OUTDOOR EXPOSURE STUDY ON THE PERFORMANCE OF NINE DIFFERENT TYPES OF INDUSTRIAL PV MODULES UNDER 35° AND UNDER 90° TILT

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ABSTRACT: Societal acceptance and aesthetics are of increasing importance with the raising number of PV installations. The favorable choice of installing PV in double-use applications such as BIPV, Agri-PV and others results in a variety of installation angles. This leads to an electricity generation that is even advantageous in respect to the shape of the load profile. The use of all-black and of colored modules under non-optimal orientations does, however, result in a lower yield that we quantify here for exemplary cases.

MOTIVATION

The generation profile of PV installations is broadened by vertical installations in differently oriented facades which supports morning and evening load requirements. Of course, the non-optimal orientations come at the cost of lower yield. The use of black instead of white backsheets decreases the performance to a minor extend but so does notably the coloring that is important to facilitate the use of PV in the building market and enhances acceptance. The percentage decrease measured under STC cannot directly be translated to an annual yield difference of a colored BIPV system operating under the site specific irradiance conditions. This study measures the differences in the field.

Experimental Setup

At the outdoor testbed in Berlin we installed - south facing under optimum tilt and vertically - respectively 9 pairs of PV modules of different manufacturers and technologies (Fig.1 from left to right):

- PERC half cell modules with white and black backsheets monofacial (*PERC HC wbs*, *PERC HC bbs*)
- SHJ half cell modules with black backsheet monofacial, with transparent double glass, with white backsheet monofacial (*SHJ bbs, SHJ bifi, SHJ wbs*)
- CIGS blue-colored and a reference transparent double glass module monofacial (*CIGS blue, CIGS ref*)
- PERC shingled cell modules with black backsheet (*PERC sh bbs*)
- PERC IBC full cell module with white backsheet monofacial (*PERC IBC wbs*)

All modules are monitored including IV-scans every 10 s, MPP tracking in between and acquisition of module rear-temperature. Diffuse and global irradiance, ambient temperature, and, spectral data are recorded under the same two orientations [1].

Fig. 1: Outdoor labs in Berlin. Above: nine different module types installed on open racks tilted 35° and 90° facing south. Right: building with facade integrated CIGS blue modules [2].

RESULTS

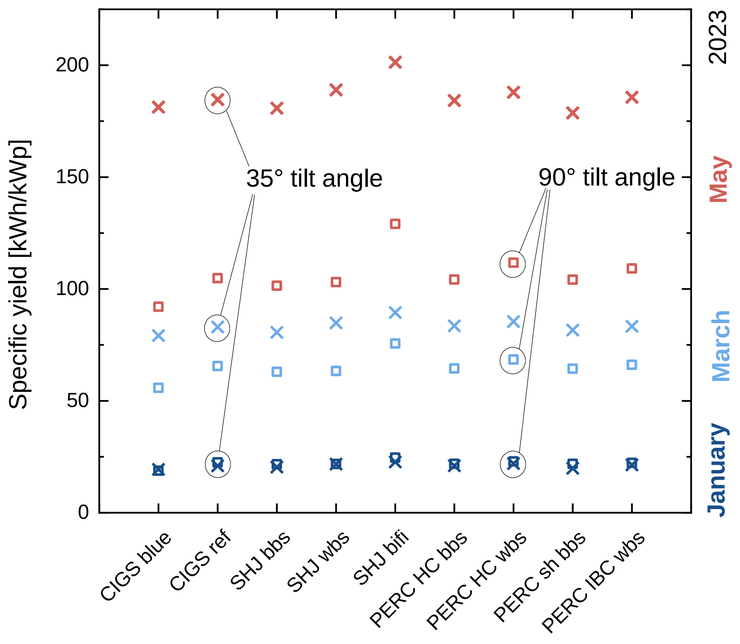


***Fig. 2**: Specific yield of the different module types under 35° and 90° tilt facing south for exemplary months in 2023.*

- SHJ bifi outperforms the monofacialer modules under 35° and 90° - despite a shadowing holder blocking some light on the rear side. Also, as expected, the bifacial yield gain over monofacial is highest in May. (Fig. 2)
- The influence of the tilt angle vanishes for modules in January due to the angles of direct incoming irradiance being flatter. The more diffuse the incoming light, the more favorable for 35° tilted modules. (Fig. 2)
- While the specific yield of modules with black backsheets compared to white is lower under diffuse light/low incidence angles, the difference is more pronounced the higher the irradiance and yield (Fig. 2).
- The specific yield of CIGS blue (135 Wp) compared to the reference module (140 Wp) of the same series is reduced by 12%/15%/17% in the month May/Mar/Jan respectively under 90°, by 2%/5%/8% under 35° (Fig. 2).

