Minimising the Uncertainty in Performance Loss Rate Calculation for Photovoltaic Systems: A Clustering-Based Year-on-Year Approach

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Better performance loss estimation

- Accurate **yield assessments** are critical for financing photovoltaic (PV) projects [1].
- **Performance loss rate** (PLR), including **degradation** [1], and its **confidence interval** (CI) quantify underperformance and uncertainty.
- **Example:**
  - A PV plant with a PLR of -0.5%/year and a CI of (-0.6, -0.4)%/year
  - A specific yield of 1,400 kWh/kWp/year, with an average electricity price of A$100/MWh
  - This CI results in **A$4/kW/year of uncertainty in revenue**.

Objective

Reduce PLR estimation uncertainty by employing cluster-based like-for-like comparisons to account for environmental variability.

Methodology

The **cluster-based year-on-year (CI-YoY)** mitigates weather variability in PLR estimation [2] by comparing performance on similar days across different years.

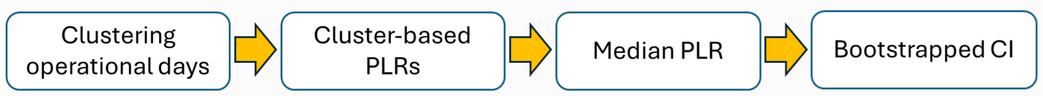

Fig. 1 – Block diagram of the CI-YoY.

- **Clustering** based on **plane-of-array** irradiation (POA) and **ambient temperature**

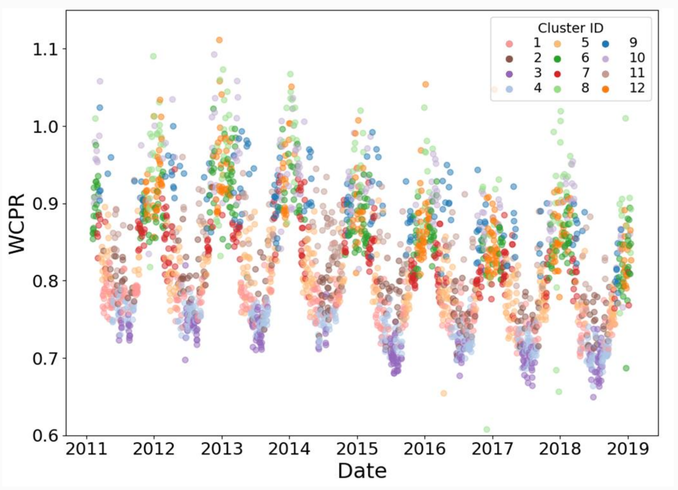

Fig. 2 – Clustered daily weather-corrected performance ratio (WCPR) for a sample site.

Table 1 – Cluster-based PLR values with a 95% CI for the sample site in Fig. 2.

Cluster	PLR	CI (low, high)
1	-0.7	(-0.82, -0.58)
2	-0.8	(-1.21, -0.48)
3	-0.8	(-0.96, -0.71)
4	-0.9	(-0.94, -0.78)
5	-0.9	(-1.09, -0.83)
6	-1	(-1.17, -0.82)
7	-1.1	(-1.21, -0.88)
8	-1.2	(-2.08, -0.37)
9	-1.2	(-1.52, -0.91)
10	-1.3	(-2.02, -0.89)
11	-1.5	(-1.78, -1.07)
12	-1.5	(-1.74, -1.32)

- In each cluster, **performance loss** between **same-day-of-year pairs** in each cluster is **normalised** by the number of intervening years.

