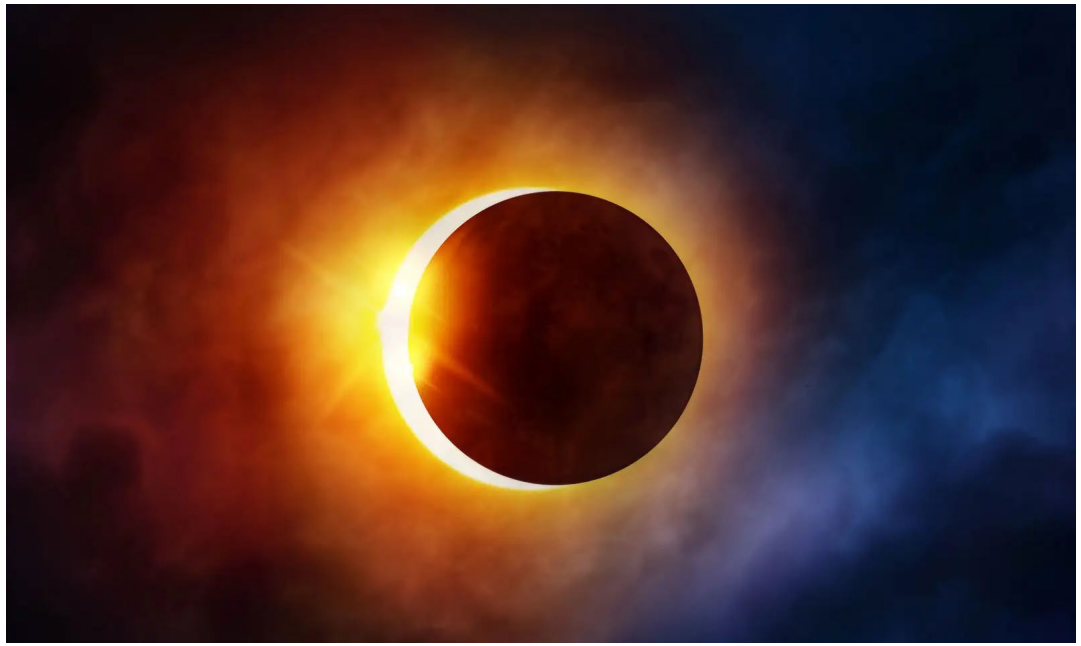
University of Applied Sciences and Arts of Southern Switzerland
Department for Environment Constructions and Design
Institute for Applied Sustainability to the Built Environment
SUPSI PVLab laboratory

SUPSI

Definition of PV shading classes and criticalities in PV applications



IEA PVPS

IEA PVPS TASK 13 – RELIABILITY AND PERFORMANCE OF PV SYSTEMS

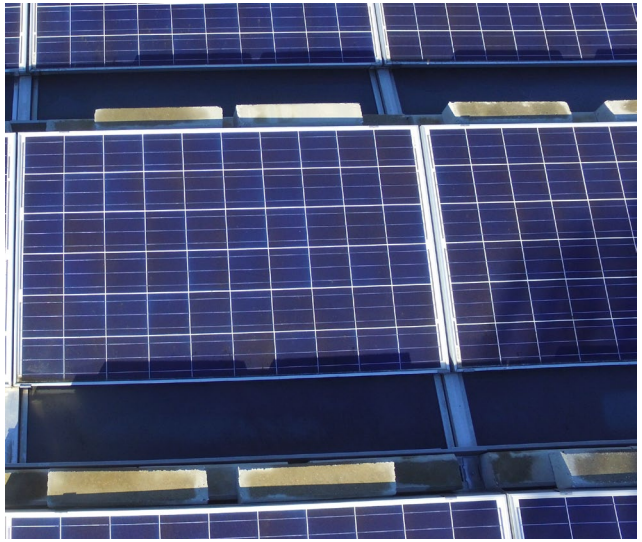
EUPVSEC 2023 - Parallel event
System design of partial shaded PV generators operated by optimized power electronics.

