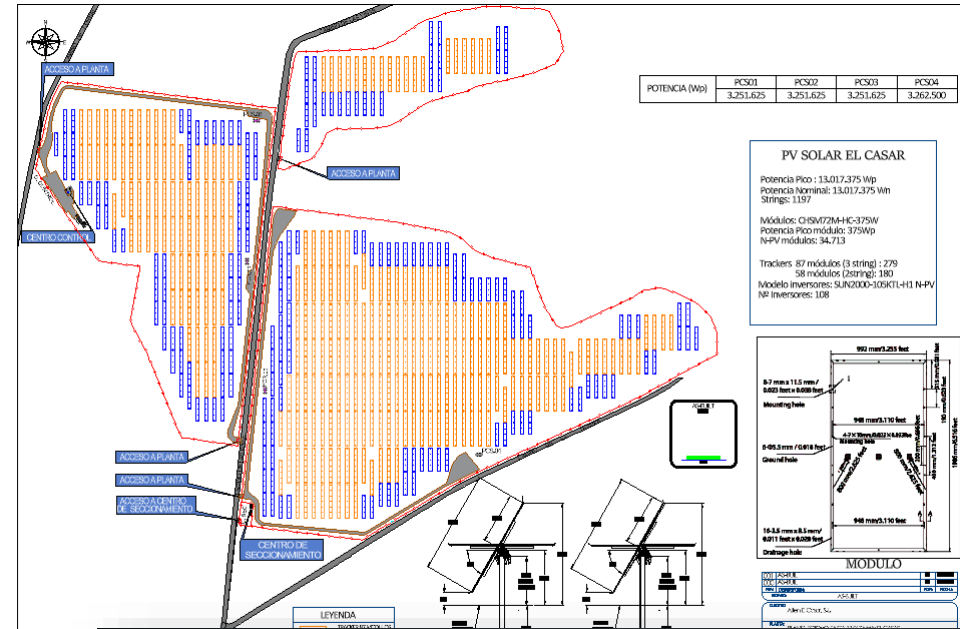
All data is provided by RatedPower customers.

Three step process:

- Request for PV plant data: layout, topographical data, equipment datasheets, SCADA measurements.
- Model construction: generating a RatedPower PV plant as identical as possible to real life counterpart, processing meteorological data.
- Simulation and comparison with real production.

It is key to identify sources of uncertainty, and to choose the best possible models.

Validation report available for [download here](#).



The screenshot shows an Excel spreadsheet with a report template. The data is organized in columns labeled A through P, representing different assets or elements. The rows show time intervals from 01/01/2022 01:00 to 01/01/2022 17:00. The values represent power production in Watts (Wp).

Asset:	El Casar	El Casar	El Casar	El Casar	El Casar	El Casar	El Casar	El Casar	El Casar	El Casar	El Casar	El Casar	El Casar	El Casar	El Casar	El Casar	El Casar	El Casar
Element:	INV01.01- INV01.02- INV01.03- INV01.04- INV01.05- INV01.06- INV01.07- INV01.08- INV01.09- INV01.10- INV01.11- INV01.12- INV01.13- INV01.14- INV01.15																	
Signal:	Potencia	Potencia	Potencia	Potencia	Potencia	Potencia	Potencia	Potencia	Potencia	Potencia	Potencia	Potencia	Potencia	Potencia	Potencia	Potencia	Potencia	Potencia
Date/Name	El Casar IN	El Casar IN	El Casar IN	El Casar IN	El Casar IN	El Casar IN	El Casar IN	El Casar IN	El Casar IN	El Casar IN	El Casar IN	El Casar IN	El Casar IN	El Casar IN	El Casar IN	El Casar IN	El Casar IN	El Casar IN
01/01/2022 01:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01/01/2022 02:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01/01/2022 03:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01/01/2022 04:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01/01/2022 05:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01/01/2022 06:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01/01/2022 07:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01/01/2022 08:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01/01/2022 09:00	0.611406	0.513009	0.632351	0.586486	0.500382	0.521254	0.518682	0.542512	0.49676	0.592192	0.553484	0.513738	0.580789	0.632076	0.53			
01/01/2022 10:00	20.07384	19.88604	24.18379	21.6056	19.31244	19.99275	20.92331	21.41015	19.87822	23.54529	21.30459	19.18303	21.58521	22.97938	20.80			
01/01/2022 11:00	49.79965	55.1779	59.77978	60.00224	54.48193	51.50439	55.10339	55.72476	50.62971	57.08564	58.68875	54.48168	56.10516	56.97587	55.51			
01/01/2022 12:00	50.54005	55.08993	59.68821	60.66658	55.80453	51.14025	56.32317	56.36944	50.92353	56.26611	60.8238	55.62419	56.11818	56.31495	55.64			
01/01/2022 13:00	48.51229	52.57225	56.92711	58.12337	53.38934	49.36325	54.69554	54.22084	49.19375	54.08652	59.21646	53.98385	54.42605	54.64567	53.97			
01/01/2022 14:00	45.40394	49.06335	53.21003	54.53516	49.93638	46.37271	51.53242	50.82468	46.21249	50.70435	55.63214	50.62599	50.9683	51.21638	50.61			
01/01/2022 15:00	43.68348	46.64862	50.67667	51.74284	47.24316	43.7146	48.56466	47.69936	43.46844	47.63245	52.64137	47.56534	47.89479	48.17095	47.47			
01/01/2022 16:00	50.85807	53.56368	58.31047	59.35765	54.18169	50.00376	55.69372	54.51199	49.75625	54.65056	61.43953	54.85529	55.19277	55.29893	54.47			
01/01/2022 17:00	27.6475	29.8697	42.82422	46.16170	40.76629	39.23199	41.14119	42.16699	37.40322	41.47551	47.13200	42.401	42.762	43.76706	42.22			

