Challenges, Opportunities and Approaches for new Service Life Estimation Models for PV Modules- Results from IEA-PVPS-Task 13 Subtask 1.4

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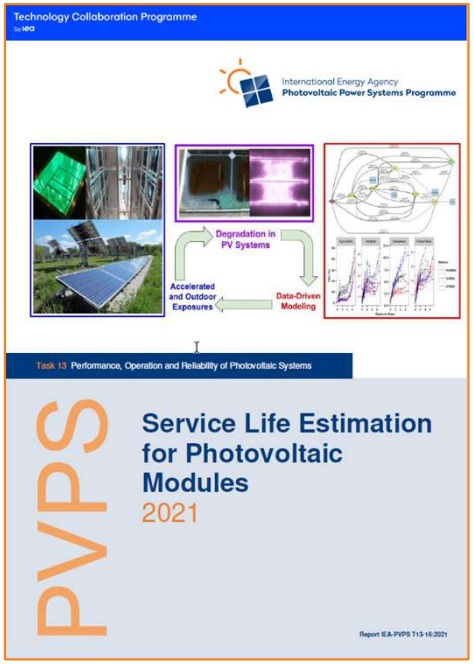
What is IEA PVPS?

- The International Energy Agency (IEA), founded in 1974, is an autonomous body within the framework of the Organization for Economic Cooperation and Development (OECD).
- The Technology Collaboration Programme was created with a belief that the future of energy security and sustainability starts with global collaboration. The programme is made up of thousands of experts across government, academia, and industry dedicated to advancing common research and the application of specific energy technologies.
- The IEA Photovoltaic Power Systems Programme (PVPS) is one of the Technology Collaboration Programme established within the International Energy Agency in 1993
- 32 members - 27 countries, European Commission, 4 associations
- *"To enhance the international collaborative efforts which facilitate the role of photovoltaic solar energy as a cornerstone in the transition to sustainable energy systems"*

