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IEA PVPS Task 13: Subtask 1.2: Bifacial PV - Bifacial PV Modeling Comparison

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Sandia National Laboratories

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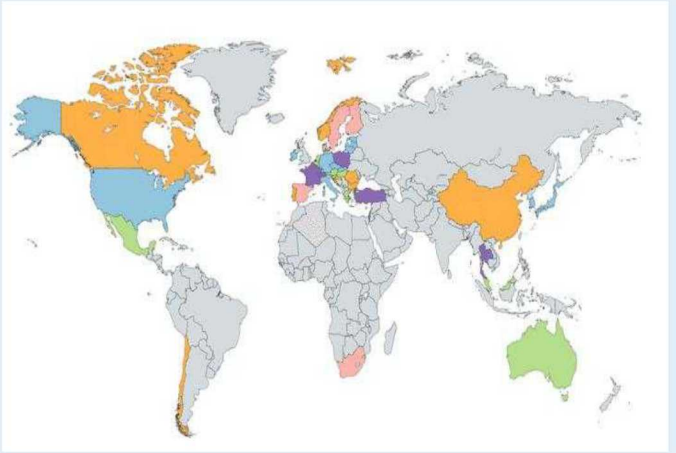
International Energy Agency PVPS Task 13: Performance, Operation and Reliability of Photovoltaic Systems



- IEA-PVPS is a global network of 32 members: 27 countries, European Commission, SolarPower, SEPA, SEIA, and Copper Alliance
- PVPS currently has seven active tasks related to photovoltaics
- Information as reports are available at http://www.iea-pvps.org

- Task 13 is comprised of 20+ countries, 36+ institutions → 45 participants and 60+ members
  - Subtask 1: New Module Concepts and System Designs
  - Subtask 2: Performance and Photovoltaic Systems
  - Subtask 3: Monitoring – Operation and Maintenance
  - Subtask 4: Dissemination

- Task 13 is in its 3rd period (Sept 2018 to Aug 2021)

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Activity 1.2: Bifacial Photovoltaic Module and Concepts

Motivation

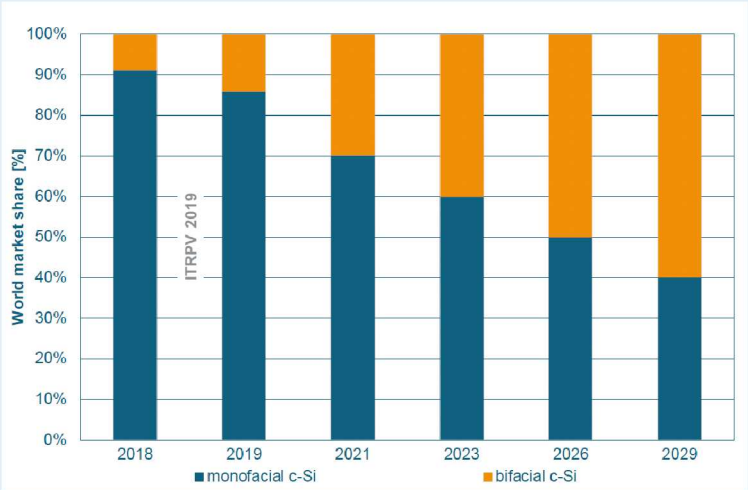
- Bifacial ~~will be~~ is a major new PV technology being installed around the world.
- Yield prediction tools are not standardized nor validated sufficiently.
- Greater certainty in bifacial performance is needed.

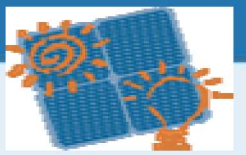
Task 13 Work Program

- A. Collect and examine bifacial field data and results from international studies
- B. Evaluate and summarize bifacial standards, guidelines, and models being used around the world.

Current Contributions from 13+ countries:

- Netherlands, France, Austria, Belgium, Switzerland, Germany, Denmark, Finland, Sweden, Italy, South Africa, Chile, USA.





A. Collect Field Data and Results

We have developed a simple data query form that allows those with bifacial data to contribute summary results anonymously.

