Bifacial gain simulations of modules and systems under desert conditions

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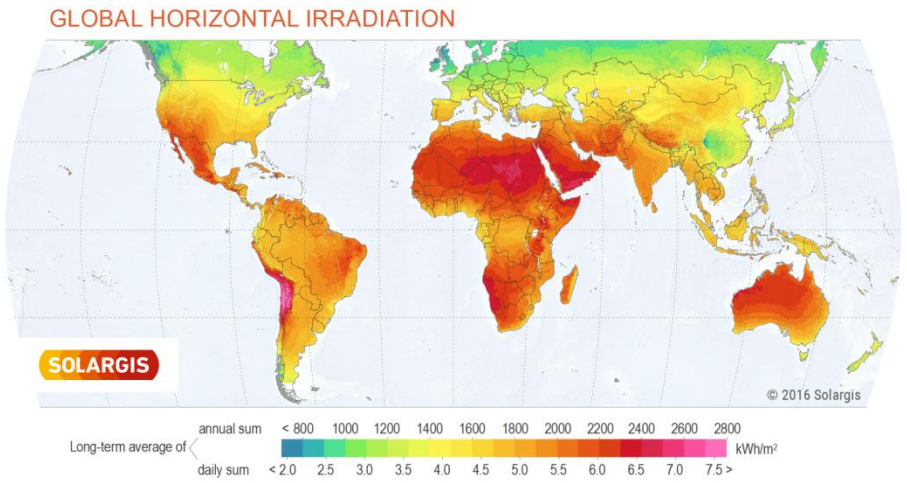
Application of bifacial modules in desert conditions



GHI dose world map (© Solargis)

- **Desert climates makes bifacial modules more interesting**
  - Significantly higher irradiance dose than in moderate climate
  - Bright ground with albedo up to 40% (➔ E-W vertical)
  - More diffuse light due to dust in the atmosphere

- However, high continuous dust deposition (**soiling**) makes yield estimation difficult
- ➔ Investigation of module performance and their benefit in desert environment are required

Dusted solar modules in desert (© PI Berlin)

