Preview of SAM's New Model for Bifacial PV Modules

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August 16, 2018

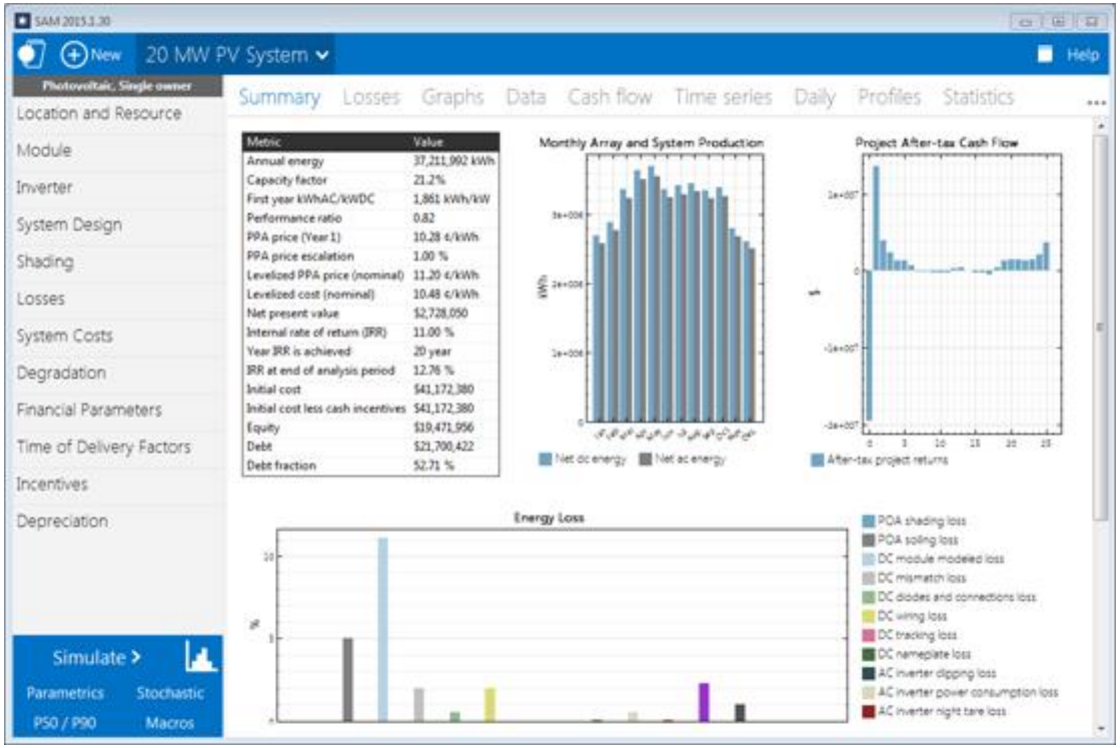
SAM Webinars 2018

- **Preview of SAM's New Model for Bifacial PV Modules, Today**
- Preview of SAM's New Solar Resource Data Download Features, September 13
- Modeling PV Systems with Multiple MPPT Inverters, October 18

- sam.nrel.gov/webinars

System Advisor Model (SAM)

SAM is free software for modeling the performance and economics of renewable energy projects.



http://sam.nrel.gov
github.com/NREL/SAM

- Developed by NREL with funding from DOE
- Windows, OSX, and Linux
- One or two new versions per year
- Software Development Kit (SDK)
- Support
  - Help system
  - Documents on website
  - Online forum
  - Contact form on website

SAM Beta Release

Beta releases expire on 8/13/2019, official release in September 2018.
Please post any feedback to sam.nrel.gov/support or email sam.support@nrel.gov

Windows
https://sam.nrel.gov/sites/default/files/content/public_releases/sam-beta-windows-2018-8-13.exe

Linux
https://sam.nrel.gov/sites/default/files/content/public_releases/sam-beta-linux-2018-8-13.run

