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Smart energy flow

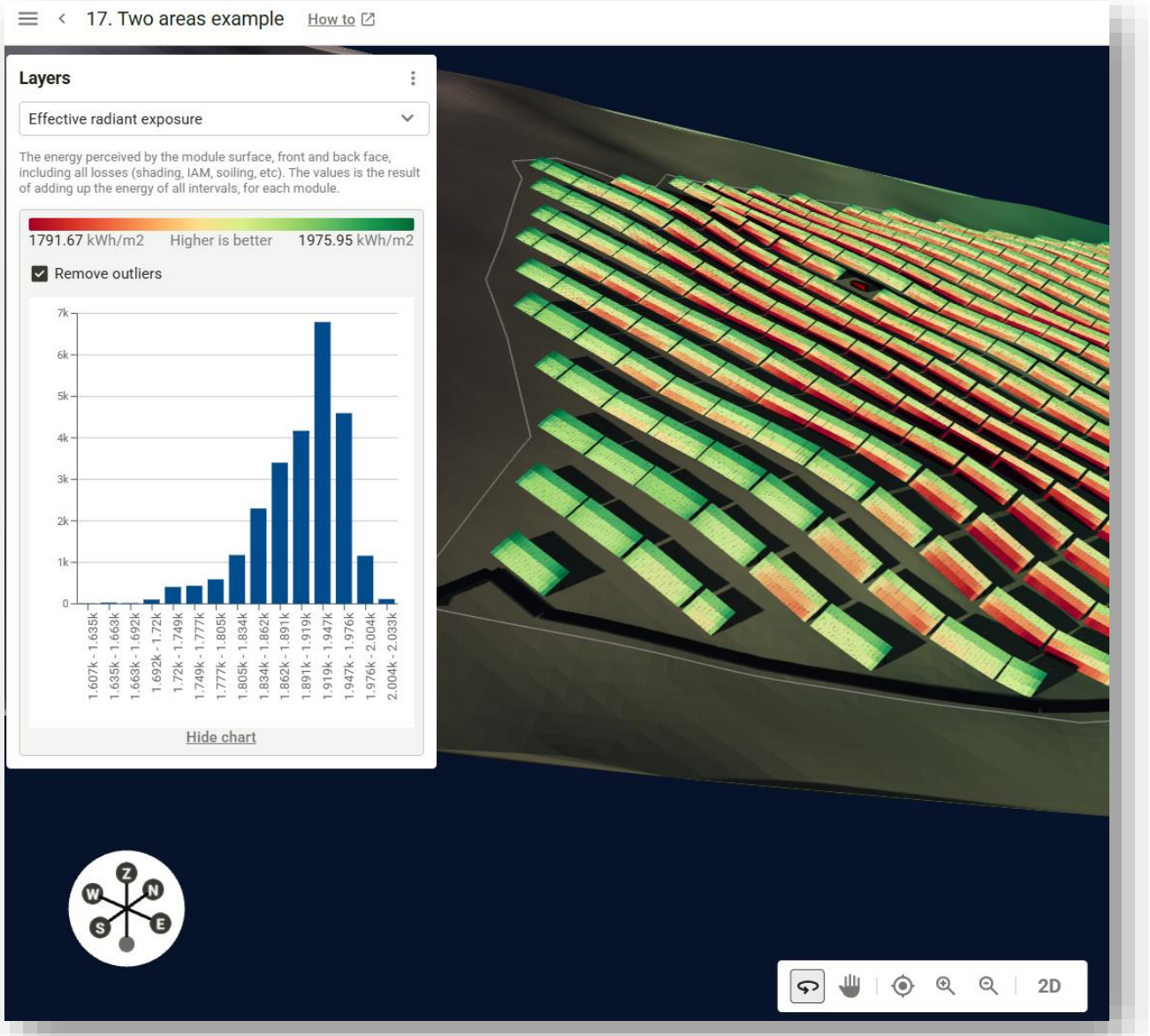
Validation with PV plant data and updates of the 3D energy yield calculation model for the RatedPower software