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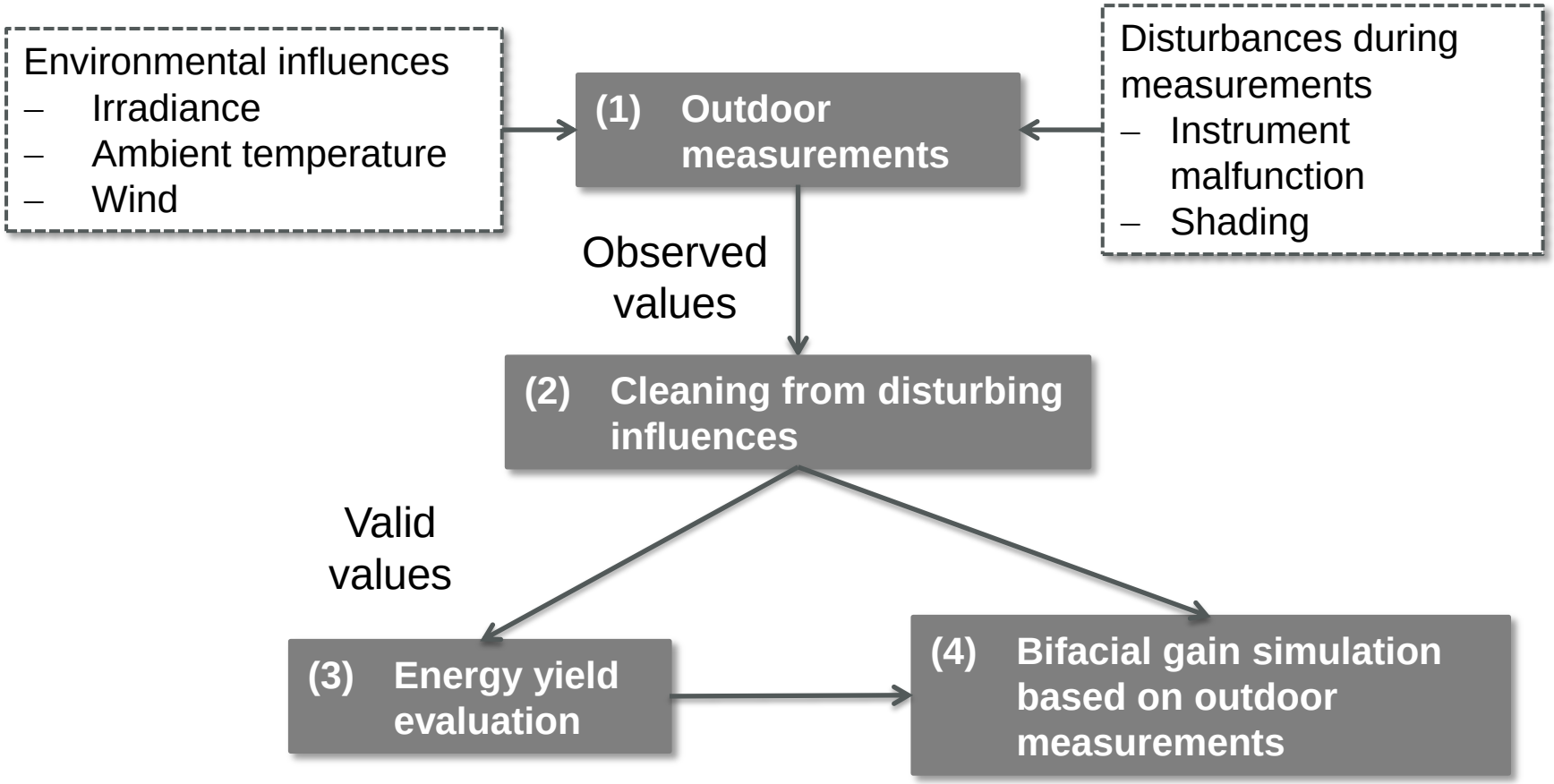
Approach of outdoor investigation and bifacial gain simulation



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(1) Outdoor measurements in Qatar

- Single and system measurements since 09/2016 in Doha, Qatar
  - Bifacial modules with 270 Wp, installed 2016
  - Reference: monofacial module 220 Wp, installed 2012
- Module data: IV-curve, module temperature
- Environmental data: irradiance, amb. temp., rel. humidity, wind
- Outdoor measurements provided by Qatar Environment & Energy Research Institute

Installation of bifacial module (front and rear side) at Solar Test Facility at Doha