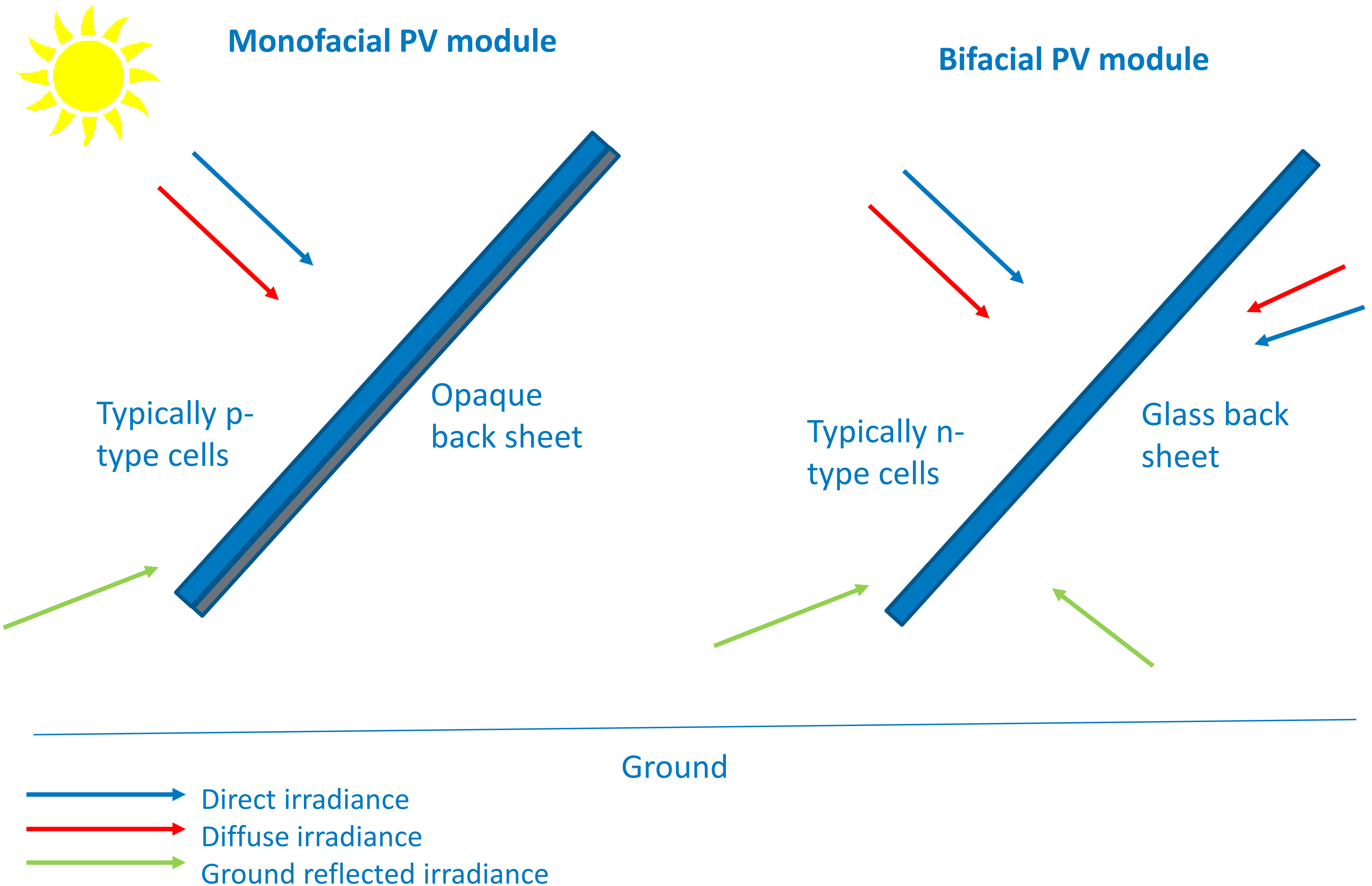
macOS
https://sam.nrel.gov/sites/default/files/content/public_releases/sam-osx-beta-2018-8-13.dmg

SDK version 191
https://sam.nrel.gov/sites/default/files/content/sdk/sam-sdk-191_2018.8.13.zip