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 methodology

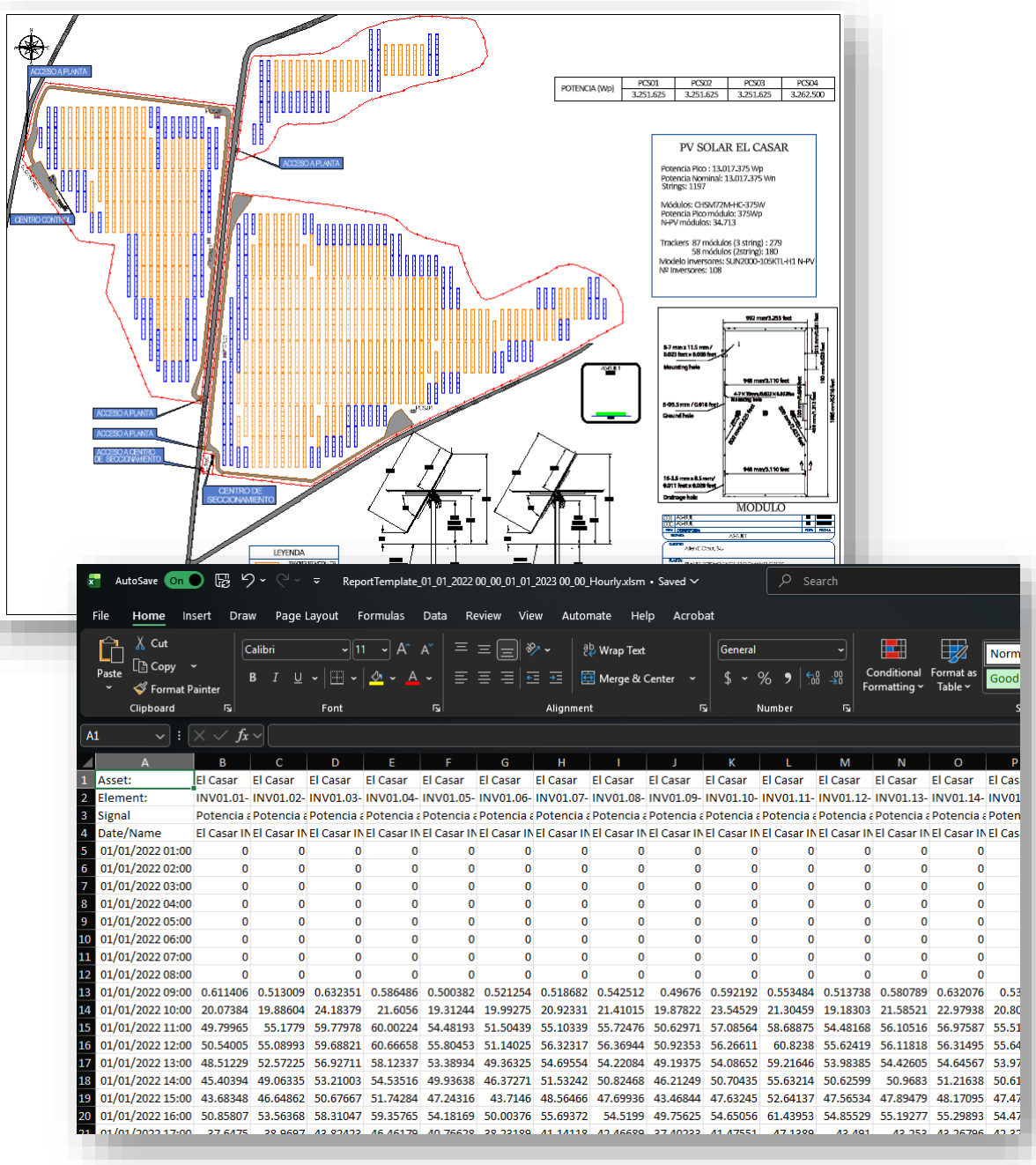
All data is provided by RatedPower customers.

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.



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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%.