Mauro Caccivio, Head of SUPSI PV sector

Shadows and PV: a common problem: in industrial plants…

Images from :"Analysis on the Effect of Shading on the Characteristics of Large-scale on-grid PV System in China" Yunlin Sun, Xiangzhi Li et al.https://livingroofs.org/introduction-types-green-roof/biosolar-green-roofs-solar-green-roofs/

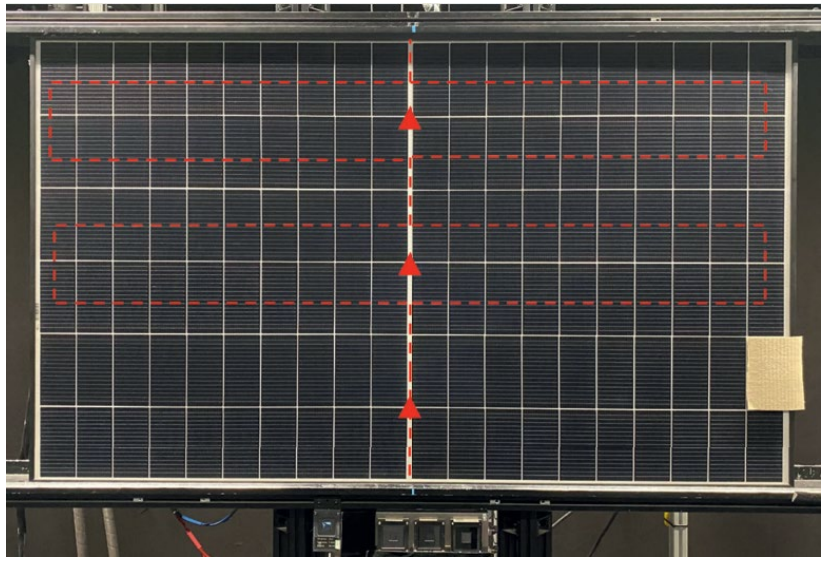
…and residential ones

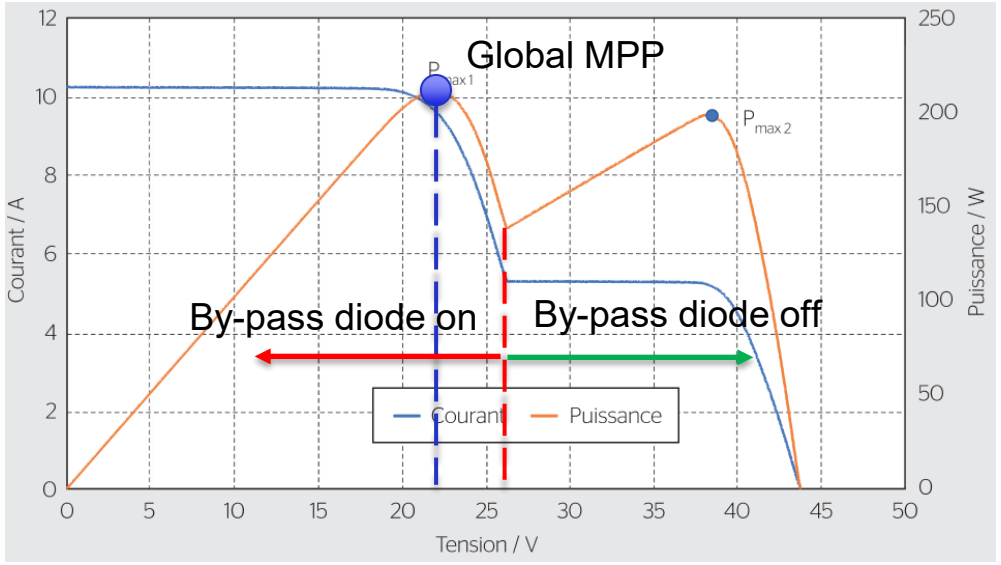