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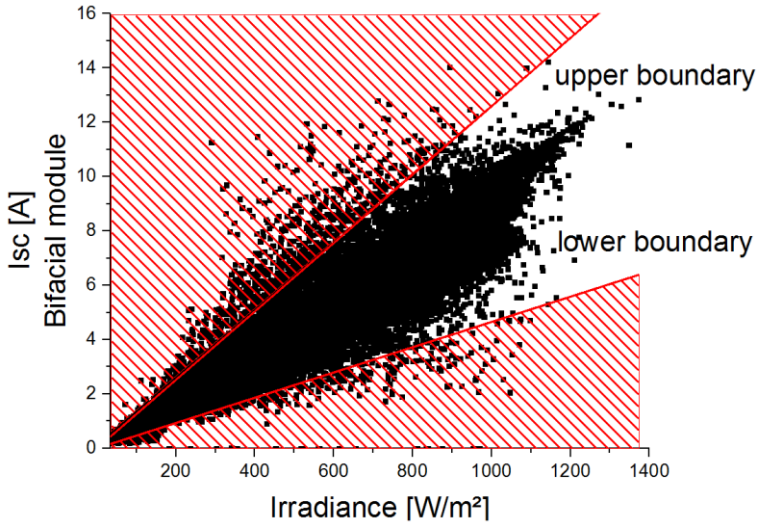
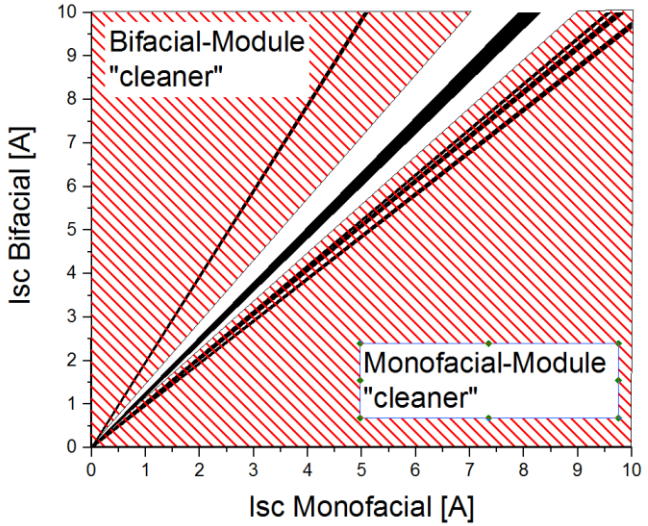
(2) Cleaning from disturbing influences

(1)



- To get a reliable data-set:
  - **Plausibility**:
    data within physical correct limits and only day-values
  - **Excluding outliers**: (2)
    data within 3-sigma intervall[1] of quotient I_{SC}/G and P_{MPP}/G, Fig. (1)
  - **Simultaneous cleaning state**:
    by linear regression of $I_{sc,bi}$ vs. $I_{sc,mono}$ daily slopes within statistical range,
    Fig. (2)

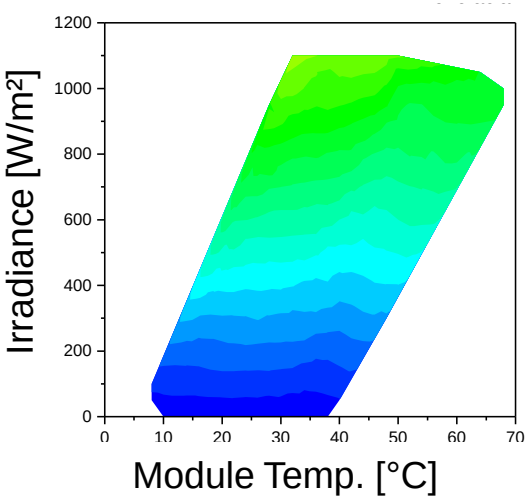


[1] Zhu: Outlier identification in outdoor measurement data –effects of different strategies on the performance descriptors of photovoltaic modules", IEEE 2009