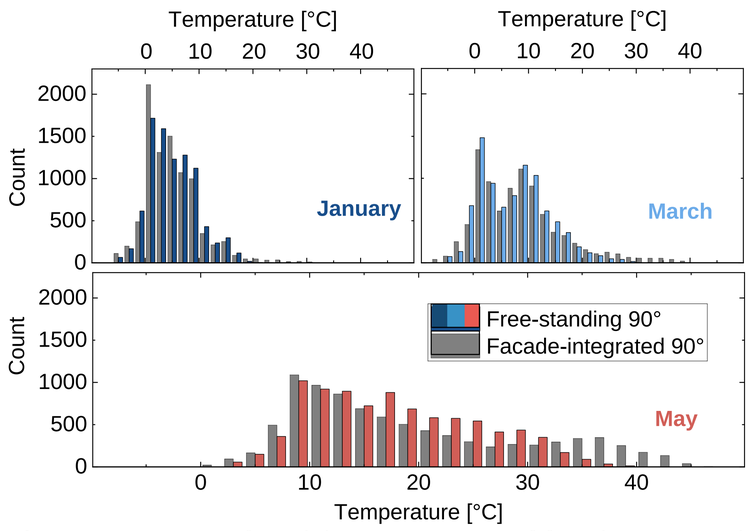
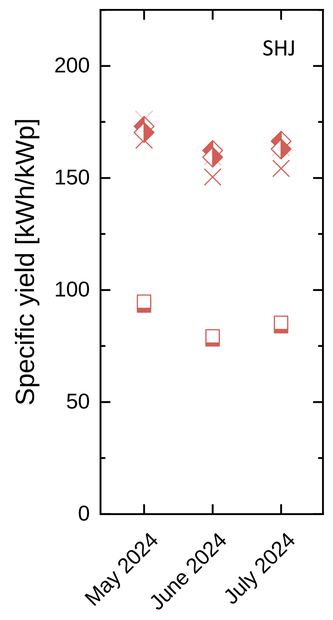


***Fig. 3**: Histograms of module temperatures of facade-integrated and free-standing CIGS blue under 90° facing south in exemplary months in 2023.*



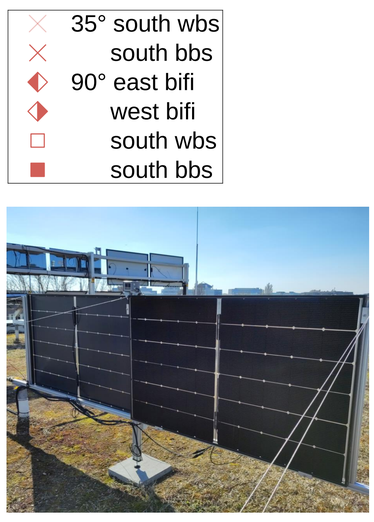


***Fig. 4**: Specific yield of the different SHJ module types under different orientations for exemplary summer months in 2024.*

***Fig. 5 (above)**: Picture of the SHJ bifacial PV modules (now mounted facing east/west)*

- Despite the yield reduction for vertical installations, the facade-integrated modules still amortize for south and west facing facades well within their lifetime. [3]
- Maximum module temperatures of facade-integrated and free-standing systems are very similar in January and March. In May, the facade-integrated system only heats up to max. 10 K above the free-standing system. (Fig. 3)
- SHJ bifi under 90° east-west perform comparable to 35° SHJ bbs and SHJ wbs as shown for May, June, July 2024 (Fig. 4).

SUMMARY

- In May, vertical monofacial modules show a reduced specific yield by in average 44% compared to 35° tilted installations. The difference turns into a 4% gain in Winter.
- The bifacility of SHJ bifi compensates the disadvantage in specific yield due to orientation and tilt compared to monofacial modules installed 35° tilted facing south, during Summer.
- CIGS 90° tilted on open rack: The efficiency delta of 1%$_{abs.}$ between the module with blue-colored front glass and the non-colored reference results in a reduction of specific yield by 12% in May 2023.
- Maximum temperature differences between facades and free standing < 10 K.

MORE INFORMATION

REFERENCES

[1] Paudyal et. al.: „ *Analysis of spectral irradiance variation in northern Europe using average photon energy distributions*.” Renewable Energy, 2024

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[3] Albinius et.al.: „*A comprehensive case study of a full-size BIPV facade*.“ Manuscript submitted to *Solar Energy*, 2024

FURTHER QUESTIONS? GET IN TOUCH!

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