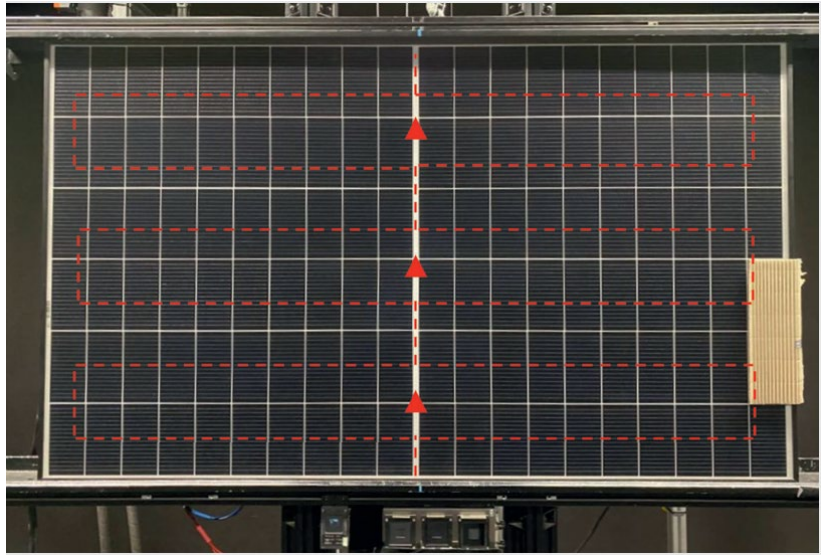
Images from "Investigations on the Main Causes for Reduced Performances during the Early Stage of Life of Rooftop PV Systems" D.Chianese, M.Caccivio, EUPVSEC 2020

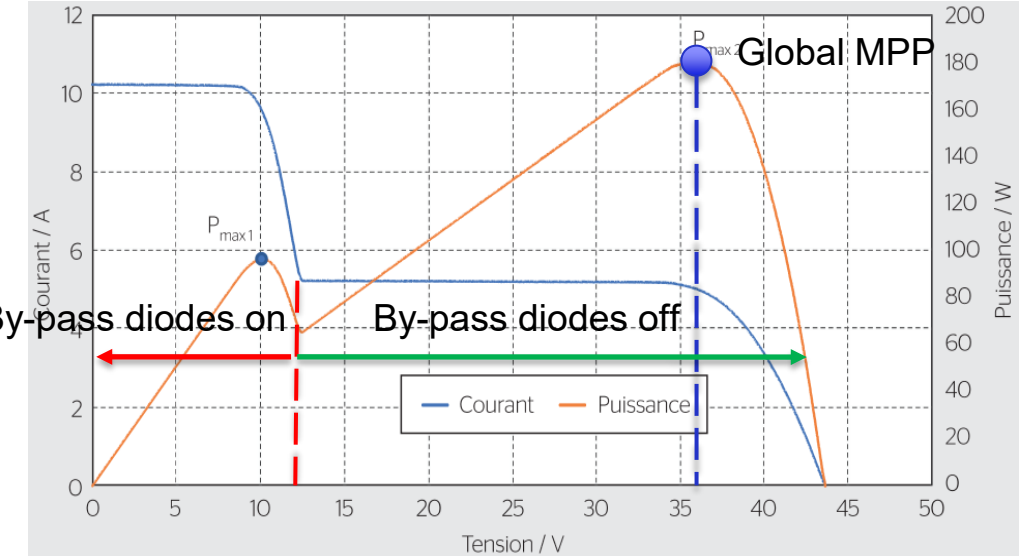
What happens when a shadow is covering a PV module ?





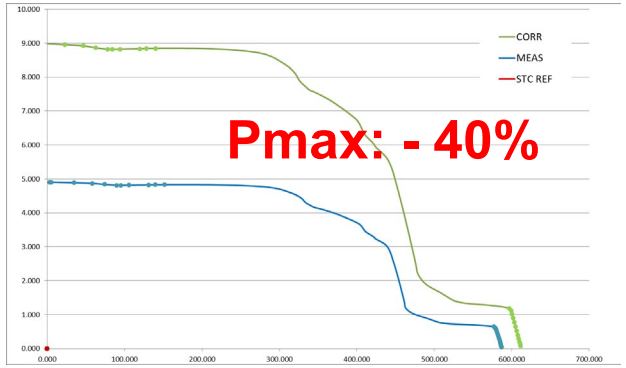
- Hot spot of the cell
- By-pass diode activated and heating