European Copper Institute Copper Alliance · SEIA · SEPA · SolarPower Europe

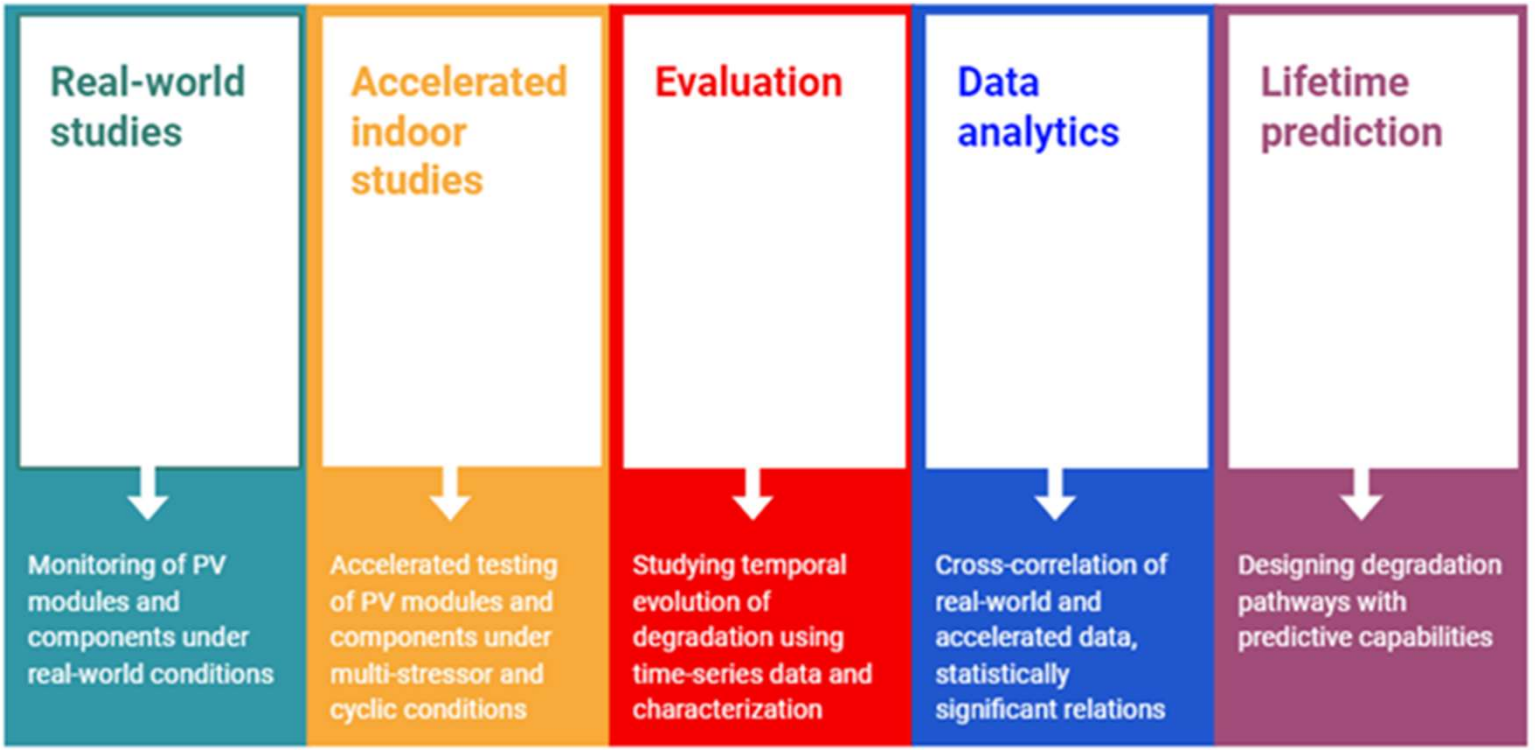
IEA PVPS Task 13

- IEA-PVPS-TASK 13 **Performance, Operation and Reliability of Photovoltaic Systems**
  - Active since 2010 - Third phase ending
  - Fourth phase planned from 2022 on
- Subtask 1 New Module Concepts and System Designs
  - Subtask 1.4 Service Life Prediction
  - Report **Service Life Estimation for Photovoltaic Modules**
- Subtask 2 Performance of Photovoltaic Systems
- Subtask 3 Monitoring – Operation & Maintenance
- Subtask 4 Information Dissemination
- Report available (now also in Korean!!):
  - **https://iea-pvps.org/key-topics/service-life-estimation-for-photovoltaic-modules/**



