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Institute for Renewable Energy,  
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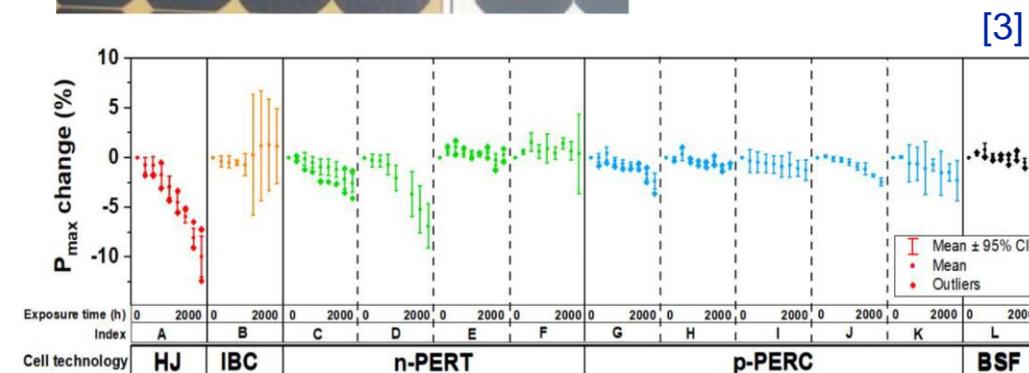
# UV-induced degradation on vertical PV installations: a site-dependent investigation for materials optimization

This study was developed in the framework of the research activities carried out within the Project “Network 4 Energy Sustainable Transition–NEST”, Spoke 1., Project code PE0000021, funded under the National Recovery and Resilience Plan (NRRP), Mission 4, Component 2, Investment 1.3– Call for tender No. 1561 of 11.10.2022 of Ministero dell'Università e della Ricerca (MUR); funded by the European Union–NextGenerationEU.

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# Background and motivations

- PV modules are exposed to decades of UV radiation, which is causing several UV-induced (UV-ID) degradation mechanisms [1], particularly UVB shorter wavelengths.
- Novel n-type solar cells are particularly susceptible to UV-ID [2,3]
- Novel encapsulants with low UV cut-off are emerging in the market, resulting in higher energy yields [4]
- No proper standards dedicated to the long-term UV aging of PV modules [5]
- **How are stressors factors varying for vertical installations?**



**NREL researchers warn of unexpectedly high UV-induced degradation in n-type solar modules** [7]

A research team from the U.S. National Renewable Energy Laboratory has analyzed n-type modules deployed in a 3 MW commercial PV project in an effort to assess the high degradation rate reported by the plant owner. The scientists found that ultraviolet-induced degradation (UVID) was a major factor affecting the facility's performance.

SEPTEMBER 17, 2025 EMILIANO BELLINI



# Background and motivations

Several studies focused on the degradation of modules across different climatic zones, but almost none on the effect of inclination. Vertical installations are emerging, especially in the BIPV field.

Effect of UV irradiation on PV modules and their simulation in newly designed site-specific accelerated ageing tests

Birinchi Bora , Supriya Rai, Arup Dhar, Chandan Banerjee

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[8]

**Comprehensive review on performance, reliability, and roadmap of c-Si PV modules in desert climates: A proposal for improved testing standard**

[5]

Baloji Adothu , Sagarika Kumar, Jim Joseph John, Gernot Oreski, Gerhard Mathiak, Bengt Jäckel, Vivian Alberts, Jabir Bin Jahangir, Muhammad Ashrafal Alam, Ralph Gottschalg

First published: 02 June 2024 | <https://doi.org/10.1002/pip.3827> | Citations: 19

EU PVSEC PAPER |  Open Access | 

[9]

**Climate specific accelerated ageing tests and evaluation of ageing induced electrical, physical, and chemical changes**

Gabriele C. Eder , Yuliya Voronko, Simon Dimitriadis, Karl Knöbl, Gusztáv Újvári, Karl A. Berger, Martin Halwachs, Lukas Neumaier, Christina Hirschl

First published: 19 November 2018 | <https://doi.org/10.1002/pip.3090> | Citations: 36