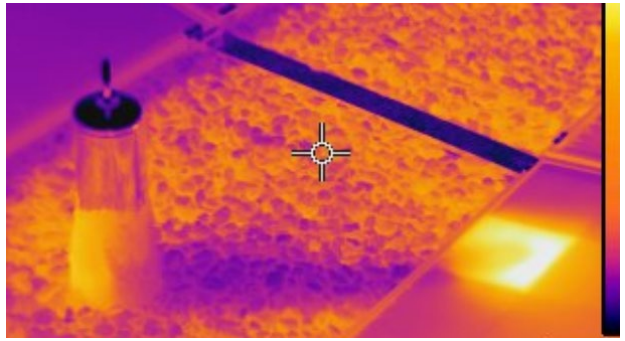


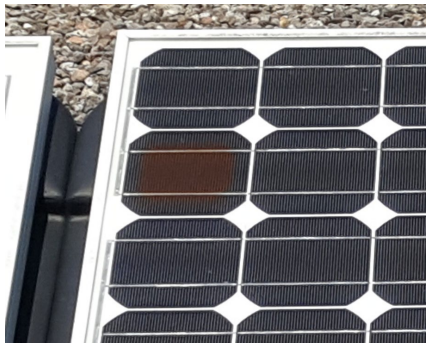


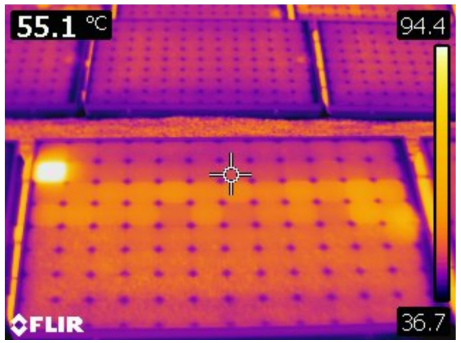
- No hot spot
- Bypass diodes not activated

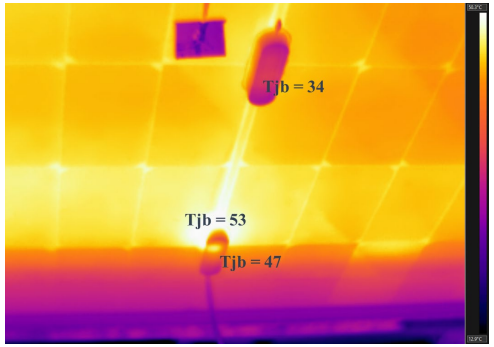
Consequences of shadows on performance and reliability











- Power loss
- Hot spot
- Repeated stress on cells, diodes, materials
- Degradation processes

METRO PV project: approach for a shading resistance classification of PV modules

- **Requirements for a rating scheme that can be transferred to a standard later:**
- easy and quick to perform experiments
- no new equipment needed
- should cover all relevant modules
- should cover most relevant shading situations, but not more than needed
- reproducible by testing laboratories

Metro-PV

"An approach for a shading resistance classification of PV modules": Hendrik Sträter, Stefan Riechelmann, Stefan Winter, Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, Germany

METRO PV project: approach for a shading resistance classification of PV modules

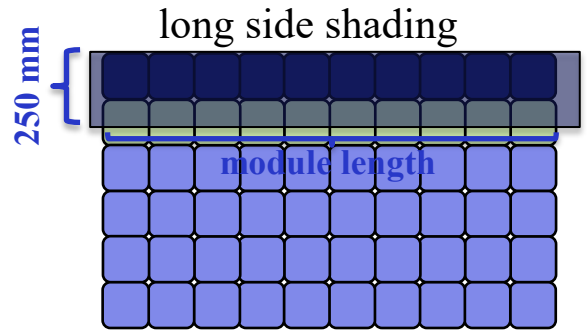
The following patterns are proposed:

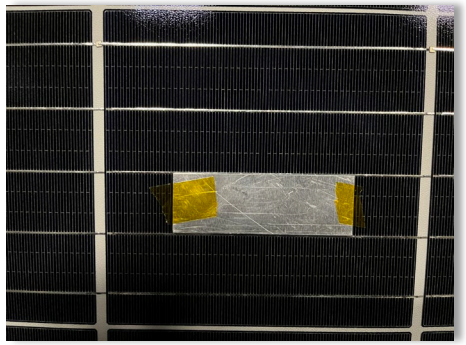
a) shading of the long side of a PV module

b) shading of the short side of a PV module

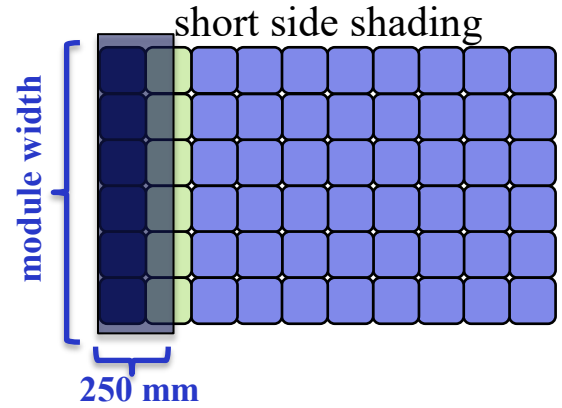
c) partial shading of a single cell of a PV module