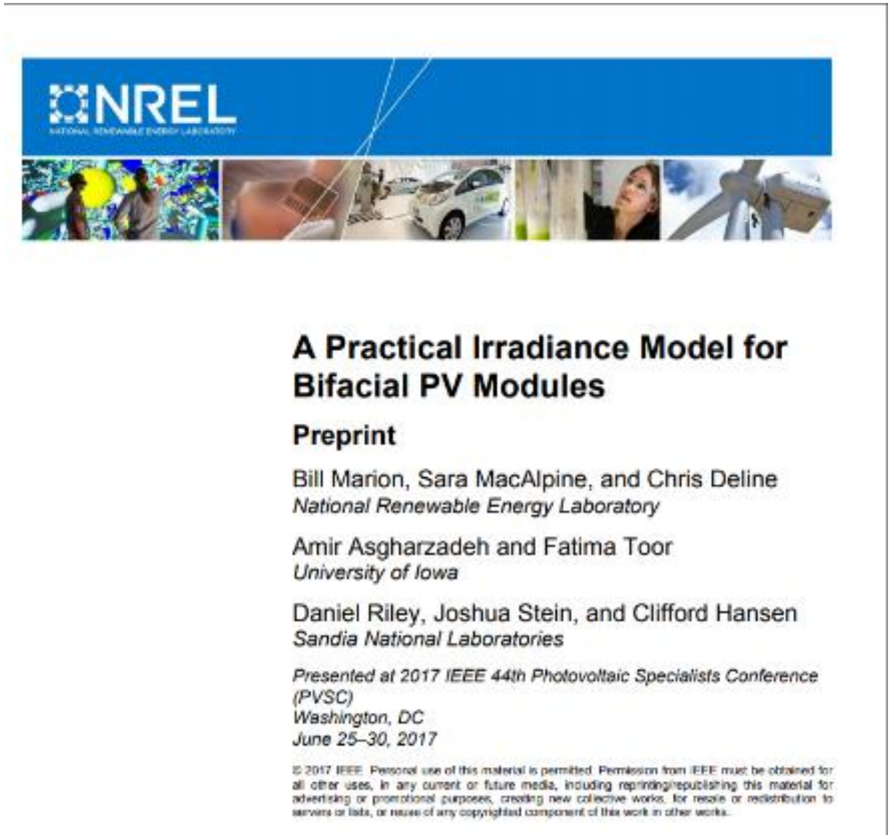
Outline

- Bifacial PV
- Overview of bifacial irradiance model
- Bifacial model implementation in SAM
- Demo
- Q&A

Bifacial vs. monofacial



Bifacial irradiance model


NREL
NATIONAL RENEWABLE ENERGY LABORATORY

A Practical Irradiance Model for Bifacial PV Modules

Preprint

Bill Marion, Sara MacAlpine, and Chris Deline
National Renewable Energy Laboratory

Amir Asgharzadeh and Fatima Toor
University of Iowa

Daniel Riley, Joshua Stein, and Clifford Hansen
Sandia National Laboratories

Presented at 2017 IEEE 44th Photovoltaic Specialists Conference (PVSC)
Washington, DC
June 25–30, 2017

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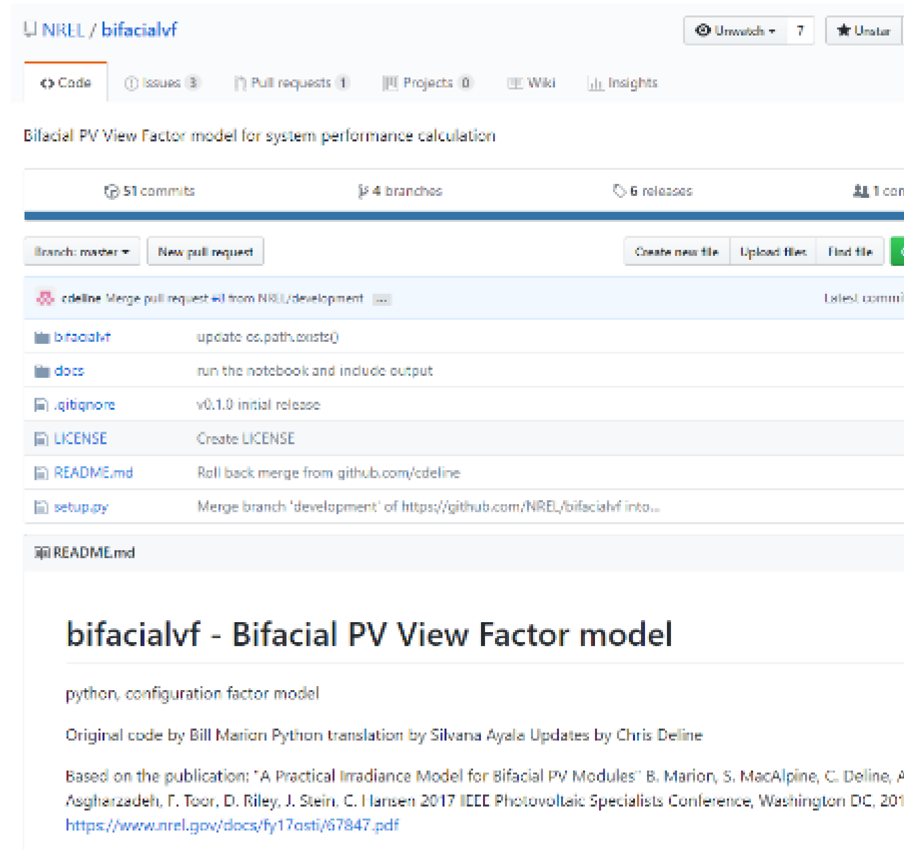
https://www.nrel.gov/docs/fy17osti/67847.pdf

