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Evaluation of PV system data collected in COST Action Pearl PV Database –

Analysis of PR, Yield & PLR of a large fleet of PV systems

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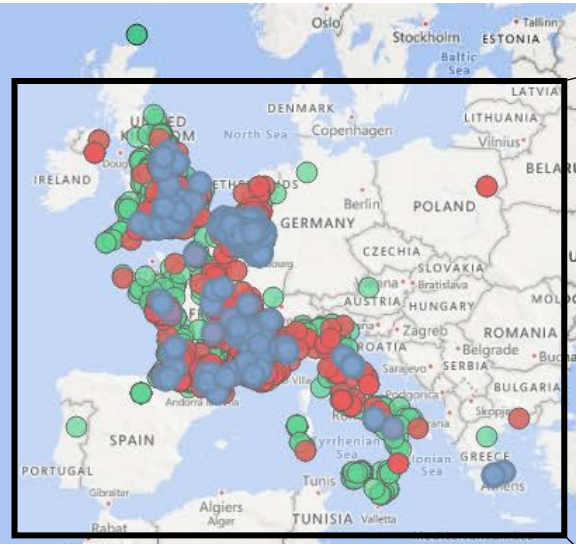
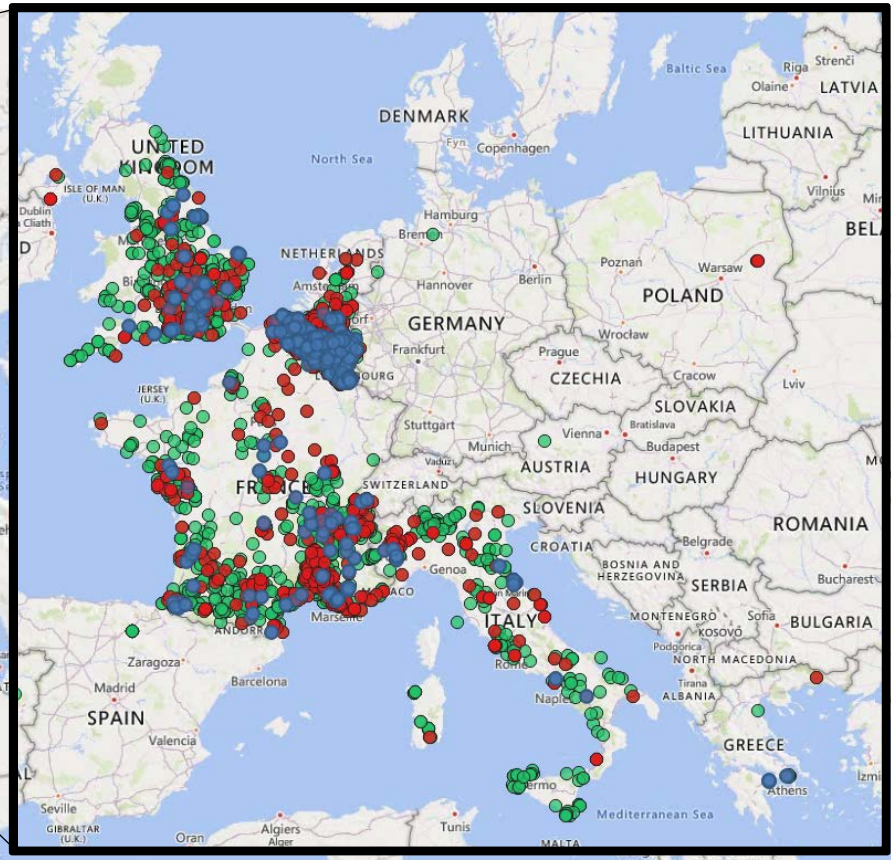
PEARL PV

Overview PV systems

Country	# of plants
Belgium	5418
France	1355
UK	872
Italy	323
Malaysia	140
Guadeloupe	69
Luxembourg	68
Netherlands	68
Martinique	48
Reunion	47
Spain	19
Greece	10
French Guiana	4
Germany	3
Switzerland	3
Australia	2
Poland	2
Austria	1
Portugal	1





- Filtered datasets
- Calculated PR
- Calculated PR & PLR

Initial Data Quality Grading

Letter Grade	Outliers [%]	Missing percentage [%]	Longest gap [days]
A	Below 10	Below 10	Below 15
B	10 to 20	10 to 25	15 to 30
C	20 to 30	25 to 40	30 to 90
D	Above 30	Above 40	Above 90

Pass/fail criteria	Time series > 24 months => PASS

[1] S. Lindig, et al., "International collaboration framework for the calculation of performance loss rates: Data quality, benchmarks, and trends (towards a uniform methodology)," *Progress in Photovoltaics: Research and Applications*, vol. 29, no. 6, pp. 573–602, 2021.