Results

Synthetic dataset

- **NREL synthetic dataset [3]:** 1,520 sites with realistic PV data using weather data from 38 sites across the USA spanning 2018-2024 with assumed **linear degradation**
- Compared 95% CI of the CI-YoY method and the YoY method (baseline), with the assumptions of the introduction: **35% reduction** on **average**
- PLR estimation error:
  - **YoY**: 0.91%/year
  - **CI-YoY**: 0.66%/year
  - **27% reduction**

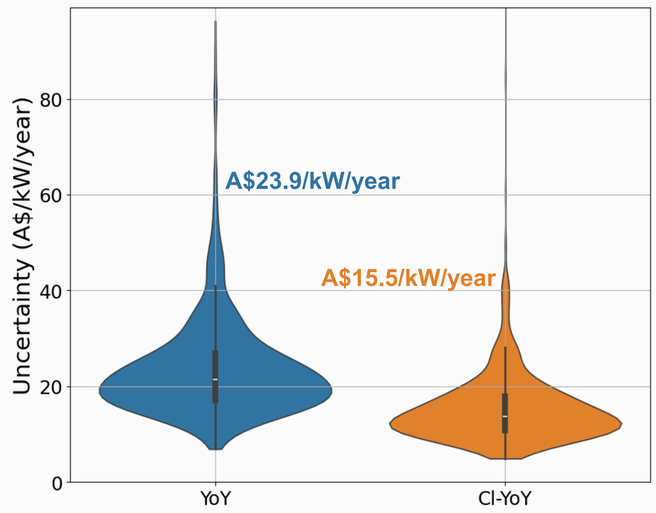

Fig. 3 – Monetary uncertainty for NREL synthetic dataset.

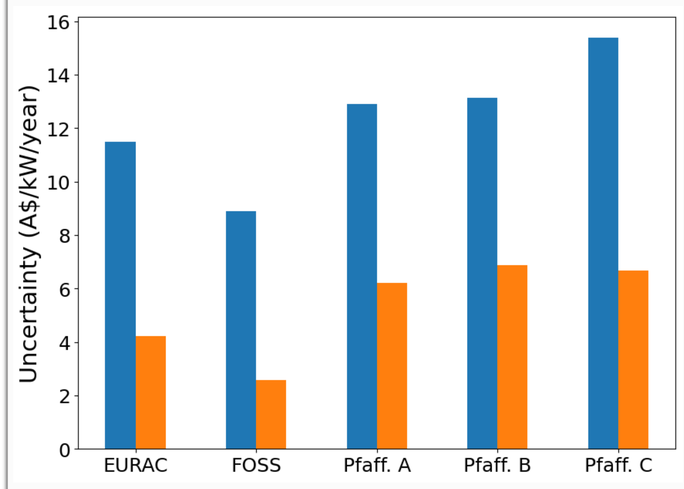

Fig. 4 –The associated uncertainty with PLR calculations in A$/kW/year.

Real-world dataset

Applying CI-YoY and YoY to five real-world datasets (Italy, Cyprus, and three in Austria) [1] to calculate the PLR and 95% CI, with the assumptions of the introduction (Table 2):

- Cyprus: CI-YoY uncertainty A$2.6/kW/year significantly lower than YoY A$8.9/kW/year
- Italy: CI-YoY reduced the YoY uncertainty from A$11.5/kW/year to A$4.2/kW/year
- Average uncertainty reduction with CI-YoY, is **58%**

Table 2 – PLR and 95% CI.

Method	YoY			CI-YoY		
Dataset	PLR	CI	Uncertainty (A$/kW/year)	PLR	CI	Uncertainty (A$/kW/year)
Italy	-0.83	(-1.17, -0.55)	11.5	-1.03	(-1.14, -0.91)	4.2
Cyprus	-0.68	(-0.92, -0.46)	8.9	-0.67	(-0.74, -0.60)	2.6
Austria 1	-3.46	(-3.97, -2.86)	12.9	-3.72	(-3.72, -3.18)	6.2
Austria 2	-3.33	(-3.85, -2.74)	13.1	-2.98	(-2.97, -2.45)	6.9
Austria 3	-1.59	(-1.98, -1.05)	15.4	-1.31	(-1.63, -1.23)	6.7

Conclusions

- CI-YoY: Significantly reducing the impact of environmental variability, enabling more **accurate** like-for-like performance comparisons (as evidenced on the synthetic data):
  - 27% decrease in PLR **estimation error**
  - 35% reduction in **revenue uncertainty**
- A substantial 58% average reduction in uncertainty was observed across real-world datasets.

Acknowledgements
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