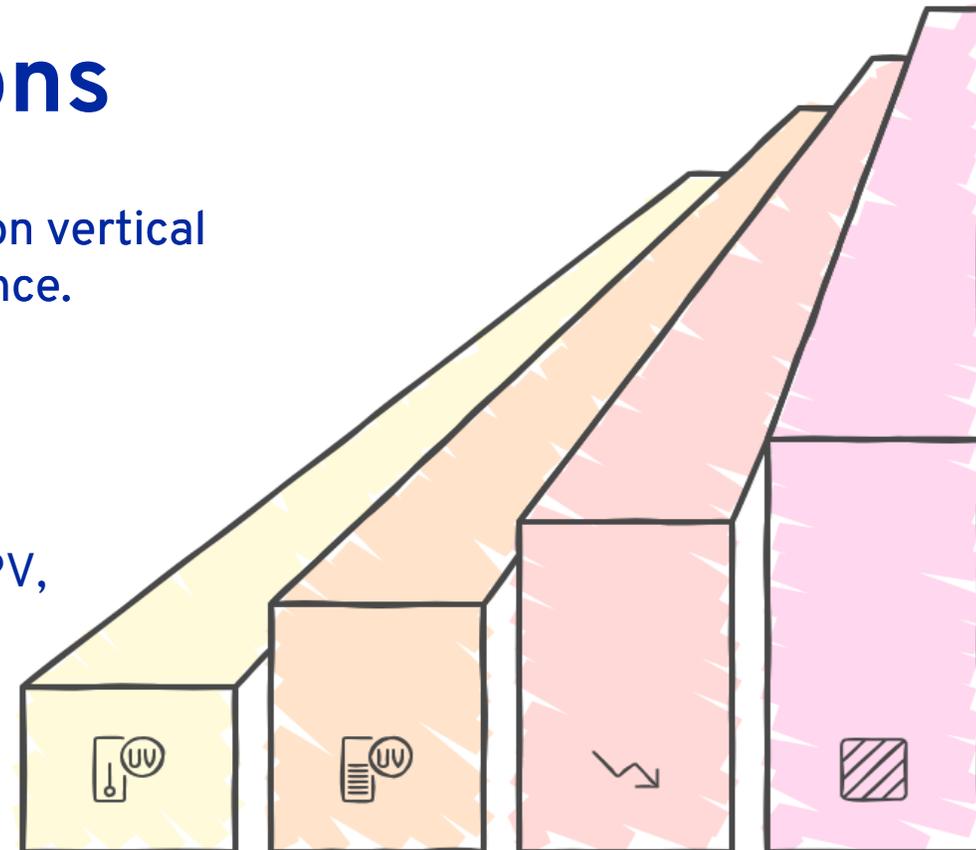


# Background and motivations

**Aim of this research:** Fulfill the existing research gap on vertical PV installations, estimating the reduction in UV irradiance.

## Key messages:

- Different orientations/inclinations = different environmental stress (UV and T)
- Potential adoption of novel materials for vertical BIPV, without excessive UV-ID



### Estimate UV Irradiance

Use SMARTS model to simulate UV exposure on different surfaces.

### Conduct UV Aging Tests

Experimentally test minimodules with different materials under UV exposure.

### Correlate Degradation Rates

Analyze data to link UV exposure to material degradation.

### Optimize Material Selection

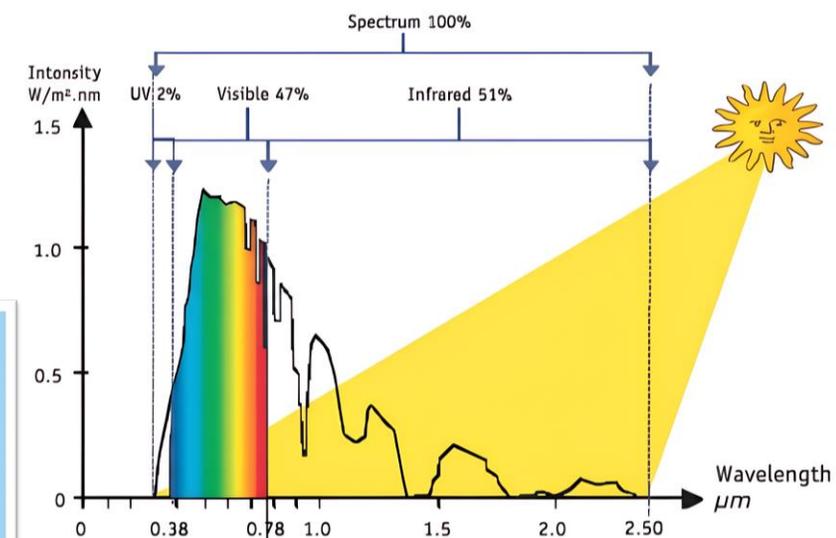
Choose materials that balance energy yield and durability.