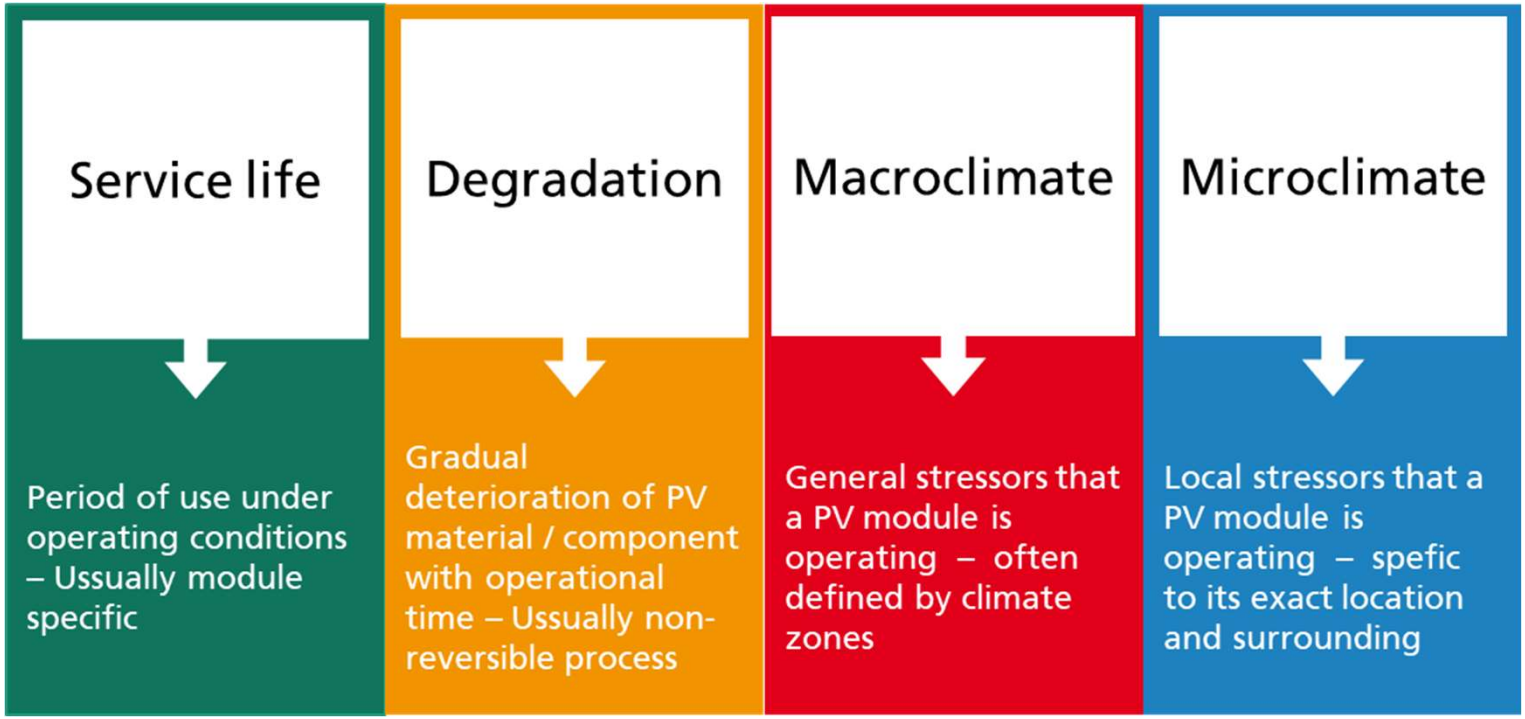
Service Life Estimation for PV Modules

- Major steps in PV service life and degradation science
- Report tries to give overview on state of the art



Service Life Estimation for PV Modules

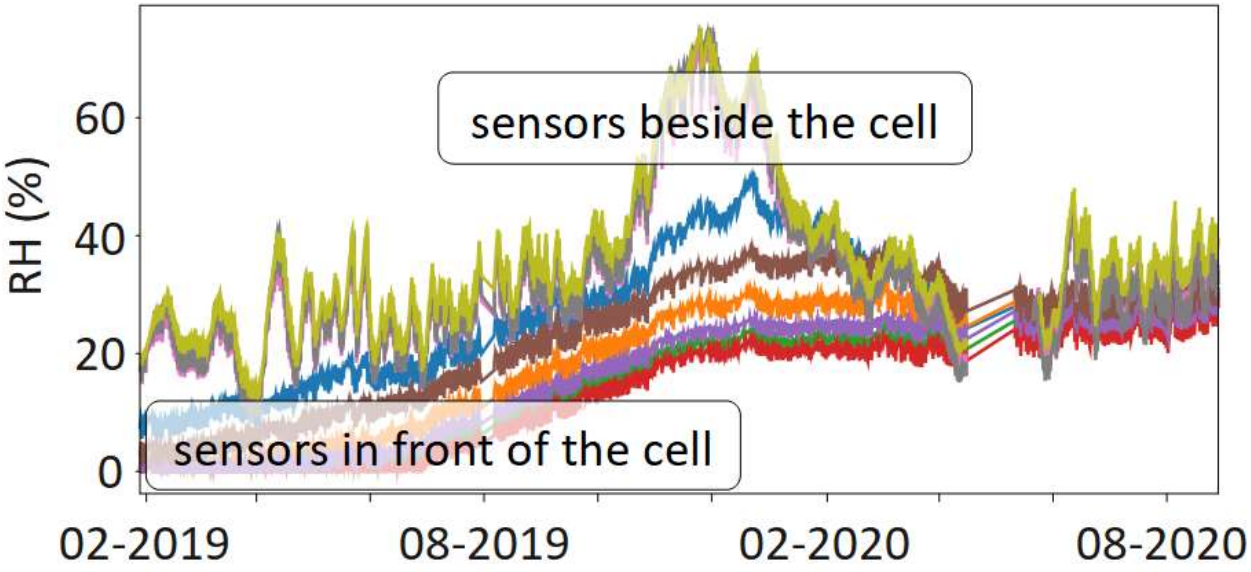
- Overview – Some terminologies
  - See also Glossary in Report