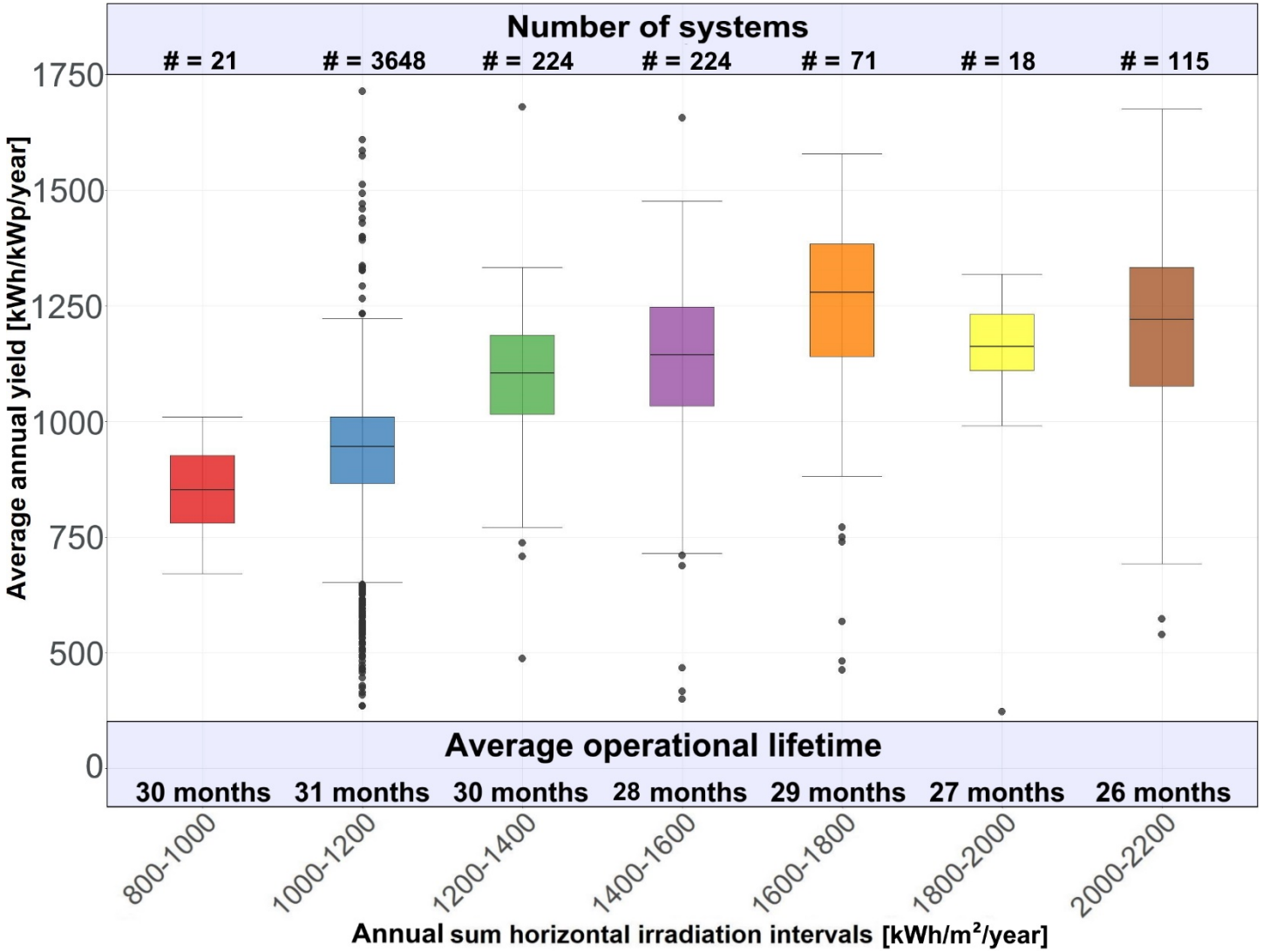
Initial Data Quality Grading

Letter Grade	Outliers	Missing percentage	Longest gap
A	**8,367**	**5,773**	**7,655**
B	**0**	**2,216**	**280**
C	**0**	**164**	**291**
D	**0**	**214**	**141**
D	Above 30	Above 40	Above 90

Pass/fail criteria	P: 4,323	F: 4,044

[1] S. Lindig, et al., "International collaboration framework for the calculation of performance loss rates: Data quality, benchmarks, and trends (towards a uniform methodology)," *Progress in Photovoltaics: Research and Applications*, vol. 29, no. 6, pp. 573–602, 2021.