No	*Information*	*Value*	*Unit*	*Comment*
1	System ID			For internal reference, no need to disclose site names or commercial project names
2	Task 13 contact			E-mail address of task 13 contact person for further clarifications
3	Site latitude		deg E/W	
4	Site longitude		deg N/S	
5	System size		kWp	
6	System type			Fixed tilt / fixed vertical / HSAT / ...
7	Site albedo		%	
8	Bifacial gain		%	

- We have initially collected data from 21 modules or systems from 7 partners
- We would like to get many more submissions.
- We plan on mining the literature as well.
- *Please contact me and I will send you the form.*

9	Time period		h	Instantaneously / one day / one year / ...
10	Mounting height		m	Lower module edge above ground
11	Tilt angle		deg	if applicable
12	Ground cover ratio		%	Ratio of module row width to row-to-row distance
13	Further data?			Mention availability of time series or other detailed measurements

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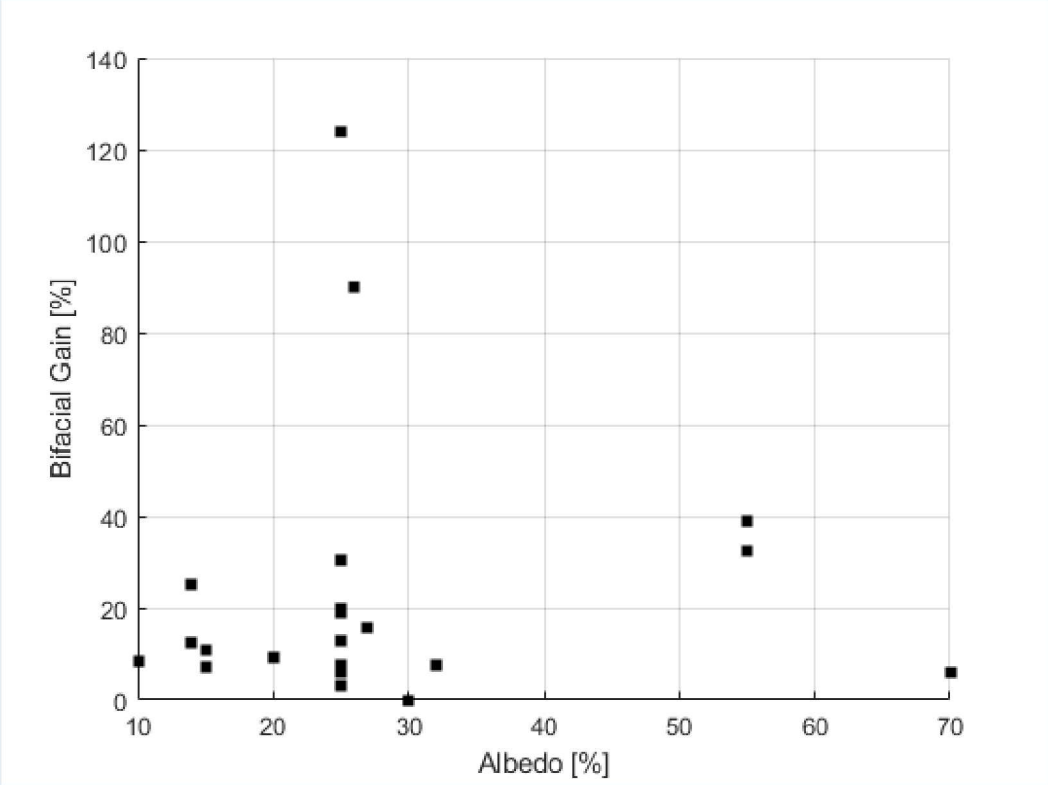
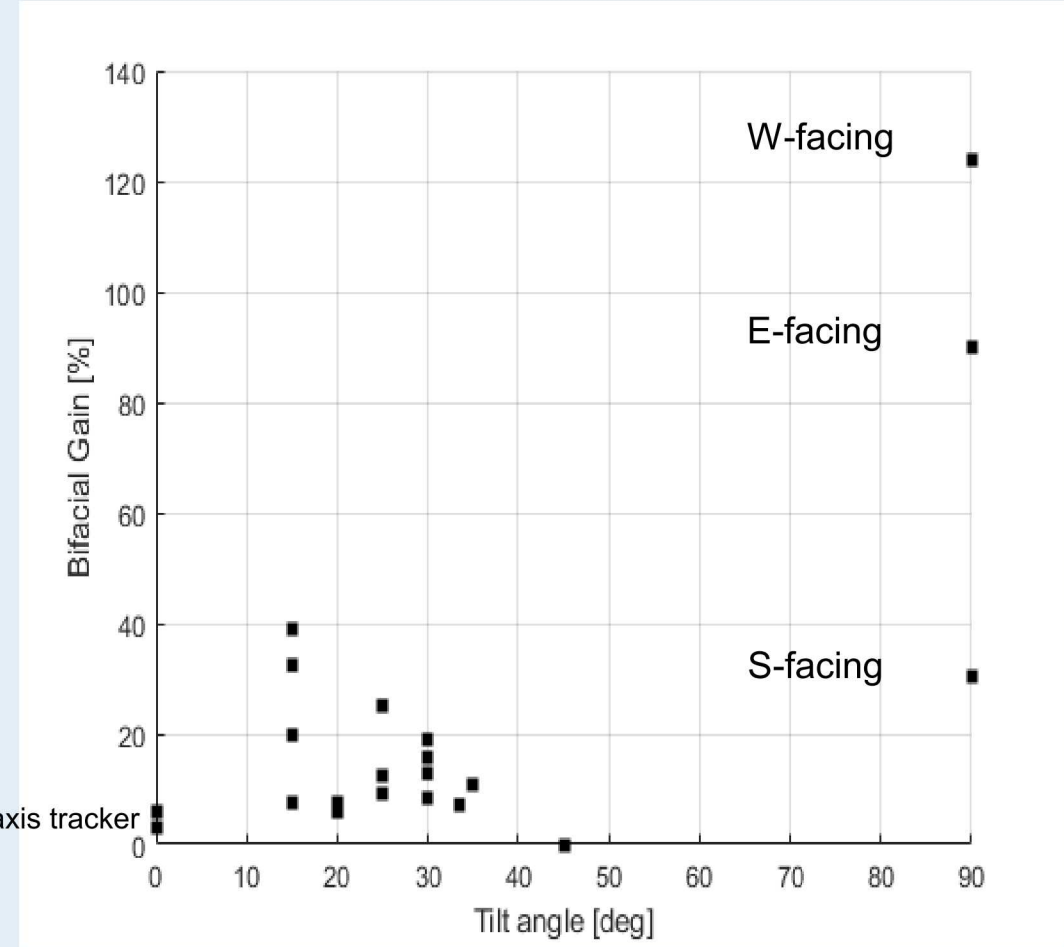
Very Initial Results