Microclimates are ussually needed as inputs for service life models

Service Life Estimation for PV Modules

- Experimentally – From macro- to micro-climate (Relative humidity in the module)

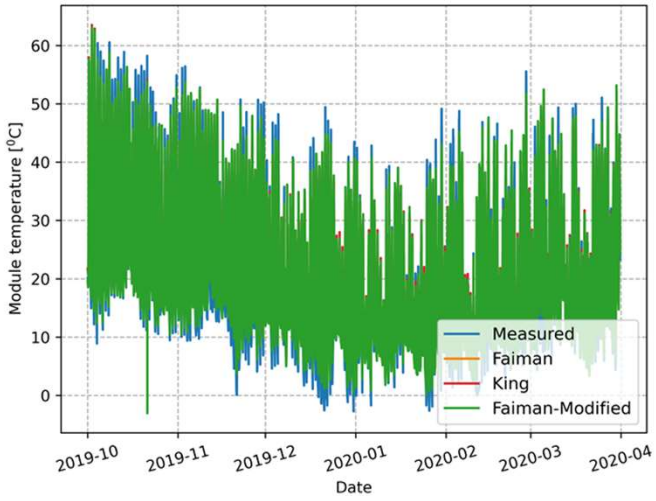


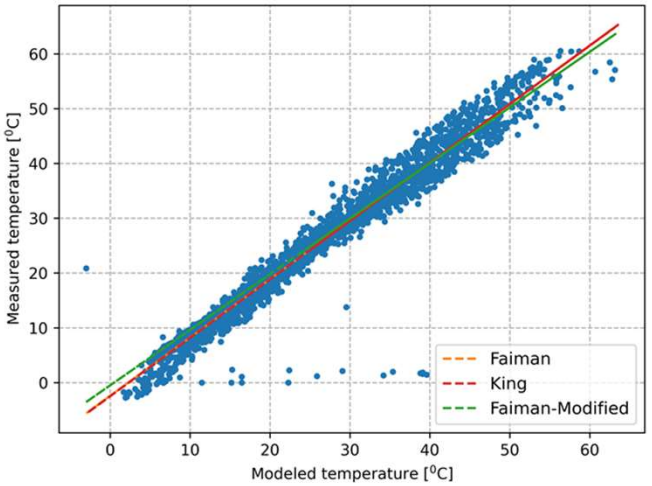
Moisture ingress measured at different cell location under natural weathering [1] -> Crusian to validate and improve microclimate models and hence reliable service life estimation

[1] S. Mitterhofer et al., "Measurement and simulation of moisture ingress in PV modules in various climates," presented at the 37th EUPVSEC, Online, 2020.

Service Life Estimation for PV Modules

- Modelling – From macro- to micro-climate (Module temperature)





Model	MSE [°C]	R2
Faiman	3.18	0.948
King	3.18	0.948
Modified-Faiman	2.98	0.955

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[2] J. Ascencio-Vásquez1 et al., "Application Of Machine Learning To Assess The Thermal Behaviour Of PV Modules In Different Climate Zones

