

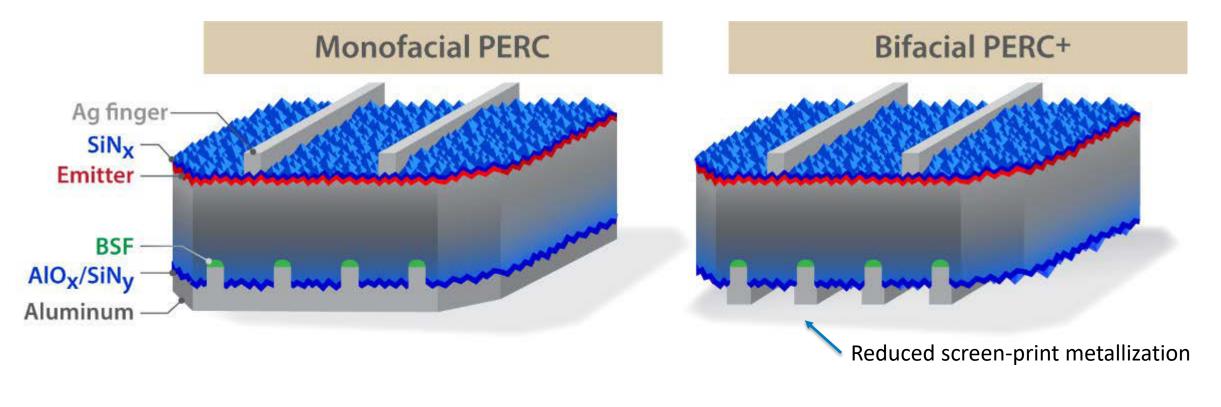
Understanding Bifacial Photovoltaics Potential: Field Performance

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Taiyang News Webinar

December 3, 2019

PERC Cell Technology – Easily Bifacial

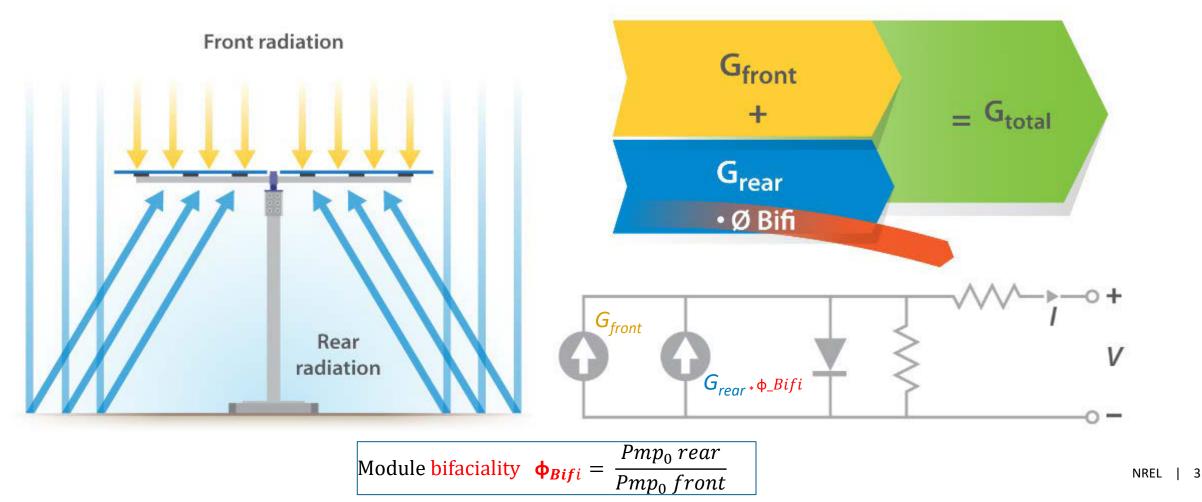


Module bifaciality
$$\phi = \frac{P_{Rear}}{P_{Front}} =$$
0.65-0.800.75-0.900.85-0.95(p-PERC)(n-PERT)(Si heterojunction)

T. Dullweber et al., "PERC+: Industrial PERC solar cells with rear Al grid enabling bifaciality and reduced Al paste consumption," *Prog. Photovolt: Res. Appl.* (2015).