# UV radiation analysis

Estimation of annual total and UV irradiance incident on surfaces with different inclinations, orientations and climatic zones, by using the Simple Model of Atmospheric Radiative Transfer of Sunshine (**SMARTS**) [10,11]. Atmospheric parameters are retrieved from satellite data (Nasa and NREL databases).

Factors affecting UV irradiance:

- **Air mass (AM)** (season, location, inclination)
- Ozone layer thickness
- **Clearness index**
- Water vapor
- Aerosols, pollution, dust
- **Albedo of surrounding environment**



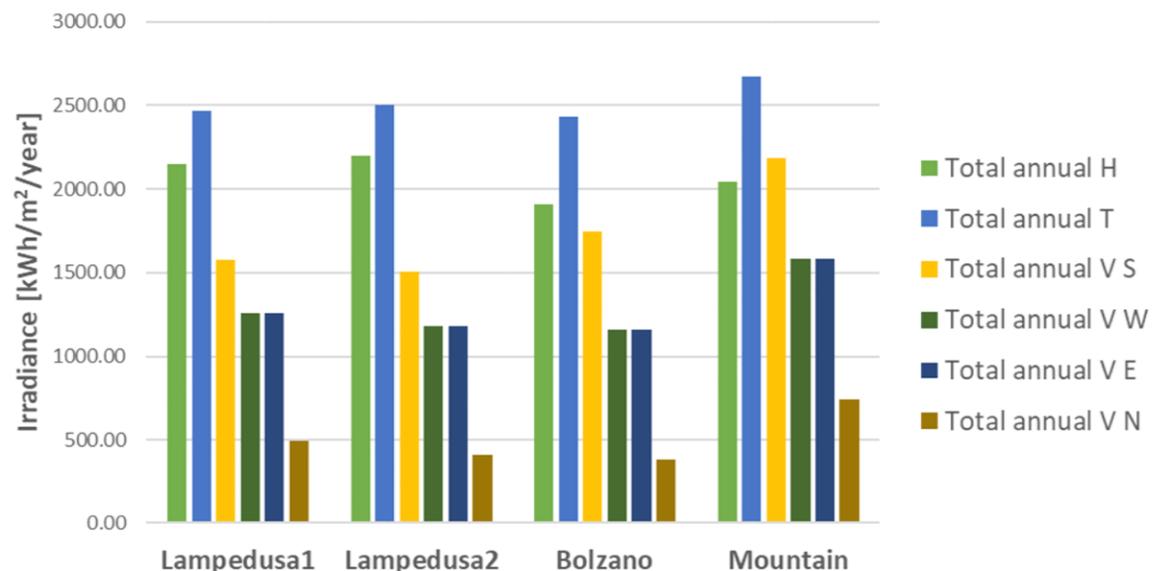
# UV radiation analysis

Calculation of annual irradiance and annual UV dose

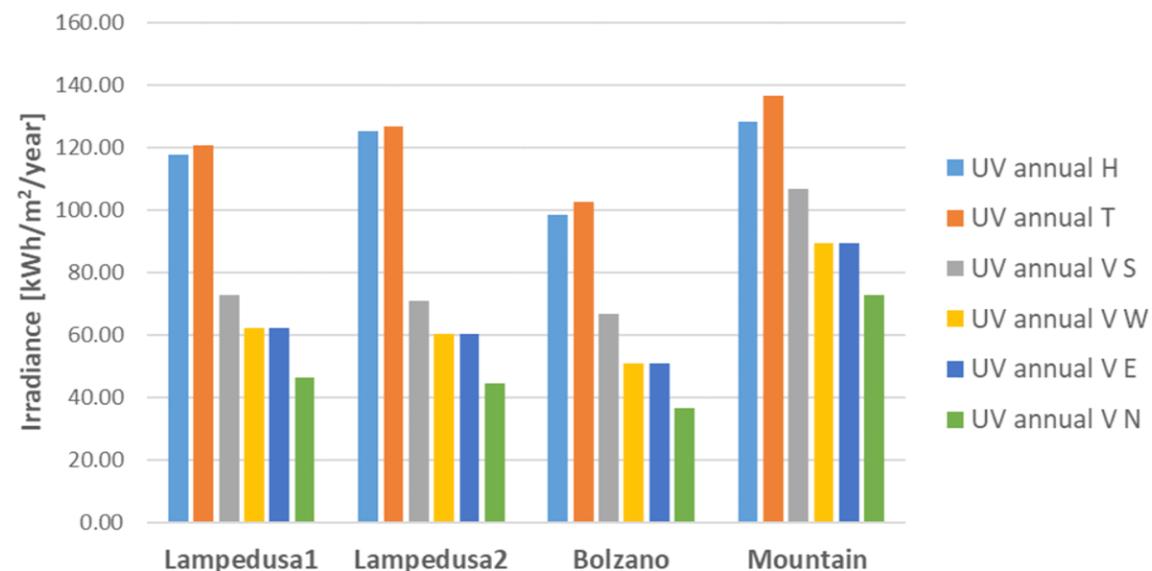
Three representative locations in Italy:

- Lampedusa (mediterranean area)
- Bolzano (continental zone)
- Monte Vioz (TN) (alpine environment)

Annual irradiance by location and orientation



Annual UV irradiance by location and orientation

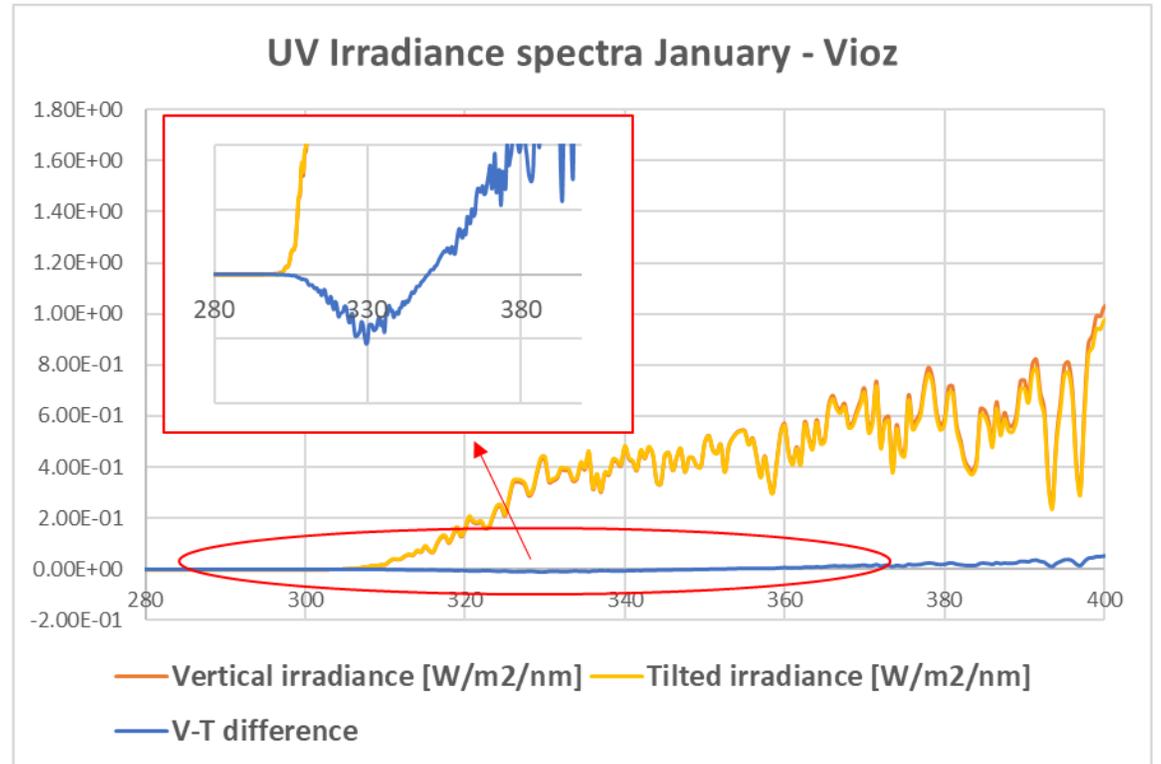
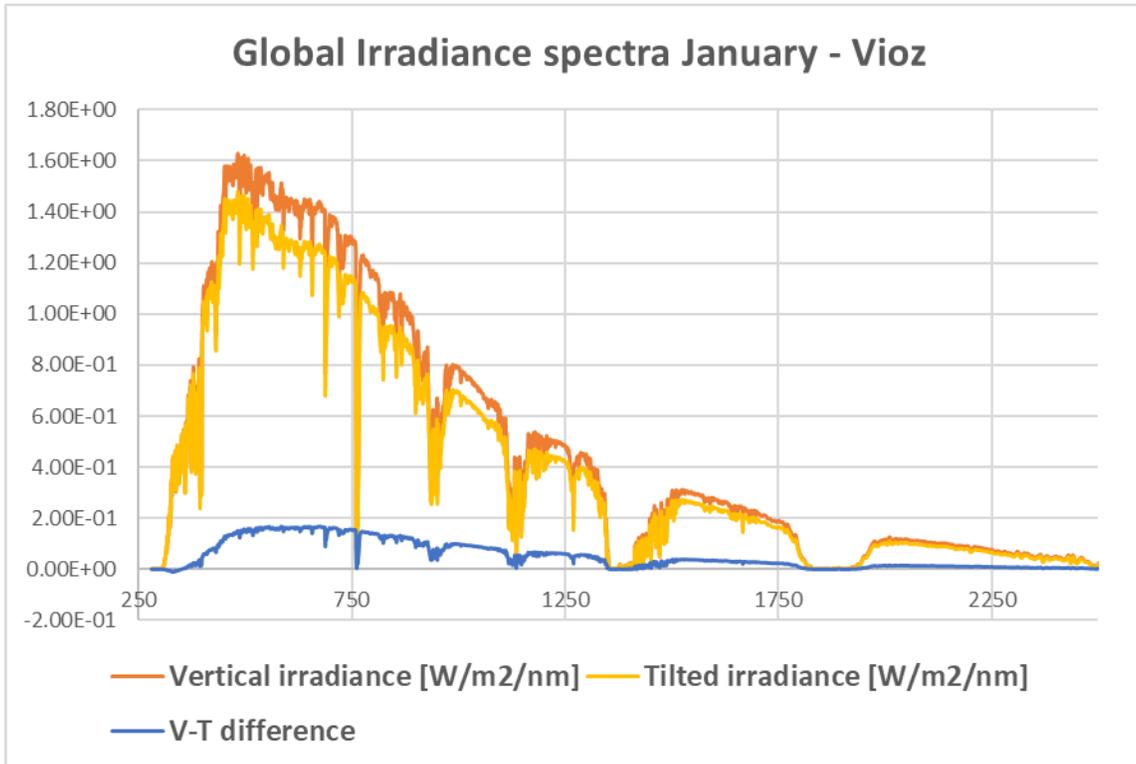




