Uncertainty Quantification of Bifacial Performance Modeling

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Abstract

Analysis on uncertainty in the annual energy of PV systems that can be attributed to parameters of particular importance to bifacial PV modules is presented. Monte Carlo simulations are used to evaluate the effect of uncertain module bifaciality factors, module transmission fractions, albedo values, and ground clearance. The analyses cover a wide spectrum of potential PV array archetypes through variation of installation parameters. The results of the Monte Carlo analysis reveal that the uncertainty is largely dependent on albedo uncertainty, but more simulations are needed to identify trends across system archetypes. The simulations are aimed at attributing an annual energy uncertainty factor for bifacial considerations that can be applied in post-processing of project probability of exceedance analysis.

Introduction

- Bifacial modeling in pySAM [1,2]: Python wrapper of System Advisor Model (SAM) detailed PV and financial calculations
- Four key bifacial variables that are difficult to measure/quantify:
- **Albedo**: percentage of light reflected from ground surface; useful for ground reflected irradiance on both module front and rear surfaces
- **Bifaciality:** rated performance of module back surface relative to front surface performance for same reference conditions
- **Hub height**: height of fixed-tilt module midpoint, single-axis tracker array tracker height above ground
- **Transmission factor**: percentage of light that is transmitted through rear surface of module

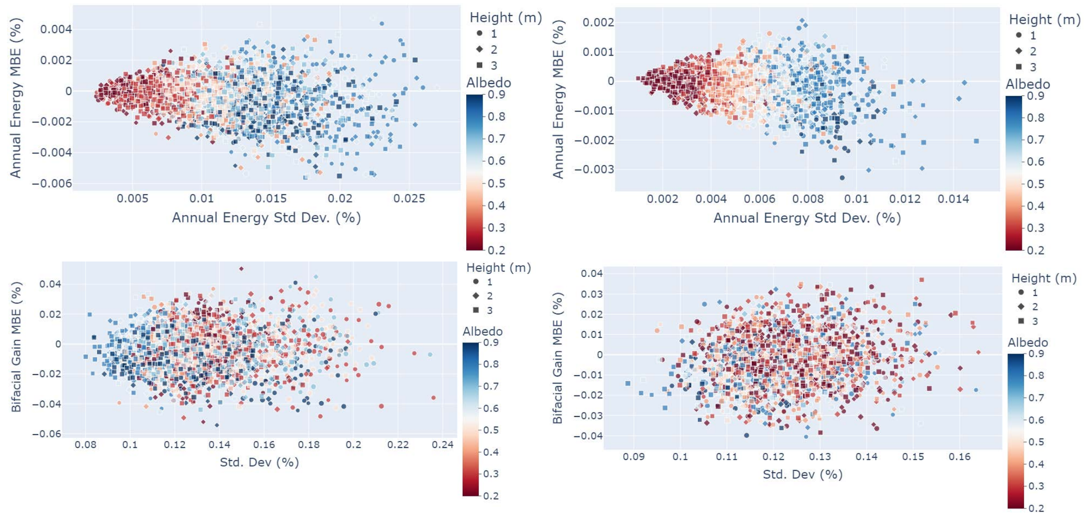
Bifacial Modeling

- Four variables varied +- 10% of original archetype value:
- 100 variable distribution samples based on Monte Carlo sampling
- Each archetype: calculate annual energy reference point and annual bifacial gain
- Pull Monte Carlo sample, calculate annual energy MBE and Std Dev from reference
- Average MBE and Std for 100 samples, examine results from various archetypes for trends

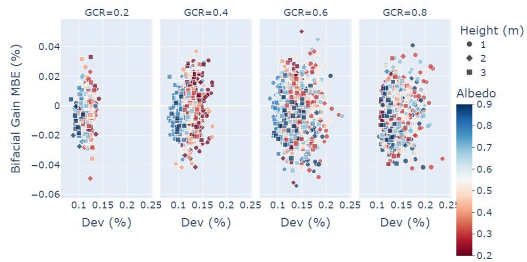
System archetype variable bounds for bifacial sensitivity analysis

Variable	Units	Lower Bound	Increment	Upper bound
Tilt angle	deg	0	10	40
Azimuth	deg	0	90	270
Ground clearance height	meters	1	1	3
Ground coverage ratio	none	0.3	0.1	0.6
Albedo	none	0.2	0.1	0.9
Bifaciality	none	0.65	0.1	0.95
Transmission fraction	none	0	0.013	0.026
Tracking type	0/1	0 (fixed tilt)	1	1 (single-axis)

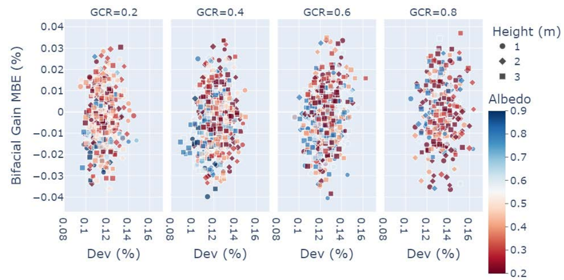
Results



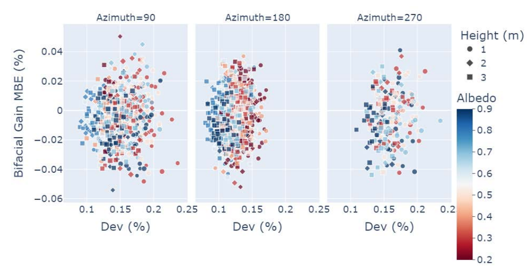
Scatter plot of annual energy (top) and bifacial gain (bottom) for non-tracking (left) and single-axis tracking (right) system archetypes



Fixed-tilt bifacial gain for different system GCR values



Single-axis tracking bifacial gain for different system GCR values



Fixed-tilt bifacial gain for different system azimuth values

Conclusions

- Annual energy comparisons: sensitivity of front surface output combined with rear surface output
- Fixed tilt: high albedo, ground clearance height leads to most narrow bias, lowest deviation from reference energy
- Albedo primary driver in bifacial modeling bias, standard deviation
- Trends less clear in single-axis tracker systems
- Analysis can be used to quantify uncertainty in bifacial modeling
- Scripts, methodology to be made available for project-specific sensitivity analysis

References

[1] P. Gilman, A. Dobos, N. DiOrio, J. Freeman, S. Janzou, D. Ryberg, "SAM Photovoltaic Model Technical Reference Update". 93 pp.; NREL/TP-6A20-67399, 2018.
[2] PySAM . National Renewable Energy Laboratory. Golden, CO. Accessed. https://github.com/nrel/pysam

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