

Analysis and Reduction of Uncertainties in Yield Assessments of Large-Scale Bifacial PV Projects

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Summary



1

Introduction



Motivation

What is the actual bifacial gain on System level in simulation and operation for large-scale projects?



KEY SALIENT FEATURES

-  **Global, Tier 1 bankable brand, with independently certified state-of-the-art automated manufacturing**
-  **Bifacial technology enables additional energy harvesting from rear side (up to 25%)**
-  **Industry leading lowest thermal co-efficient of power**
-  **Industry leading 12 years product warranty**



Außerordentlich witterungsbeständig und robust

Front side performance equivalent to conventional low LID mono PERC:

- High module conversion efficiency (up to 19.3%)
- Better energy yield with excellent low irradiance performance and temperature coefficient
- First year power degradation <2%

Bifacial technology enables additional energy harvesting from rear side (up to 25%)

Glass/glass lamination ensures 30 year product lifetime, with annual power degradation < 0.45%, 1500V compatible to reduce BOS cost

30mm frame design enables easy installation and robust mechanical strength

Solid PID resistance ensured by solar cell process optimization and careful module BOM selection

Multi-Busbar Module could be the option

COMPREHENSIVE CERTIFICATES







The backside makes use of the reflected and scattered light from the surroundings, the modules can yield up to 5%~30% power more, depending on the albedo.



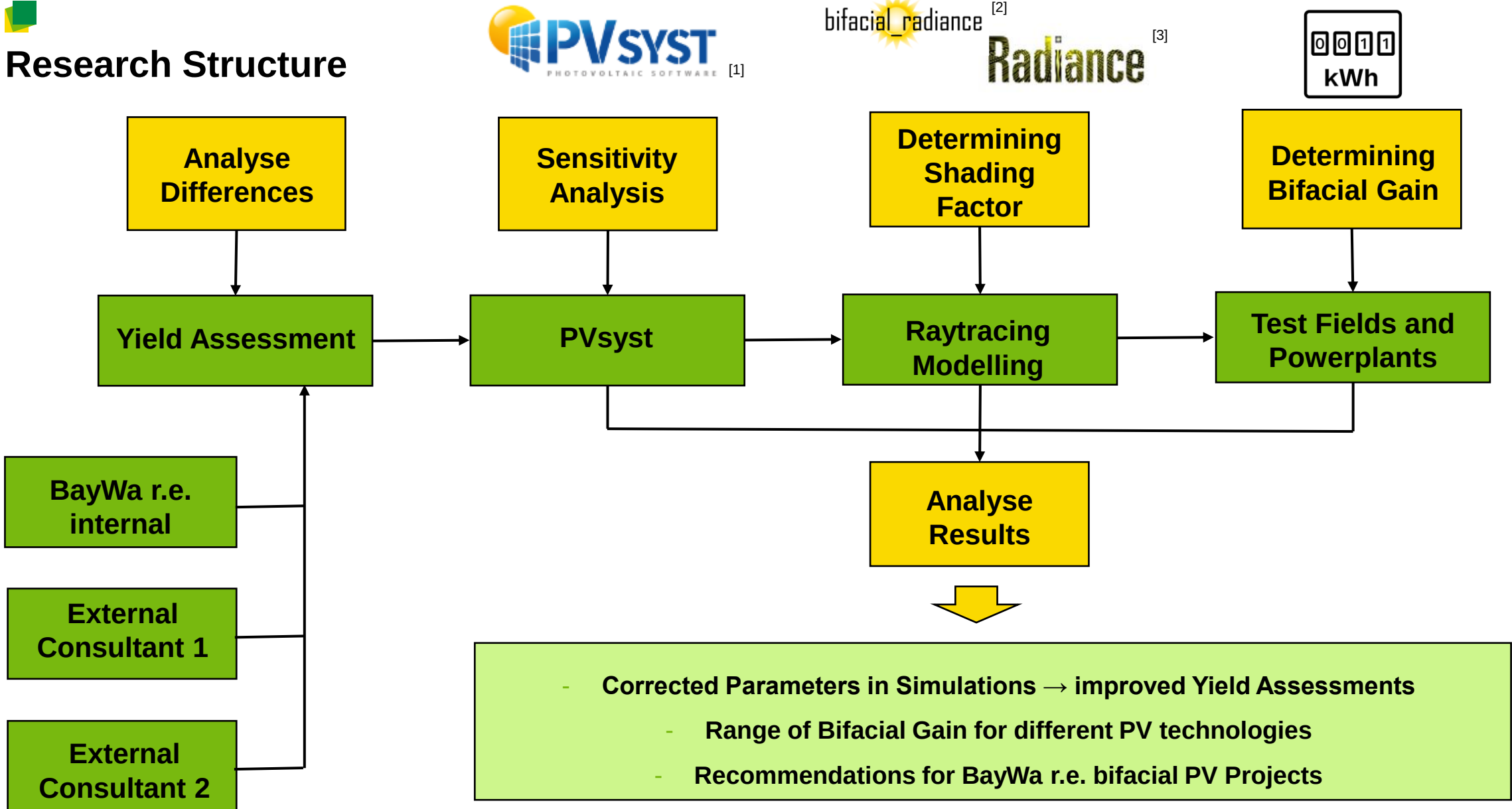
REDUCE INTERNAL MISMATCH LOSS
Reduces mismatch loss and improves output.