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# UV radiation analysis

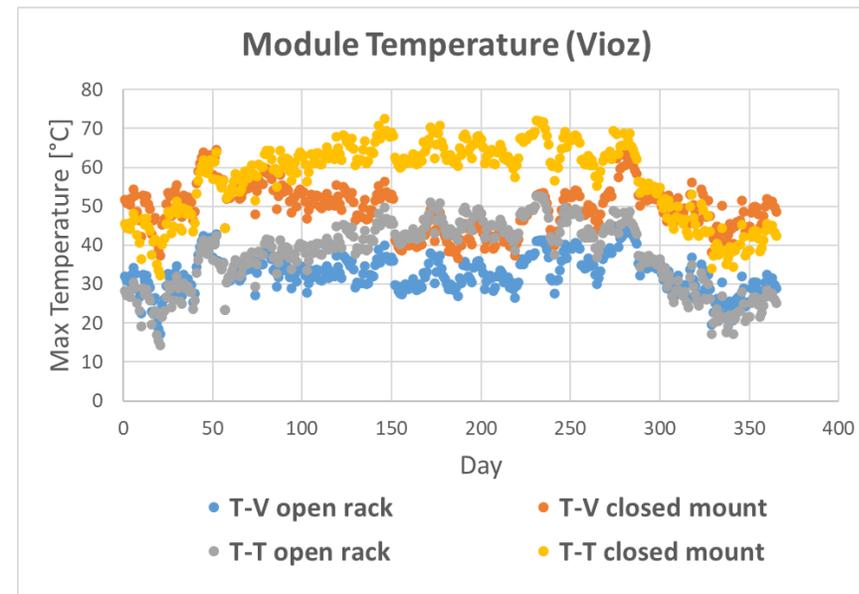
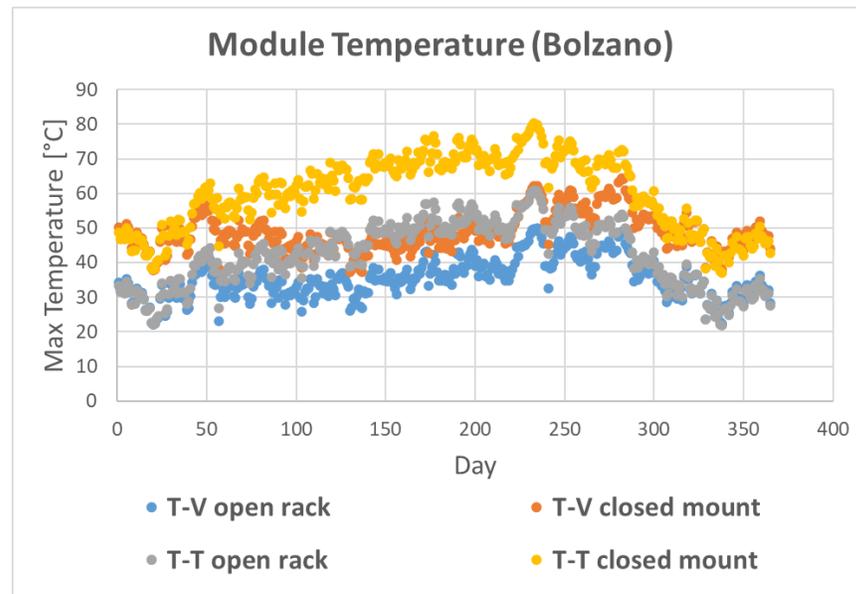
Worst case: alpine environment in winter, but UV-B is always lower