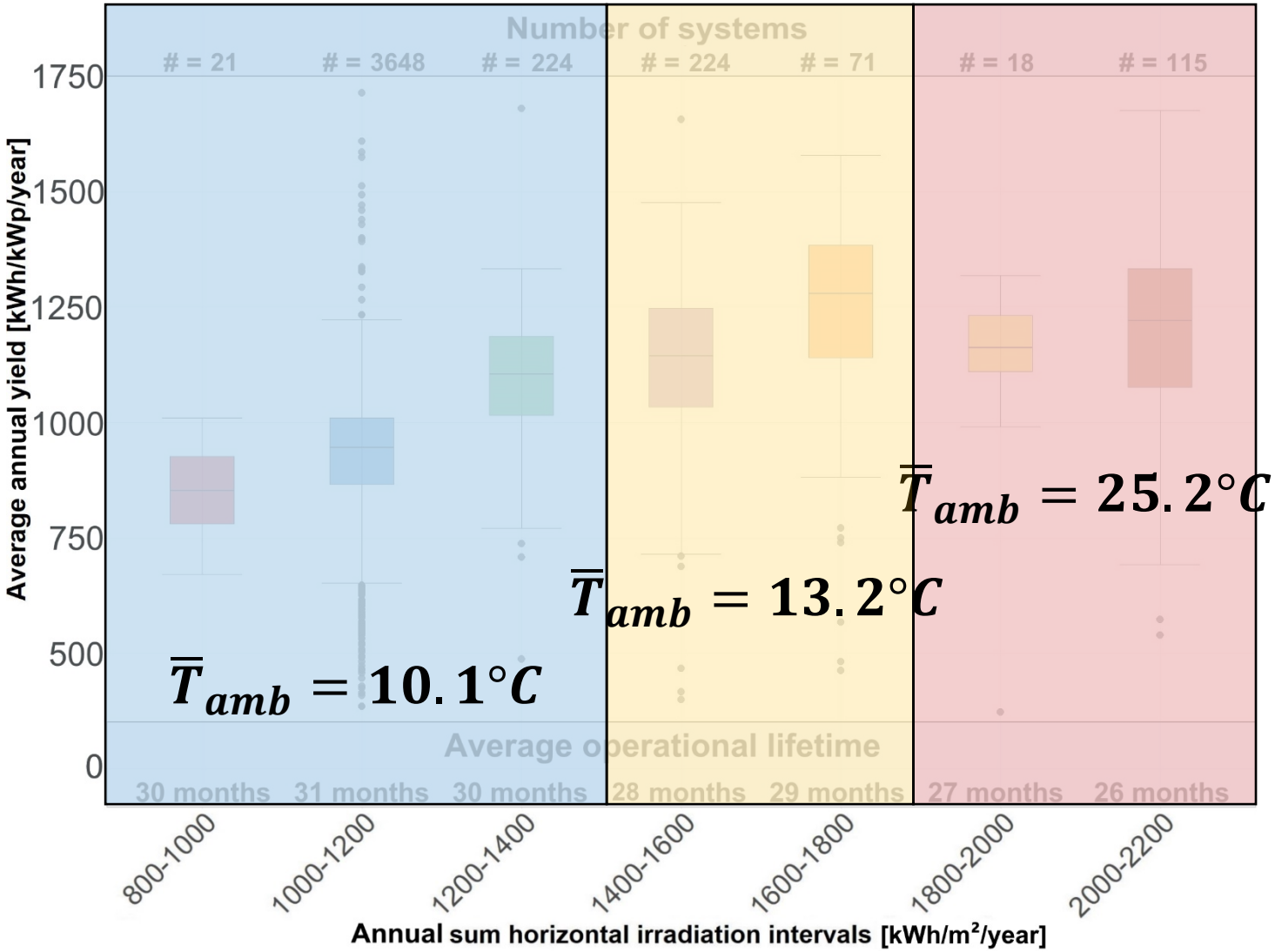
Energy Yield



$\overline{yield} = 954.9 \frac{kWh}{kWp}$ per year

$\widetilde{yield} = 961.5 \frac{kWh}{kWp}$ per year

Energy Yield



$\overline{yield} = 954.9 \frac{kWh}{kWp}$ per year

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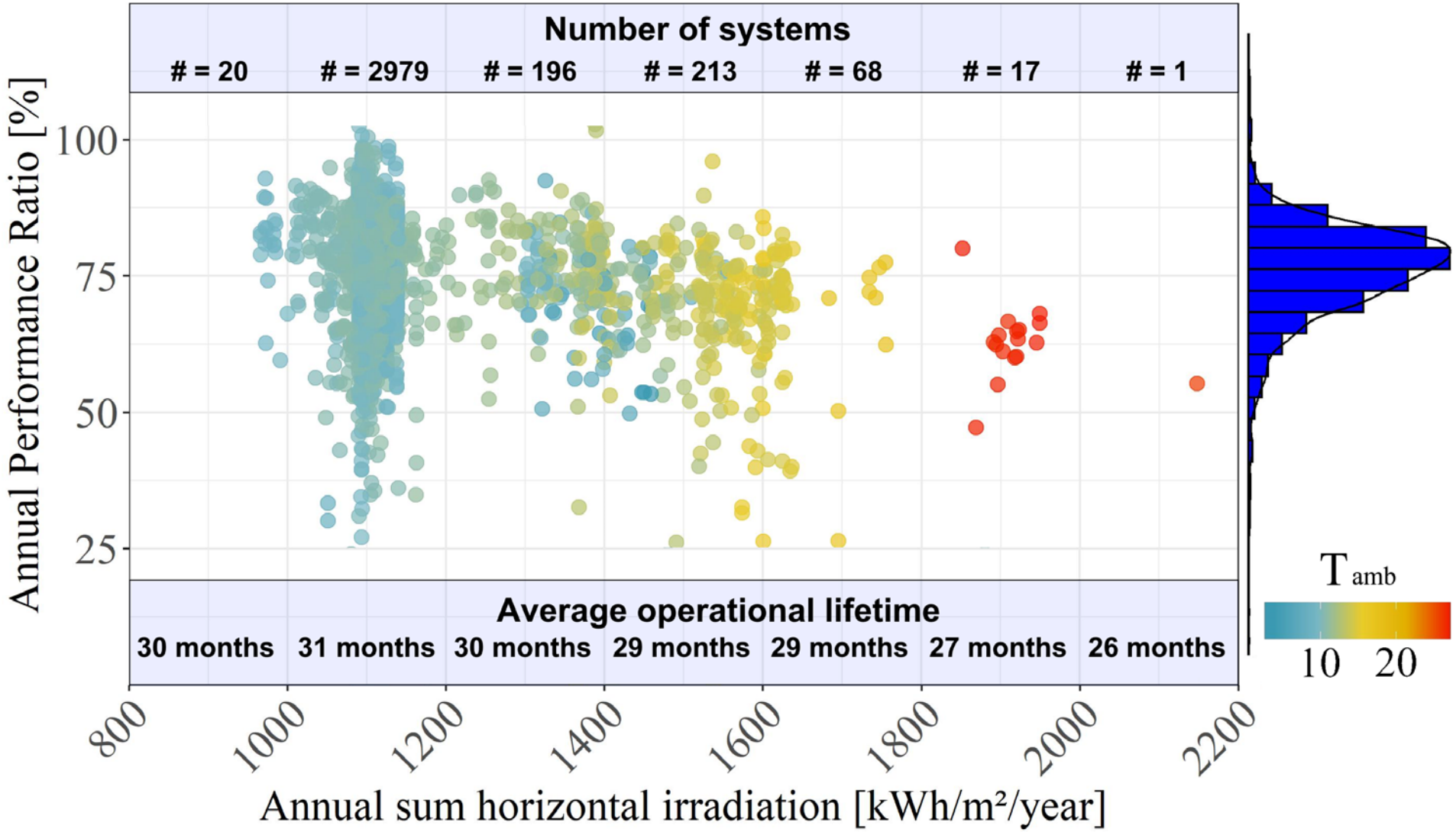
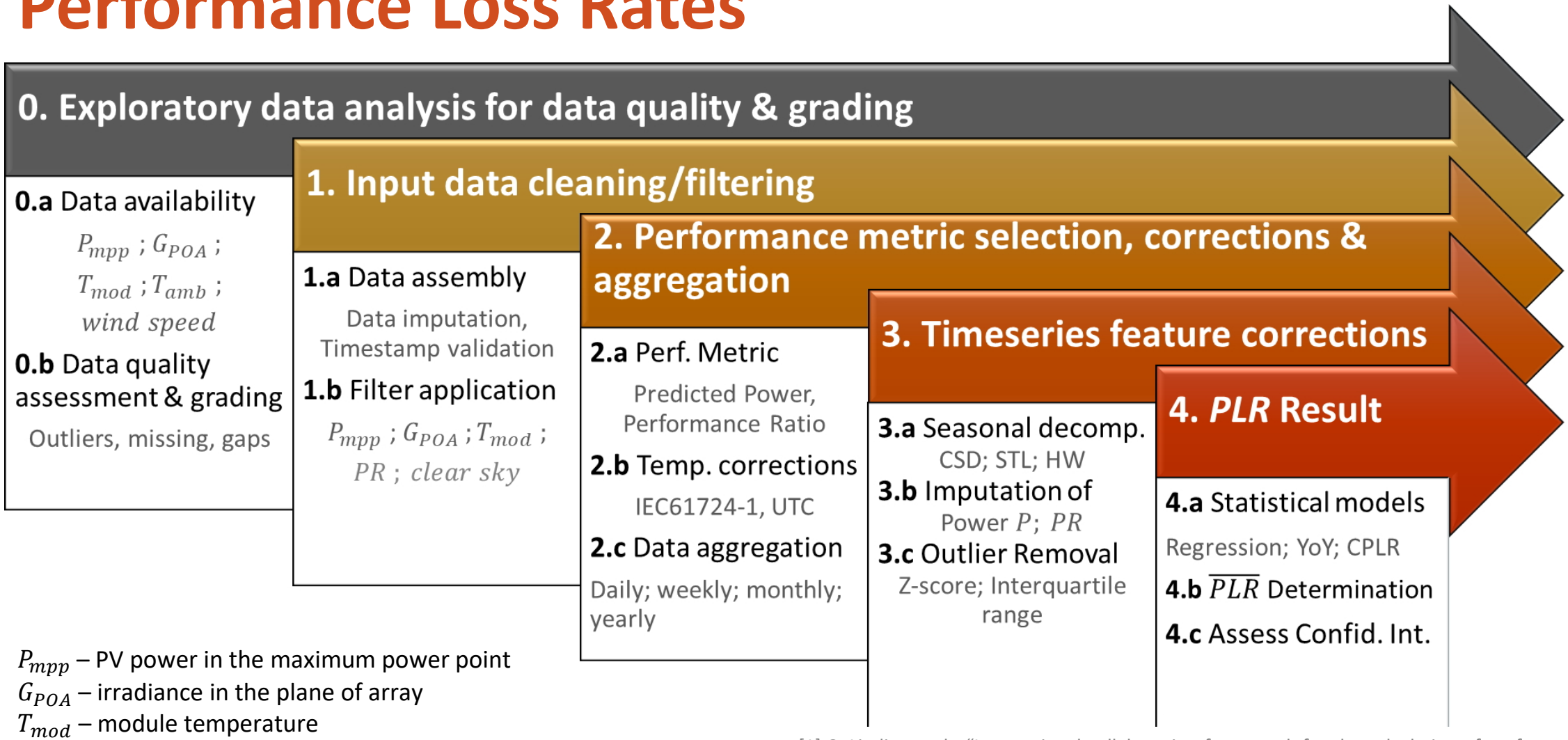
Performance Ratio



$$\overline{PR} = 76.7\%$$

$$\widetilde{PR} = 78.4\%$$

Performance Loss Rates



P_{mpp} – PV power in the maximum power point
G_{POA} – irradiance in the plane of array
T_{mod} – module temperature
T_{amb} – ambient temperature
PR – Performance Ratio

[1] S. Lindig, et al., "International collaboration framework for the calculation of performance loss rates: Data quality, benchmarks, and trends (towards a uniform methodology)," *Progress in Photovoltaics: Research and Applications*, vol. 29, no. 6, pp. 573–602, 2021.

Performance Loss Rates

Data input & Data quality analysis

- 10 min power time series
- Hourly ERA5 in-plane irradiation[2]