APPLICABLE FOR MULTI DIFFERENT ENVIRONMENTS
The wide range of applications, such as BIPV, vertical installation, snow area, high humidity area and strong sandstorm area, etc.



Research Structure



[1] PVsyst Software. <https://www.pvsyst.com/>

[2] Ayala Pelaez and Deline, (2020). bifacial_radiance: a python package for modeling bifacial solar photovoltaic systems. Journal of Open Source Software, 5(50), 1865, <https://doi.org/10.21105/joss.01865>

[3] Ward Larson, G. & Shakespeare, R., 1998. Rendering with Radiance: The Art and Science of Lighting Visualization. San Francisco: Morgan Kaufmann Publishers, Inc.



Bifacial Gain ^[4,5]

Optical Bifacial gain BG_{opt} :

$$BG_{opt} = G_{rear}/G_{front} []$$

With G_{rear} : Irradiation rear side $[kWh/m^2]$

Module Bifacial gain BG_{mod} :

$$BG_{mod} = \varphi * BG_{opt} []$$

With Module Bifaciality φ

System Bifacial gain BG_{sys} :

$$BG_{sys} = E_{rear}/E_{front} = (E_{bifa} - E_{mono})/E_{mono} []$$

With E : Energy output bifacial modules and monofacial modules $[kWh]$

- **Consultants do not always** express the **bifacial gain** based on the **same definition** and do not state clearly which definition they used -> makes comparison difficult

[4] J. S. Stein, C. Reise, J. B. Castro, G. Friesen, G. Mauger, E. Urrejola, and M. Wang, "Bifacial Photovoltaic Modules and Systems: Experience and Results from International Research and Pilot Applications," Report IEA-PVPS T13-14, 2021.

[5] D. Valencia and P. Berthelemy, *PV Modules: Bifacial technology: Global Optimization of Integrated Photovoltaic System for Low Electricity Cost*.

Methodology of Analysing field-measured Data

Comparison Method

- Comparison of the normalized energy output of monofacial and bifacial modules [6]

$$BG_{sys} = \frac{(E_{bifa}/P_{max,bifa} - E_{mono}/P_{max,mono})}{E_{mono}/P_{max,mono}} []$$

With E: Energy output bifacial modules and monofacial modules [kWh]

Irradiance Method

- With two pyranometers, the irradiance received by the rear side and the irradiance received by the front side in the orientation of the array are measured [4]

$$BG_{opt} = G_{rear}/G_{front} []$$

With G_{rear} : Irradiation rear side [kWh/m²]

[4] J. S. Stein, C. Reise, J. B. Castro, G. Friesen, G. Mauger, E. Urrejola, and M. Wang, "Bifacial Photovoltaic Modules and Systems: Experience and Results from International Research and Pilot Applications," Report IEA-PVPS T13-14, 2021.