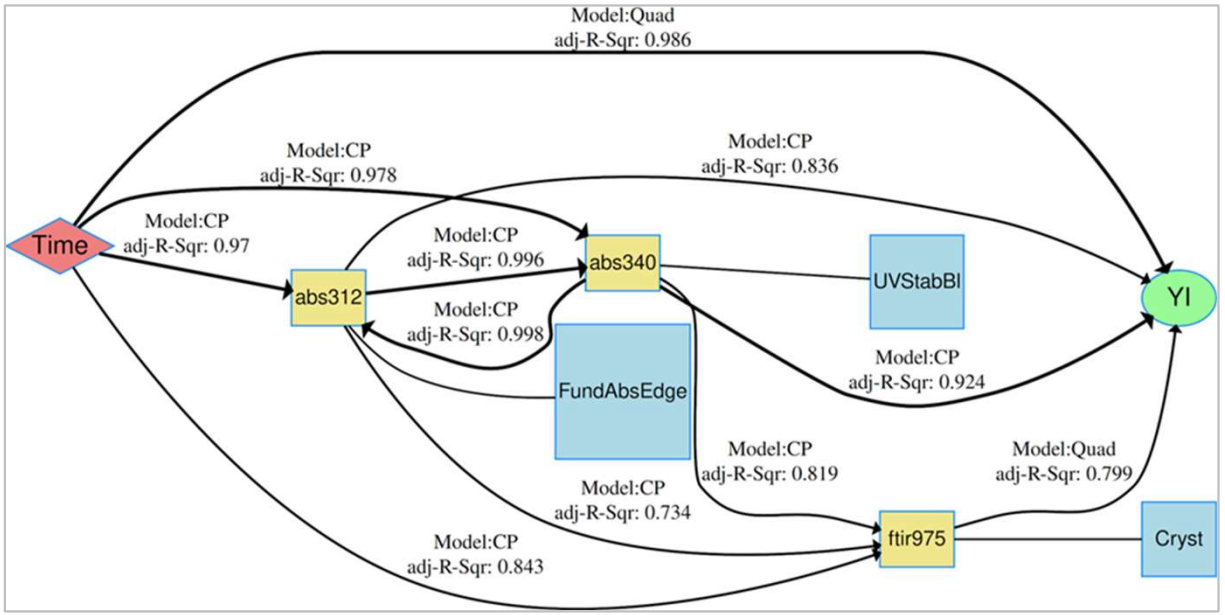
Service Life Estimation for PV Modules

- Modelling approaches – Models for PV module materials and components

→ network modelling and structural equation models (netSEM)

netSEM approach→ provides possibility to discern degradation mechanisms/effects under influence of stressors.

Relationships between stressors, (mechanisms) and responses can be mapped.



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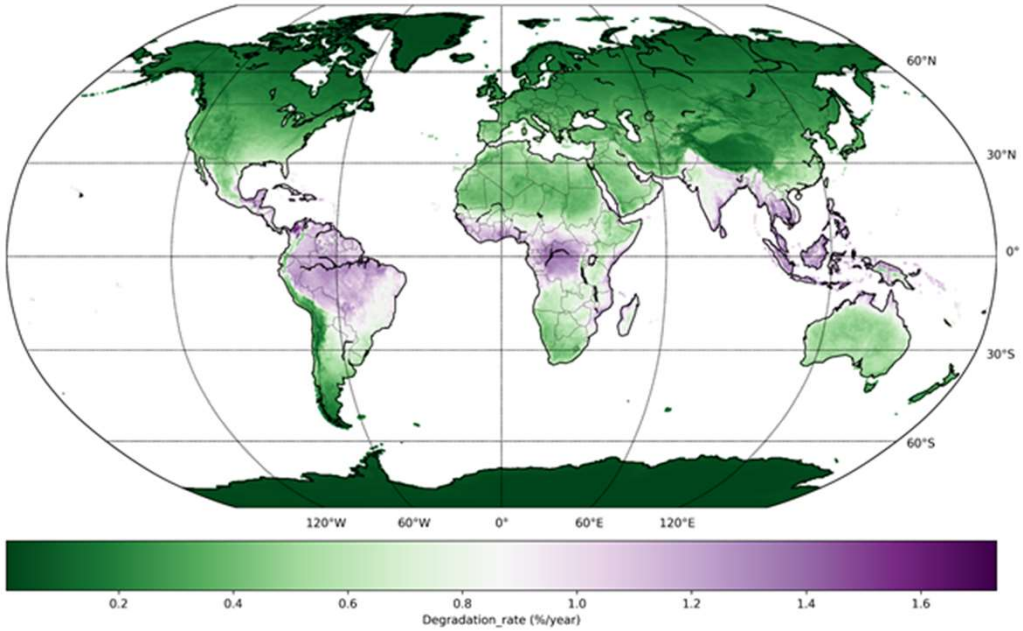
Service Life Estimation for PV Modules