Error evaluation and sanitization

We use two metrics to measure error:

- Total production relative error, serves as a global indicator of simulation accuracy.
- NRMSE (normalized root mean square error) of hourly intervals, serves to evaluate if error compensation is occurring between intervals.

Sanitization is key: real data has issues which cannot be accounted for in the simulation, such as curtailment, sensor error, or plant unavailability.

Our approach was to remove from the error calculation any interval with an error exceeding 20%.

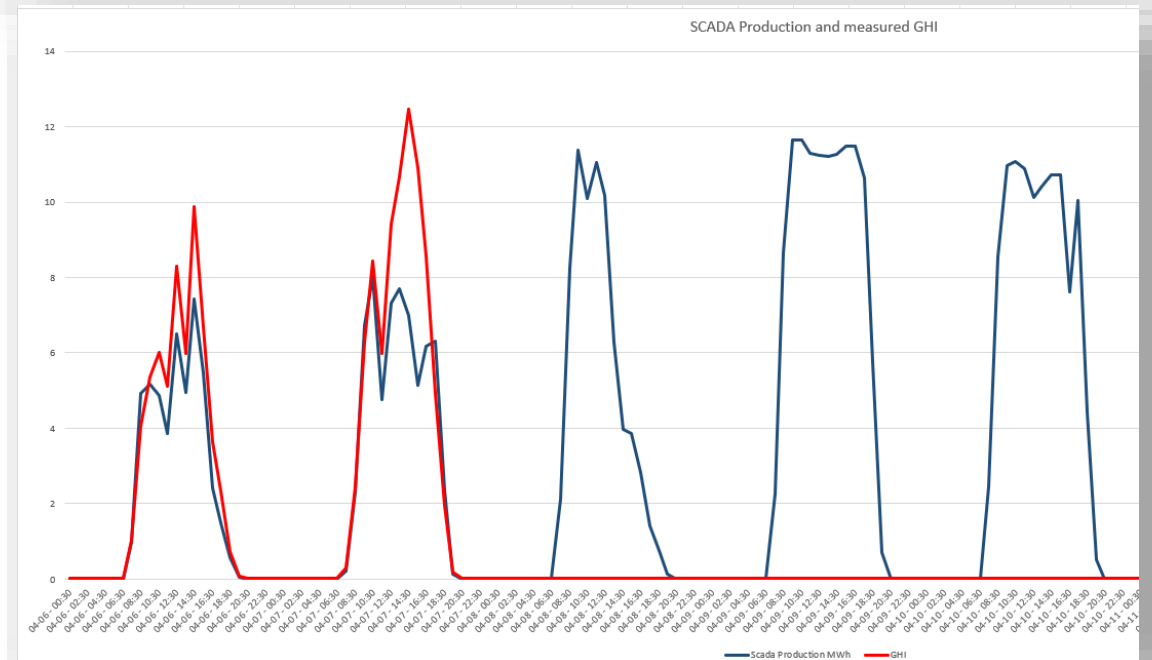
Results will be given with and without sanitization.

$$E_{rel} = \frac{|v_{model} - v_{real}|}{v_{real}} \quad (1.1)$$

$$NRMSE = \frac{\sqrt{\frac{1}{n} \cdot \sum_{i=1}^n (v_{model} - v_{real})^2}}{|\max(v_{real}) - \min(v_{real})|} \quad (1.2)$$

Where:

- E_{rel} is the relative error between two measurements.
- v_{model} is the value produced by the model (3D energy simulation).
- v_{real} is the value measured at the real PV plant.
- $NRMSE$ is the normalized root mean squared error.