[6] Internal BayWa r.e. Document, "Quantifying the Field-Measure Bifacial Gain"



2

Results



Yield Assessment Analysis

Parameters to determine bifacial gain

Incident irradiance on the ground

Beam ground factor From sun's position, model

Diffuse ground factor 0.0 % From 2D model

Shed transparent fraction 5.0 % not sensitive

Ground albedo 0.200 ☐ Monthly values

Reflected irradiance on backside

View factor 50.4 % From 2D model

Structure shading factor 5.0 % (0 = no shadings)

PV Array behavior

Mismatch loss factor 10.0 %

Module bifaciality factor 70.0 % from PV module

Parameter	External Consultant 1	External Consultant 2	BayWa r.e.
Albedo	20%	20%	15% - 25%
Structure Shading Factor	20% - 25% (Fixed Tilt) 5% - 7.5% (Tracker)	5%	5% - 6%
Shed Transparent Fraction	?	2% - 8%	5%

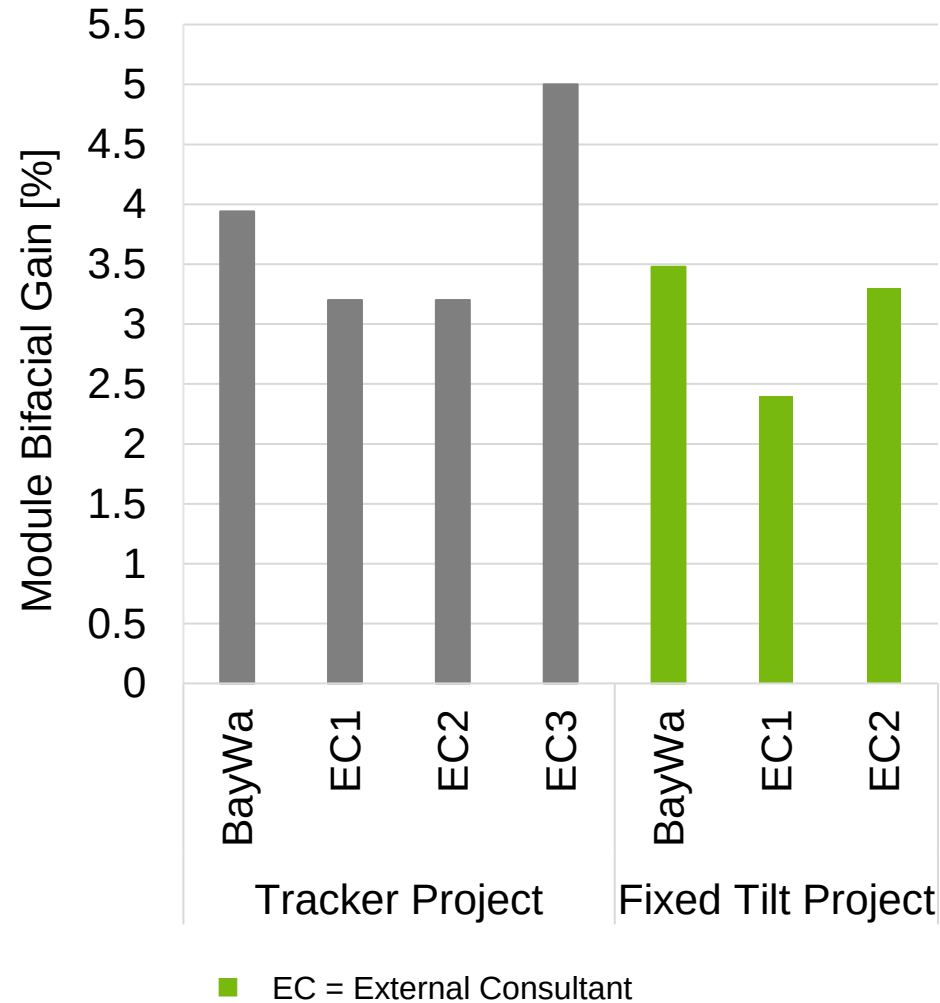
[1] PVsyst Software. <https://www.pvsyst.com/>



Yield Assessment Analysis

Deviations in the Assessment of bifacial gain for Tracker and Fixed Tilt projects