- Modelling approaches – Models for PV performance

→ Physical degradation rate models

$$k_T(T, RH, UV, \Delta T, T_{max}) = A_N \cdot (1 + k_H(T, RH)) \cdot (1 + k_P(UV, T, RH)) \cdot (1 + k_{Tm}(\Delta T, T_{max})) - 1$$

Useful to relate climate impacts but based on basic assumptions
doesn‘t include all stressors (e.g salt impact near oceans)



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Service Life Estimation for PV Modules

- Modelling approaches – Models for PV performance

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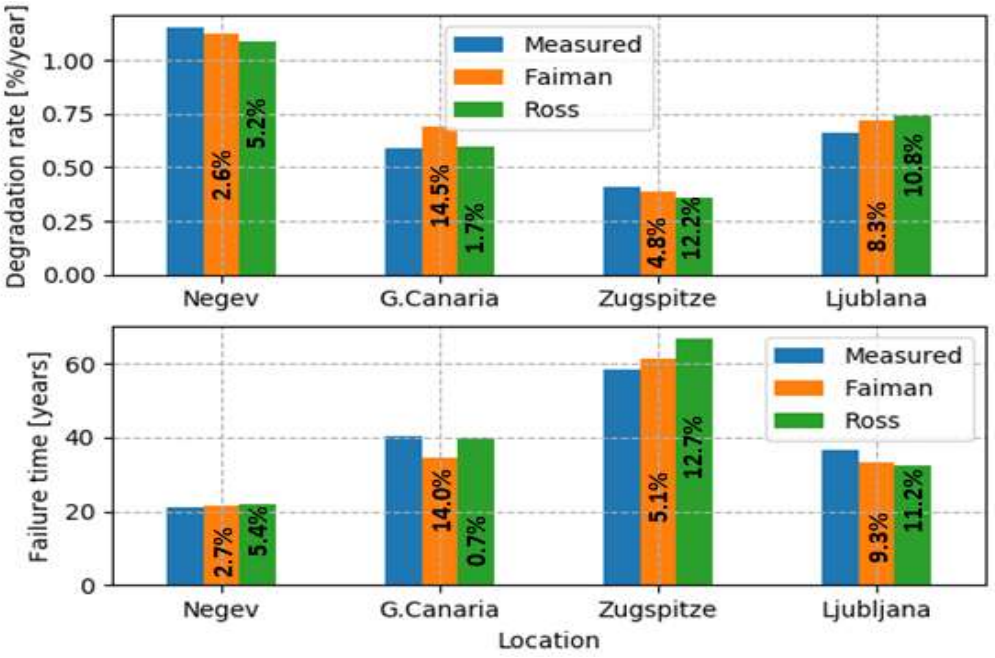
Variations in estimated degradation rates due to estimations of microclimate variables – They are also location dependent [3]



