Horizontal Axis Trackers with Bifacial Modules in PVsyst

10th PVPMC Workshop

1-2.5.2018 Albuquerque NM, USA

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Overview

- **Bifacial Models in PVsyst**
  - Fixed Tilt Sheds
  - Horizontal Axis Trackers
- **Bifacial Tracker Simulations**
  - Bifacial Gain
  - Impact of Pitch (GCR), and Height
  - Impact of Latitude and Climate
- **Summary and Outlook**

Introduction

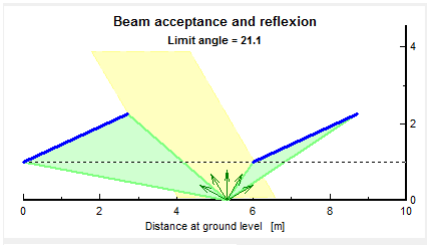
Bifacial Shed Model was introduced in PVsyst V6.60

- 2D Model for fixed tilt sheds
- Can be used for long regular rows

Bifacial Tracker Model since PVsyst V6.70

- 2D Model for horizontal axis trackers
- Generalization of shed model with varying tilt

Bifacial model
for fixed tilt sheds
(since V6.6.0)



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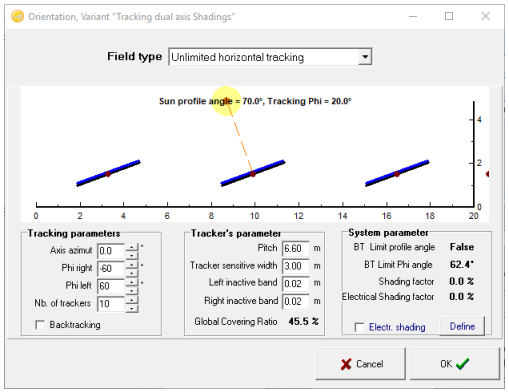
Unlimited trackers:
first step towards
horizontal bifacial tracking model
(since V6.6.7)



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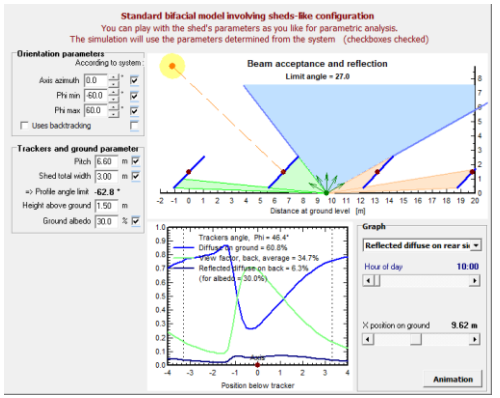
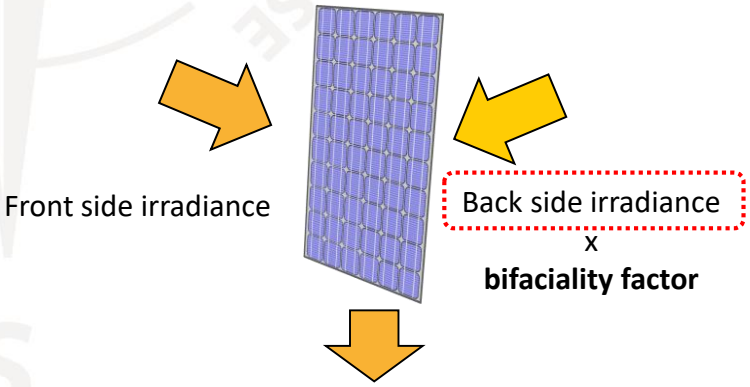
Bifacial tracking
for horizontal axis
(since V6.7.0)