Case study 1

SAT plant in Spain

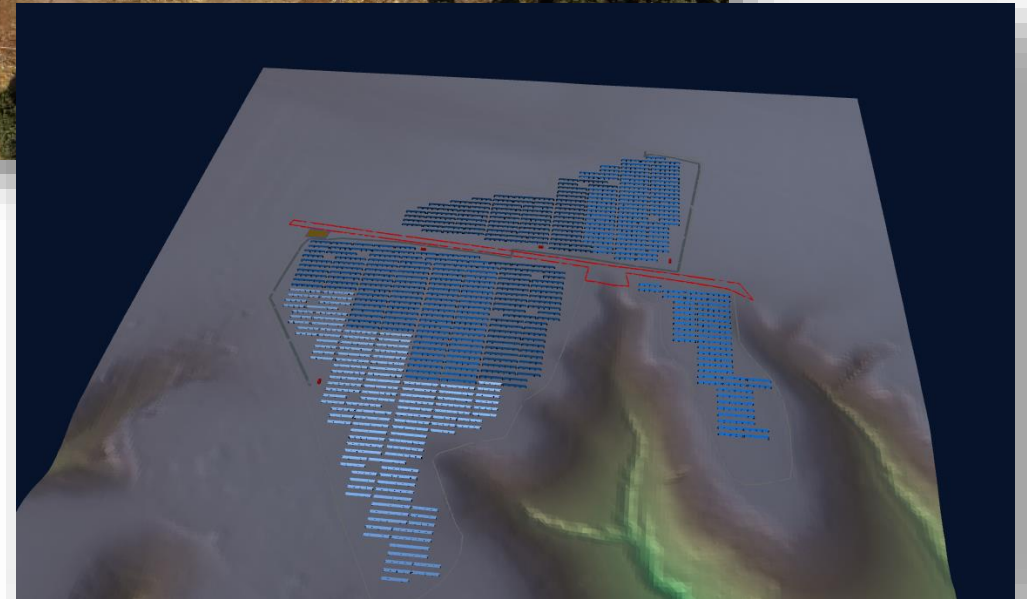
Characteristics:

- Located in Guadalajara, peak power 13 MW DC, rated power 12.5 MW AC.
- 2P tracker, monofacial PV panels, string inverter.
- Very flat terrain.

The plant was particularly suited to the validation study:

- No curtailment, due to administrative details regarding interconnection.
- Soiling data provided, very low soiling and no cleaning schedule.

Thank you Alten for providing the data!



Case study 1

SAT plant in Spain

Results

- In 2023 (year A), very low error with and without sanitization.
- In 2024 (year B), very high error without sanitization, but consistent with 2023 after sanitization.

	Production real	Production simulation	Error	NRMSE
Raw	100.00%	100.00%	0.21%	3.87%
Sanitized	95.84%	95.55%	-0.09%	1.91%

Table 1.1: Case 1: Results for year A

	Production real	Production simulation	Error	NRMSE
Raw	100.00%	100.00%	-11.11%	15.45%
Sanitized	81.74%	91.73%	-0.25%	2.21%

Table 1.2: Case 1: Results for year B

Case study 1

SAT plant in Spain

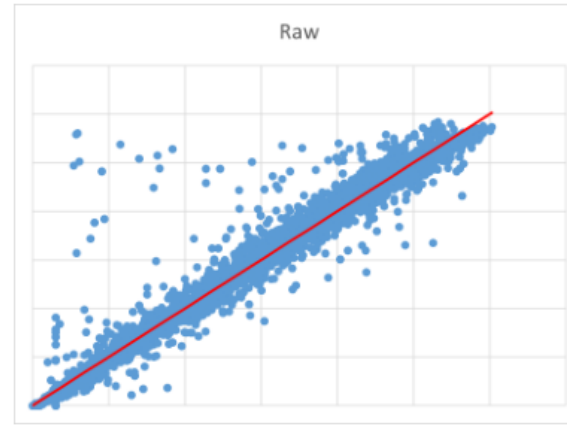
Figures show the plant production in the X axis, and simulated production in the Y axis.

The perfect result would be the red line, $y=x$.

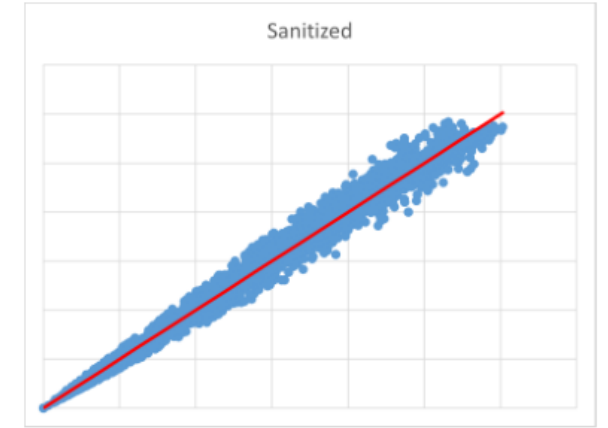
Some of the issues we see:

- Model overestimation when over the red line, possibly due to sensor error or unavailability.
- In year B (2024) we see:
 - Vertical line, indicating that there are intervals where a non-zero power value is repeated.
 - Horizontal line at $y=0$, due to sensor error ($GHI = 0$).
- Sanitization cleans up these intervals.