- *For a given system design bifacial gain will increase linearly with albedo.*
- *System design has a larger effect on bifacial gain than albedo alone.*

- *Dual axis trackers usually have lots of backside obstructions unless specially designed for bifacial.*
- *Vertical tilt has high bifacial gains (due in part to low front side output)*



Dual axis tracker

Very Initial Results

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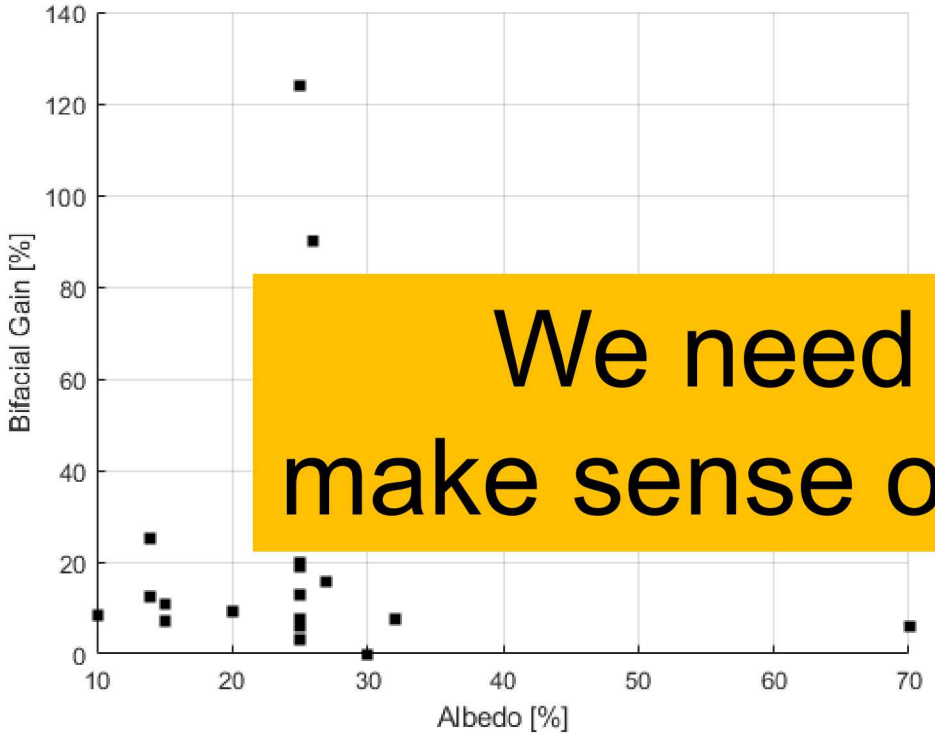
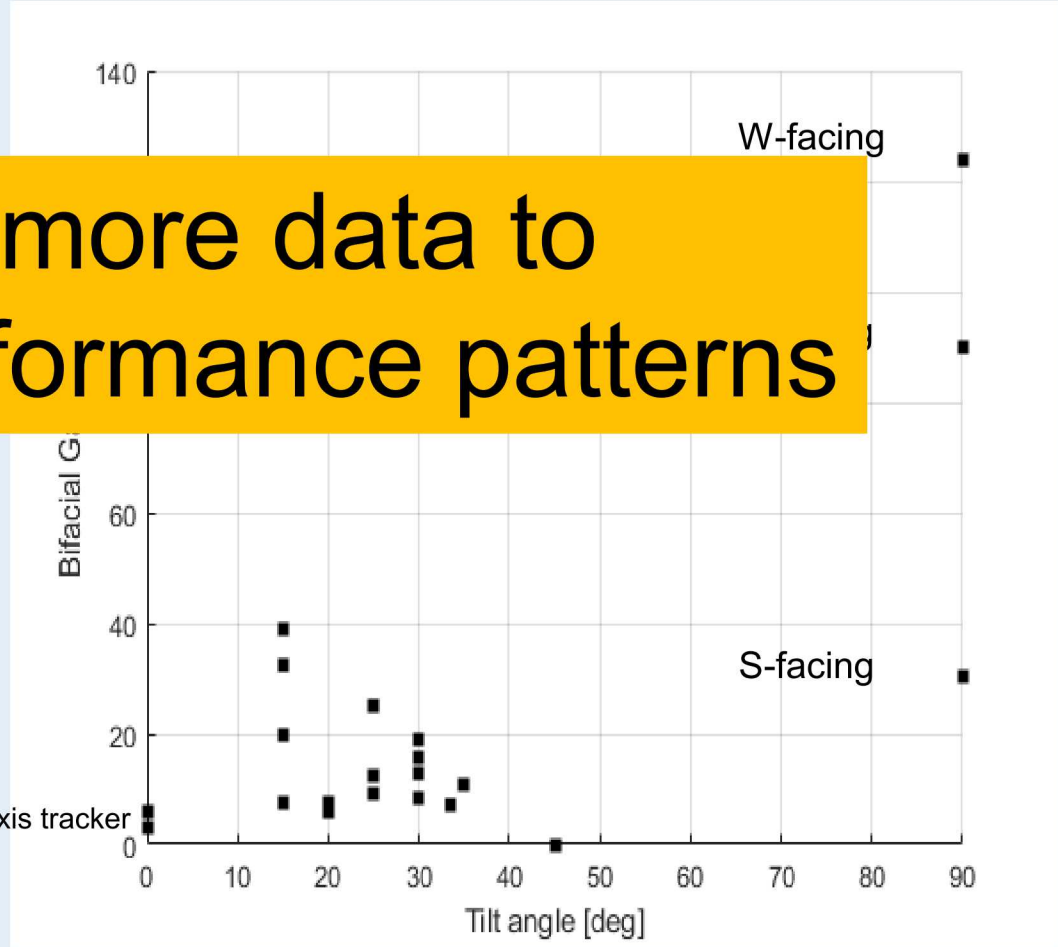


We need a lot more data to make sense of performance patterns



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B. Evaluate and Compare Models

- Collect technical descriptions of bifacial performance models
  - These will be included in the final report
- Define a set of bifacial system designs to run in each model (include both real and theoretical systems)
- Models would be run by model developers and results sent to subtask 1.2 leads and or a T13 representative from your country.
- Compare results between models and to measured data

Interested parties include: Sandia, NREL, ENGIE, SUPSI, ISE, EDF, ECN, and others.

Please let us know if you want to participate!