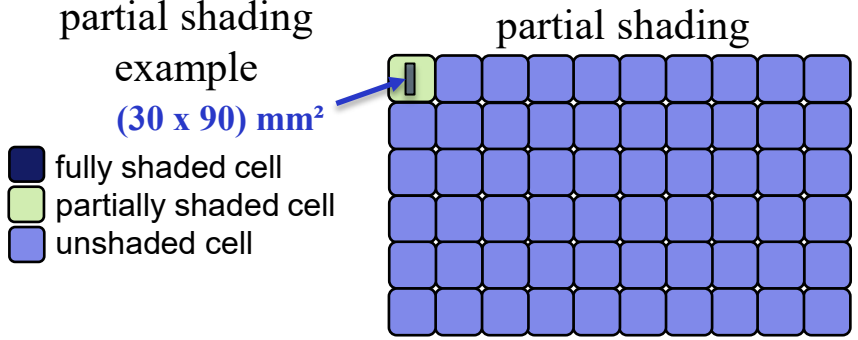
Shade material for a) and b) shall be non-transparent and have a width of 250 mm. **Place the material flush with the module edge**.
Shade material for c) shall be non-transparent and have a size of 30 x 90 mm². **Place the material always on only one cell**.
For outdoor measurements, a thin aluminum piece turned out to be most suitable due to hot-spot issues under constant light.





partial shading example





Metro-PV

"An approach for a shading resistance classification of PV modules": Hendrik Sträter, Stefan Riechelmann, Stefan Winter, Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, Germany

METRO PV project: approach for a shading resistance classification of PV modules

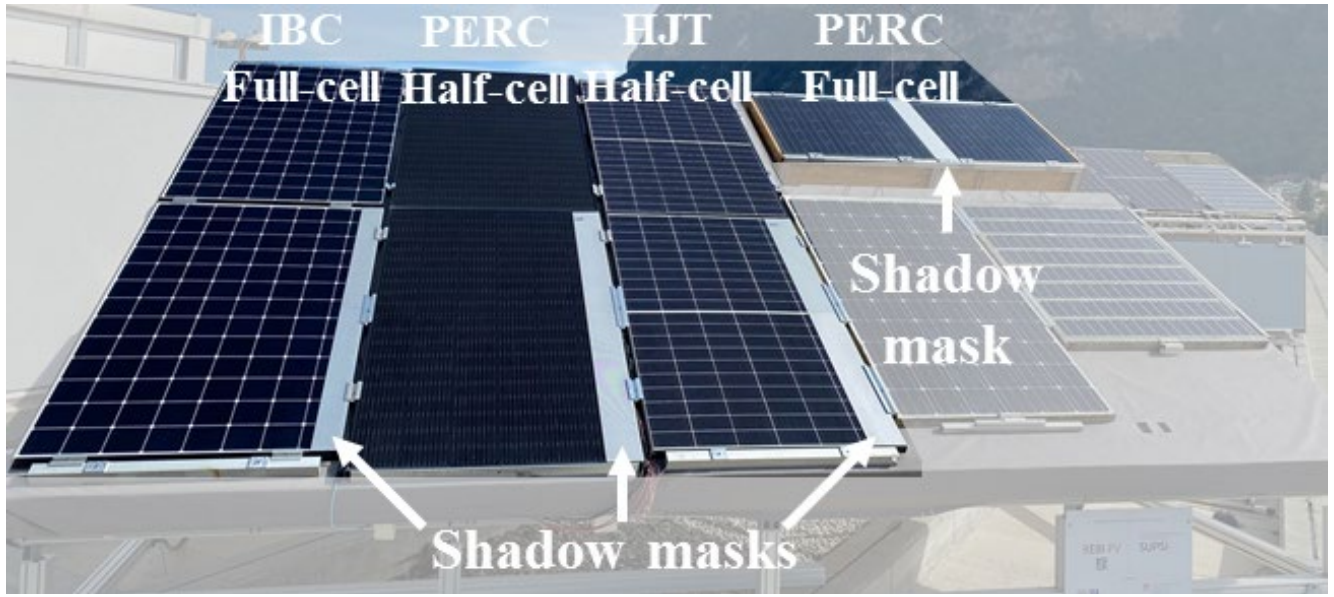
- The metric for the classification is based on the concept of the additional loss (AL).
- AL is calculated from the difference of expected loss (EL) and measured power loss (PL) compared to unshaded condition.
- Expected loss (EL) is calculated by dividing the shaded area of the module by the total module area. This is the minimal power loss one would expect if a shade is applied to a module.
- The measured loss (ML) is the module power with applied shading divided by the module power without shading applied.