Tracker Module BG:
range of 2.2% - 6.0%

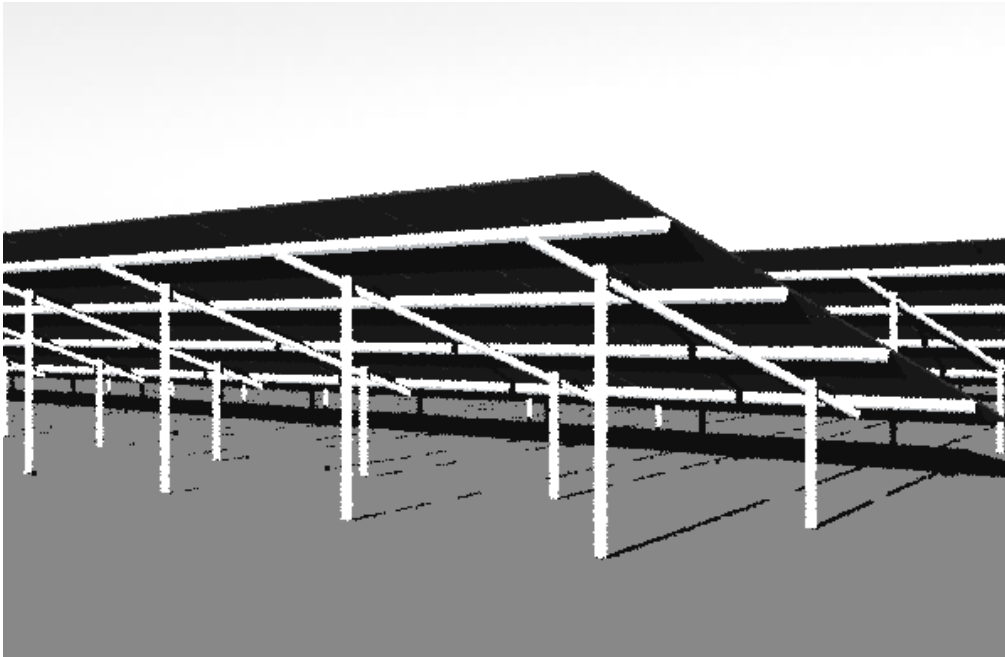


Fixed Tilt Module BG:
range of 0.7% - 4.5%

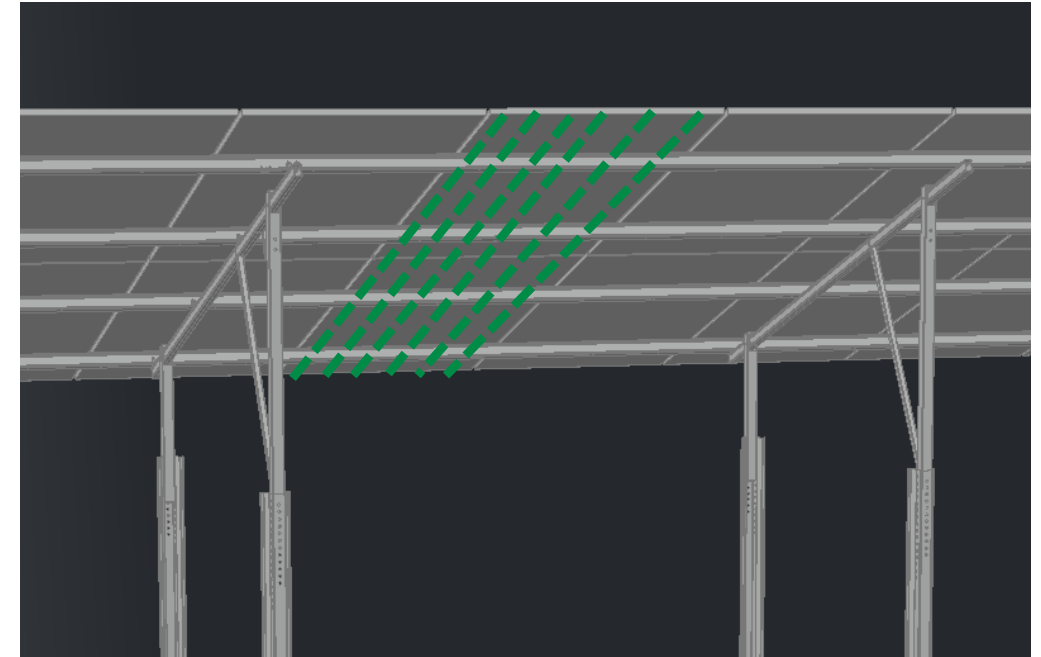


Simulations

Shading Factor Analysis



➤ Rendering picture



➤ AutoCAD drawing with sensor placement

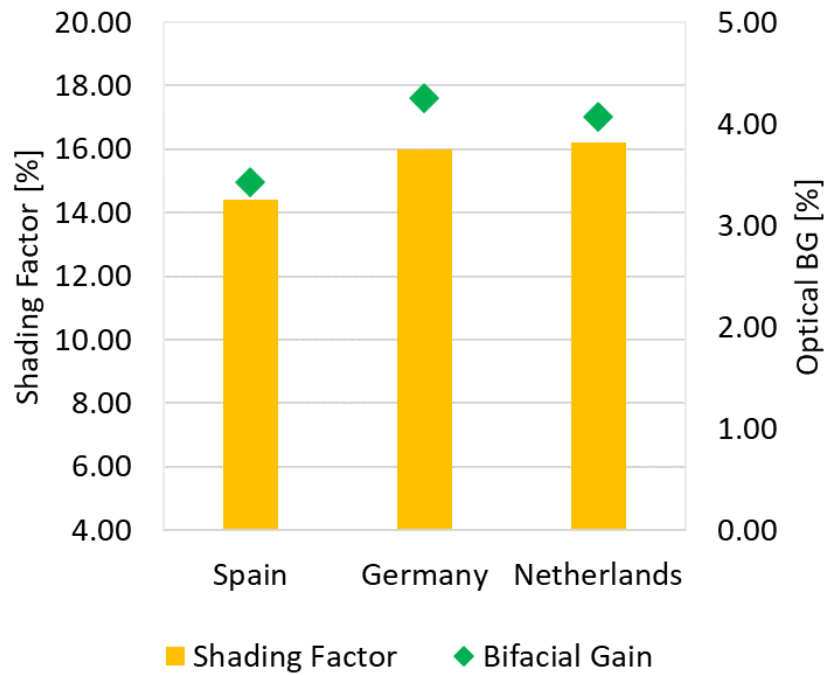
$$SF [\%] = \frac{\sum_{n=0}^N G_{rear,without\ substructure} - \sum_{n=0}^N G_{rear,with\ substructure}}{\sum_{n=0}^N G_{rear,without\ substructure}} * 100 \quad [7]$$