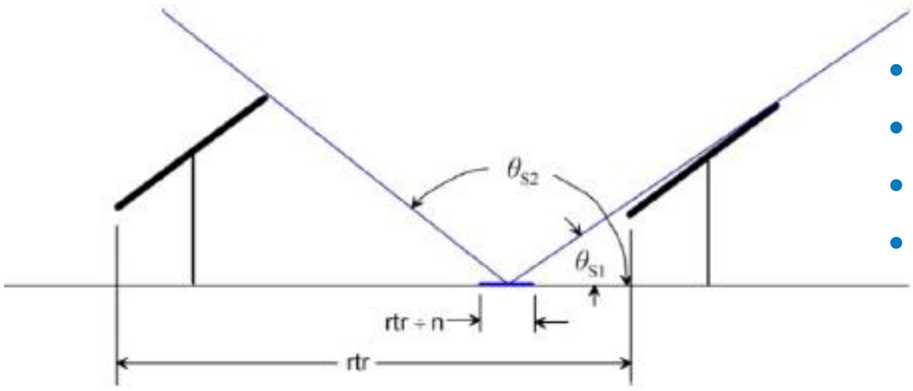


https://github.com/NREL/bifacialvf

SAM Implementation
https://github.com/NREL/ssc/tree/bifacial

Bifacial Irradiance Model Steps

1. Identify ground that is shaded by the PV array



- Calculate sun position
- Project shadows into row-to-row dimension
- Divide row-to-row into n (100) segments
- Identify whether each segment is shaded or not

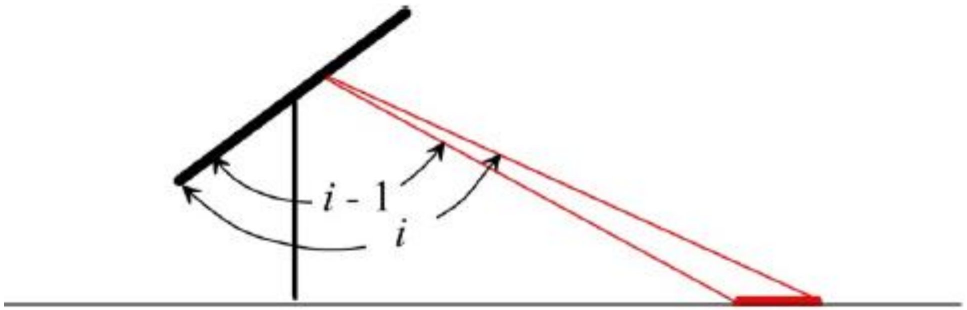
2. Determine irradiance received by the ground by accounting for shading and restricted view of the sky

- Use Perez tilted surface model with DNI and DHI to decompose DHI into circumsolar, sky and horizon components
- For each segment, compute ground irradiance

Images from "A Practical Irradiance Model for Bifacial PV Modules", Marion et al.

Bifacial Irradiance Model Steps

3. Determine the irradiance for the rear-side, which is a sum of:
    a. Irradiance from sky
    b. Irradiance reflected from the ground
    c. Irradiance reflected from the front surface of PV modules in the next row (considering only diffuse radiation)
    d. Irradiance from the sun and circumsolar region of the sky for AOI $< 90°$