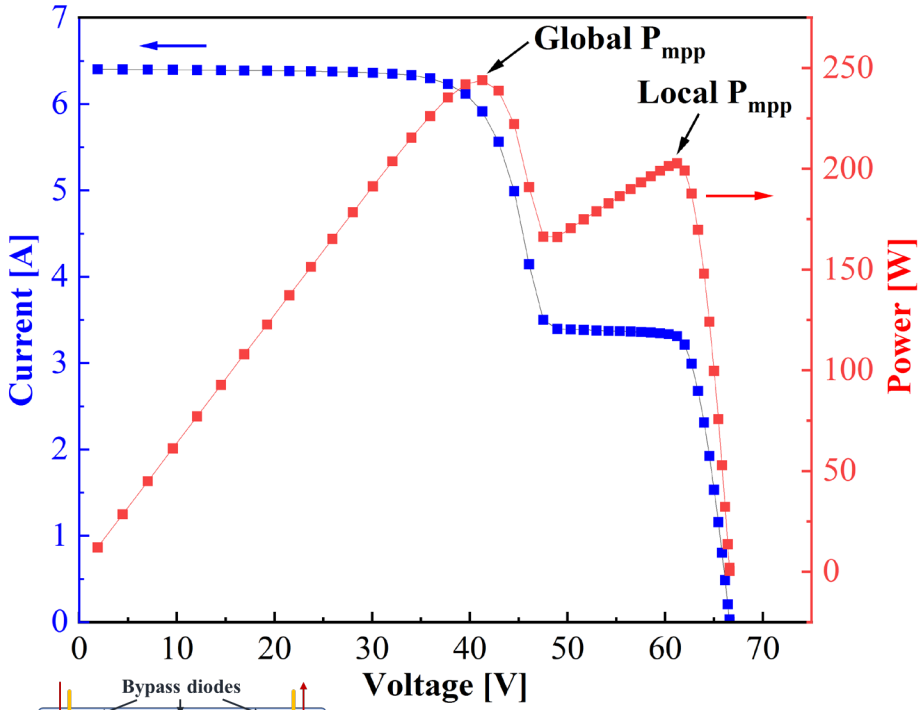
$$AL = \left(1 - \frac{P_{\mathrm{mpp,shaded}}}{\mathrm{P_{mpp}}} - \frac{A_{\mathrm{shaded}}}{A_{\mathrm{total}}}\right) \cdot 100\ \%$$

- **A ROUND ROBIN (indoor/outdoor) between the different laboratories part of the project is presently running**

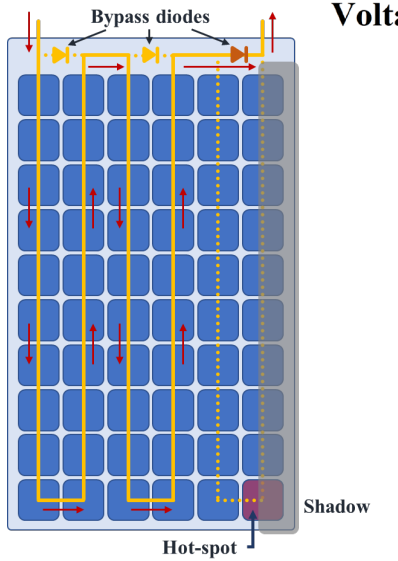
"An approach for a shading resistance classification of PV modules": Hendrik Sträter, Stefan Riechelmann, Stefan Winter, Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, Germany

REBI-PV project: effect of partial shadow on the reliability of residential PV modules