NRMSE of 2% in both cases is “visible” in these plots.

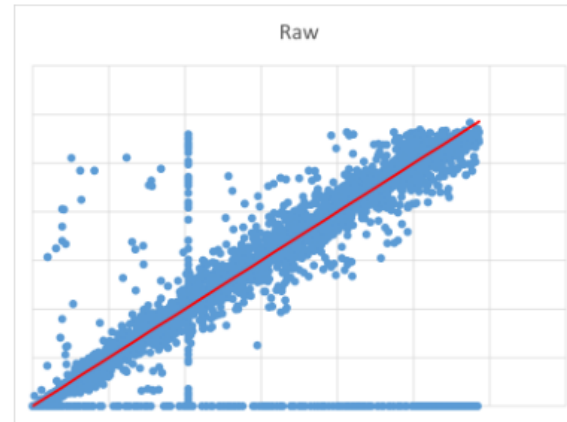


(a) Raw simulated vs real production



(b) Sanitized simulated vs real production

Figure 1.1: Case 1 Year A: Scatter plots showing the simulated values in the Y axis, and real values in the X axis



(a) Raw simulated vs real production



(b) Sanitized simulated vs real production

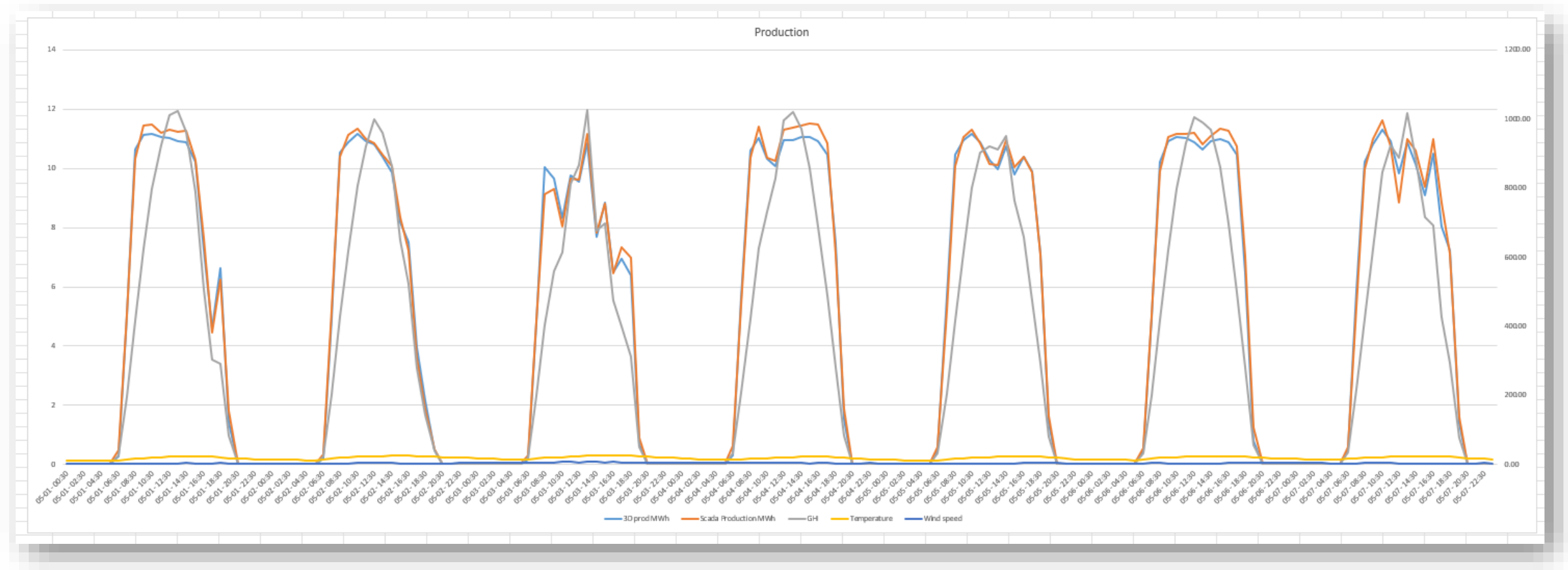
Figure 1.2: Case 1 Year B: Scatter plots showing the simulated values in the Y axis, and real values in the X axis

Case study 1

SAT plant in Spain

Low overall error but higher NMRSE indicates compensation between intervals: some days the model overestimates, some days it underestimates.

Orange line is the SCADA production, blue line is the simulation result.