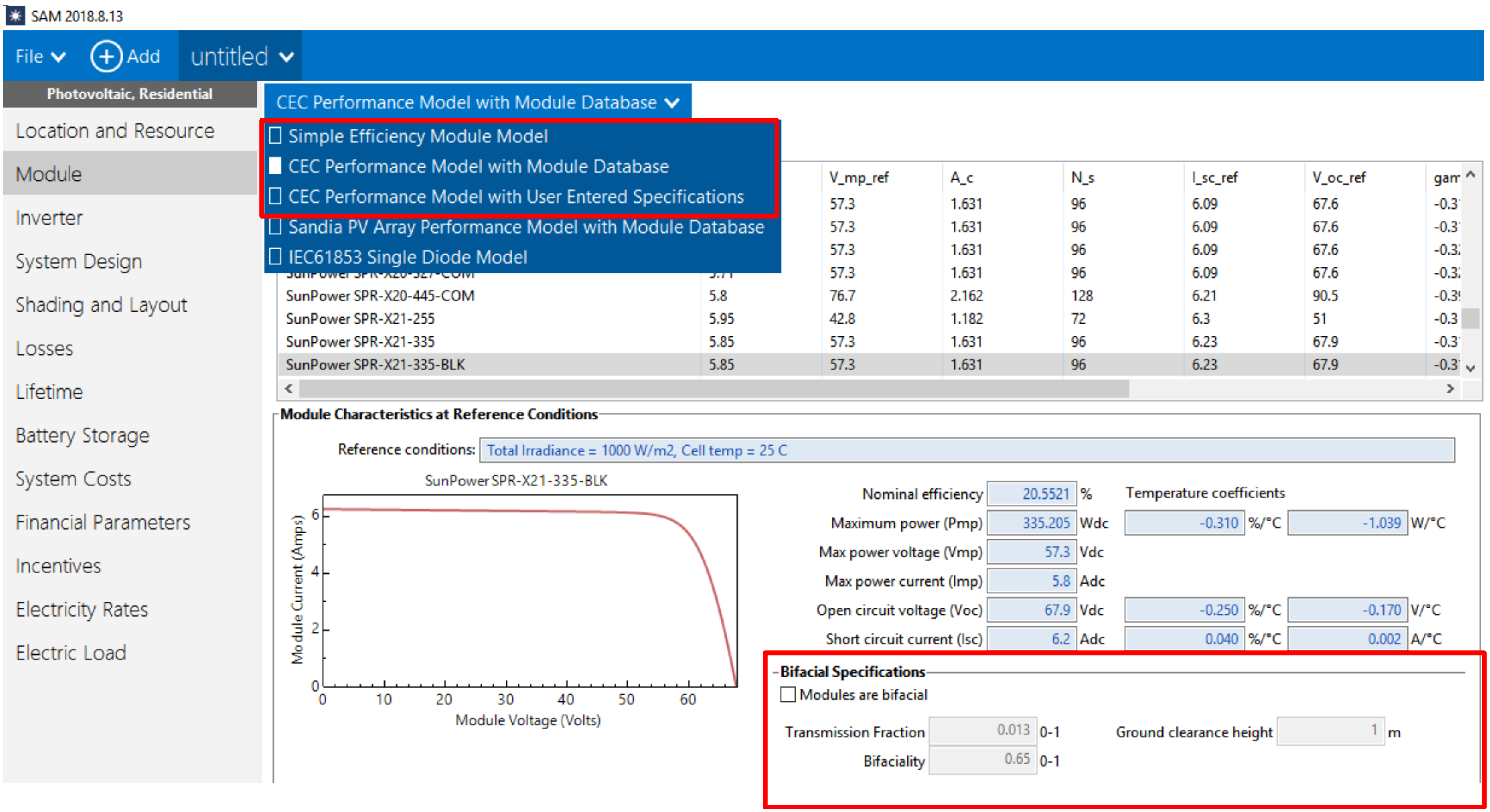


- Diffuse irradiance for back-side is summed by dividing field-of-view into 180 one-degree segments and adding each segments contribution

Model assumptions

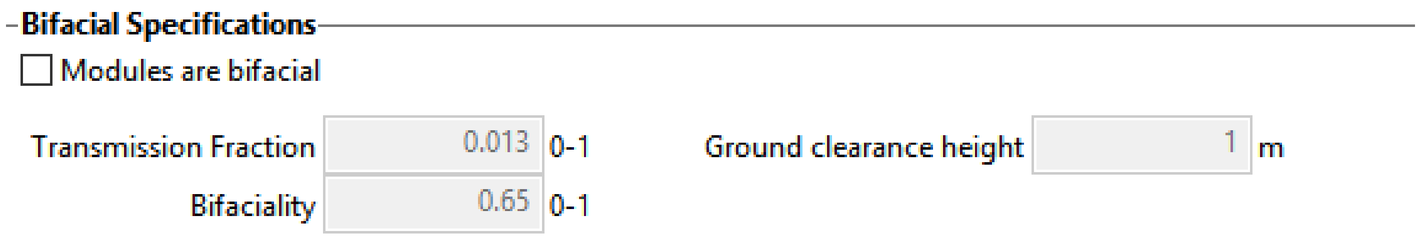
- Applicable for a row or multiple rows of PV modules
- Calculation of configuration factors assumes isotropic radiation
- Bifacial modules are arranged in rows of infinite length (no irradiance variation along length)
  - Bifacial model paper suggests edge effects insignificant for PV system with more than a dozen modules per row.
- The POA rear-side irradiance (weighted by bifaciality) adds to the front-side irradiance.
- Combined irradiance is converted to DC power using single-diode model

Bifacial model in SAM



- Bifacial model available for module models which do not require test data

Bifacial module inputs



Transmission Fraction – A fraction between 0 and 1 specifying the percentage of array row area (including through the modules) that allows light to transmit through from front to rear.

Bifaciality – A fraction between 0 and 1 specifying the relative efficiency of the rear-side compared to the front-side

Ground clearance height – The height from the ground to the bottom of the PV module. For systems with tracking, this is the height at a zero-degree tilt angle.

Bifacial system layout

Self Shading for Fixed Subarrays and One-axis Trackers

Self shading is shading of modules in the array by modules in a neighboring row.

Self shading	Standard (Non-line	None	None	None

Array Dimensions for Self Shading, Snow Losses, and Bifacial Modules

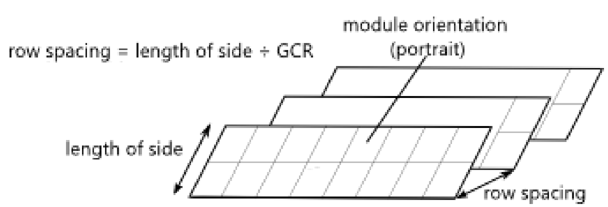
The product of number of modules along side and bottom should be equal to the number of modules in subarray.