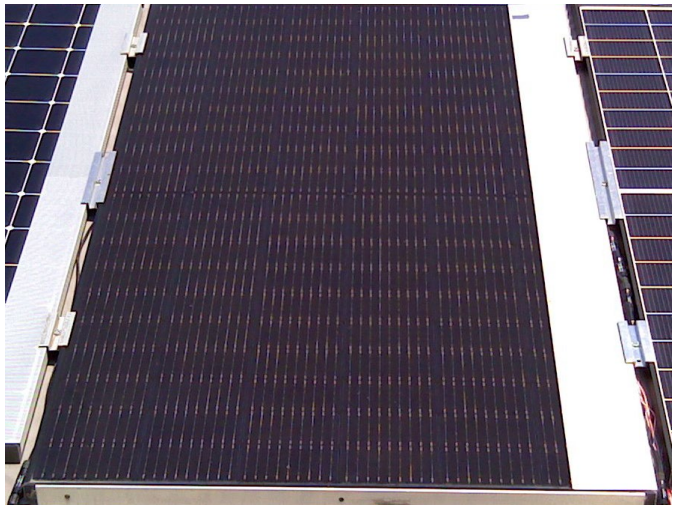


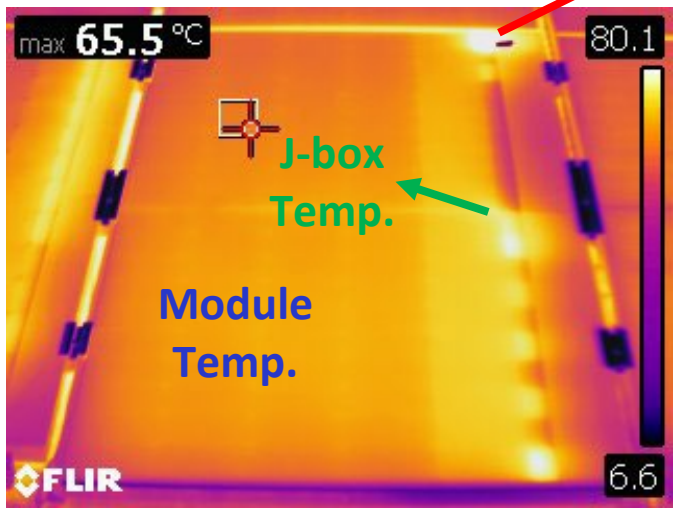
- Stress on **bypass diode** and **module**
- Difference **between Global P_{mpp} and Local P_{mpp}** is **10±5%**
- Shadow mask **36% transmittance**
- 13 months of monitoring
- **Module**, **hot-spot** and **junction box temperatures** every minute
- IV curves every minute

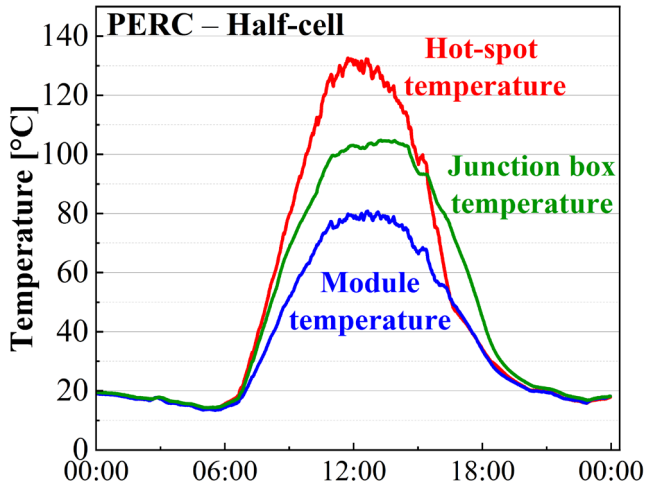


Extract From "The Effect of Partial Shadow on the Reliability of Residential PV Modules" Ebrar Özkalay et al.
EUPVSEC, 19-22 September 2023 3BO 14.2.2