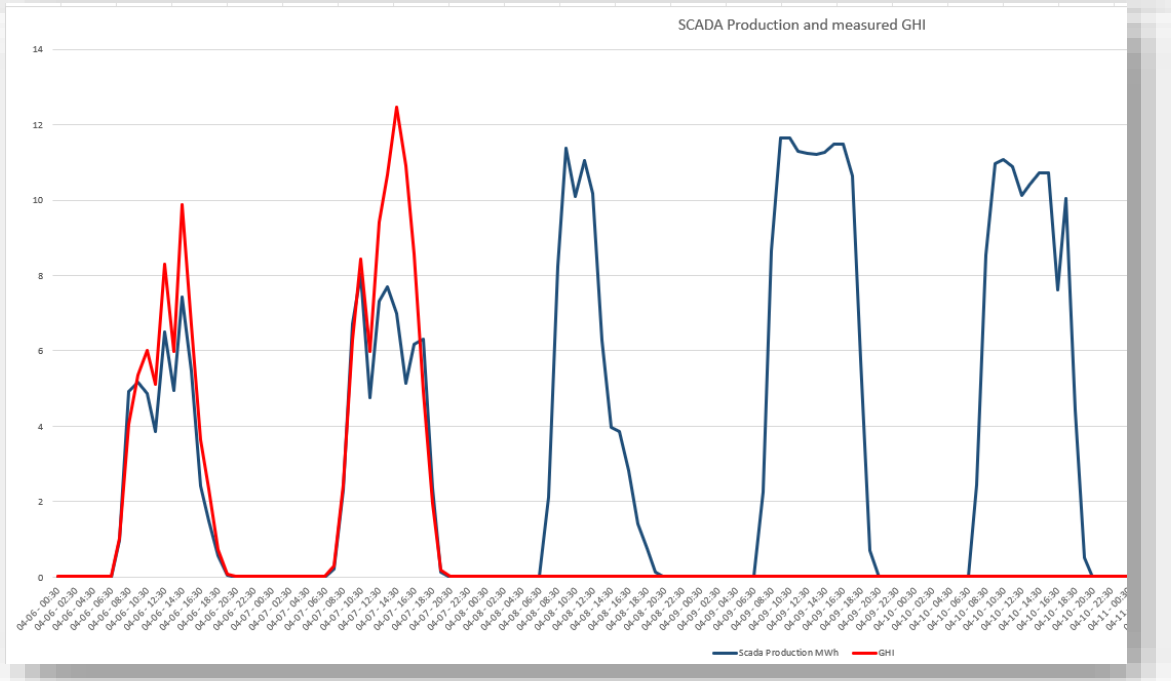
Results will be given with and without sanitization.

$$E_{rel} = \frac{|v_{model} - v_{real}|}{v_{real}} \tag{1.1}$$

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

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!

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

SAT plant in Spain

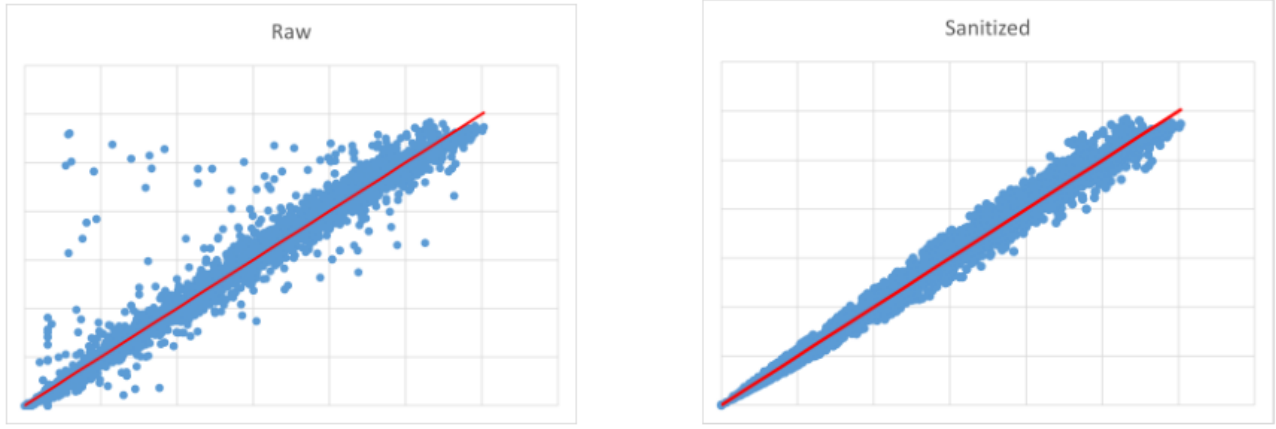
Figures show the plant production in the X axis, and simulated production in the Y axis.