# Temperature analysis

Module's temperature is influenced by plane-of-array irradiance ( $E_{POA}$ ), ambient temperature, wind speed and installation configuration. Temperature is also affecting UV-ID rate

**Sandia Model:** <sup>[12]</sup>  $T_{mod} = E_{POA} \cdot \exp(a + b \times W_S) + T_{amb}$



# Research progress – UV aging tests

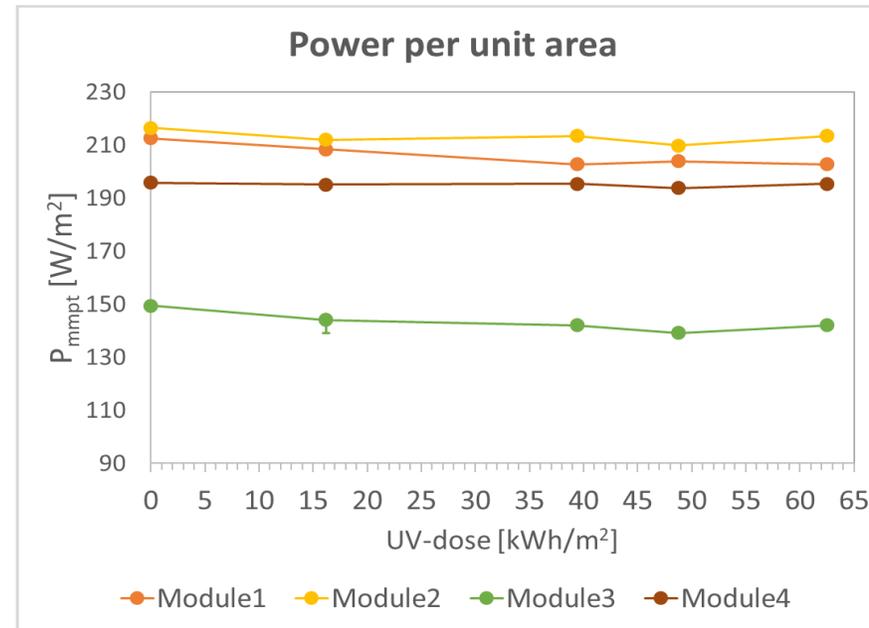
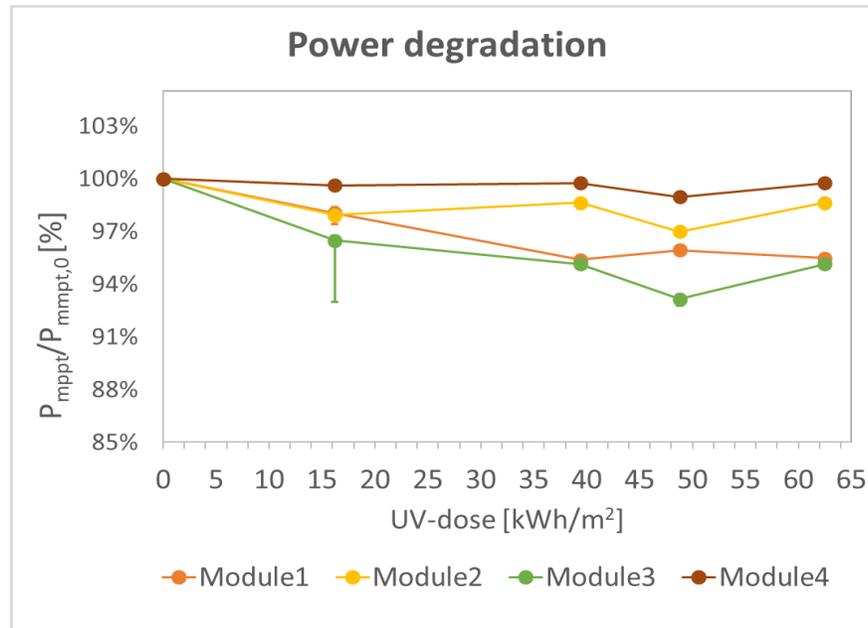
Four mini-modules were aged in a Q-SUN Xe-3 Xenon Arc lamp chamber equipped with extended UV-QB filters. Experimental conditions followed IEC 61215-2-2021 indications for UV preconditioning test:

- TUV 100 W/m<sup>2</sup> (~5% UVB) → ~2 Suns
- T back module ~60 °C
- No humidity control
- Open circuit test
- Total of ~625 hours (**total UV dose = 62 kWh/m<sup>2</sup>**)
- Progressive monitoring of electrical parameters





# Research progress – UV aging tests



## Degradation rate calculation

Kinetic model	Module1	Module2	Module3	Module4
linear fitting (k) (%/hour)	-0.007%	-0.002%	-0.009%	-0.001%
total degradation in 625 h	<b>-3.42%</b>	<b>-0.98%</b>	<b>-4.39%</b>	<b>-0.34%</b>



# Research progress – Equivalent years analysis

Calculation of outdoor equivalent years (same UV- or UVB-dose exposure) corresponding to hours of experiment (625 h).

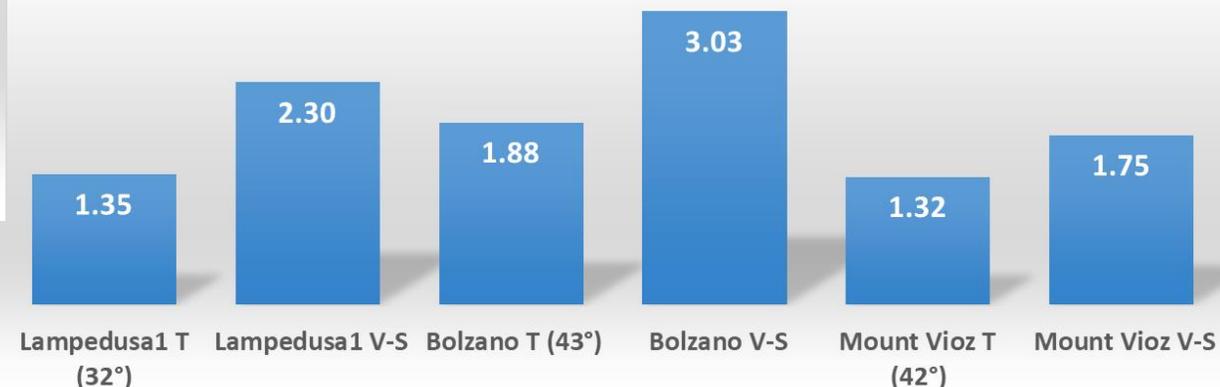
$$\frac{UV_{chamber} [kWh/m^2]}{UV_{annual,outdoor} [kWh/m^2/year]}$$

Equivalent Years of UV exposure



Larger difference when looking at UV-B only!

Equivalent years of UVB exposure





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# Research progress – Equivalent years analysis