Bifacial Total Irradiance

 $\boldsymbol{G_{Total}} = \boldsymbol{G_{Front}} + (\boldsymbol{G_{Rear}}) \times (\boldsymbol{bifaciality}) \times (1 - \eta_{Loss})$

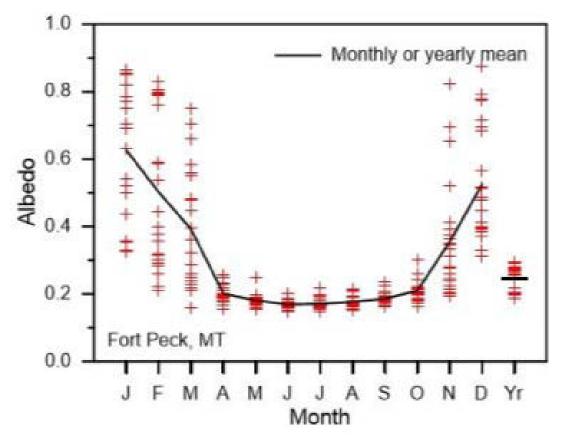


Albedo Variability

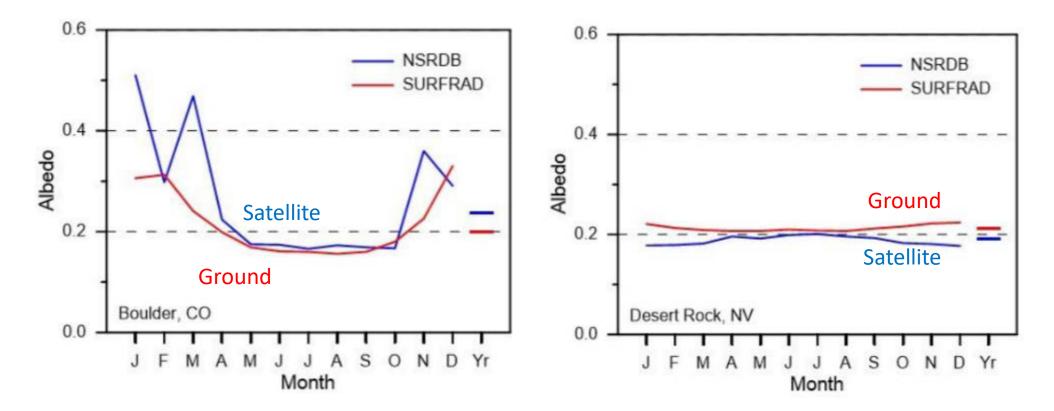
- Albedo is an essential parameter for determining the Earth's energy balance and climate change
- Monthly and year-to-year variability depends on location and ground surface, especially snow
- Site-measured albedo has best accuracy, but satellite data has better coverage.

• Ground data for 37 stations available from the DuraMAT website:

https://datahub.duramat.org/project/albedo-study



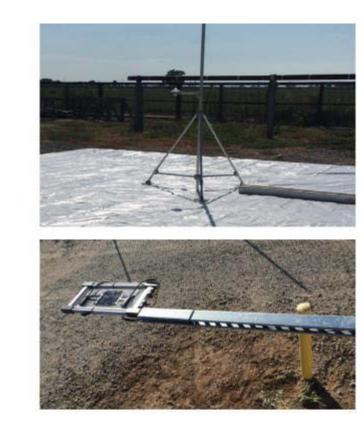
Satellite albedos can be close to measured values, but snow may be problematic for the satellite data.



Site Measurements – Albedo



<u>http://bifipv-</u> workshop.com/fileadmin/images/bifi/denver/presentations/5 Bourne-Albedo measurements bifiPV2018.pdf



Unshaded sensor for expected energy modeling

- Avoid obstructions & self-shading
- Deploy over representative ground cover

Site Measurements – Rear Irradiance

Rear POA for energy yield / capacity testing

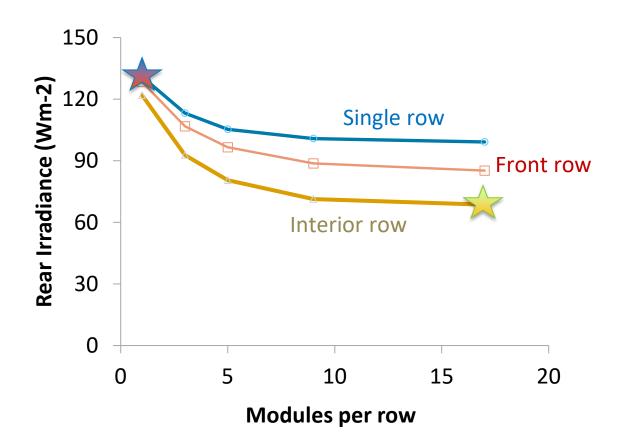
- Deploy within the array (shaded)
- Multiple sensors to capture ground / albedo variability