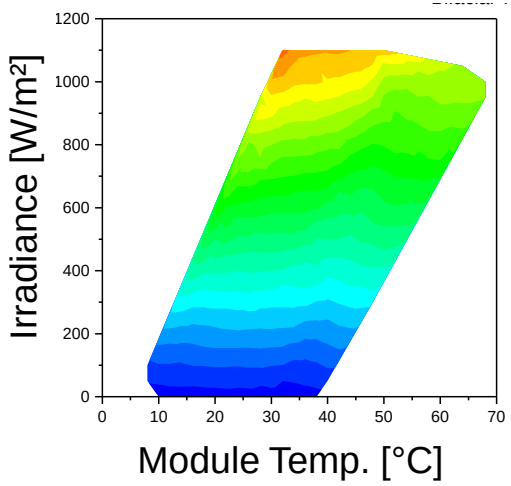
(3) Energy yield evaluation

$$\text{Factor} = \frac{E_{bi}}{E_{mono}}$$

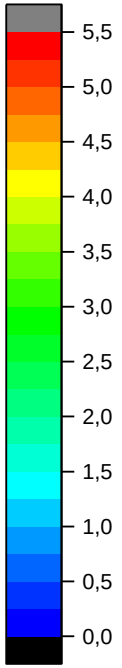
Monofacial E_{mono}

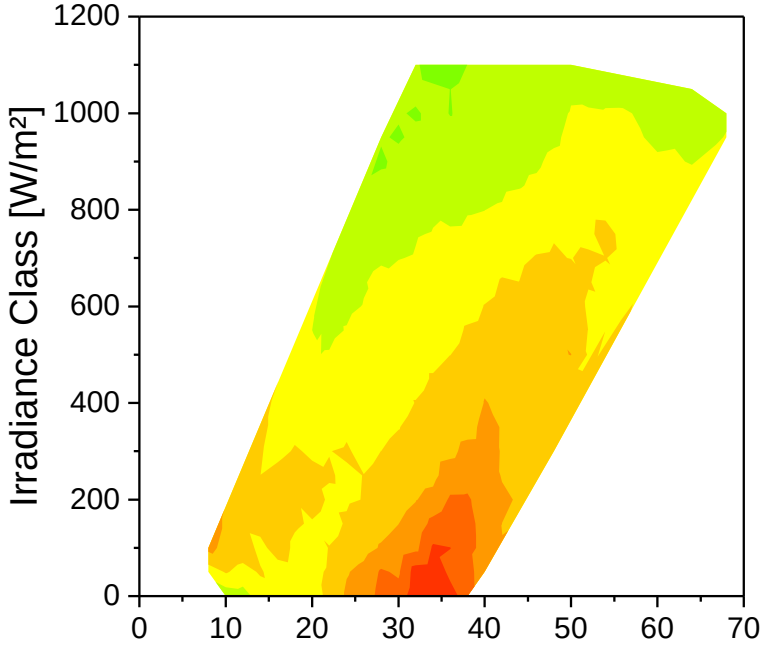


Bifacial E_{bi}

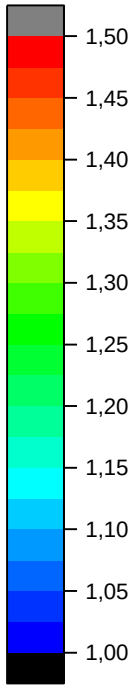


Averaged yield [Wh]





Factor



Ratio of average energy yields for irradiance and module temperature classes (width: 50 W/m²; 2 °C), first period of measurements

- Bifacial: Shift of absolute yield upwards
- Almost constant energy yield levels with rising temperatures until 800 W/m²
- Bifaciality up to 45% for moderate module temp.

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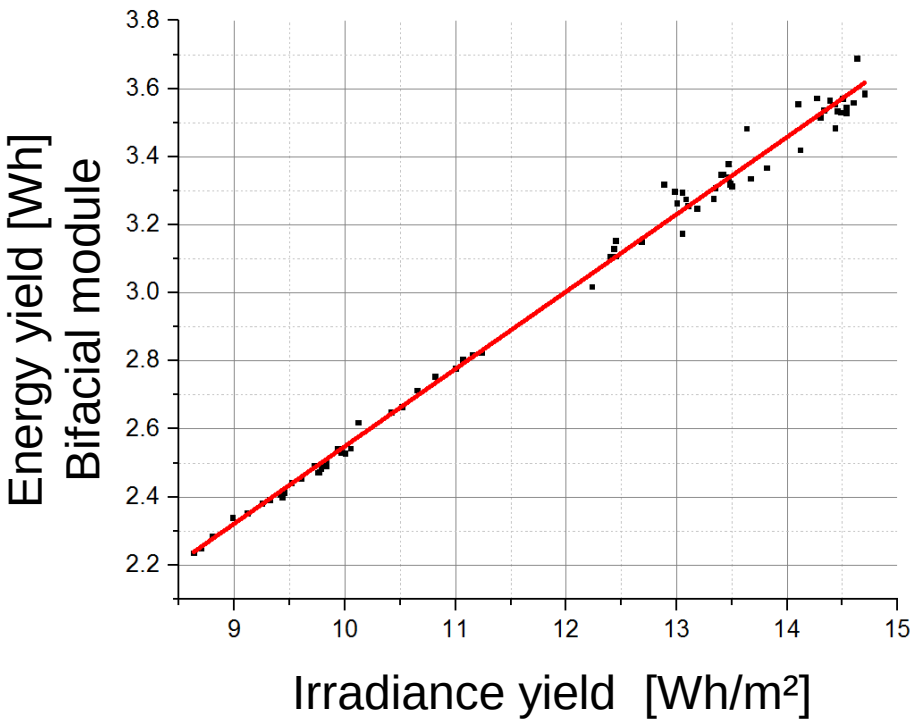
(3) Energy yield evaluation