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.

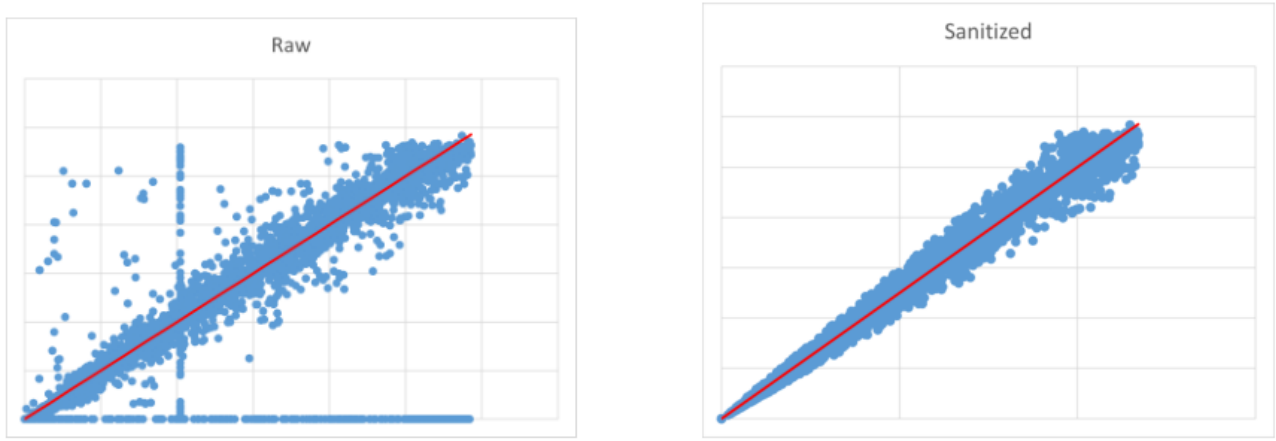
NRMSE of 2% in both cases is “visible” in these plots.



(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

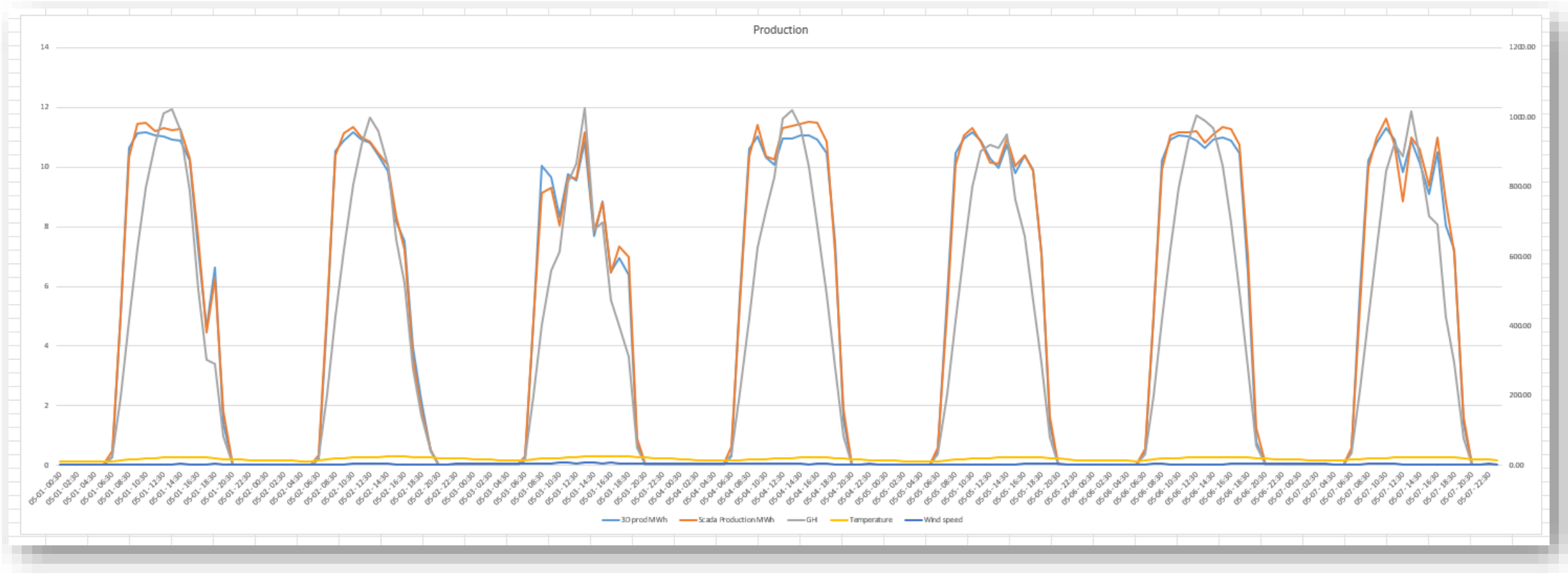
(b) Sanitized simulated vs real production