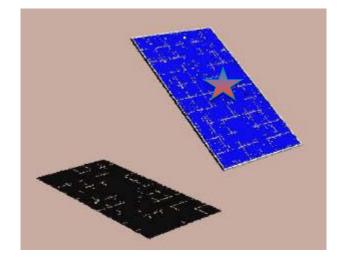
 $E_{\text{monofacial}} \approx f(G_{Front}, T_{\text{mod}}) \quad E_{\text{bifacial}} \approx f(G_{Total}, T_{\text{mod}})$ $G_{Total} = G_{Front} + (G_{Rear}) \times (\varphi_{bifi})$

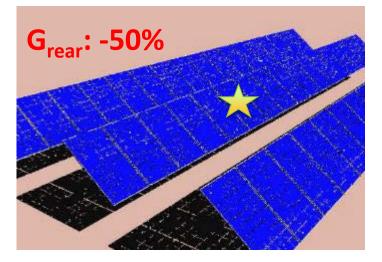


M. Waters, C. Deline, J. Kemnitz, J. Webber, "Suggested modifications for bifacial capacity testing," <u>https://www.nrel.gov/docs/fy20osti/73982.pdf</u>

System Experiences Self-Shading



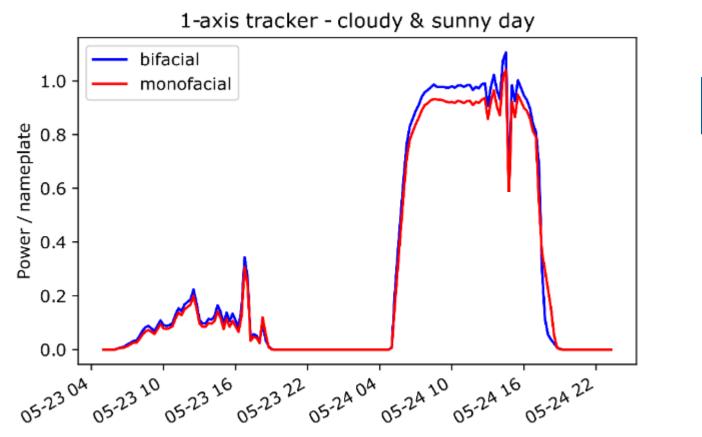




C. Deline et al., "Assessment of bifacial photovoltaic module power rating methodologies – Inside and out," *J. Photovoltaics* **7** (2017).

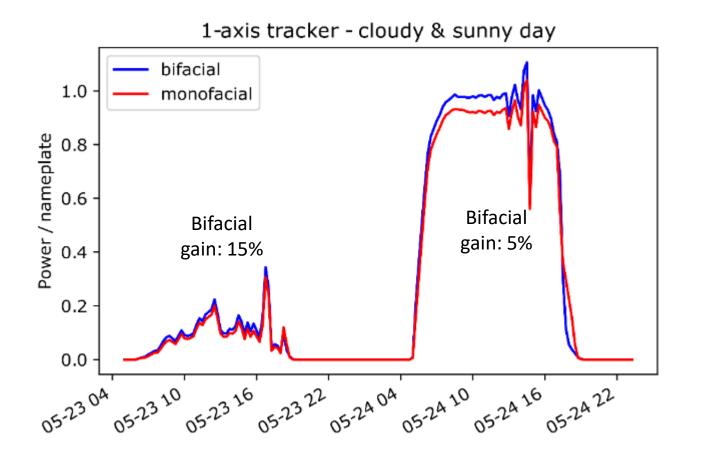
Bifacial trackers, 75 kW Five bifacial technologies

Initial Field Results – Bifacial Trackers



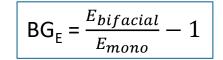


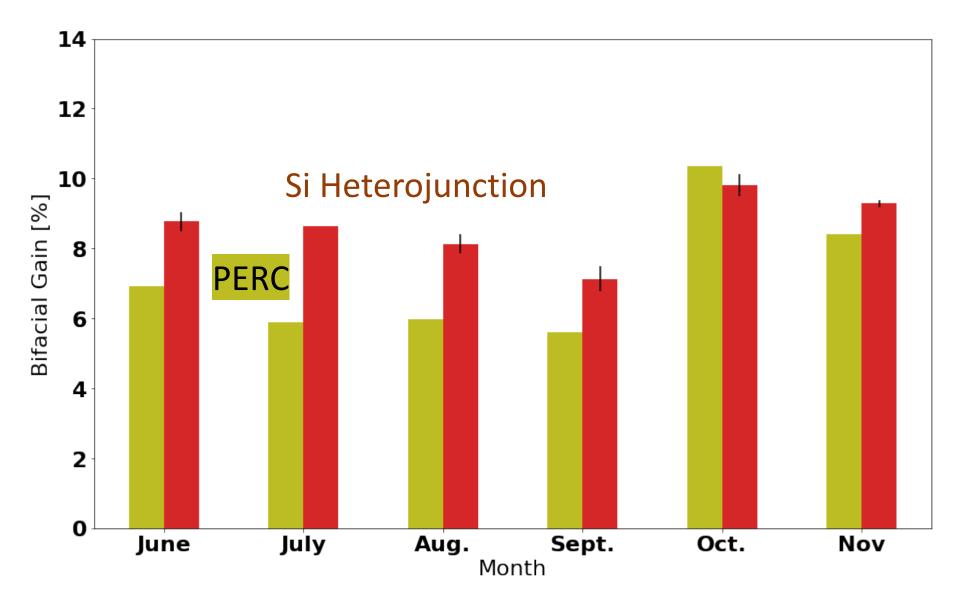
Initial Field Results – Bifacial Trackers