How is the impact of soiling on bifacial modules?

- Currently, no standard to determine the classical Performance Ratio for bifacial modules
- Introduction of "**Yield Ratio**": the slope of a linear regression between daily irradiance yield and corresponding module yield
- Yield Ratio increases by cleaning or decreases by dust deposition, but as well with rising temperature
- ➔ Filtering for module temperature at 48 °C ± 5 %



Scheme of the determination of daily Yield Ratio

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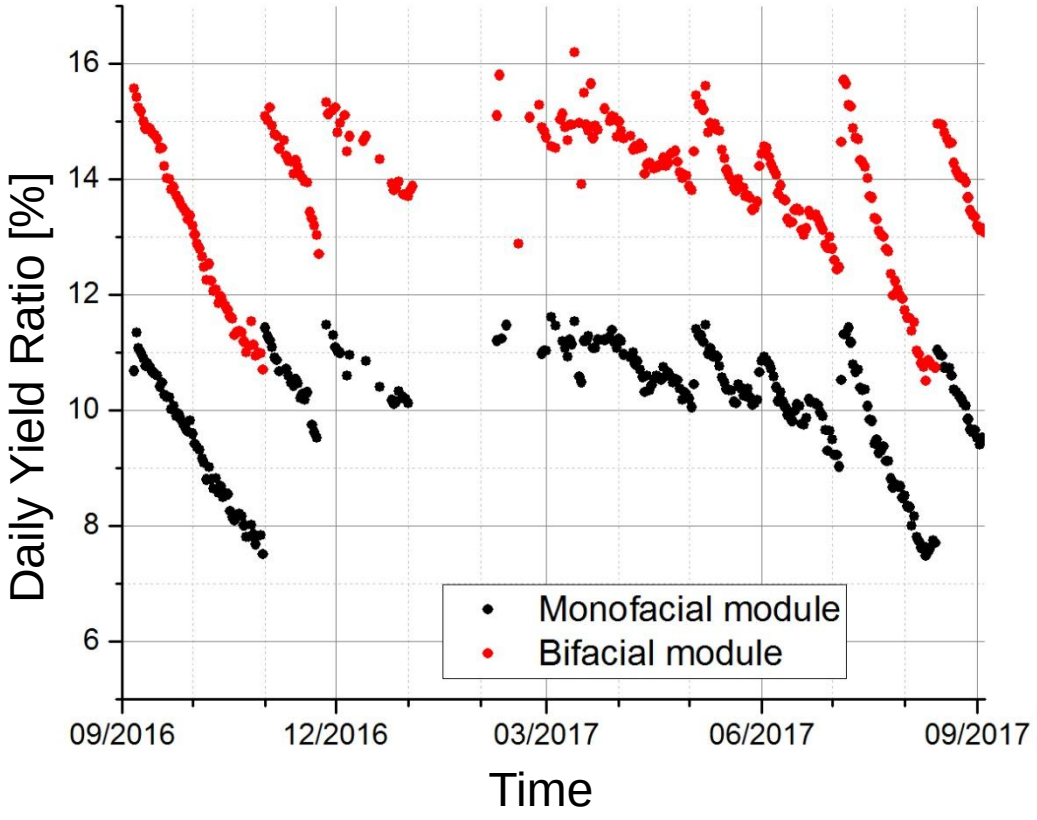
(3) Energy yield evaluation