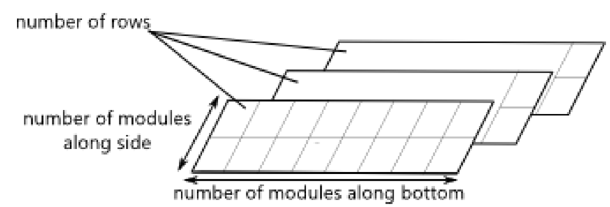
Module orientation	Landscape	Portrait	Portrait	Portrait
Number of modules along side of row	1	2	2	2
Number of modules along bottom of row	7	9	9	9

Calculated System Layout

Number of rows	100	0	0	0
Modules in subarray from System Design page	700	0	0	0
Length of side (m)	1.00031	3.261	3.261	3.261
GCR from System Design page	0.666667	0.3	0.3	0.3
Row spacing estimate (m)	1.50046	10.87	10.87	10.87

Module aspect ratio	1.63	
Module length	1.6305	m
Module width	1.00031	m
Module area	1.631	m^2

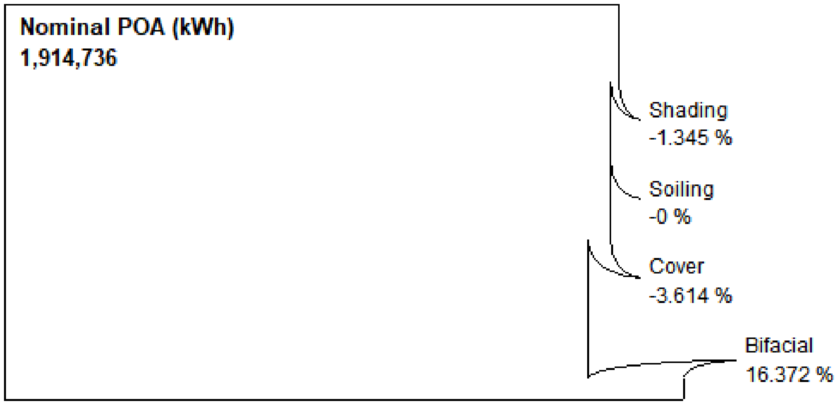




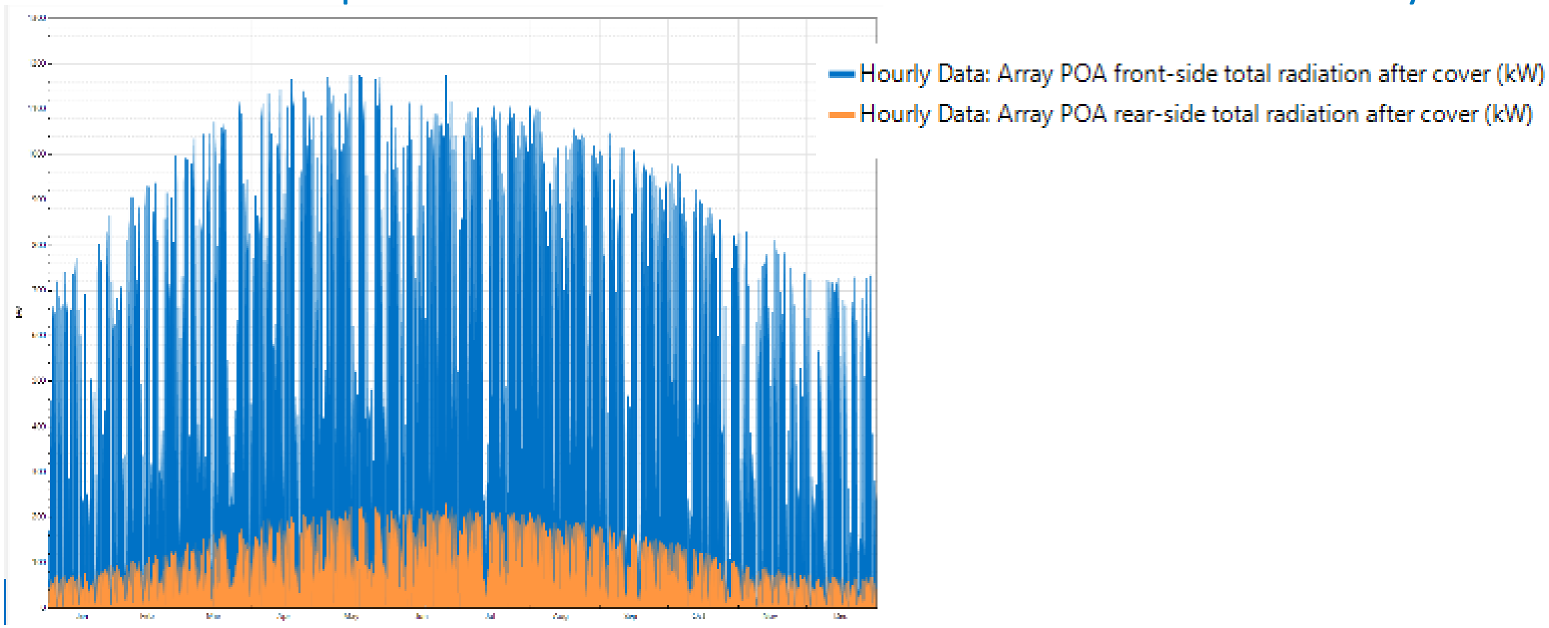
Shading and Layout – Important to turn on self-shading model and configure the geometry of the layout for correct calculation of front-side and rear-side irradiance!