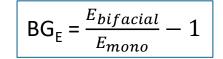


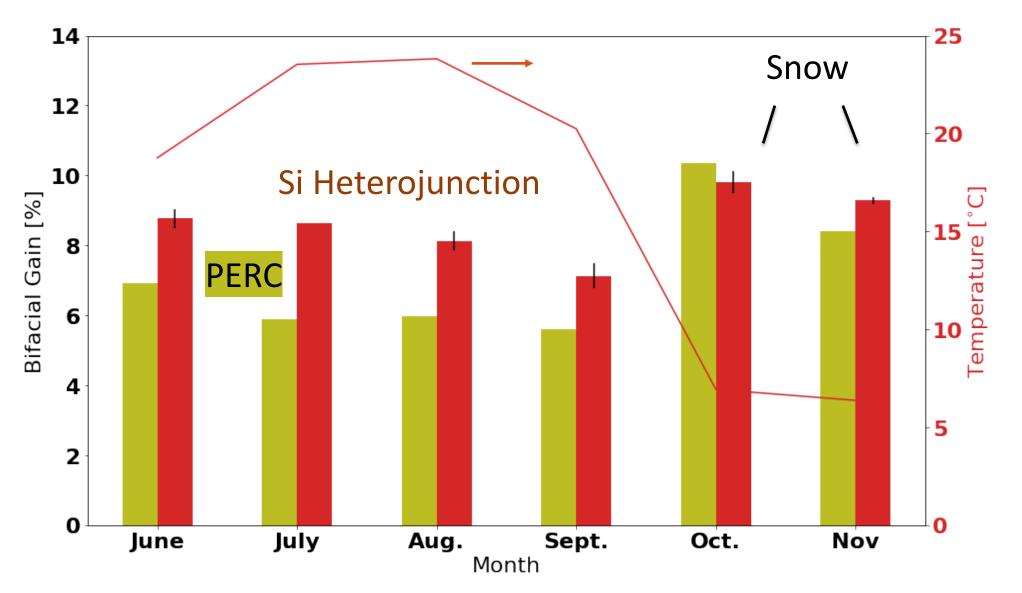
Monthly Bifacial Energy Gain





Monthly Bifacial Energy Gain

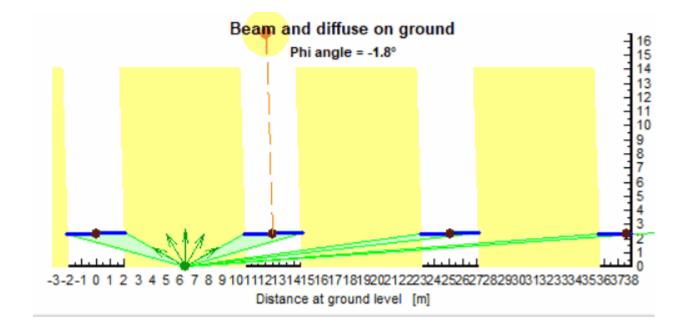




Modeled

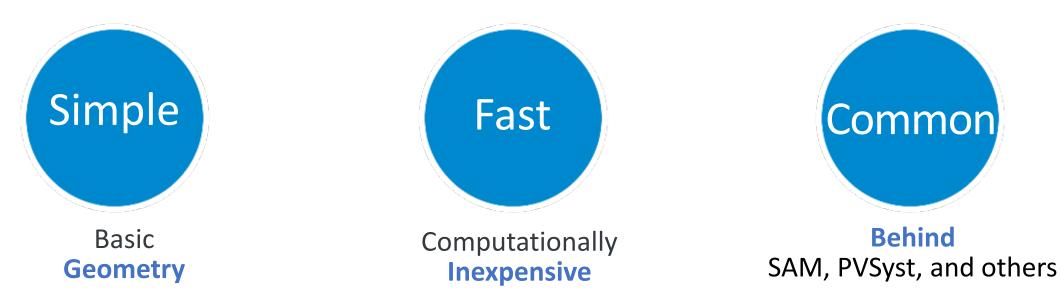
Bifacial Performance

View Factor Models for Rear Irradiance

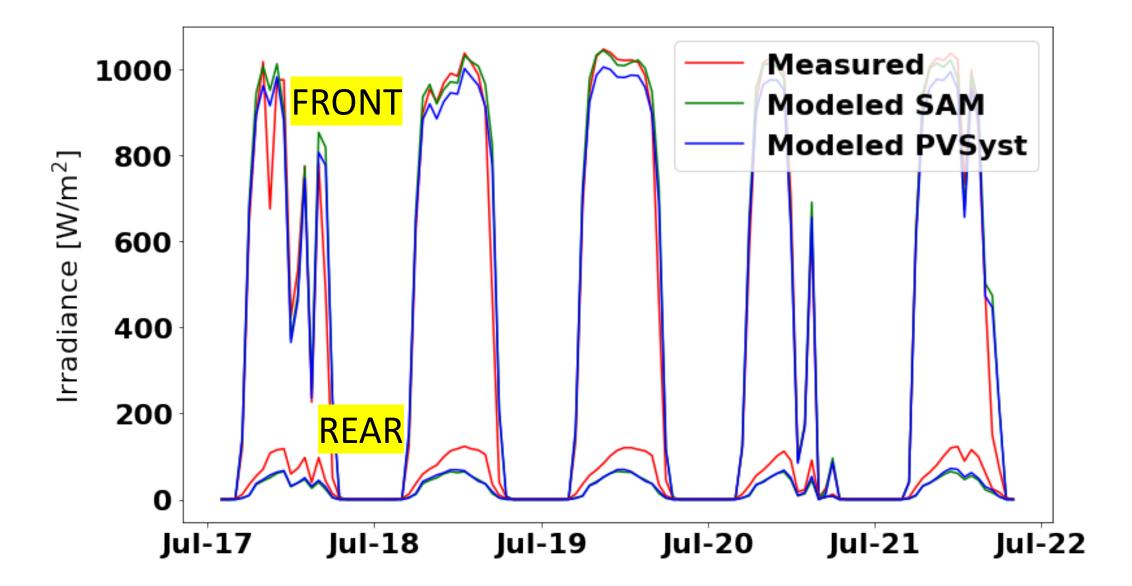


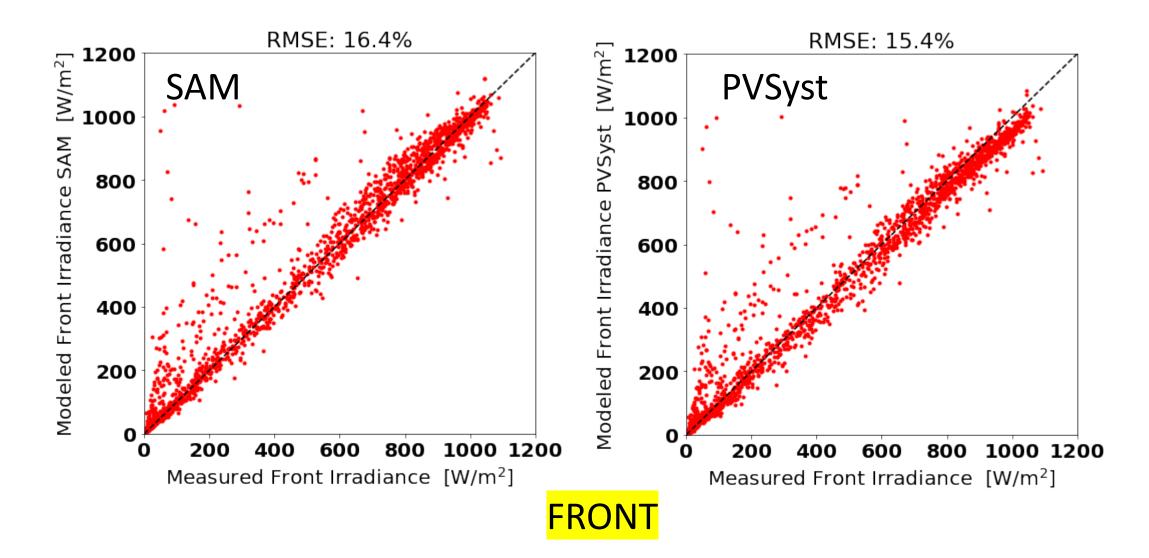
PVSyst v6.8.4

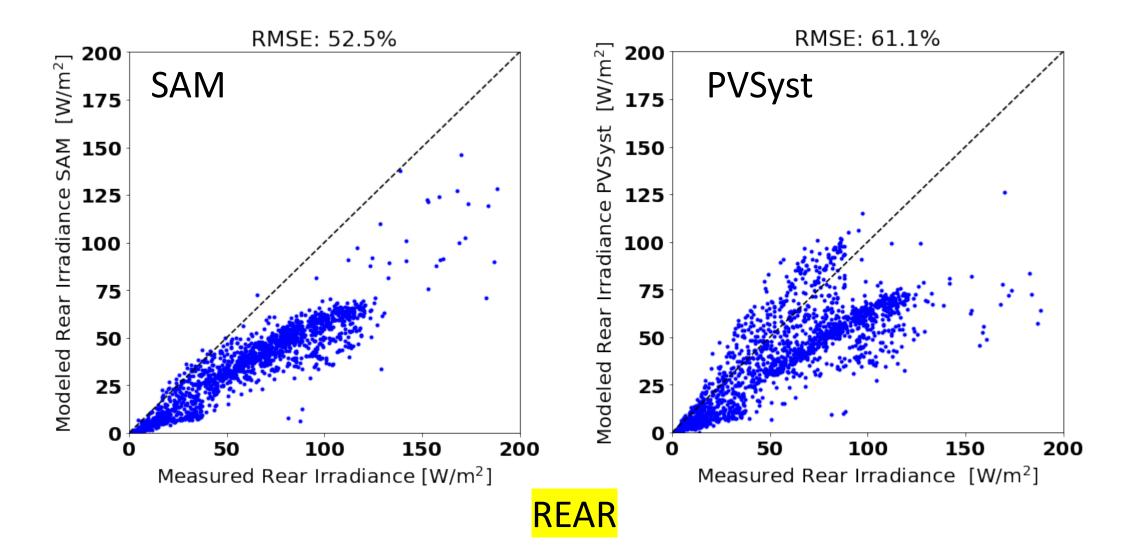
SAM 2018.11.11

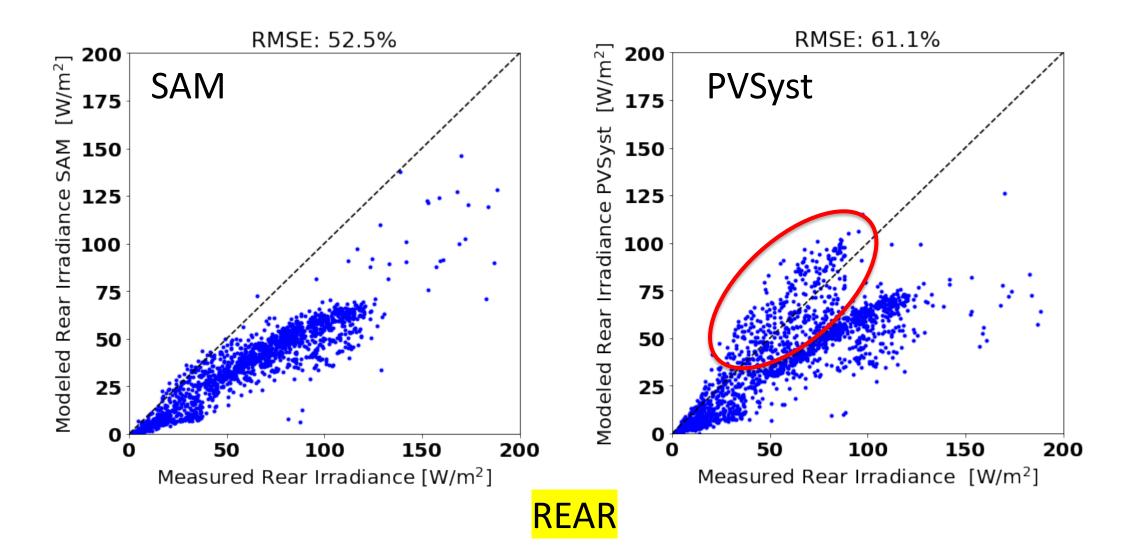


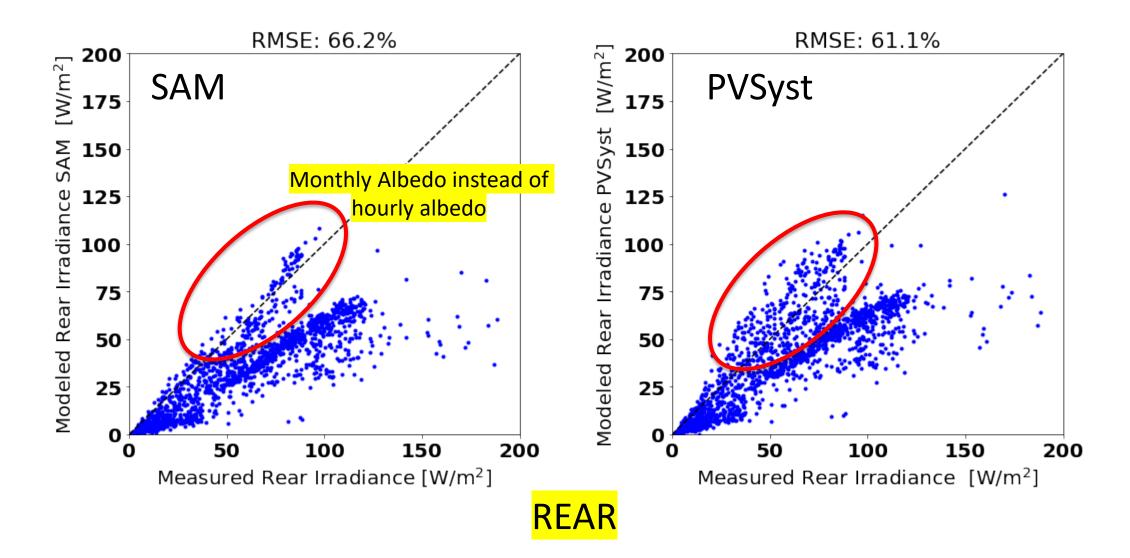
Measured vs Modeled Irradiances