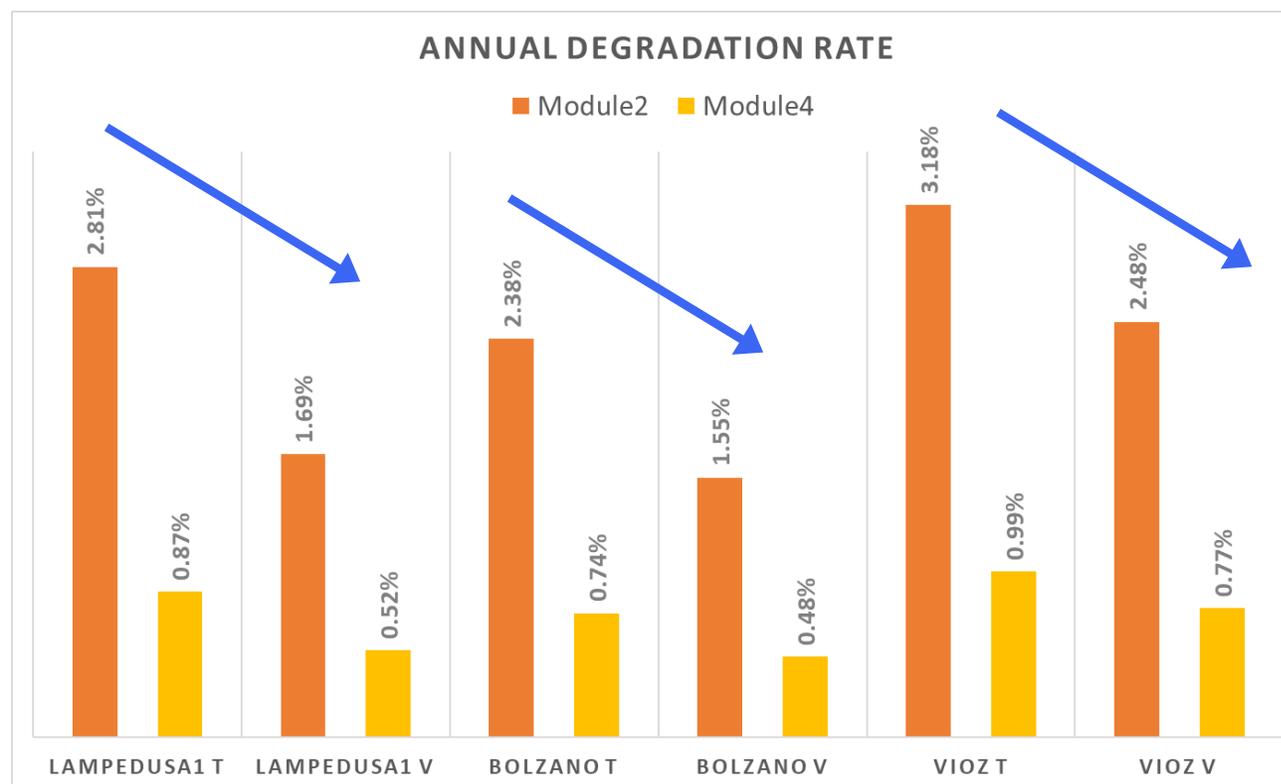
Calculation of outdoor equivalent years (same UV- or UVB-dose exposure) corresponding to hours of experiment (625 h).

$$\frac{UV_{chamber} [kWh/m^2]}{UV_{annual,outdoor} [kWh/m^2/year]}$$

Orientation- and location-specific annual degradation rate calculation

Module2: TPO-clear + IBC cell  
Module4: EVA + PERC cell

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# Main takeaways

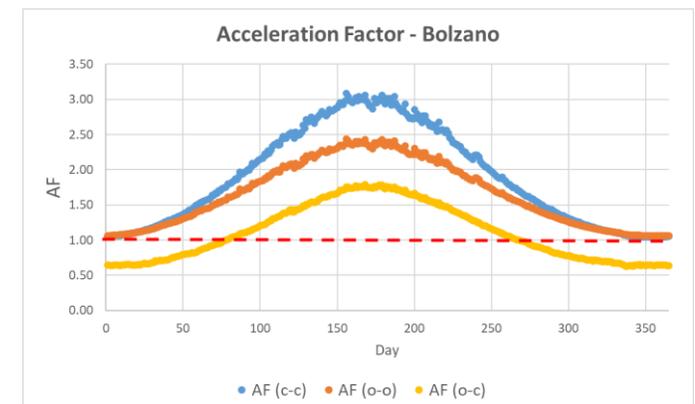
- Great influence of module's inclination on incident UV irradiance → **could impact on UV-ID effects**
- Strong influence also on **module's temperature**, but dependent on installation configuration
- Lower stress factors indicate reduced degradation rate

## Next steps

- Future studies on combined stress factors need to be conducted, for **photodegradation analysis (Acceleration Factor calculation)**<sup>[13]</sup>

$$AF_{S/\alpha} = \exp\left(\frac{-E_a}{k}\left(\frac{1}{T_S} - \frac{1}{T_\alpha}\right)\right)\left(\frac{UV_S}{UV_\alpha}\right)^n$$

- Possible use of **novel materials for vertical BIPV**, improving energy yield without compromising durability





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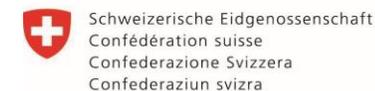
# Thank you!

This is an initiative of



Grant N°101096126. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.

**Project funded by**



Swiss Confederation

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