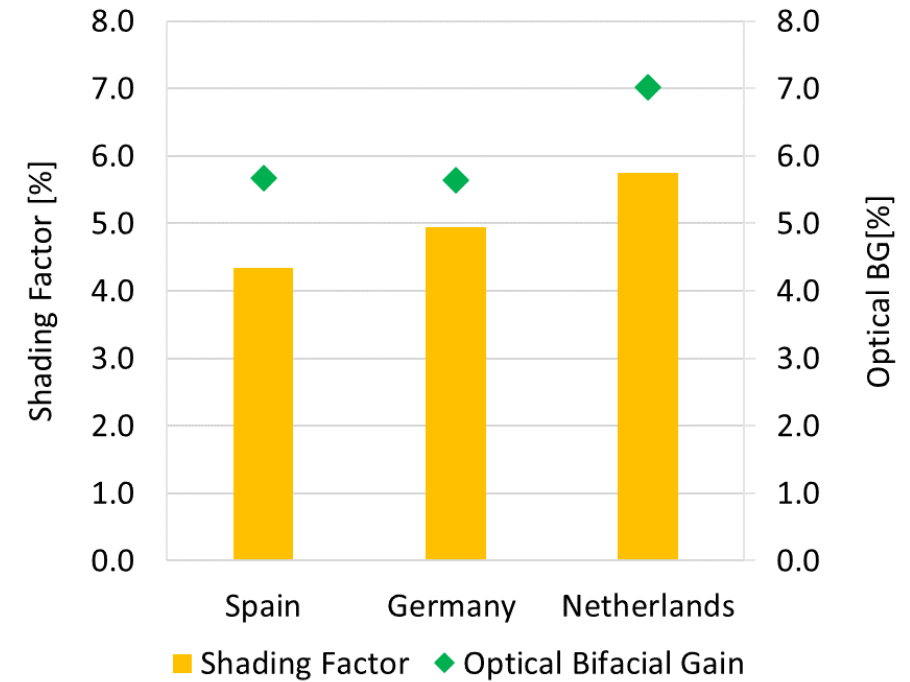
Simulations

Shading Factor Analysis

Fixed Tilt