Case study 2

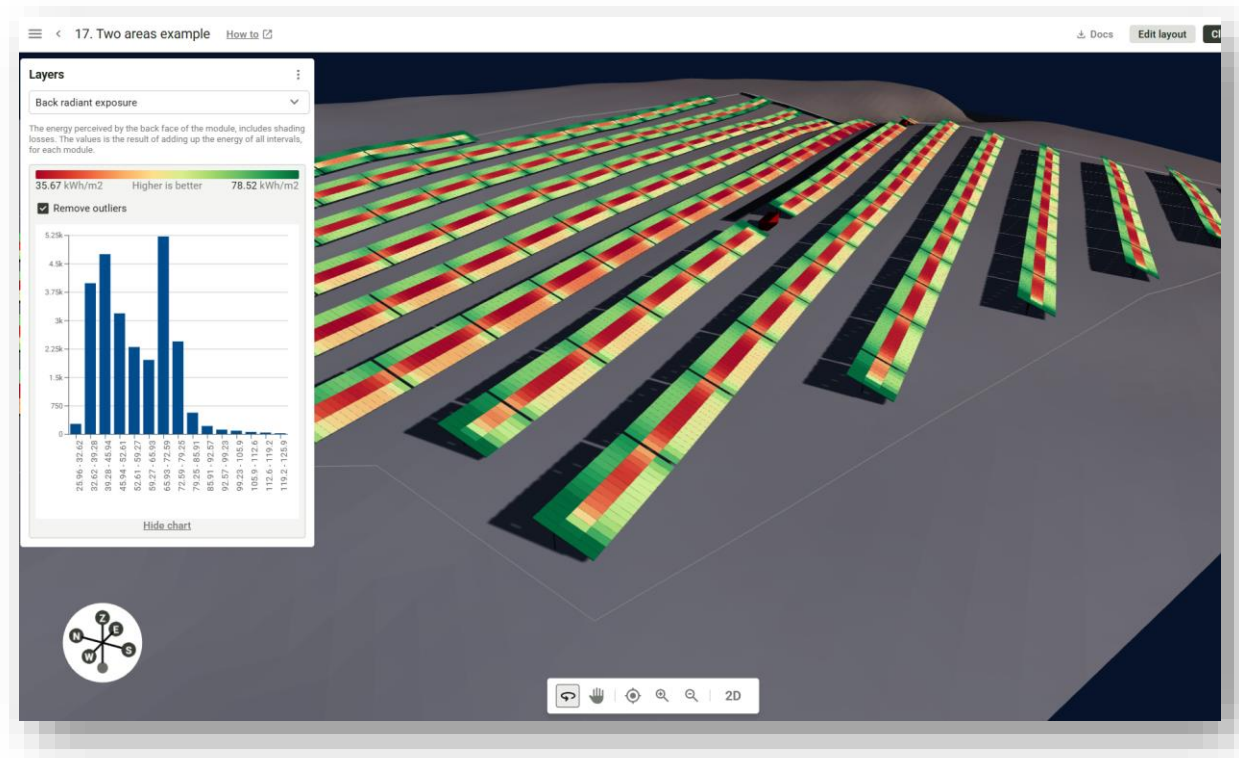
Fixed structure plant in Philippines

Characteristics:

- 2P fixed structure, GCR 80%, tilt 8 degrees.
- Bifacial PV modules, string inverters.
- Complex layout and slopes up to 10%, but low tilt negates the impact of the terrain.

Received 5 months of data after plant commissioning. No soiling data available.

Significant gaps without data.



Case study 2

Fixed structure plant in Philippines

Results:

- Higher error than before, even after sanitization.
- Monthly analysis shows that there are significant differences in error (raw) between months, pointing to either PV plant issues or data quality issues.

	Production real	Production simulation	Error	NRMSE
Raw	100.00%	100.00%	9.73%	12.90%
Sanitized	61.82%	57.34%	1.79%	3.20%

Table 1.3: Case 2: Aggregate results for all months

	Raw				Sanitized			
Month	Real	Simulation	Error	NRMSE	Real	Simulation	Error	NRMSE
A	100.00%	100.00%	11.25%	14.53%	36.1%	32.0%	-1.57%	3.10%
B	100.00%	100.00%	9.95%	11.71%	58.8%	55.0%	2.92%	3.15%
C	100.00%	100.00%	22.53%	19.27%	68.5%	56.9%	1.76%	3.37%
D	100.00%	100.00%	2.89%	9.10%	66.2%	65.3%	1.44%	3.54%
E	100.00%	100.00%	1.10%	9.70%	57.4%	57.5%	1.26%	2.98%