Input data cleaning & filtering

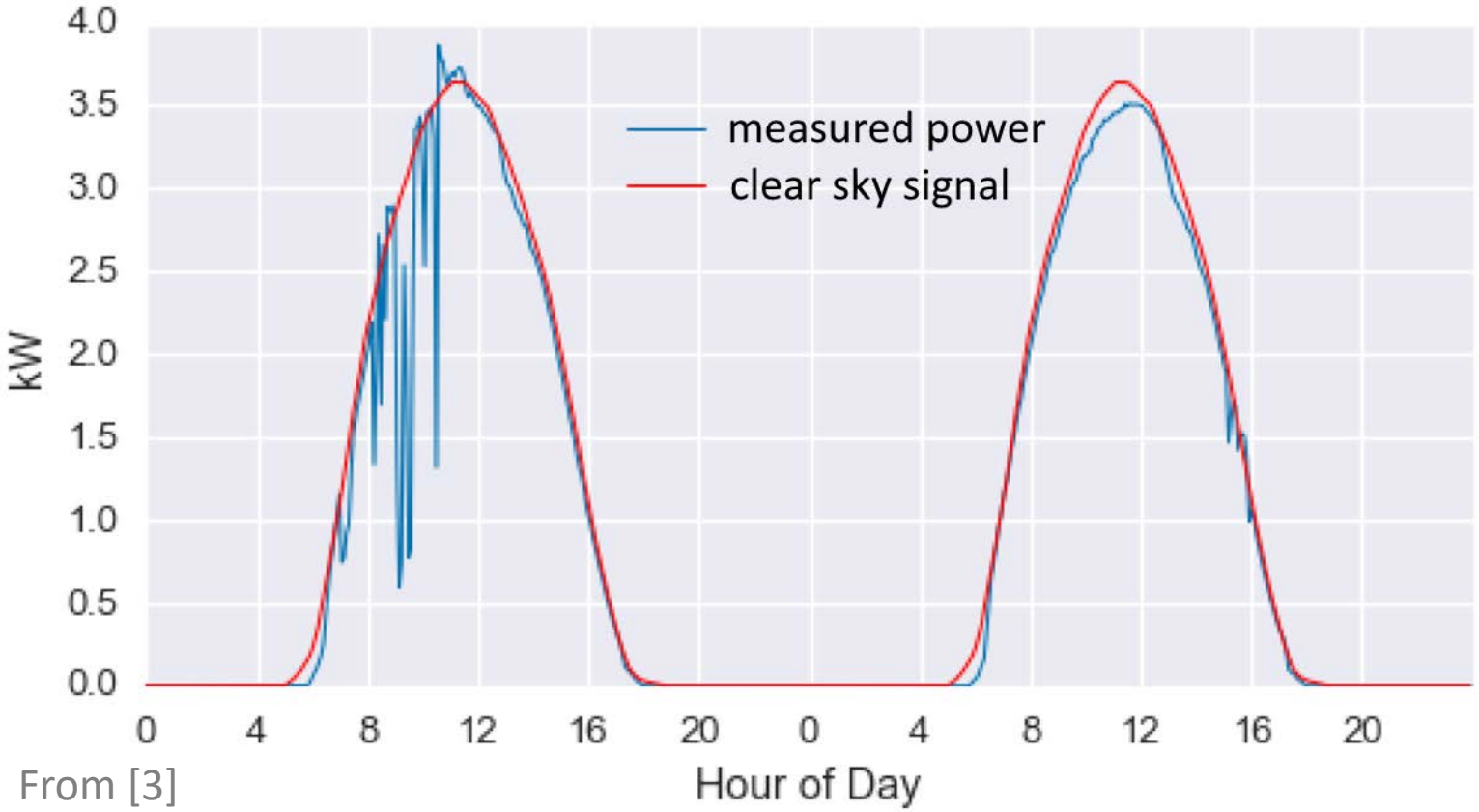
- SCSF[3] : Clear-sky filter
- YoY : Filter provided by RdTools[4,5]
- STL : Tailored threshold & statistical filter

Selection performance metric & statistical model

- Daily clear-sky energy : SCSF[3]
- Daily normalized energy : YoY[5]
- Monthly PR : STL[6]

[2] Copernicus Climate Change Service (C3S) ERA5: Fifth generation of ECMWF atmospheric reanalyses of the global climate. Copernicus Climate Change Service CDS 2017.
[3] B. Meyers, et al, "Signal Processing on PV Time-Series Data: Robust Degradation Analysis Without Physical Models," *IEEE Journal of Photovoltaics,* 2019.
[4] RdTools, “Version 2.0.5.” [Online]. Available: https://github.com/NREL/rdtools
[5] D. Jordan, et al, "Robust PV Degradation Methodology and Application," *IEEE Journal of Photovoltaics*, 2017.
[6] R. B. Cleveland et al., "STL: A Seasonal-Trend Decomposition Procedure Based on LOESS," *Journal of Official Statistics,* 1990.