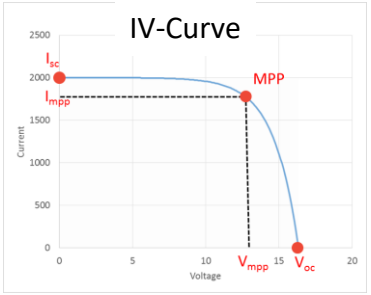


Using the Bifacial Models in PVsyst

Bifacial PV Module

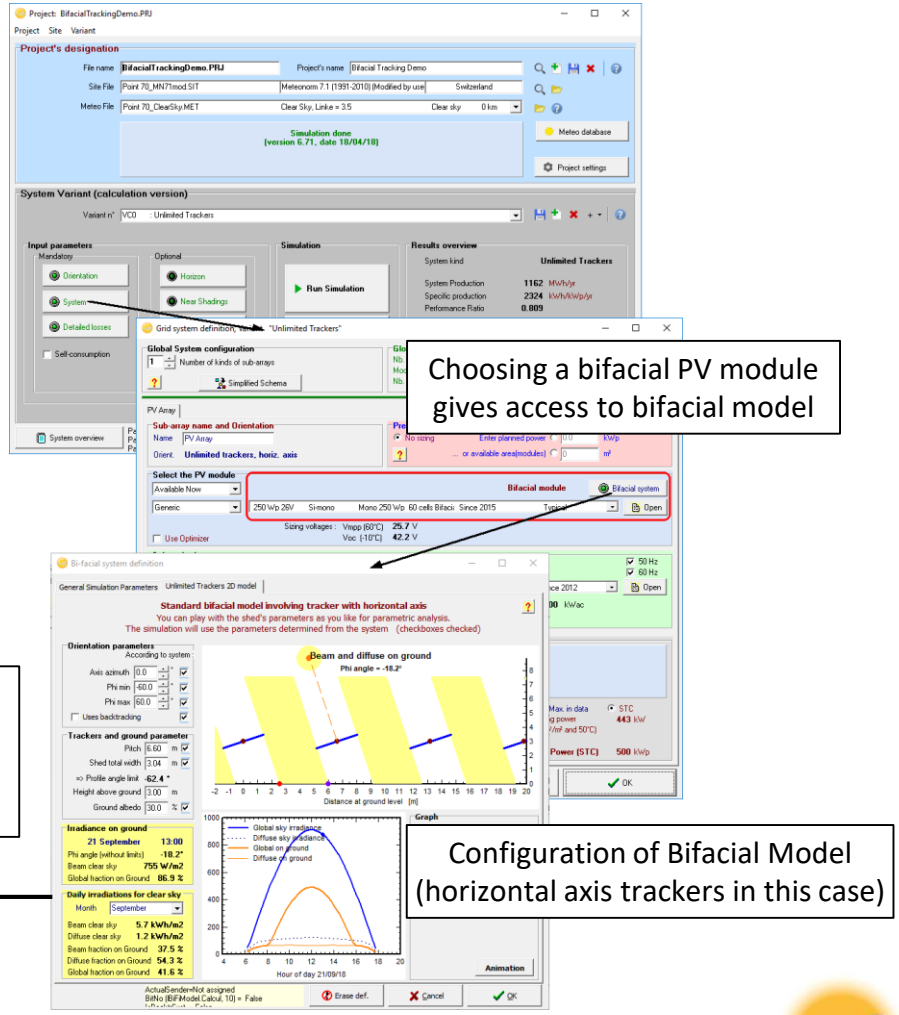


Single diode model



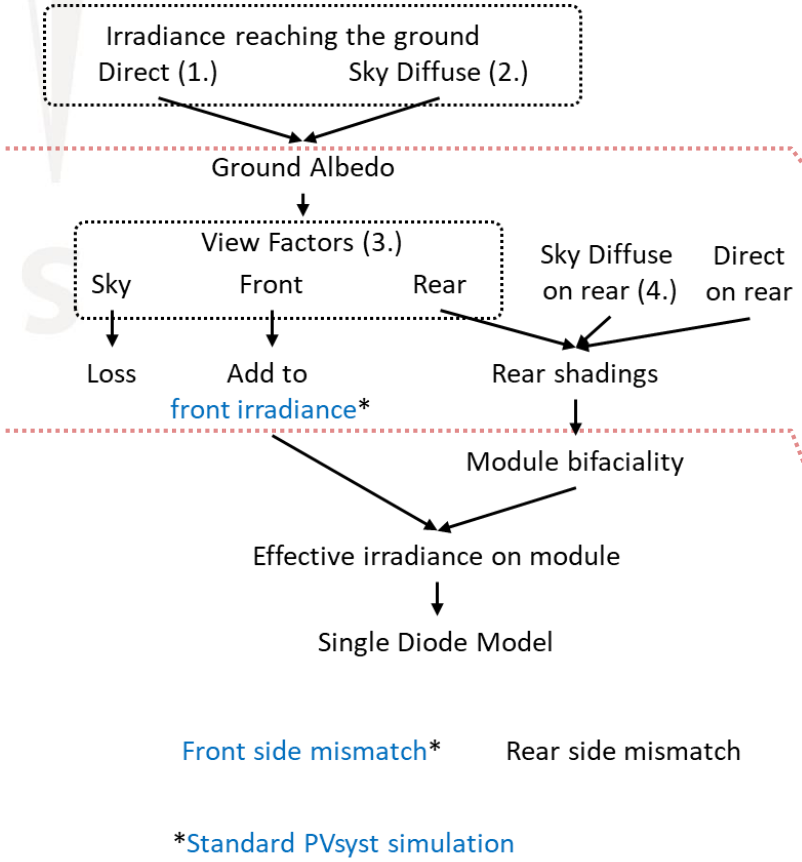
Bifacial Model computes back side irradiance