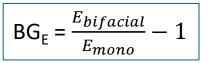


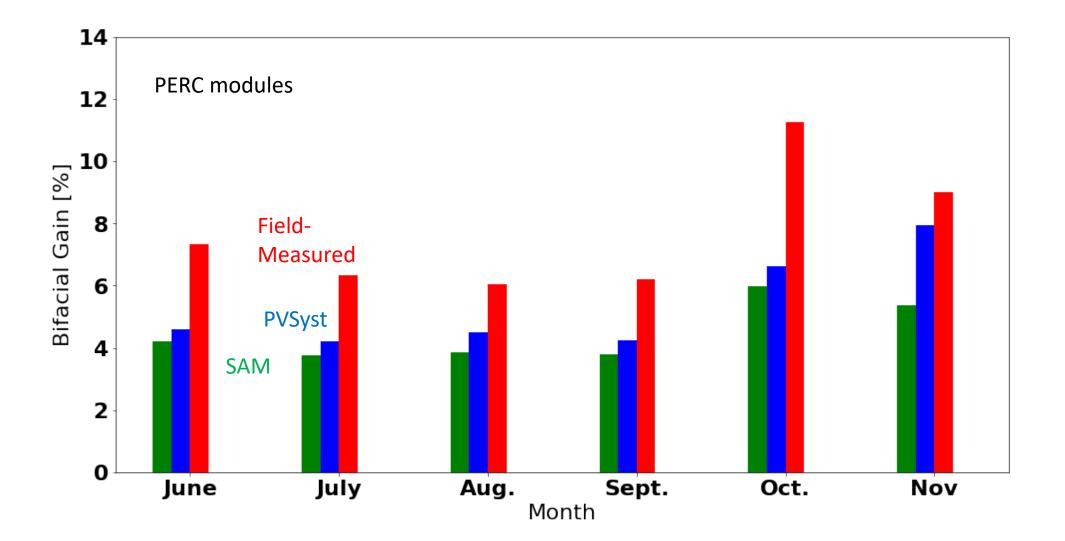






Monthly Bifacial Gain Measured vs. Modeled

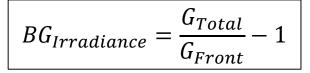


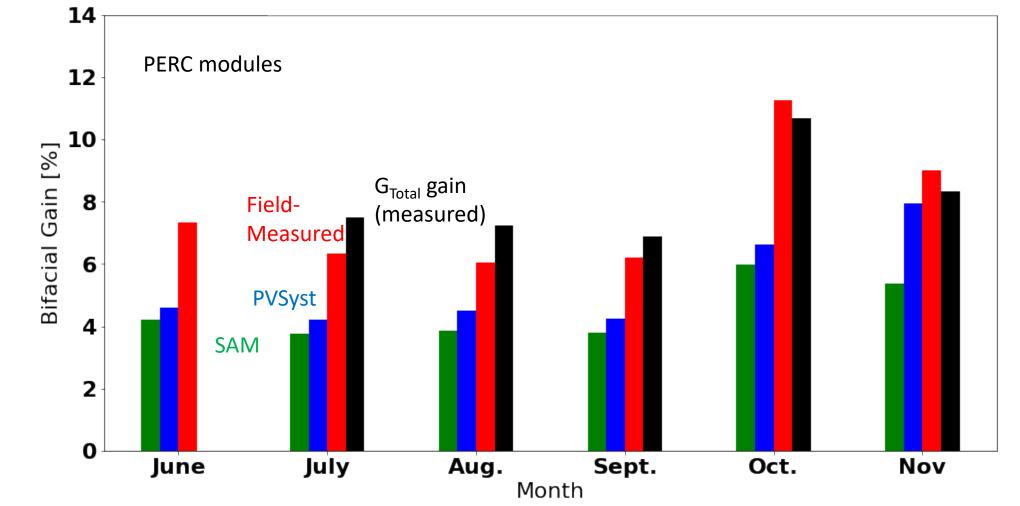


NREL | 21

Monthly Bifacial Gain Measured vs. Modeled

 $BG_{E} = \frac{E_{bifacial}}{E} - 1$ E_{mono}





NREL | 22

Bifacial Radiance Model for Rear Irradiance

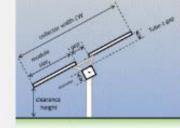


Simulation Control

Terrare Tube Material & Metal Serv. C

1 11

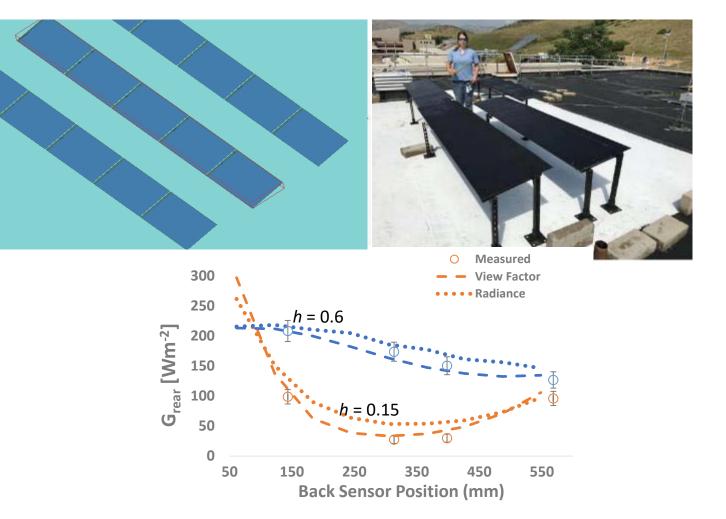
Fixed, Cumulative Sky Yearly					Module	Par