Yield Ratio

- Uniform behaviour between bifacial and monofacial modules
- Temporary degradation of Yield Ratio due to soiling events
- Jumps are as the scheduled cleaning events



Daily Yield Ratio for bifacial and monofacial module over one year

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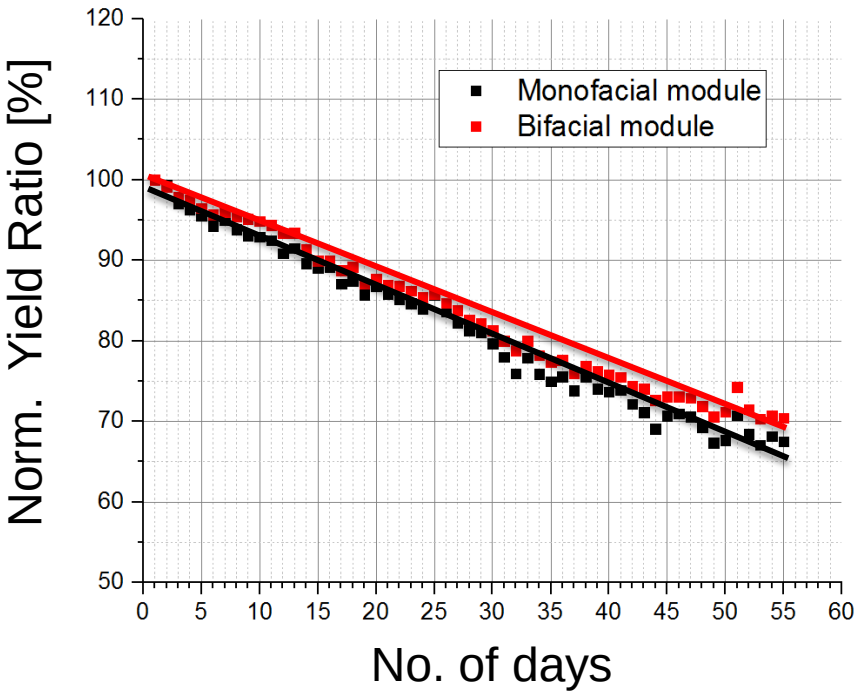
(3) Energy yield evaluation

Soiling rate

- Determination of „Soiling rate“ as linear slope over Yield Ratio, normalized to the cleaned state

	„Soiling rate“
Monofacial	0.57 %/day
Bifacial	0.61 %/day

- In this time period, a “soiling rate” around 0.6 %/day has occurred
- Independently of the installed module (➔ no influence on rear side)



Normalized daily Yield Ratio for bifacial and monofacial module (1 month and 3 weeks)