Bifacial Models



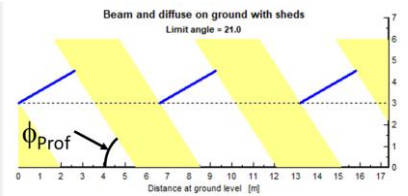
Bifacial Shed Model in PVsyst

Bifacial calculation steps



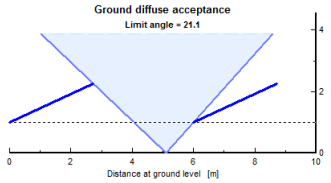
Irradiance on Ground

1. Ground Acceptance of direct light



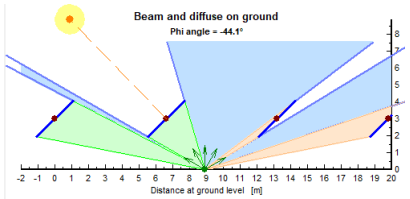
The sun profile angle is the sun height in the 2D projection

2. Ground acceptance of diffuse light



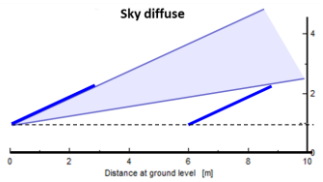
Irradiance on Module

3. View factors



Integrate over all ground points and the back side of the module

4. Sky diffuse and direct on back side



Bifacial Tracker Model in PVsyst

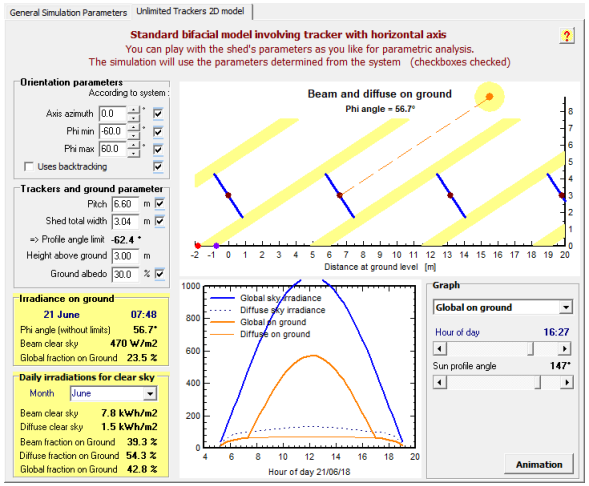
Irradiance on Ground

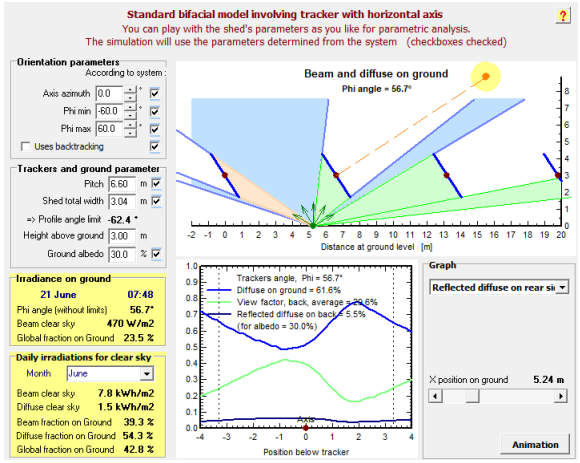
- Direct (Beam) Fraction
- Sky Diffuse Fraction

Reflection from Ground

- To back side
- To front side
- Lost to sky

Green Contributions
are constant for sheds.
With trackers, they become functions of sun position (sun profile angle).