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

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.

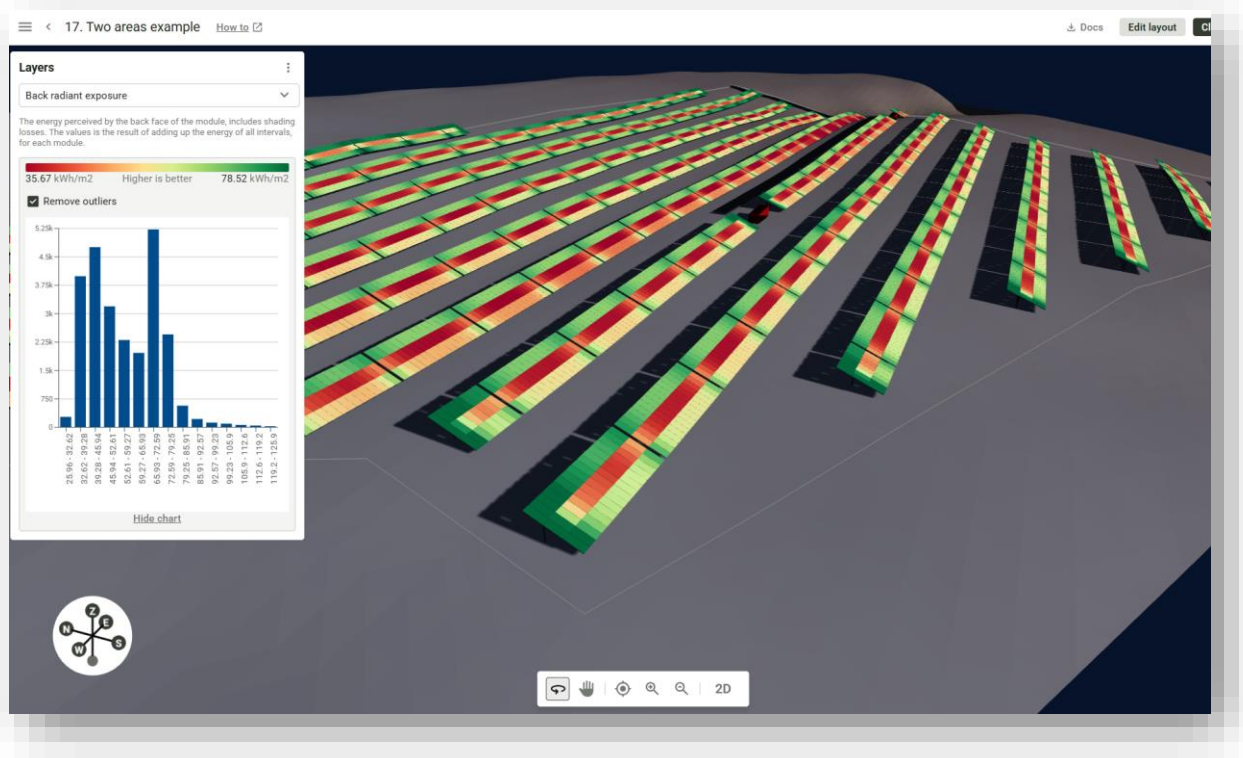


Case study 2

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.