B. Evaluate and Compare Models

Part 1: Comparing modeling results to field measurements

- Front and backside irradiance
- DC Current, Voltage and Power
- AC Power
- *Challenge: Most high quality field data is from small research systems*

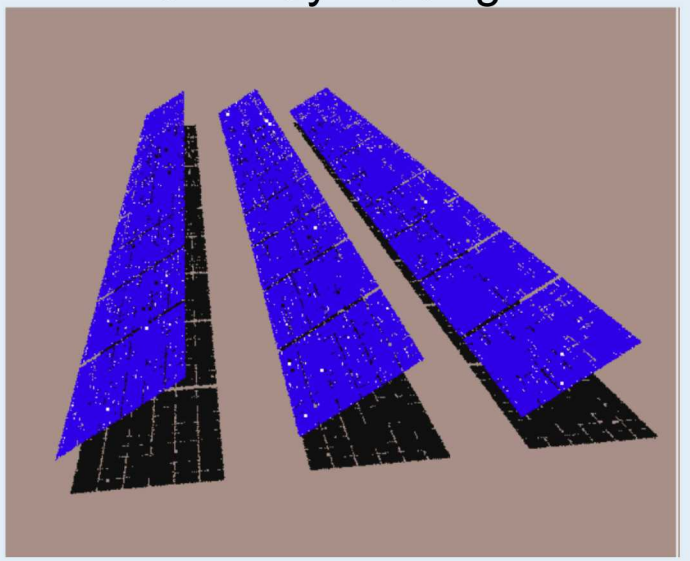
Part 2: Modeling Bifacial Output from theoretical systems

- Test of model's capability and flexibility
- Comparison of parameter sensitivity
- *Challenge: Many models are limited in the types of systems they can simulate (e.g, 2-D vs. 3D models)*

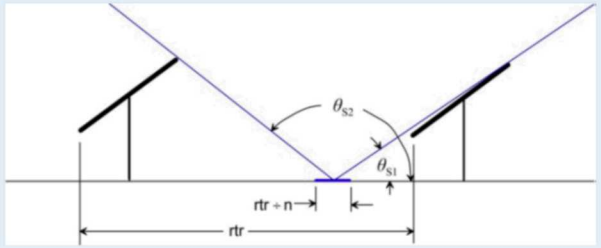
If you are interested in participating in this model comparison, please let me know (jsstein@sandia.gov) and I can include you in the distribution of the model run specifications.

- *Modeling should be ready to commence in January 2020*

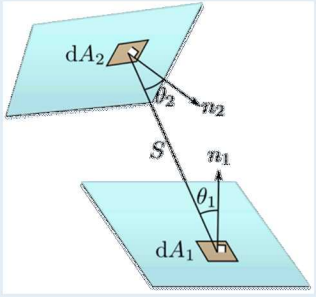
3-D Ray Tracing



2-D View Factor



3-D View Factor



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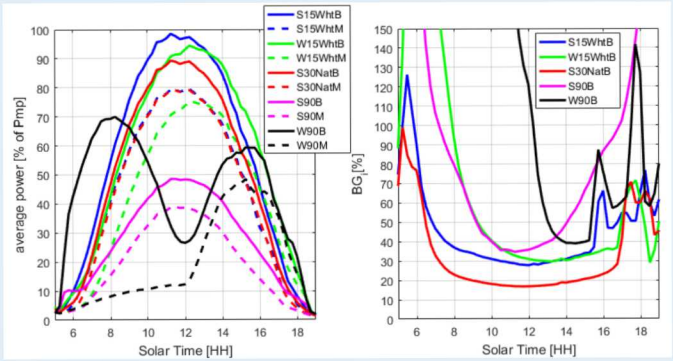
Example of Measured System Field Data