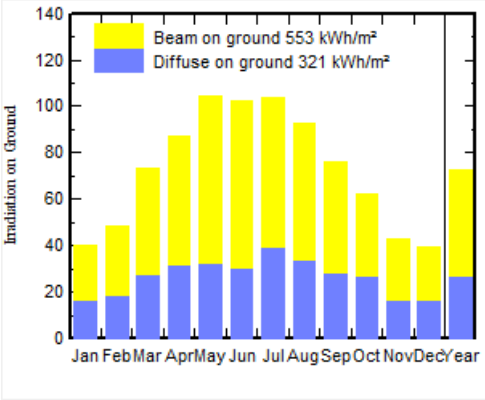
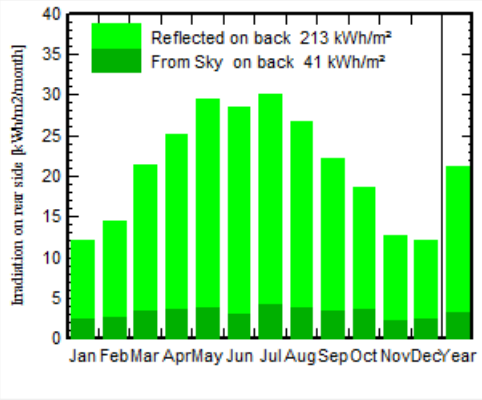
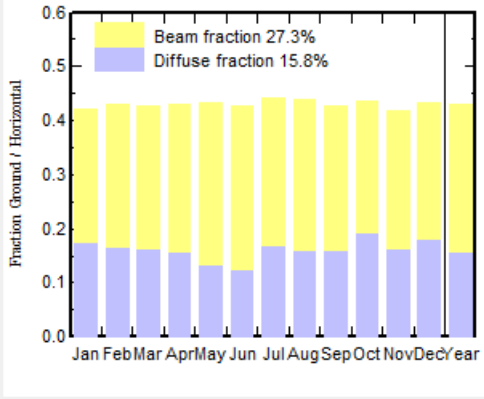
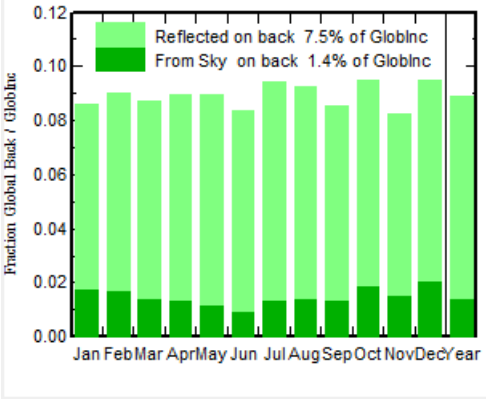
Additional contributions

- Direct (beam) fraction on rear side
- Sky diffuse fraction on rear side
- IAM losses for each contribution

This bifacial model can be used for horizontal axis trackers.
The tracking algorithm minimizes the Angle of Incidence!

Simplified Preliminary Calculation

Monthly breakdown of irradiances

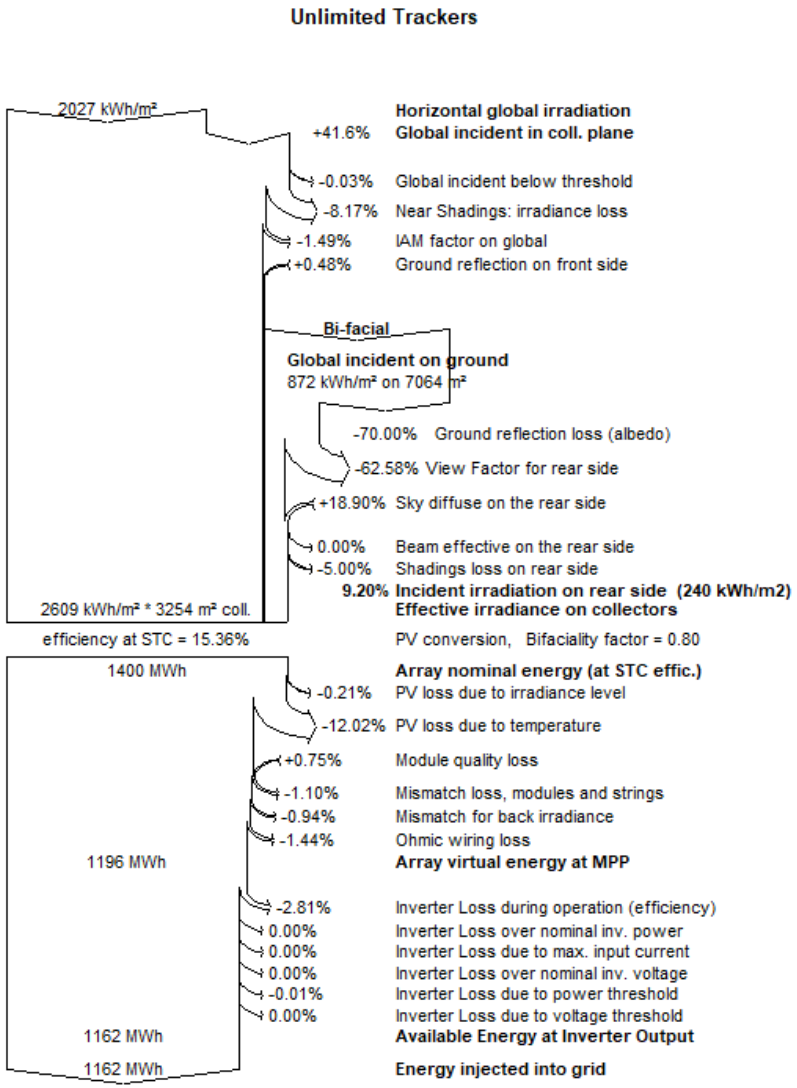
	On Ground	On PV module rear side
Absolute		
Relative		

Bifacial Simulation and Results

Additional contributions with Bifacial Models

- Global incident on ground
- Ground albedo
- View factor rear side (irradiance renormalization for ground and module surface)
- Sky diffuse on rear side
- Beam effective on rear side
- Shading loss on rear side
- Total irradiance on rear side
- Ground reflection on front side