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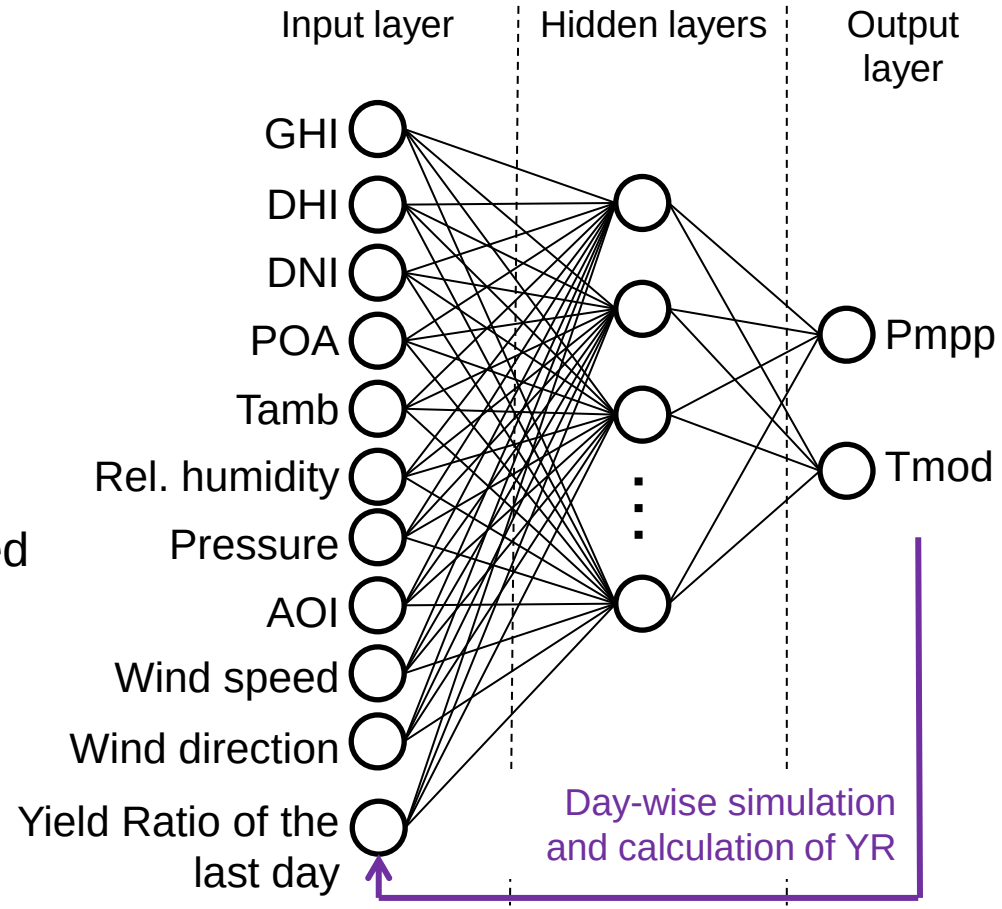
(4) Bifacial gain simulation based on outdoor measurements and yield evaluation

- Aim: Bifacial gain simulation of modules in desert regions
- Using Artificial Neural Networks (ANN)
  - Based on observed multidimensional information
  - Pattern learning and generalized knowledge after learning
  - Flexibility to uncertainties
  - Fast processing