Bifacial model outputs

Updated loss diagram, showing bifacial irradiance gain

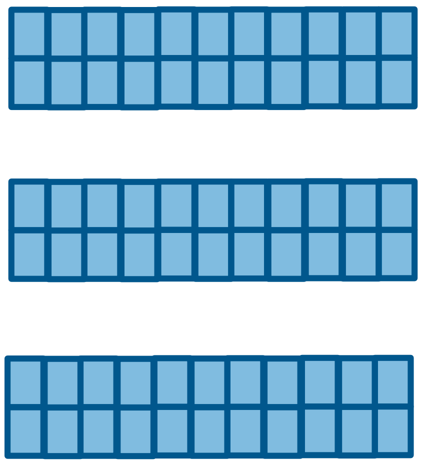


Time series outputs for front and rear-side irradiance for each subarray and total array

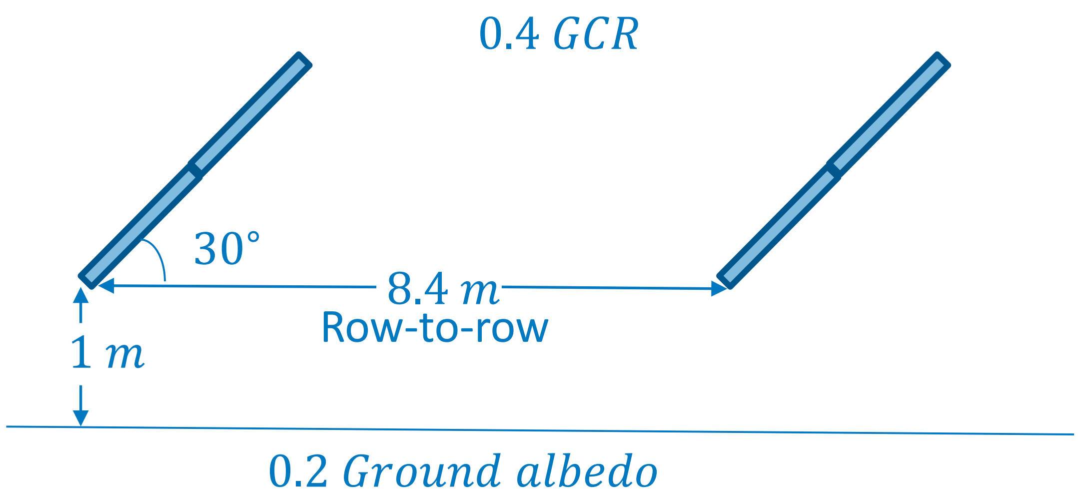


Example analysis

- Evaluate the boost in energy production with bifacial modules compared to a monofacial modules with and without tracking systems.