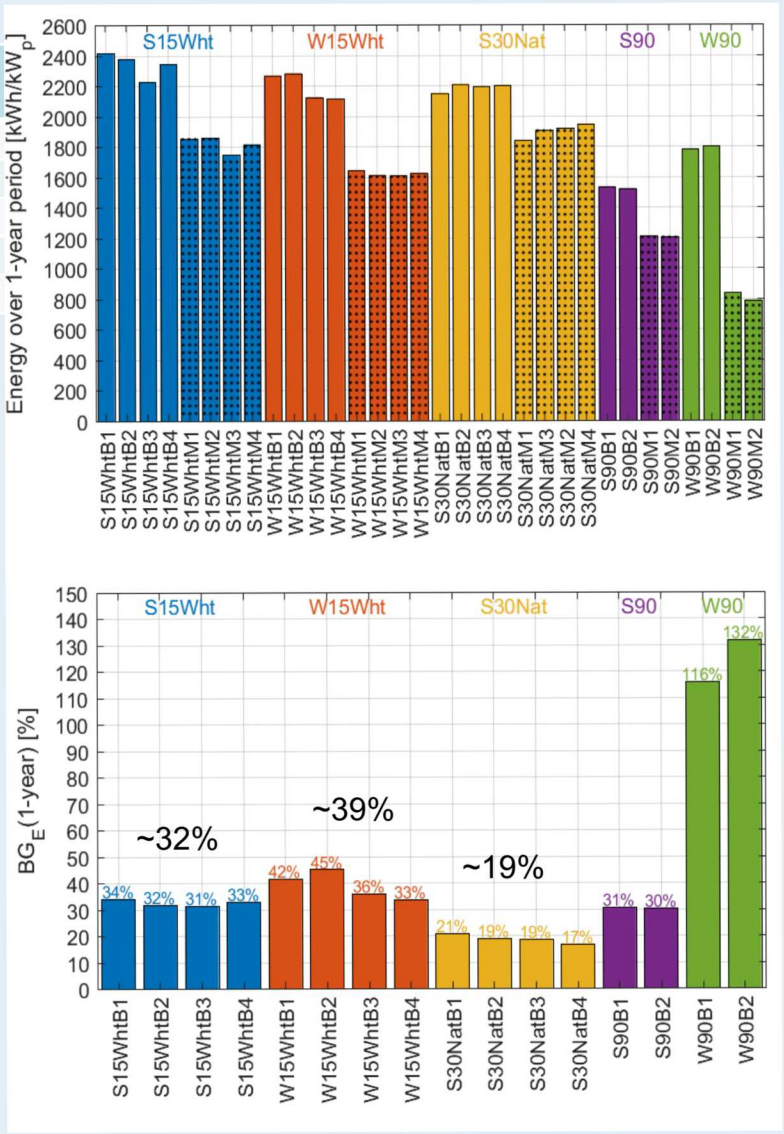
Prism Solar in Albuquerque, NM

- ~3 years of data
- Five orientations
- Two albedo values
- Bifacial and Monofacial modules
- Module level DC monitoring
- Front and Backside irradiance
- Module temperatures

Issues: System is very small and irregular design may not work in many models designed for large uniform systems.

Label	Orientation		Ground Surface
	Tilt	Azimuth	
S15Wht	15˚	180˚ (South)	White gravel
W15Wht	15˚	270˚ (West)	White gravel
S30Nat	30˚	180˚ (South)	Natural
S90	90˚	180˚ (South)	Natural
W90	90˚	270˚ (West)	Natural





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Example of Measured System Field Data

Single Axis Trackers at NREL

- <1 year of data
- Five bifacial technologies
- Bifacial and Monofacial modules
- String level DC monitoring
- Front and Backside irradiance
- Module temperatures

Issues: System is new and not all data can be shared.

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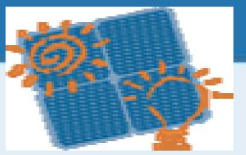
NREL
NATIONAL RENEWABLE ENERGY LABORATORY



Example Bifacial Sensitivity Study for SAT

Model: **Bifacial_Radiance** (NREL: https://github.com/NREL/bifacial_radiance)

Run on a HPC Cluster

System: Single axis tracker

Variables: see table

Weather: 1 year TMY from Albuquerque, NM

- 365 days (8760 hours)
- 36 days: (3 days sampled from each month)
  - min, median, max daily insolation

Realizations: 100 samples

Parameter sampling: Latin Hypercube Sampling (DAKOTA)

- Random sampling from uniform probability bins
- Samples reordered to minimize cross correlation.

Parameter significance measured using Stepwise Regression

Inputs	Description	Type	Range	Units
GCR	Collector width/row-to-row distance	Float	.3-.8	meters/meters
Albedo	Ratio of light reflected by ground	Float	1. [.10-.80] 2-3. [.15-.25] 4. [.75-.85]	None
Hub height	Height of tracker from ground	Float	1-2	meters
Tube gap	distance of module from torque tube in Z	Float	1-10	centimeters
Backtrack	True= backtracking False="true" tracking	Boolean	True, False	none
Tube shape	Shape of torque tube	String	Round, Oct, Square, Hex	none

Other Assumptions:

- 5 rows
- 25 modules per row (center and edge modules of middle row examined)
- 1UP portrait on tracker
- 60 cell modules (irradiance tracked on each cell)