Architecture of used ANN

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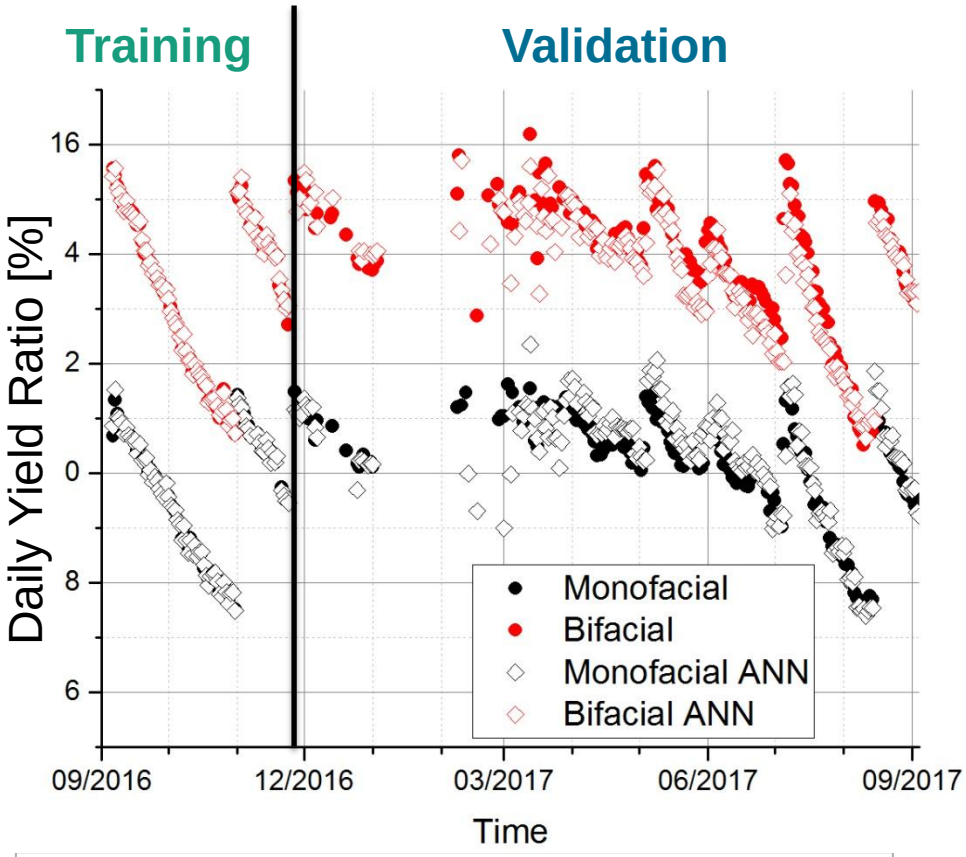
(4) Bifacial gain simulation based on outdoor measurements and yield evaluation

- Training of network based on the information (every minute) of first quarter of data
- Validation of trained network for remaining shows less averaged errors

	RMSE [1]
Monofacial	0.30 %
Bifacial	0.48 %

- Method of ANN is usable for both technologies



Measured and simulated Yield Ratio for both modules; Subdivision of the data in training and validation

[1] $\mathrm{RMSE} = \sqrt{\frac{\sum(\mathrm{YR_{meas}} - \mathrm{YR_{sim}})^2}{N}}$

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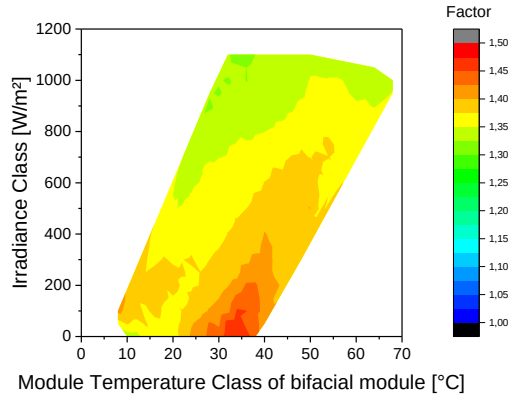
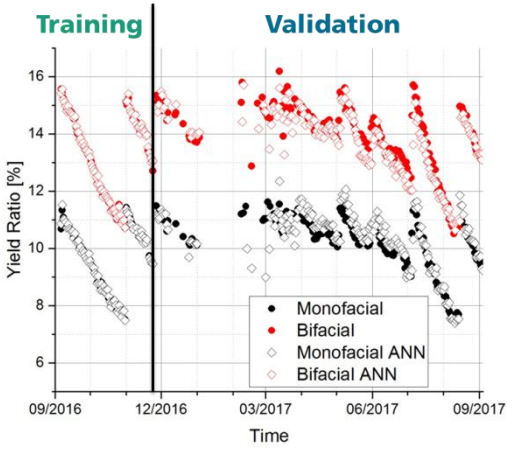
Summary and Outlook

- Application of bifacial modules in desert is still recommended.
- Bifacial gain simulation with a high resolution based on outdoor measurements
  - Promising strategy independently of the technology
  - For optimization of cleaning cycles
  - Further investigations to improve yield prediction
  - Applicable for module and system level
- Further investigations with comparison to vertical installations and of the reusability of trained data at other sites and climates





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Thank you for your attention!

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