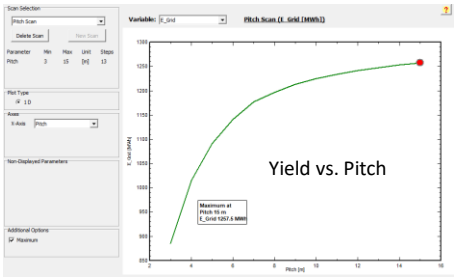
IAM losses are included in View Factor

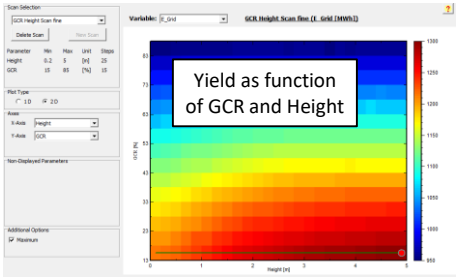


Studying Bifacial Behavior with PVsyst

Optimization Tool

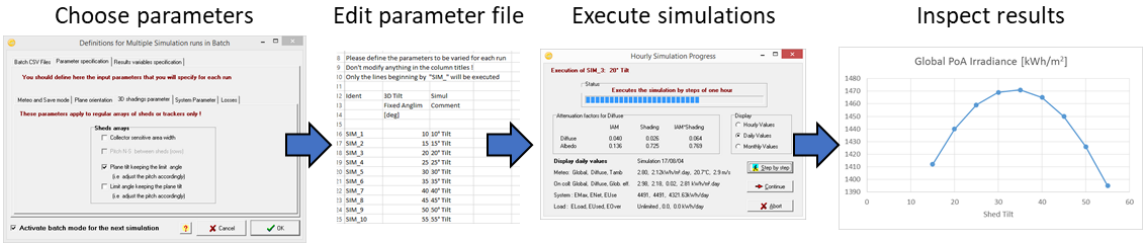
Allows quick parametric scans to optimize Irradiance or Yield





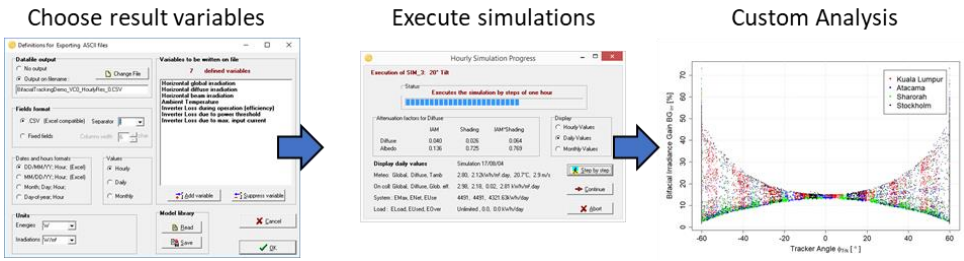
Batch Mode

Parametric scans with many parameters and output to CSV files for further analysis



Hourly Results

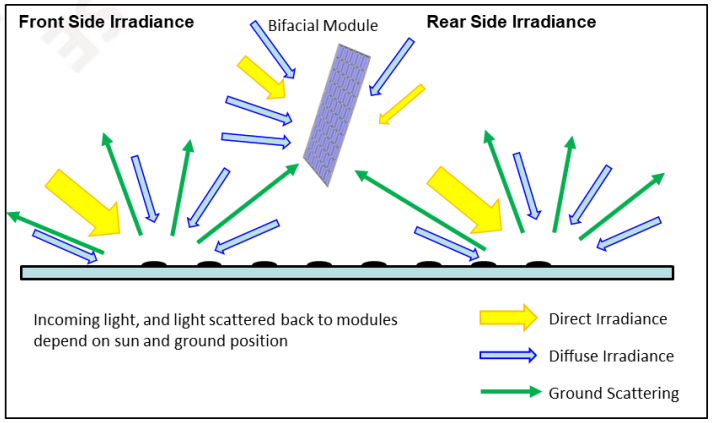
Simulation results in hourly steps for > 80 different variables



The following results were obtained with PVsyst 6.71 batch mode and hourly result files

Bifacial Gain and Tracker Gain

Bifacial Irradiance Gain (BG_{Irr})



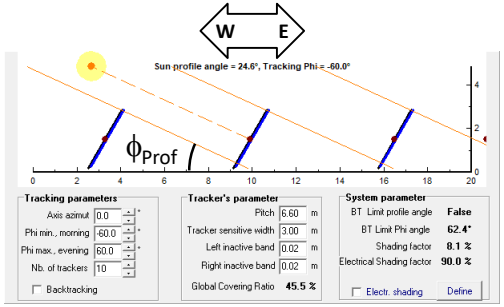
$$BG_{Irr} = \frac{Rear\ Side\ Irradiance}{Front\ Side\ Irradiance}$$