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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

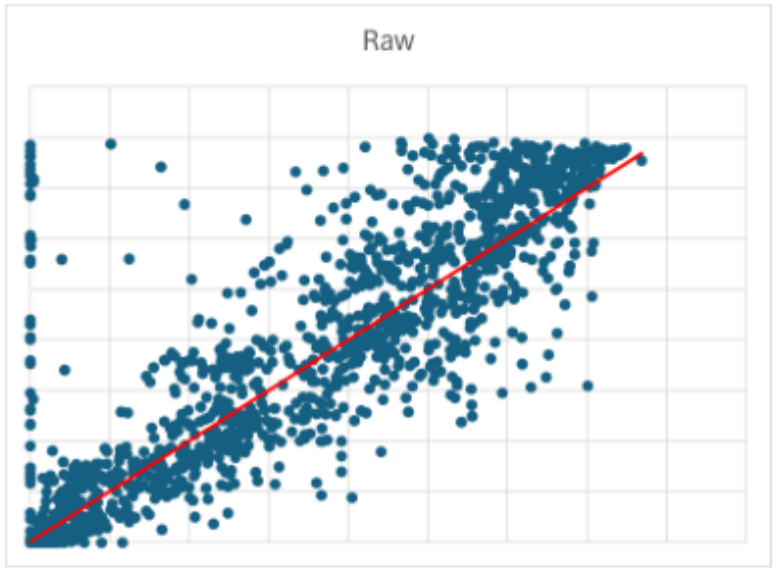
	Raw				Sanitized			
Month	Real	Simulation	Error	NRMSE	Real	Simulation	Error	NRMSE
A	100.00%	100.00%	11.25%	14.53%	36.1%	32.0%	-1.57%	3.10%
B	100.00%	100.00%	9.95%	11.71%	58.8%	55.0%	2.92%	3.15%
C	100.00%	100.00%	22.53%	19.27%	68.5%	56.9%	1.76%	3.37%
D	100.00%	100.00%	2.89%	9.10%	66.2%	65.3%	1.44%	3.54%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

Table 1.4: Case 2: Monthly analysis

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

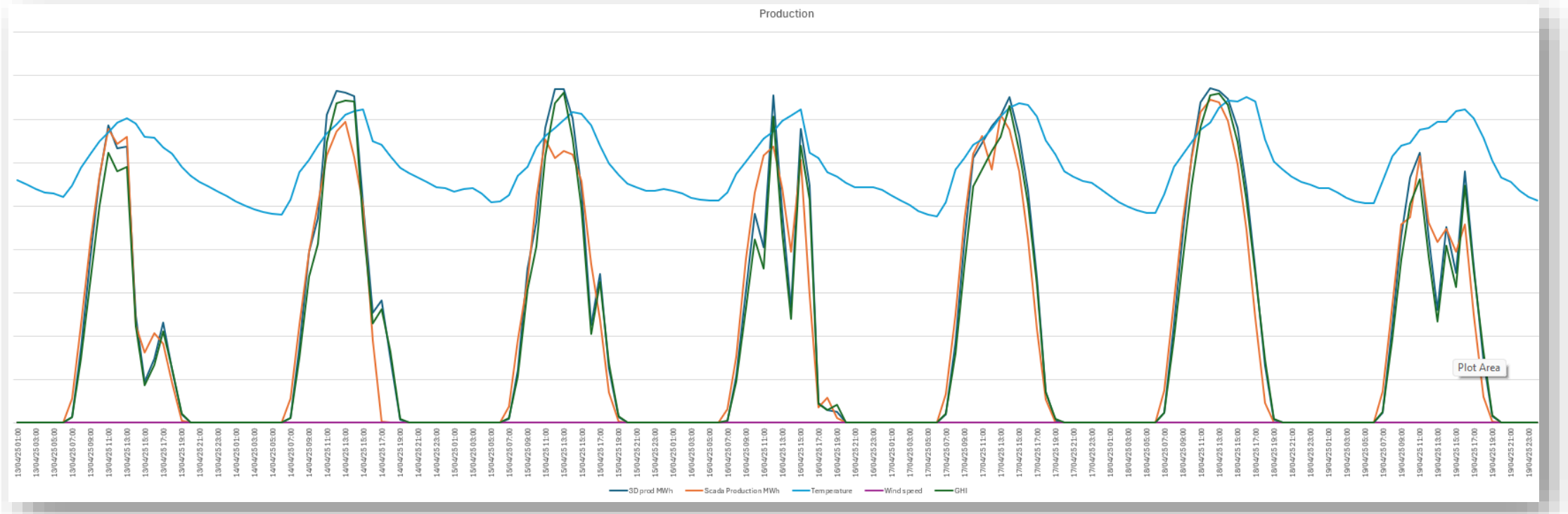
Figure 1.3: Case 2: Scatter plots showing the simulated values in the Y axis, and real values in the X axis