3 rows of 22 modules



Example results

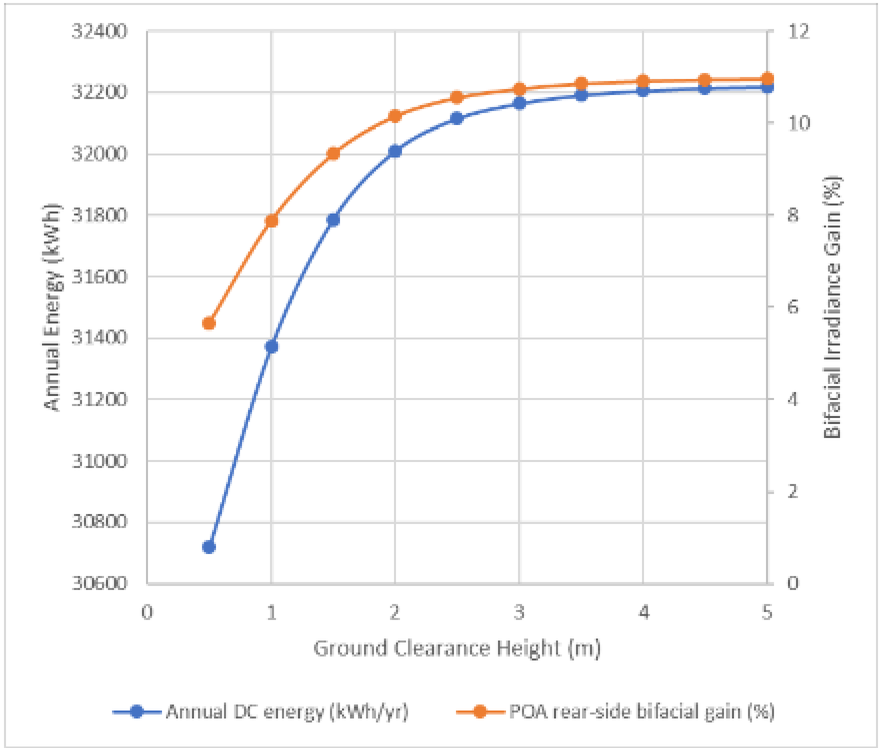
	Monofacial Fixed-tilt	Bifacial Fixed-tilt	Monofacial 1-axis track	Bifacial 1-axis track
POA Annual Irradiance (kWh)	190,961	206,030	254,943	269,416
Irradiance Gain	0%	7.9%	33.5%	41.0%
DC Annual Energy (kWh)	29,051	31,372	36,614	38,734
Energy Gain	0%	8.0 %	26.0%	33.3%

*Gains calculated relative to monofacial fixed-tilt sytsem

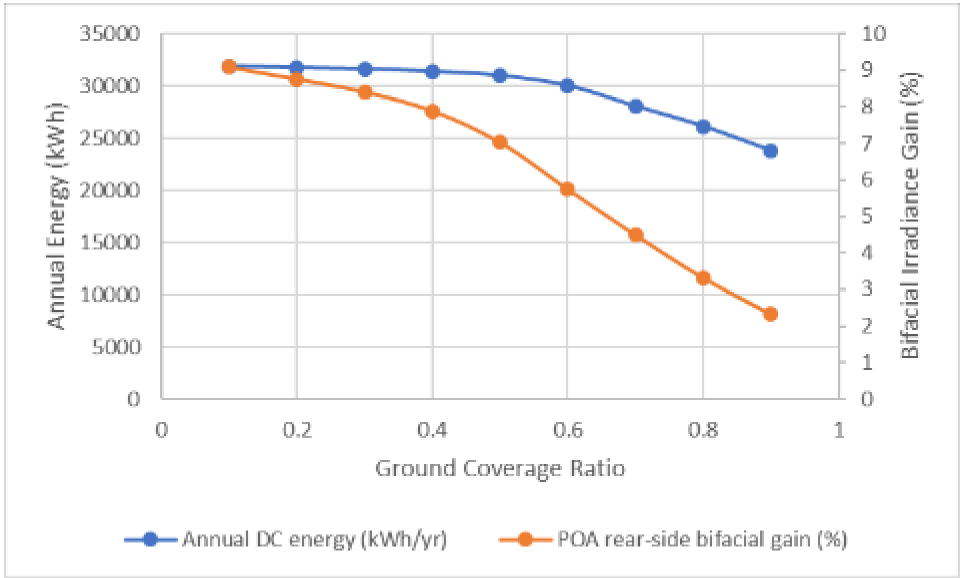
- DC energy gain is different from irradiance gain due to non-linear module response
- Installing 1-axis tracker on monofacial results in higher gain than installing bifacial (in this case).
- Installing bifacial modules with 1-axis trackers boosts annual DC energy by 33% over fixed monofacial system.

Sensitivity analysis of key variables

Ground Clearance Height



Ground Coverage Ratio



Key Variables:

- Ground Clearance Height
- Ground Coverage Ratio (row spacing)
- Albedo
- Tilt

Bifacial layout optimization

Ground clearance height (m)	Ground coverage ratio	Tilt (deg)	Annual DC energy (kWh/yr)	POA rear-side bifacial gain (%)
2	0.2	40	34221	12.226
2	0.2	45	34203	12.613
2	0.2	35	34100	12.056
1.5	0.2	45	33957	11.791
1.5	0.2	40	33949	11.323
2	0.2	30	33820	11.992
1.5	0.2	35	33803	11.068
2	0.3	40	33687	11.104
2	0.3	35	33638	11.034

Perform sweep of system layouts between:

- 0.1 – 0.5 GCR
- 15 – 45 degree tilt
- 0 – 2 m ground clearance

Sort by annual energy

SAM Demo and Parametrics

- Illustration of model
- Variation of some key parameters
- Examining outputs

Thank you!

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