The full Bifacial Gain BG includes also bifaciality factor and bifacial mismatch

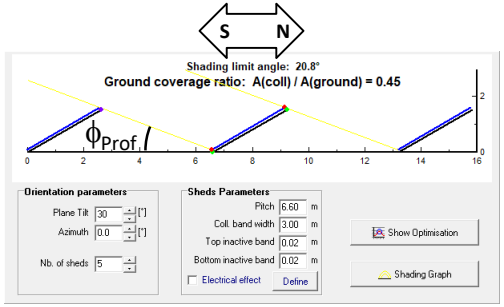
It is smaller than BG_{Irr}

Tracker Irradiance Gain (TG_{Irr})

Horizontal axis trackers



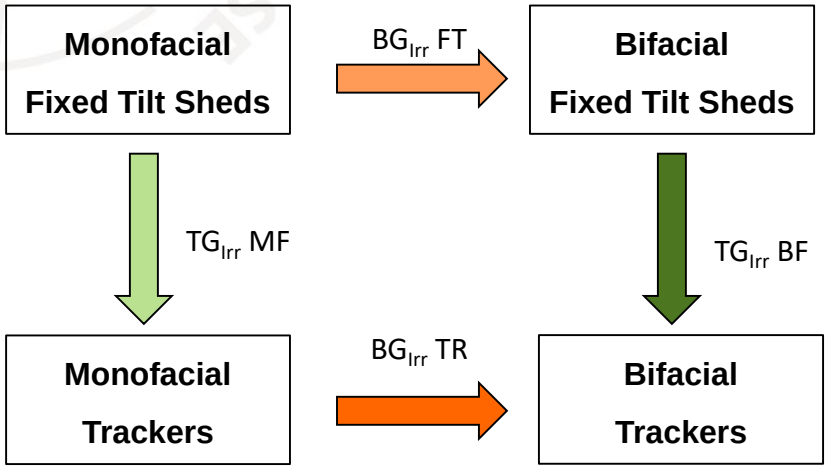
Fixed Tilt Sheds

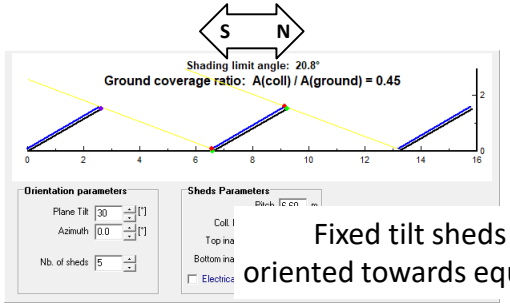


$$TG_{Irr} = \frac{GlobEff\ Tracker}{GlobEff\ Shed}$$

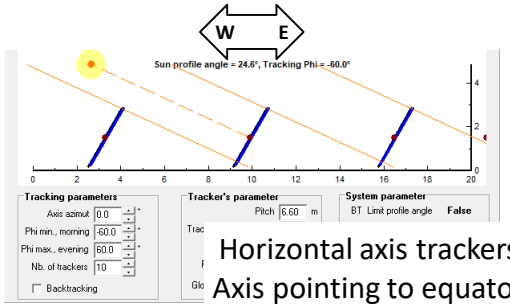
Tracker irradiance gain with respect to Fixed Tilt Sheds,
same width, pitch (GCR) and height over ground

Comparisons of Gain Factors





Fixed tilt sheds
oriented towards equator



Horizontal axis trackers
Axis pointing to equator

Bifacial Irradiance Gain

Tracker Irradiance Gain

Parameters used here:

Site: Albuquerque NM, 35.05°N, 106.62°W, 1614m ASL

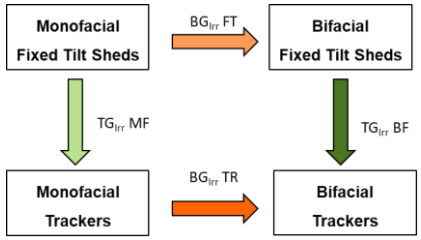
Weather data: Meteonorm 7.1, typical year