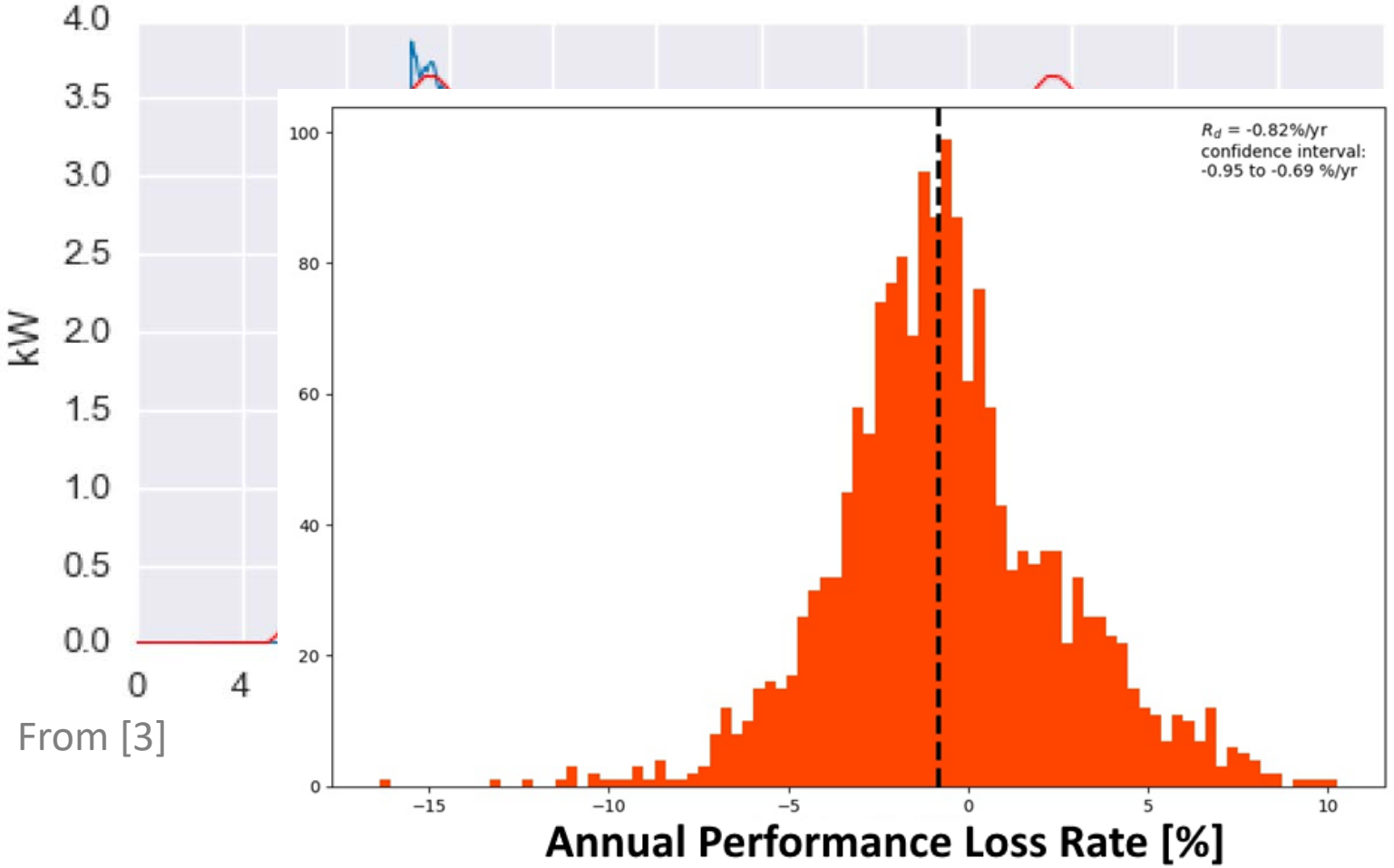
Performance Loss Rates



From [3]

[3] B. Meyers, et al, "Signal Processing on PV Time-Series Data: Robust Degradation Analysis Without Physical Models," *IEEE Journal of Photovoltaics,* 2019.

Performance Loss Rates



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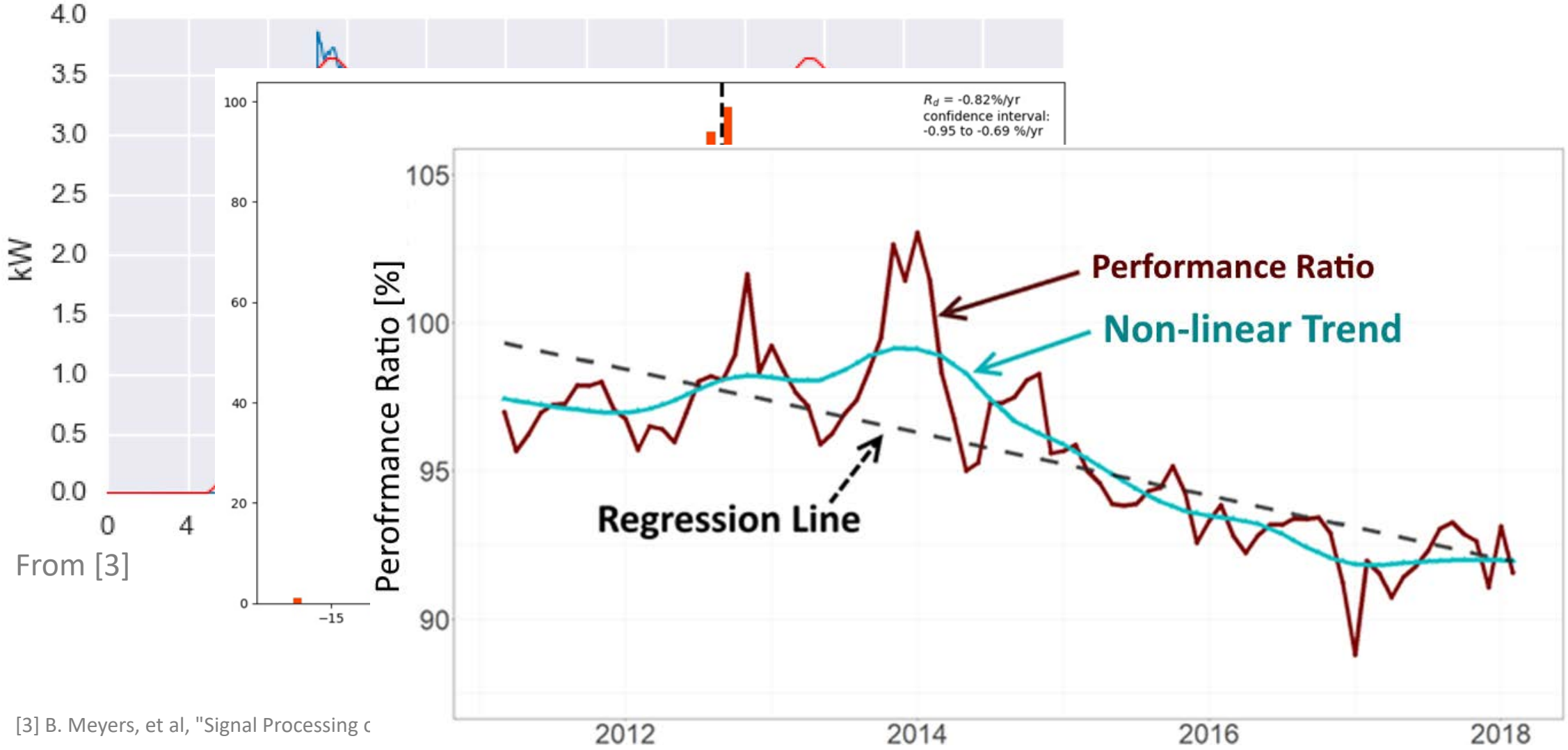
Performance Loss Rates