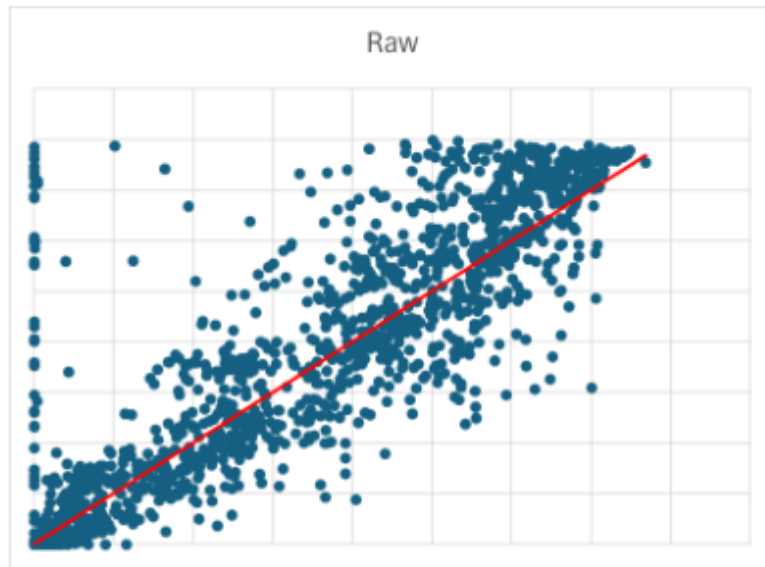
Table 1.4: Case 2: Monthly analysis

Case study 2

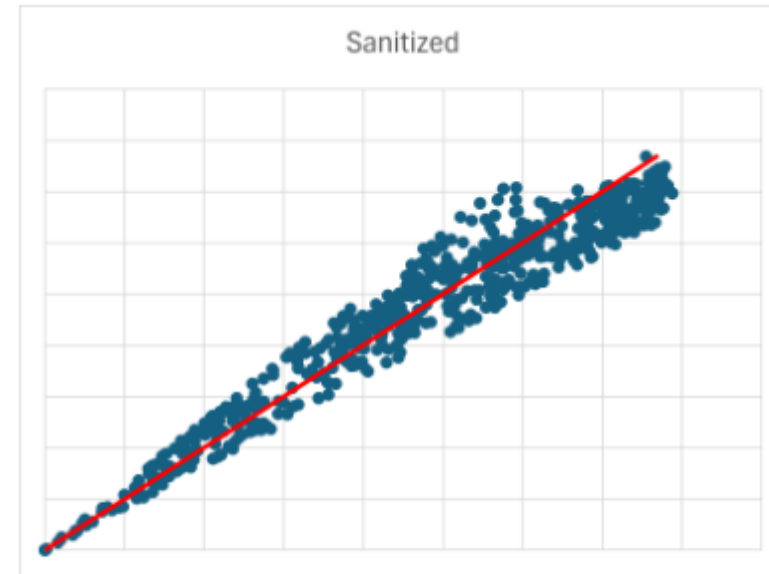
Fixed structure plant in Philippines

Looking at the same plots as before (X axis real production, Y axis simulated production, red line is $y=x$):

- Much wider distribution than in previous case study.
- Vertical line at $x=0$ indicating plant unavailability. Outliers both above and below the red line.
- Sanitization removed many intervals where the model overestimated production vs reality, especially visible towards the top right.



(a) Raw simulated vs real production



(b) Sanitized simulated vs real production

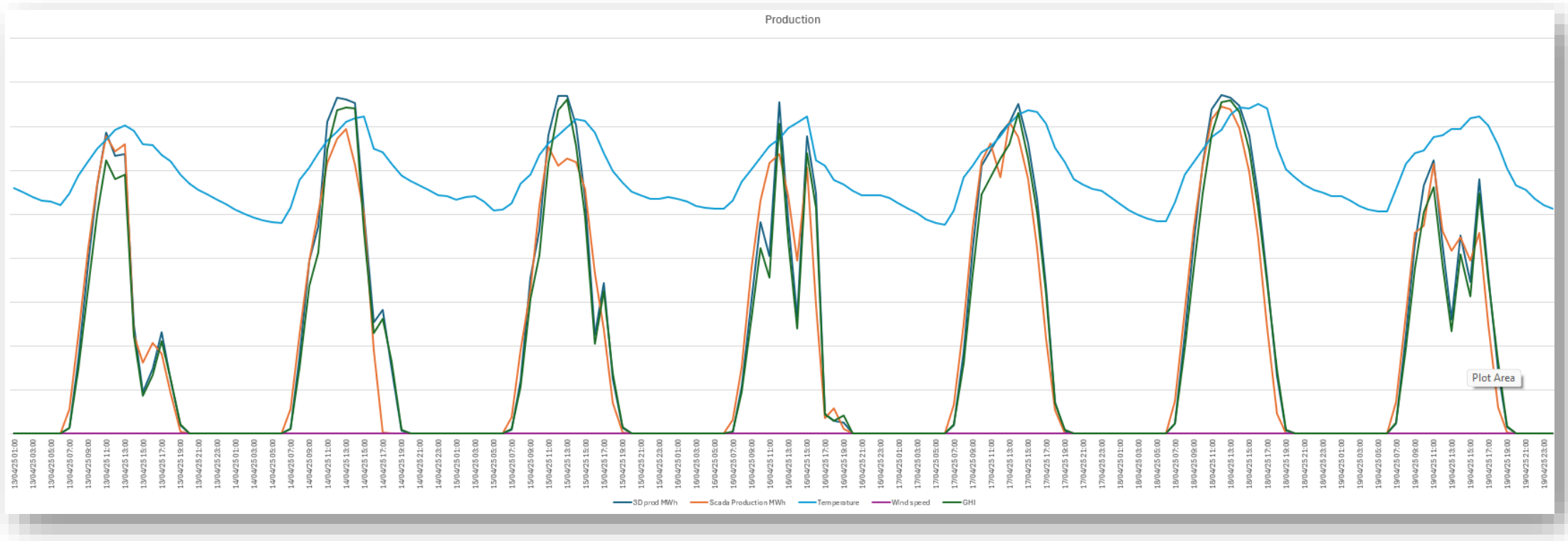
Figure 1.3: Case 2: Scatter plots showing the simulated values in the Y axis, and real values in the X axis