Tracker

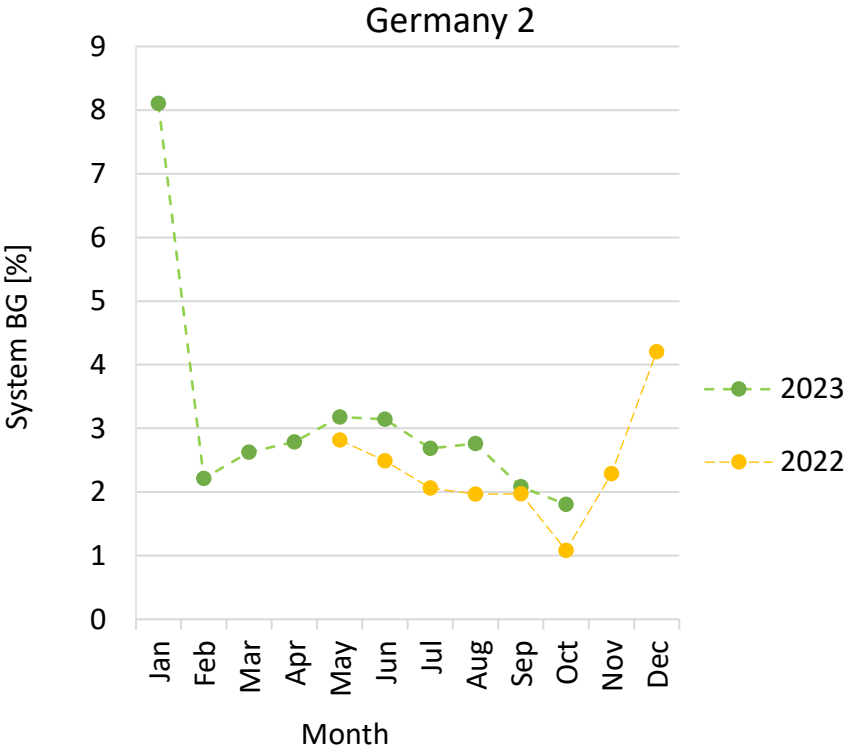
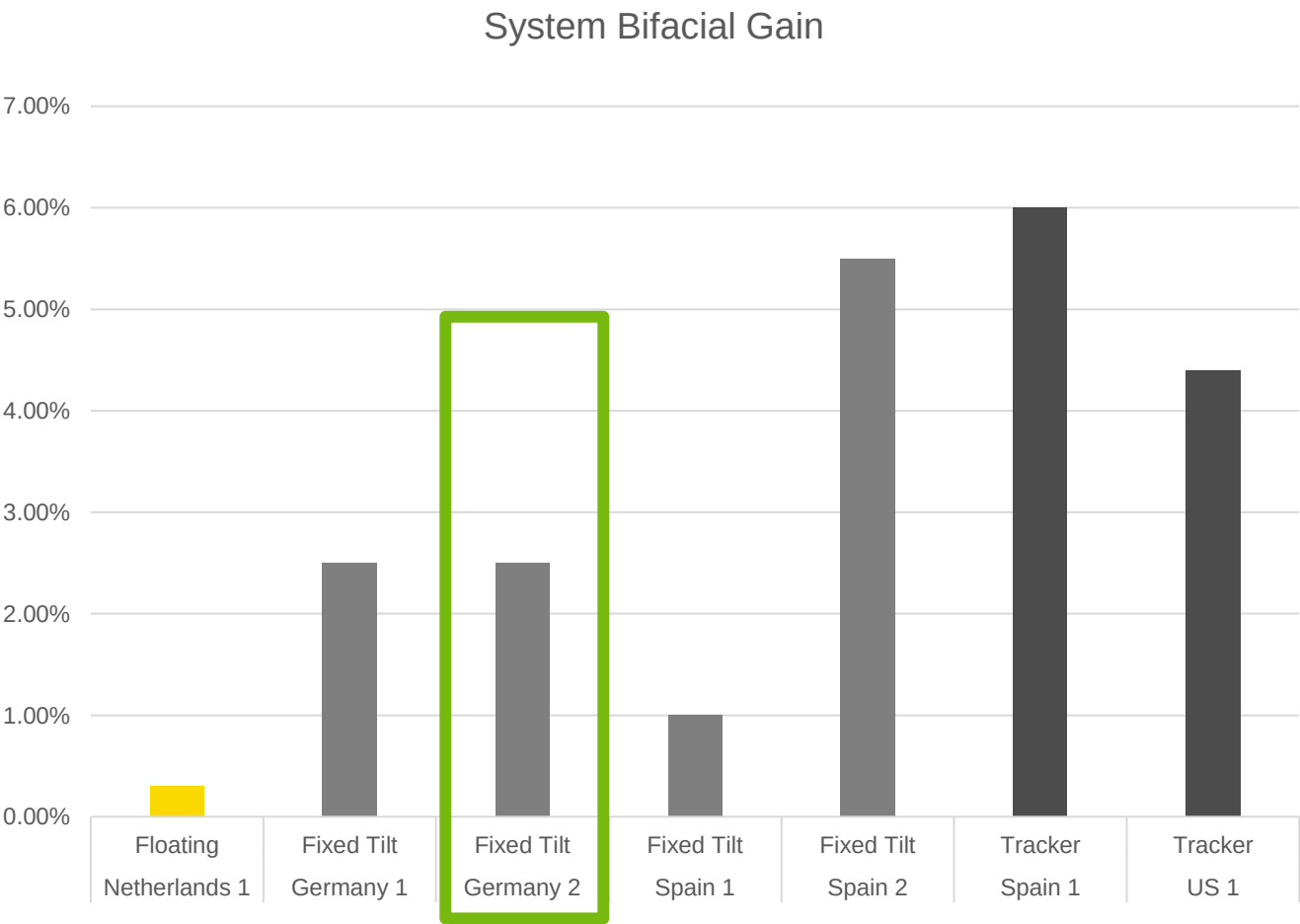