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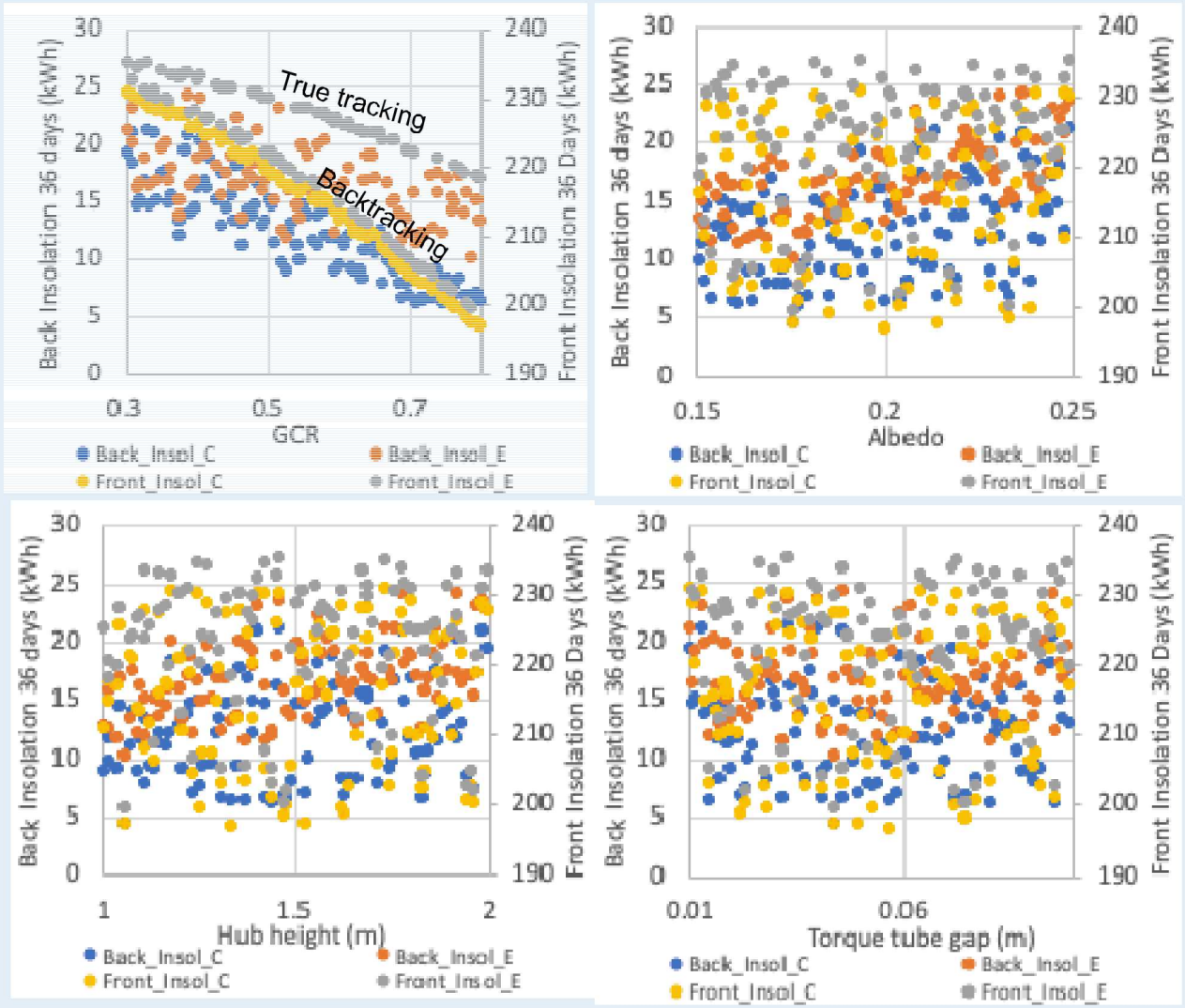
Example Bifacial Sensitivity Study for SAT

- Scatterplots show front and back insolation for each run
- Edge module gets more front insolation when true tracking due to absence of neighboring row.
- Fine differences are hidden in scatter plots due to the variability in all of the inputs.
- **Stepwise regression** is a good way to sequentially remove the most significant effects and then evaluate the left over variance.