Geometry: Pitch=6.6m, width 3m, GCR 45%, height 3m

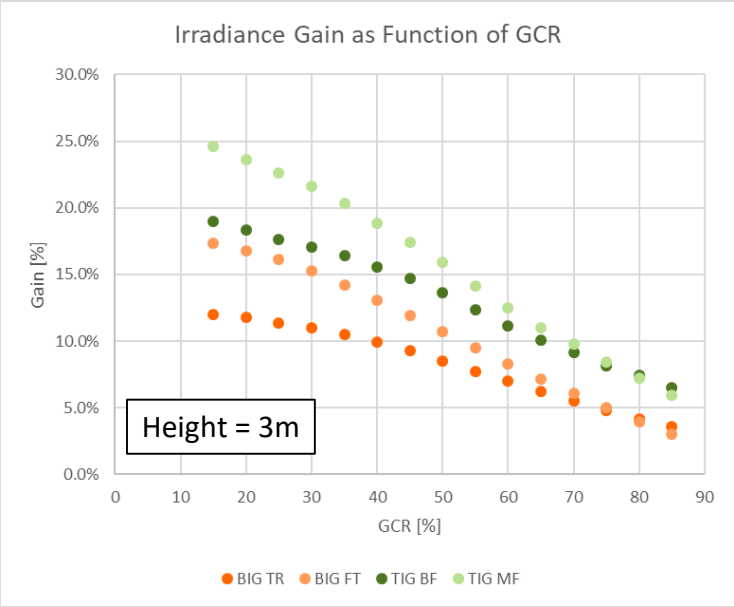
Ground albedo 30%

Impact of Layout on Irradiance Gain

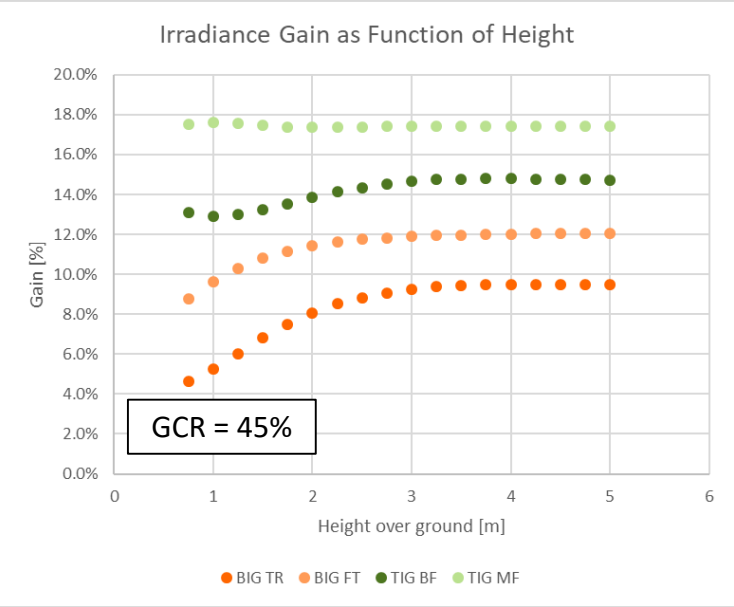
Parameters used here:
Site: Albuquerque NM, 35.05°N, 106.62°W, 1614m ASL
Weather data: Meteonorm 7.1, typical year
Geometry: Pitch=6.6m, Width 3m, GCR 45%, Height 3m
Ground albedo 30%



Ground Covering Ratio GCR:

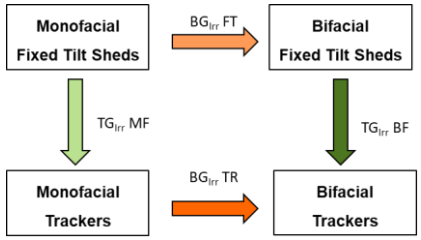


Height over Ground:

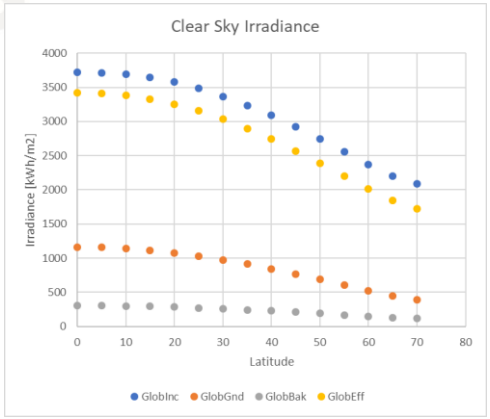


Bifacial Gain for different Latitudes (Clear Sky)