[3] B. Meyers, et al, "Signal Processing c

Performance Loss Rates

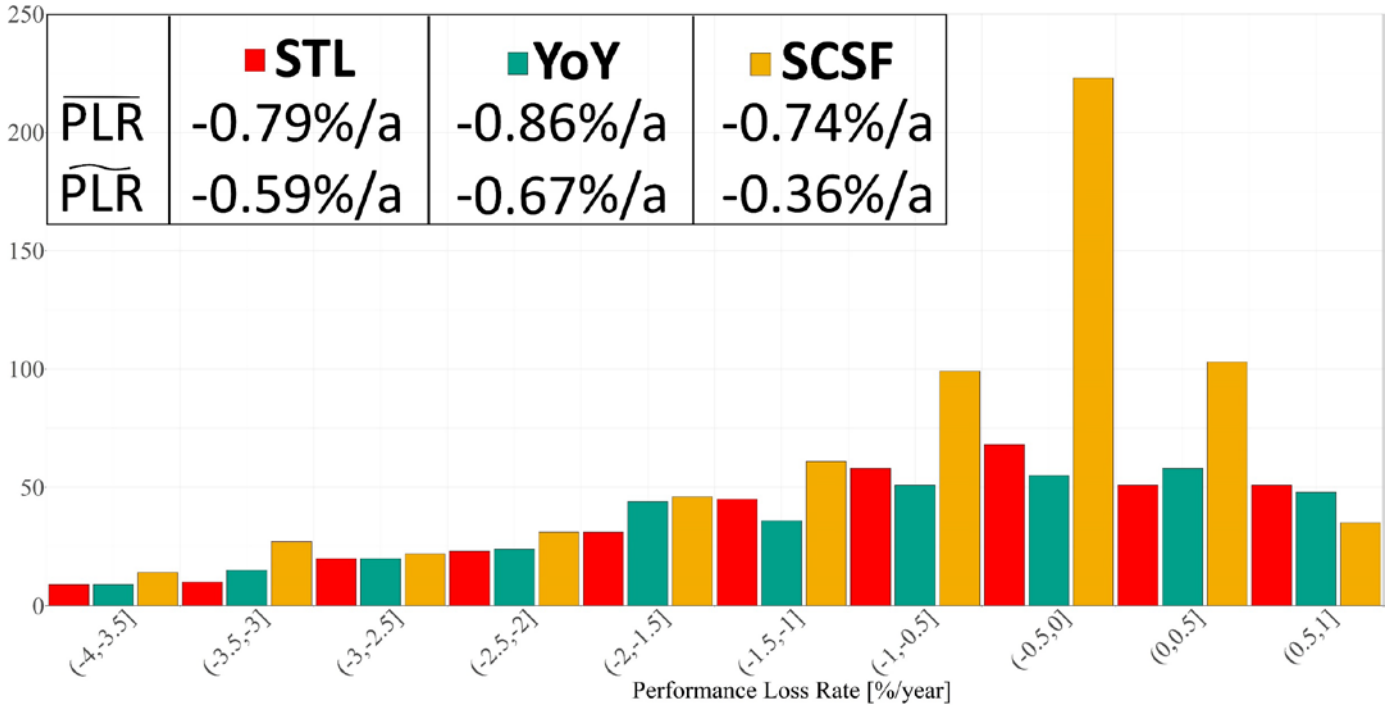
	Filter			
Statistical method	**G_{POA} [W/m²]**	**T_{mod} [°C]**	**Power**	**Performance Ratio**
SCSF	Strict clear-sky filter			
YoY	200-1200	-50 – 110	P > 0	
STL	100-1200		(0.01 – 1.05)∗ P_{nom}	$\pm 2\sigma$ around daily mean PR

	SCSF	YoY–ERA5	STL–ERA5
All systems	8,367		
FINAL	**661**	**361**	**366**

Minimum 3 years of data

-4%/a < PLR < 1%/a

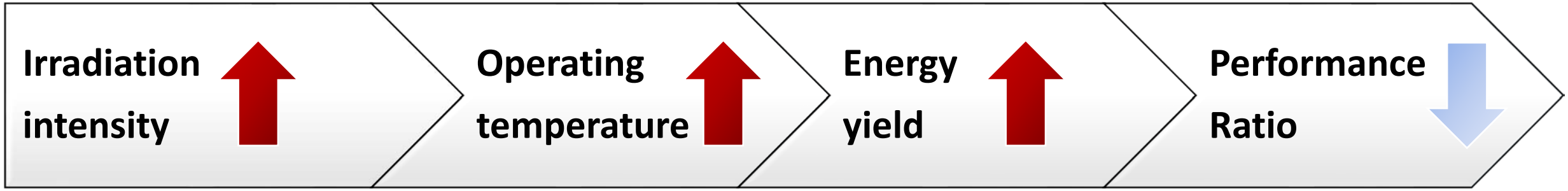
Performance Loss Rates



	Jordan[7]	Kiefer[8]
$\overline{PLR}$	-0.8 to -0.9 %/a	-0.7 %/a
$\widetilde{PLR}$	-0.5 to -0.6 %/a	

[7] D. C. Jordan, et al, "Compendium of photovoltaic degradation rates," *Progress in Photovoltaics Research and Application*, vol. 24, no. 7, pp. 978-980, 2016.
[8] K. Kiefer, et al, "Degradation in PV Power Plants: Theory and Practice," in *36th EU PVSEC, Marseille*, 2019.