Case study 2

Fixed structure plant in Philippines

Hourly results (orange line is the SCADA production, green lines is the simulated production):

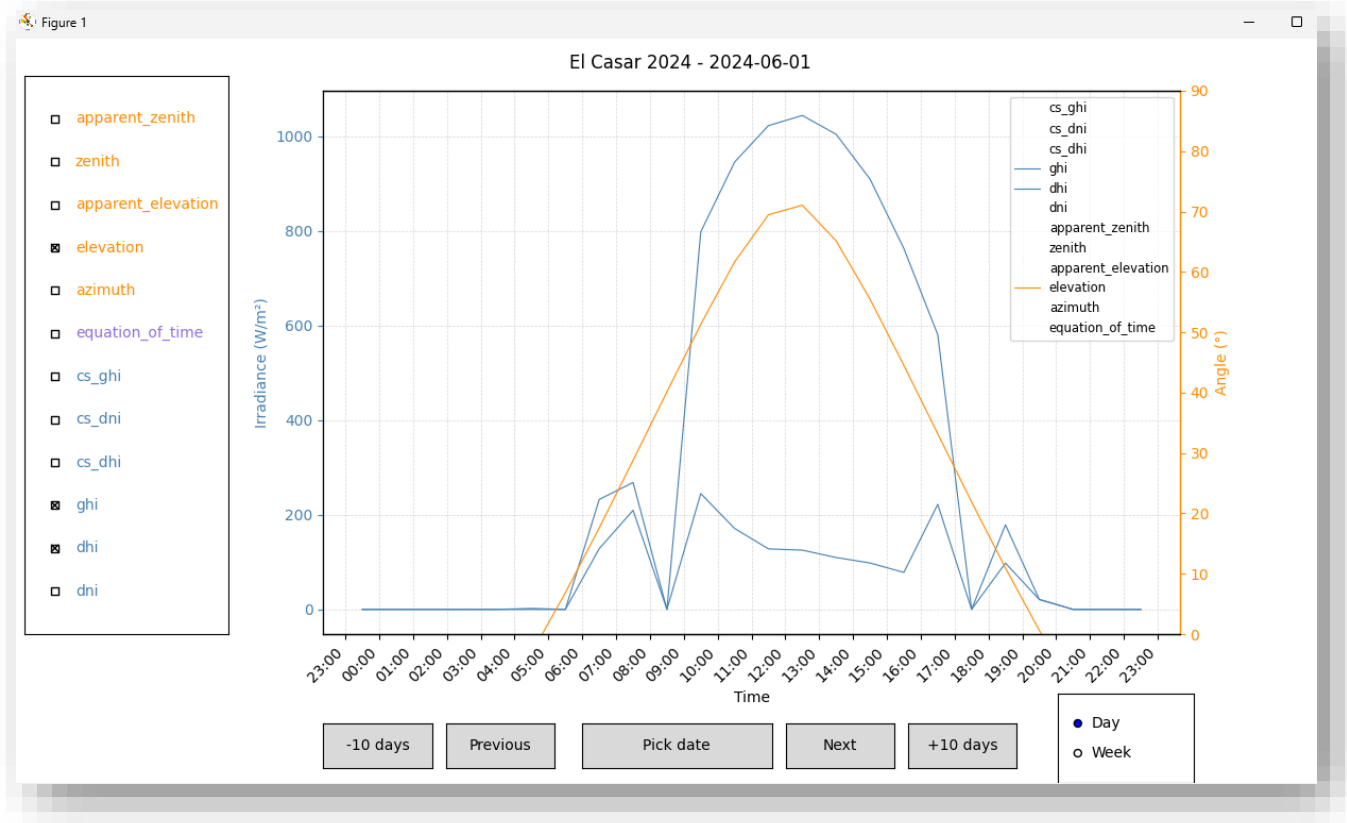
- Significant differences in many intervals, with production which looks decoupled from the GHI values at times.
- Curtailment and sensor errors remain a possibility.