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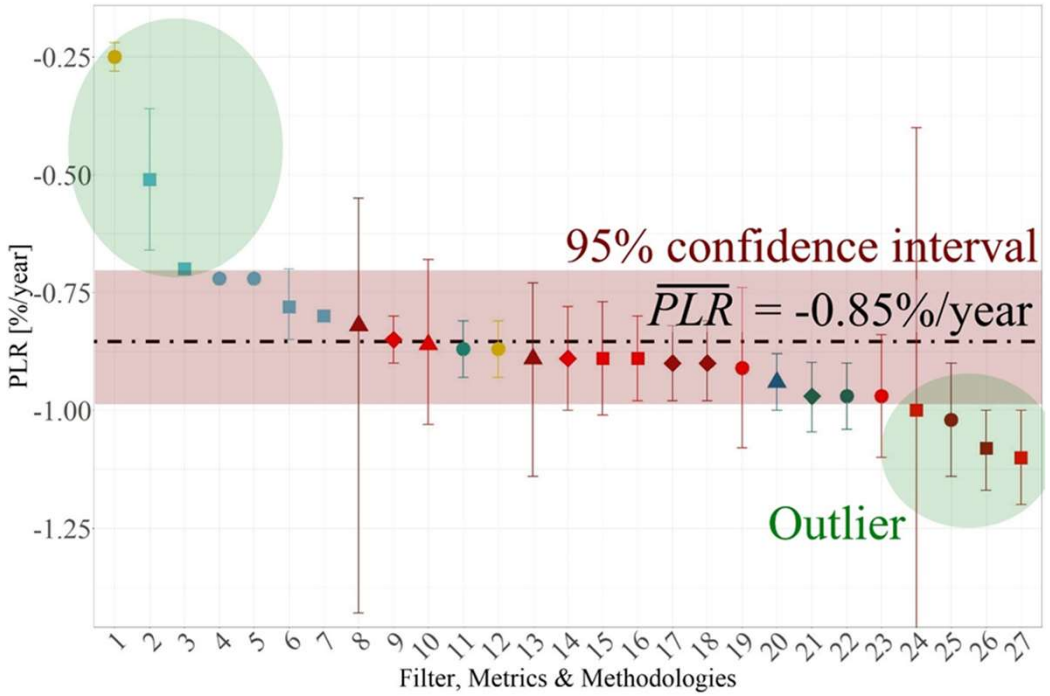
Service Life Estimation for PV Modules

- Modelling approaches – Models for PV performance

→ Statistical Performance Loss Rate (PLR)



Approach off Task 13, Subtask 2.5 [4] to reduce inconsistences in PLR calculation – averaging results of calculated PLR using many filters, performance metrics and statistical modelling approaches and assigning a 95% confidence interval for each approach

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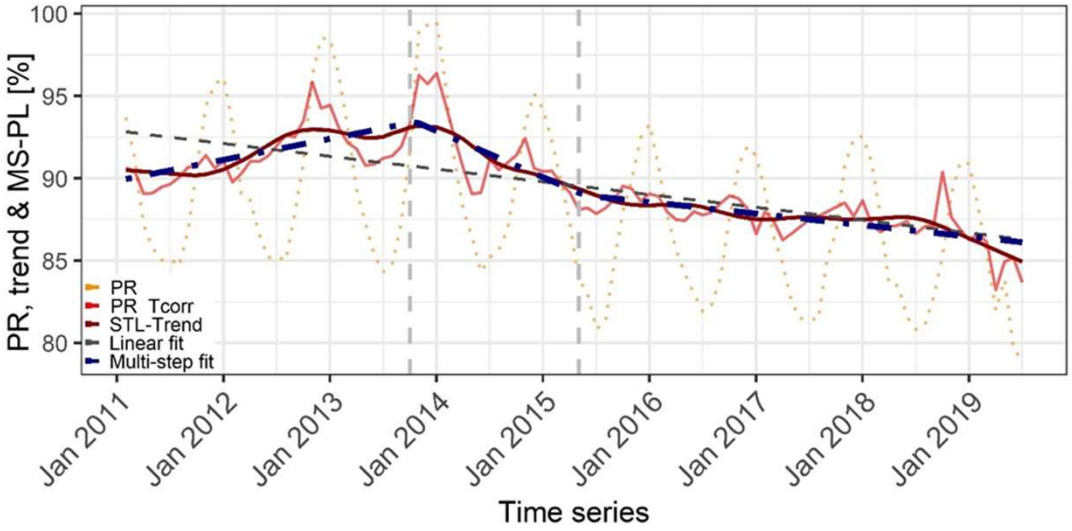
Service Life Estimation for PV Modules

- Modelling approaches – Models for PV performance

→ Multi-step performance losses (MS-PL)



Optimized	PLR [%/year]	Breakpoint
PLR_{lin}	-1.01	02/2011 – 02/2019
PLR_1	0.76	01/2014
PLR_2	-2.94	08/2015
PLR_3	-0.97	
RMSE	0.33	