Case study 2

Fixed structure plant in Philippines

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

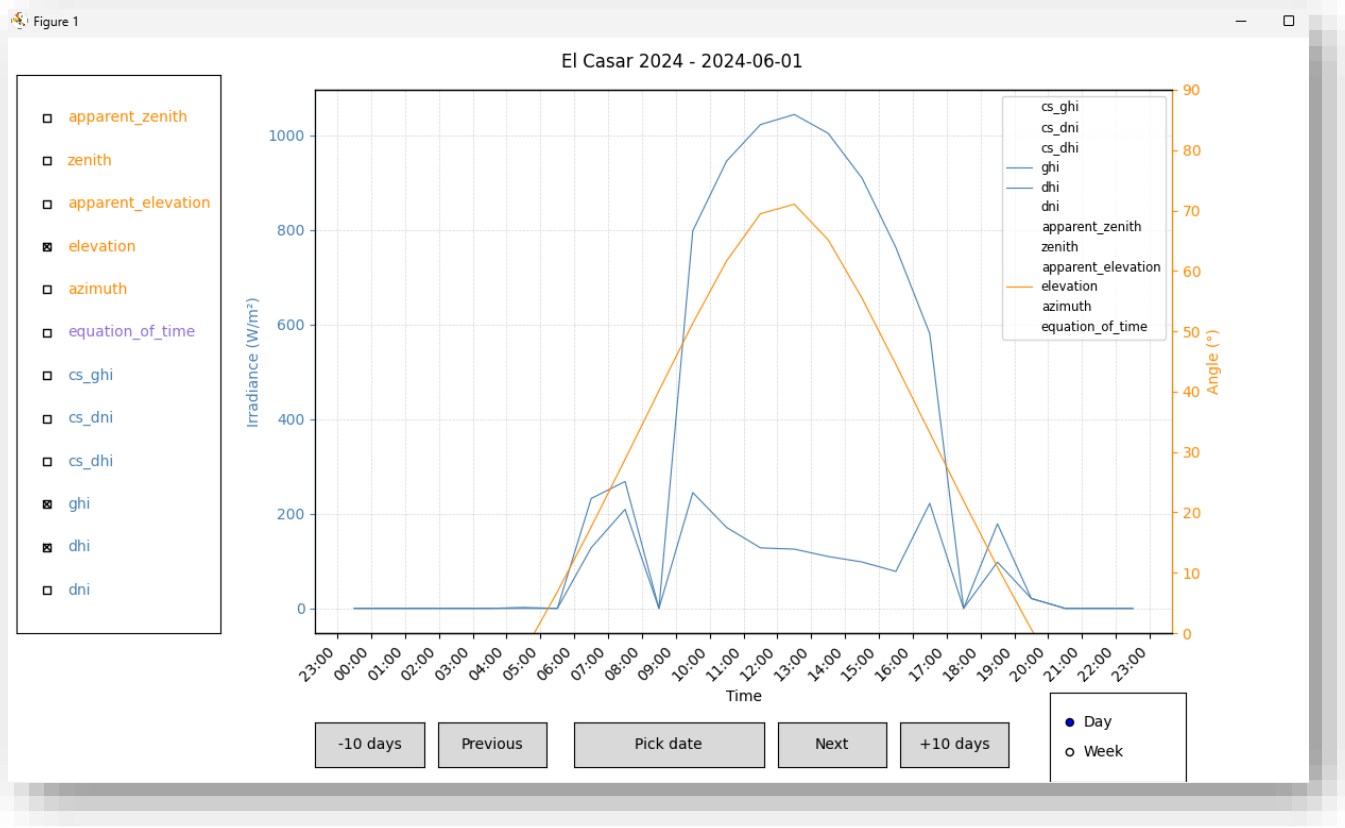
- → Significant differences in many intervals, with production which looks decoupled from the GHI values at times.
- → Curtailment and sensor errors remain a possibility.