Challenges

Throughout the project we encountered (and continue to encounter) many challenges:

- Data quality and cleanup.
 - Timestamp correction.
 - GHI decomposition into BHI + DHI.
 - Gaps without data.
- Deciding on values for fixed values and derates.
 - Soiling as the biggest unknown.
 - PV panel: degradation, LID, quality...
 - Albedo.
- Inexplicable performance differences.
- Methodology, specifically, the calculation of error and other parameters.



RatedPower software updates

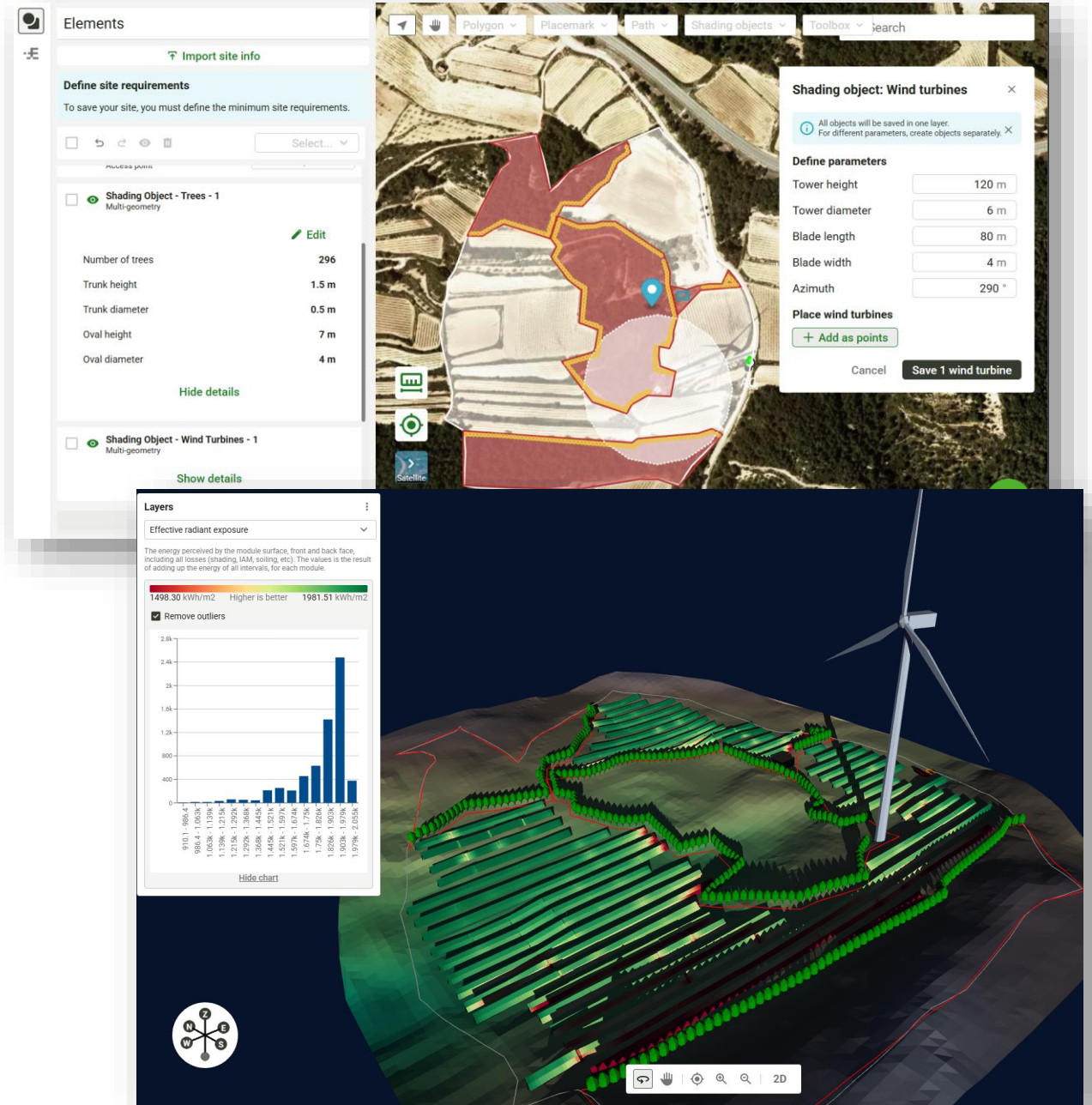
3D energy updates

Since releasing 3D energy, we added:

- Near shading objects (trees, wind turbines, buildings), included in the PVCollada file.
- Hourly results per inverter (DC and AC).
- Thin film PV panel support.

Additionally, the following RatedPower releases are relevant for 3D energy users:

- Improved earthworks model (piling earthworks).
- LV system modeling in Layout editor.
- Improved MV/LV grouping algorithm.
- New automatic terrain data source: GPXZ, with resolution up to 50cm in USA and Europe.



Thank you!



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