➤ Shading Factor increases slightly with increasing latitude



Powerplant Analysis

Analysing Test Fields and Power Plants – Results



- High peaks in winter: snow → high albedo
- Average system bifacial gain Germany 2: 2.5%



Powerplant Analysis

Analysing Test Fields and Power Plants – Irradiance Method

- Front side simulation very accurate
- Rear side simulation below measurements
- Reasons:
 - Albedo is not exact
 - Measurement Uncertainty
 - Placement of pyranometer not favorable

Optical Bifacial Gain	Pyranometer Rear Side	PVsyst
Spain 1 (Fixed Tilt)	7.5%	5.6%
Spain 1 (Tracker)	10.6%	8.4%
US 1 (Tracker)	9%	7.2%



Proposed Correction Factors

Parameter	BayWa r.e.	External Consultant 1	External Consultant 2	Correction
Albedo	15% - 25%	20%	20%	Site Specific
Structure Shading Factor Fixed Tilt	5%	20% -25%	5%	15%
Structure Shading Factor Tracking	5%	5% - 7.5%	5% - 6%	4.5%
Shed Transparent Fraction	5%	?	2% - 8%	5% (Calculation Tool for new modules)



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Summary



Summary

System Bifacial Gain for Different Technologies

Floating E-W
~0.3%



Fixed tilt
1.0% - 4.0%



Agri Fixed Tilt
3.5% - 5.0%



Tracking
4.0% - 6.0%



Agri Tracking
6.0% - 7.3%





Summary

Outcomes

- Communicate and discuss research results with **third parties** (crucial point for PR guarantee)
- Equip new plants with **albedometers and pyranometers** or **reference cells** on **multiple positions** of the module to **verify** simulated **parameters and albedo values**
- Adapt developed tools and methods to changes in standard system

Outlook

- New large-scale bifacial plants go into operation within this and next year → verify results of this research
- Topcon modules are integrated within the next year → higher bifaciality



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References

- [1] PVsyst Software. <https://www.pvsyst.com/>
- [2] Ayala Pelaez and Deline, (2020). bifacial_radiance: a python package for modeling bifacial solar photovoltaic systems. Journal of Open Source Software, 5(50), 1865, <https://doi.org/10.21105/joss.01865>
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- [5] D. Valencia and P. Berthelemy, *PV Modules: Bifacial technology: Global Optimization of Integrated Photovoltaic System for Low Electricity Cost*.
- [6] Internal BayWa r.e. Document, “Quantifying the Field-Measure Bifacial Gain”
- [7] C. Zhao, J. Xiao, Y. Yu, and J.-N. Jaubert, “Accurate shading factor and mismatch loss analysis of bifacial HSAT systems through ray-tracing modeling,” *Solar Energy Advances*, vol. 1, p. 100004, 2021.