Albedo: 0.15 – 0.25 Runs



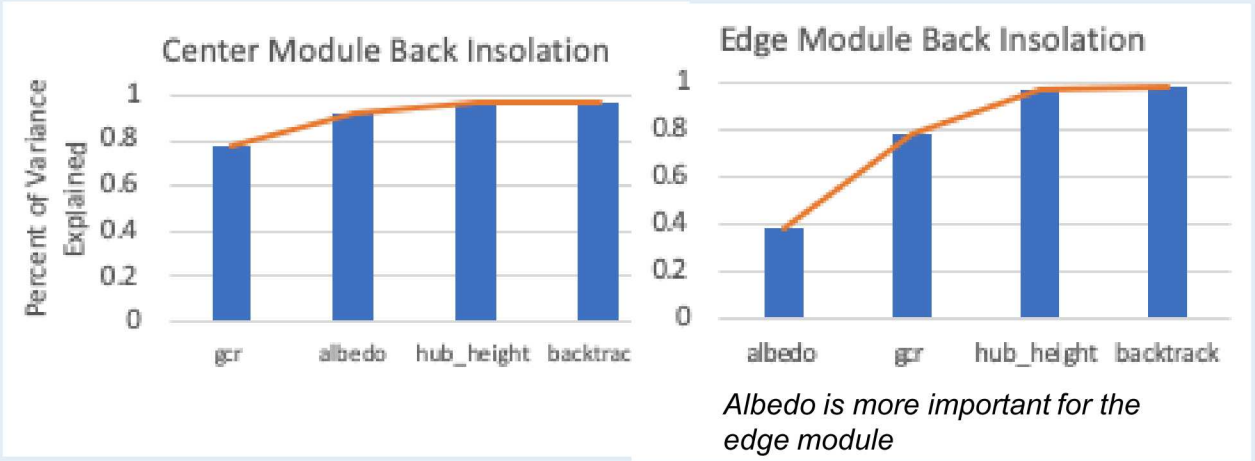
Example Bifacial Sensitivity Study for SAT

Stepwise Regression sequentially calculates the amount of the variance in the results that is due to each sampled variable.

- The albedo range changes the model sensitivity.
  - For lower albedo conditions variations in GCR and Albedo explain most of the variance
  - For higher albedo conditions (e.g., snow) variations in GCR and Hub Height are most important

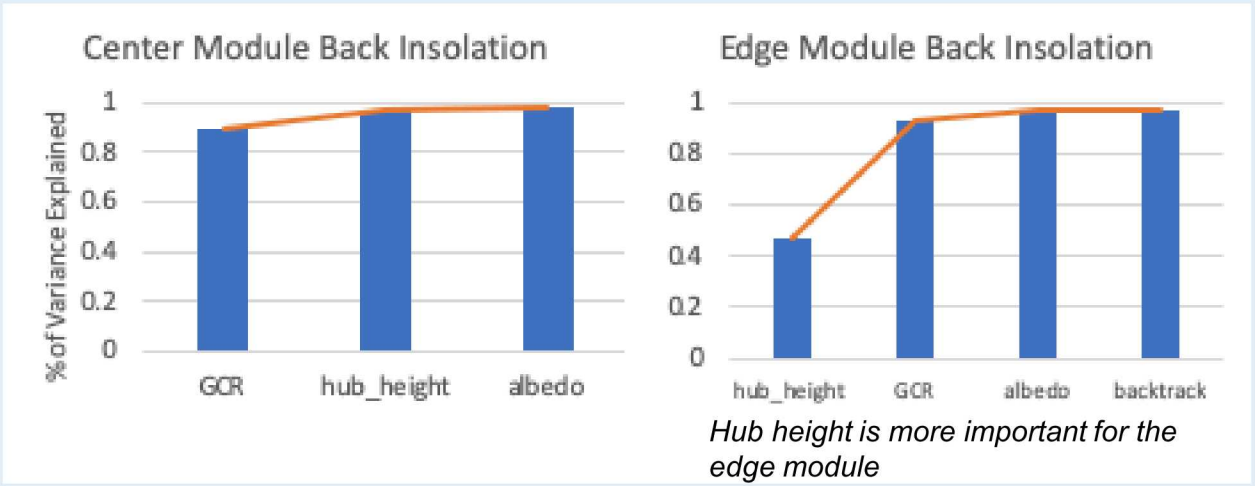
- Parameters such as torque tube shape, torque tube gap, or backtracking do not significantly affect total irradiance on the module.

Albedo: 0.15 – 0.25 Runs

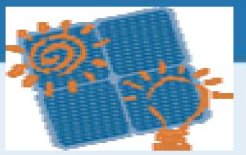


Albedo is more important for the edge module

Albedo: 0.75 – 0.85 Runs



Hub height is more important for the edge module



Summary

- IEA PVPS Task 13 is looking for contributors for a study and report on bifacial PV Performance and Modeling.
- Contributions can include:
  - Summary bifacial performance data (anonymous in report)
  - Time series of performance and weather for model validation
  - Model descriptions
  - Participate by running a set of common simulations
- Contributions can be anonymous or given credit in the report.

Please contact Joshua Stein (jsstein@sandia.gov)
or Christian Reise (Christian.Reise@ise.fraunhofer.de) with contributions are ideas

Thank you!