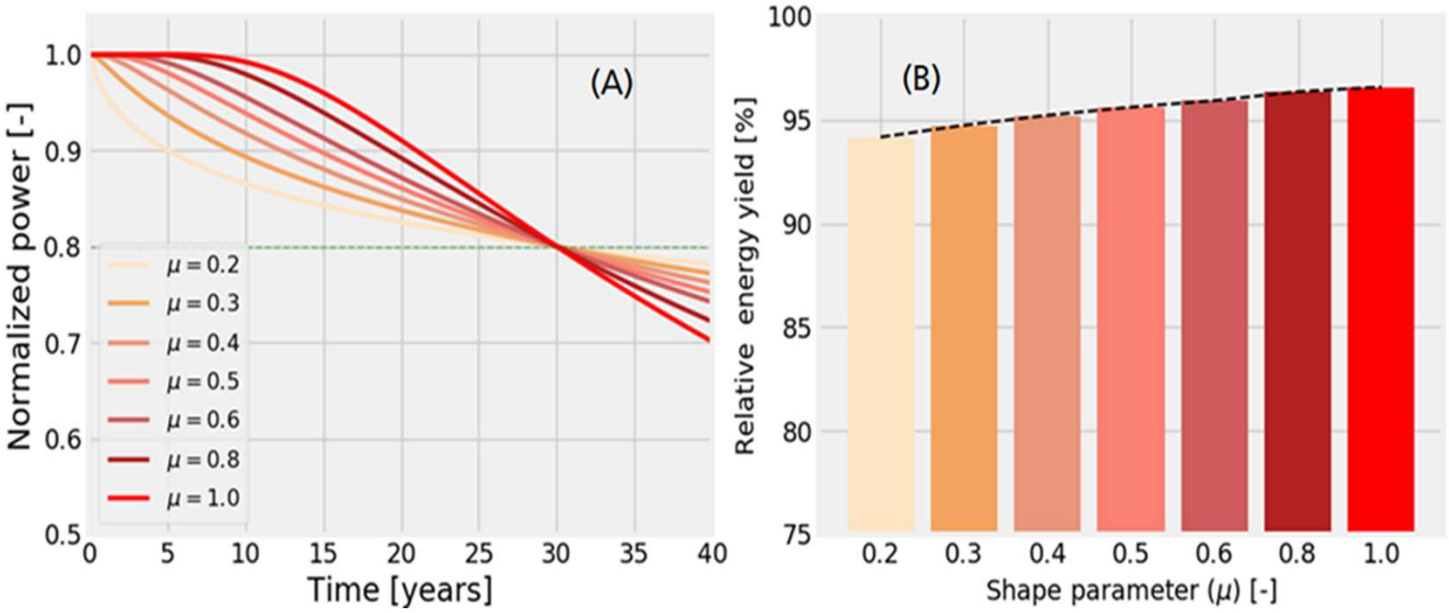
Provides a more detailed PV performance evaluation by using stepwise PLR calculation using breakpoint optimization [5]

[5] S. Lindig, D. Moser, B. Mueller, and K. Kiefer, "Application of Dynamic Multi-Step Performance Loss Algorithm," in IEEE PVSC-47, 2020.

Service Life Estimation for PV Modules

- Modelling approaches – Models for PV performance

→ Long-term extrapolation



Non-linearity in performance degradation affects long-term extrapolation [6]

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[6] I. Kaaya, S. Lindig, K.-A. Weiss, A. Virtuani, M. S. de C. Ortin, and D. Moser, “Photovoltaic lifetime forecast model based on degradation patterns,” Progress in Photovoltaics: Research and Applications, vol. 28, no. 10, pp. 979–992, 2020].

Conclusion

- Main degradation stressors are well understood; however, the corresponding induced, or activated, degradation mechanisms are difficult to generalize
- netSEM analysis is useful and robust approach to map stressors, mechanisms, and responses. It can help to understand the complex interactions between variables – can help to develop more reliable degradation kinetics models
- Little developments are available for physical models that combine different degradation mechanisms. Basic assumptions of models limit generalization
- Statistical models for PLR still show different variations and mainly applicable for historical performance analysis not service life estimations. – However new approaches are being developed
- Connection of modelling approaches can create robust and reliable service life prediction

https://iea-pvps.org/key-topics/service-life-estimation-for-photovoltaic-modules/

iea-pvs.org

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