Fixed, Cumulative Sky with Start/End times			Number of Panels			
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Xgap Ygap Zgap:	0.05	0.15	0.10
Bifacial Factor (i.e. 0.9	0:0.9	VIEW	1
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Albedoi	0.62		
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Analysis	Paramet	ers	
# Sensors	9		
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Field validation shows good agreement with close-mount rooftop mockup

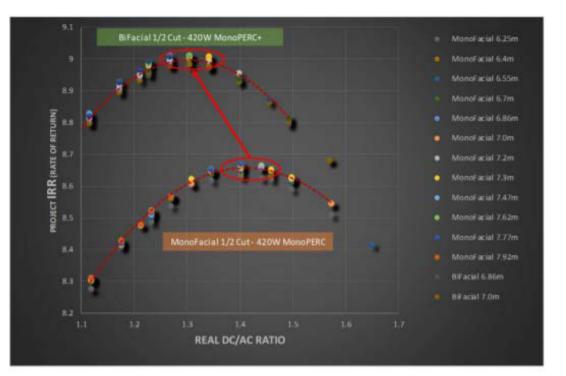
Open-source software freely available at http://www.github.com/NREL/bifacial radiance

S. Ayala Pelaez, C. Deline, S. MacAlpine, B. Marion, J. Stein, R. Kostuk, "Comparison of bifacial solar irradiance model predictions with field validation," IEEE Journal of Photovoltaics 9(1), 82-88 (2019).

BIFACIAL VS. MONOFACIAL SYSTEM DESIGN OPTIMIZATIONS

Project site in California (lower DHI/GHI)





Bifacial field optimizations: GCR <<

DC/AC ratio <<

Itai Suez, 2019 BifiPV Workshop (Amsterdam) <u>http://bifipv-workshop.com/fileadmin/layout/images</u> /bifiPV/presentations2019/bifiPV2019-Silfab_Suez.pdf



Conclusions

- Bifacial PV is becoming mainstream with gigawatts of installed projects.
- Energy gain depends on the site configuration and surface albedo. Models like SAM, PVSyst, and bifacial_radiance can assist with system design and power estimation.
- 1-axis tracker validation is underway at NREL and is showing good bifacial annual energy gain of 6.5% and 9% for PERC and Si-HJT, respectively.
- Model validation is underway, and current VF software (SAM, PVSyst) appears to be conservative relative to measured rear irradiance.

Thank you

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