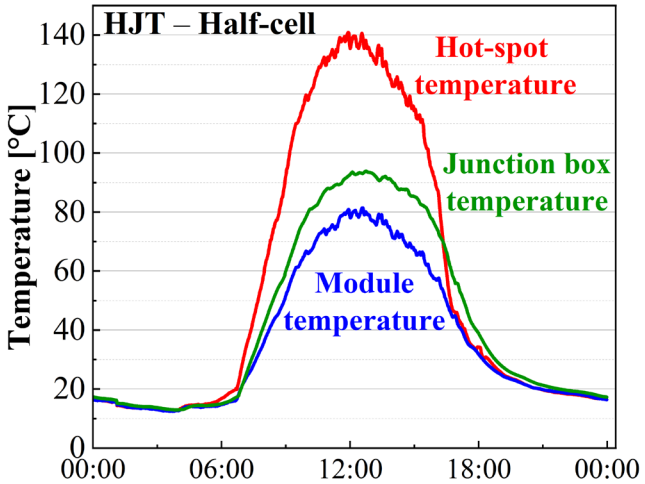
REBI-PV project: Daily Temperature Profiles of different technologies/layouts



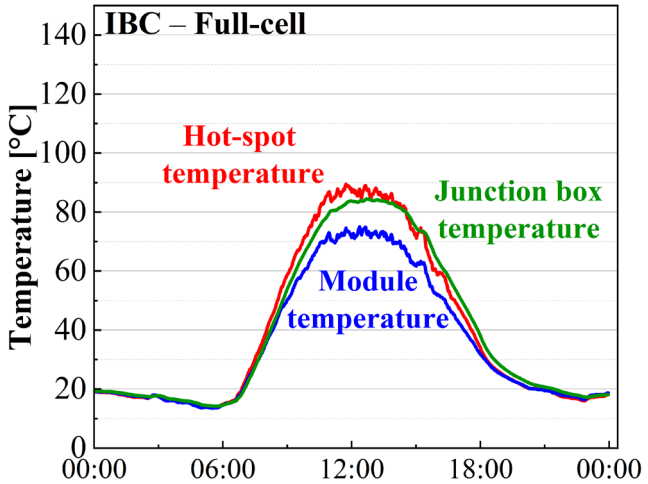




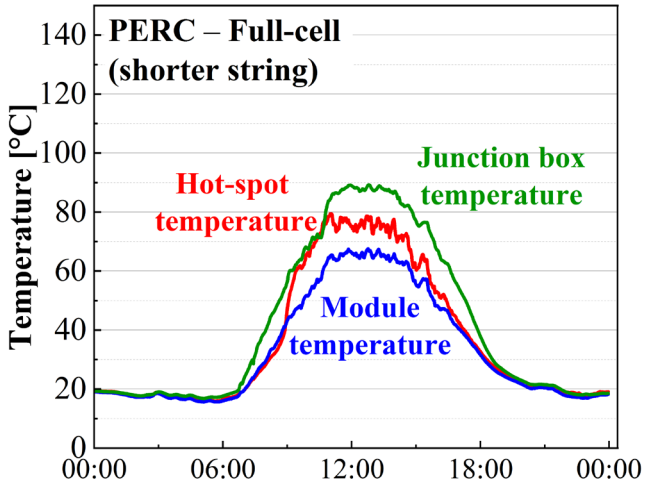
BIPV-Insulated (no ventilation)



BIPV-Insulated (no ventilation)



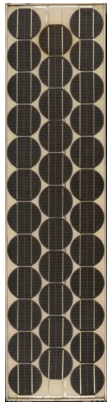
BIPV-Insulated (no ventilation)



BIPV-Partially Ventilated

Extract From "The Effect of Partial Shadow on the Reliability of Residential PV Modules" Ebrar Özkalay et al.
EUPVSEC, 19-22 September 2023 3BO 14.2.2

Evolution of PV modules with respect to shadows



No diode:

- Unlimited reverse bias of cells
- Destructive Hot spot

Diodes:

- Limited reverse bias of cells
- Hot spot (for full cell shaded)
- Bypass diode heating

Half-cut cells, diodes:

- Limited reverse bias of cells
- Hot spot when global MPP activates diode (for full cell shaded)
- Bypass diode heating
- Secondary hot spots in case of diode activation

Solar module with optimizer, 3 diodes:

- MPP tracking on each module
- Limited reverse bias of cells thanks to diodes
- Hot spot when global MPP activates diode (for full cell shaded), at module level.
- Bypass diode heating
- Secondary hot spots in case of diode activation


SHADOW IS
NOT
AN OPTION
?
NASA
KENNEDY SPACE CENTER

THANK YOU!