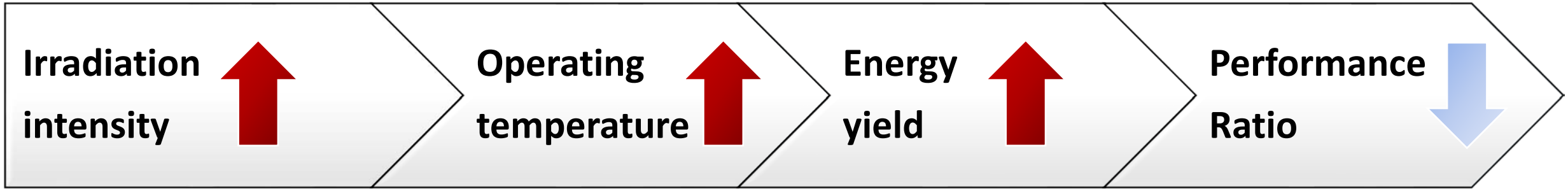
Conclusion



PLR is an important parameter to assess the **health status of a PV system**

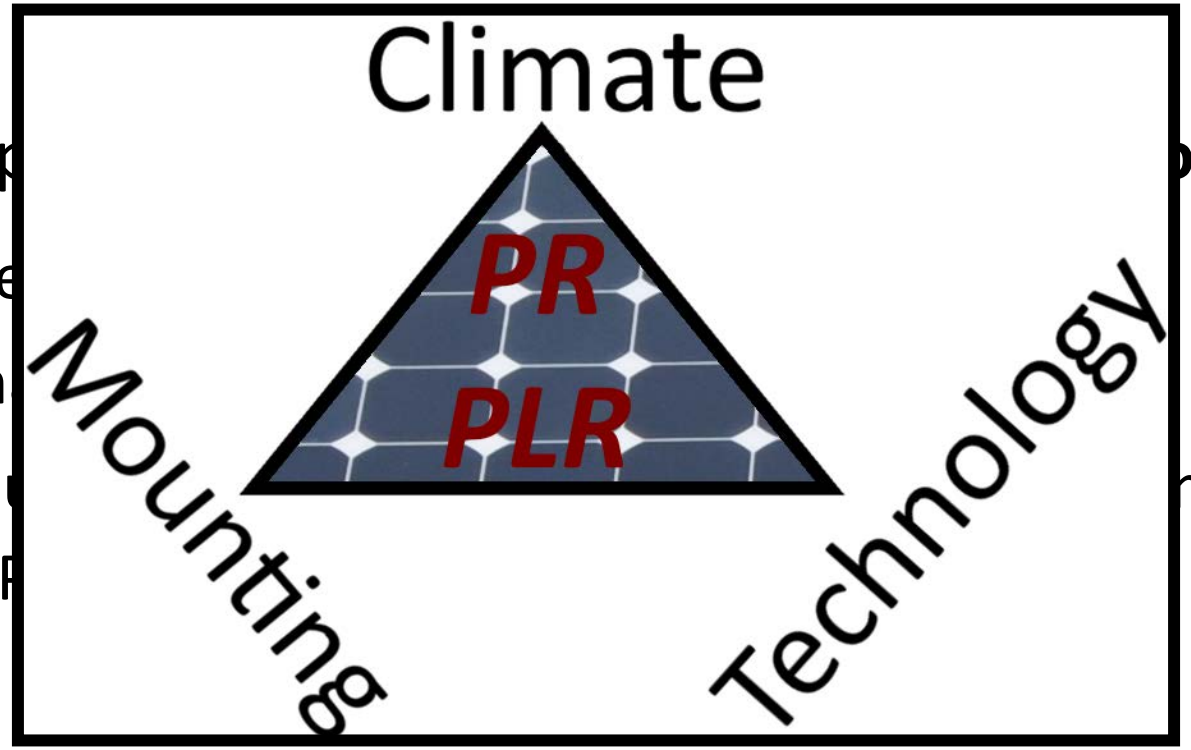
- Calculating PLR values is not straightforward
  - Many variables have to be considered
  - The length and quality of the PV system time series is the most important characteristic of PV performance analyses

Conclusion



PLR is an important p **of a PV system**

- Calculating PLR value
  - Many variables h
  - The length and qu most important characteristic of P



Performance Analysis and Degradation of a Large Fleet of PV Systems

Performance Analysis and Degradation of a Large Fleet of PV Systems

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Abstract

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I. Introduction

II. Cost Action Pearl PV Database

III. Experimental Setup—Data Description

IV. PV System Performance Assessment

V. Performance Loss Rate Evaluation and Data Requirements

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Authors

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Keywords

Abstract:
This article presents an initial performance analysis of a database of photovoltaic (PV) system performance time series collected within the European funded COST Action PEARL PV. The database contains monitoring data of over 8400 PV systems with accompanying metadata. The PV plants are small residential systems, primarily installed in Europe, with a high density in Belgium. In this initial study, the annual average performance ratio, the annual energy yield, and the performance loss rate of the systems are determined and evaluated. The systems have an average lifetime of 30.5 months. The annual mean performance ratio across all systems is 76.7% and the average yield is 954.9 kWh/kWp per year. The performance loss rate is calculated using three different statistical approaches and one irradiance data source. Average performance losses between −0.74%/year and −0.86%/year are calculated depending on the used approach. Furthermore, certain weather-dependent correlations are detected, such as decreasing performance ratio and increasing yield values with increasing irradiation. This study is a stepping-stone for further populating the present database, lessons learnt for handling large amounts of PV performance data, and carrying out performance studies of PV system fleets installed across Europe.

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