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.



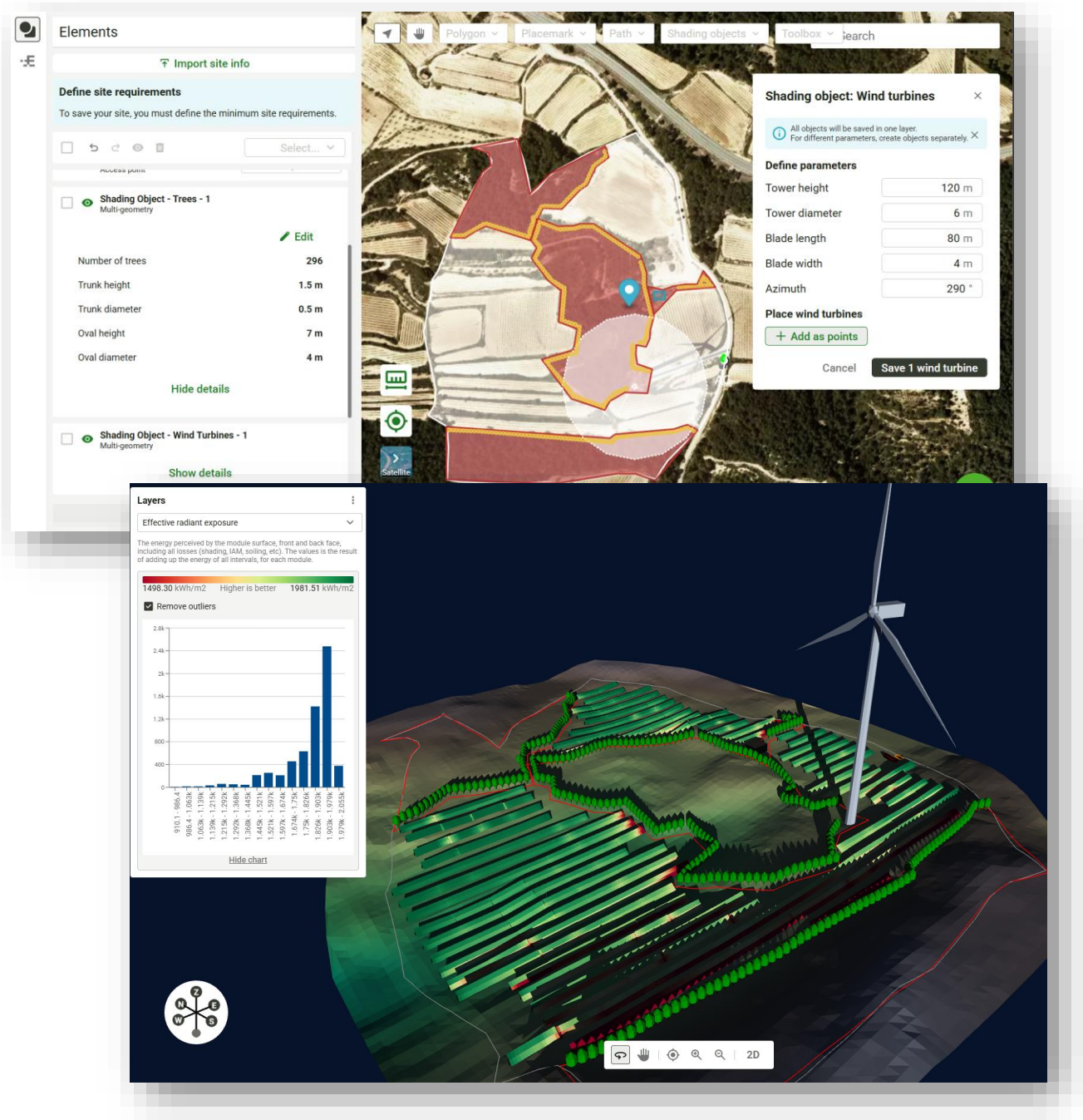
3D energy updates

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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