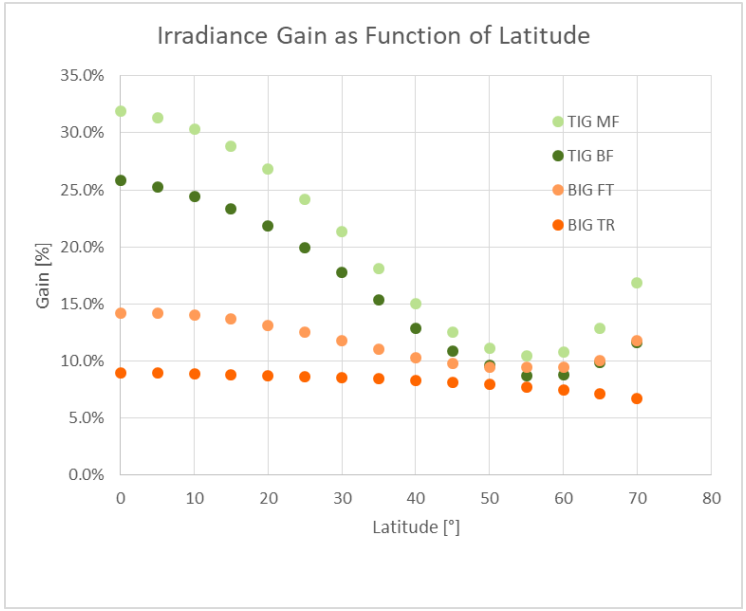
Parameters used here:
Site: Artificial points from Equator to 70°N, 0m ASL
Weather data: Clear sky model
Geometry: Pitch=6.6m, Width 3m, GCR 45%, Height 3m
Ground albedo 30%



Irradiance Values

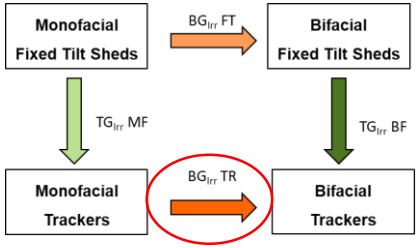


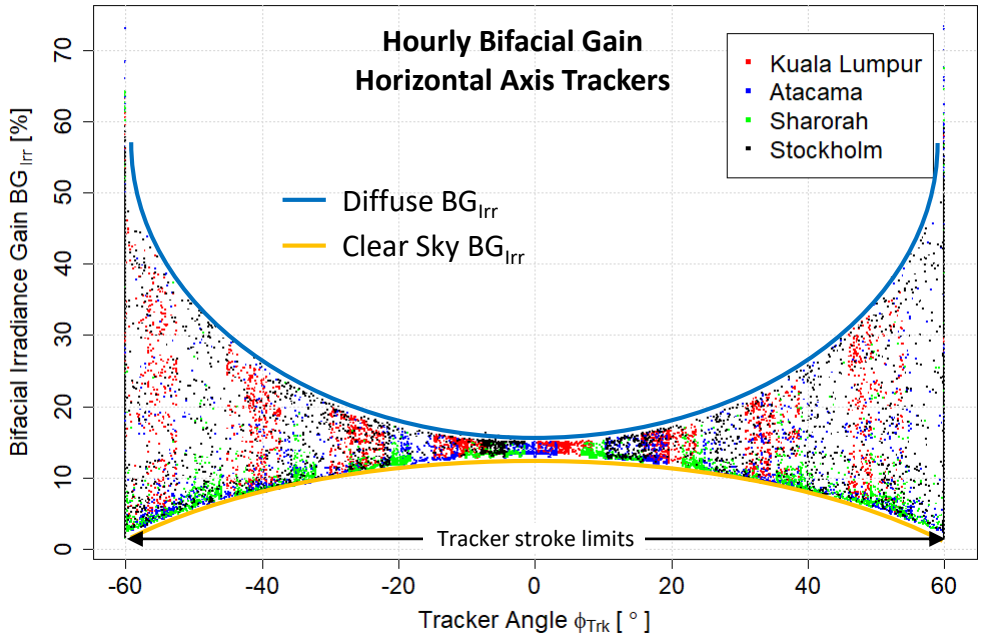
Bifacial Irradiance Gain (BG_{Irr})



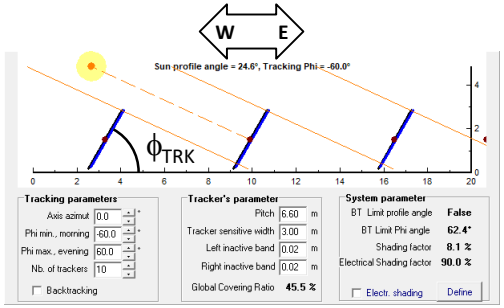
Bifacial Gain in different Climates (Trackers)

Site	Stockholm	Sharorah	Atacama	Kuala Lumpur
Latitude	59.35	17.5	-23.42	3.12
Diff/Glob	49.5%	26.1%	28.6%	58.9%
GlobEff	1225	2999	2889	1753
GlobGnd	435	1059	1008	804
GlobBak	137	286	276	236
BG_{Irr} TR	**11.2%**	**9.5%**	**9.5%**	**13.5%**





With horizontal axis trackers the bifacial gain is always larger for the diffuse component



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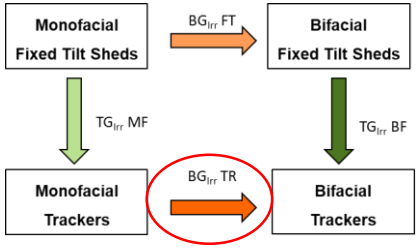

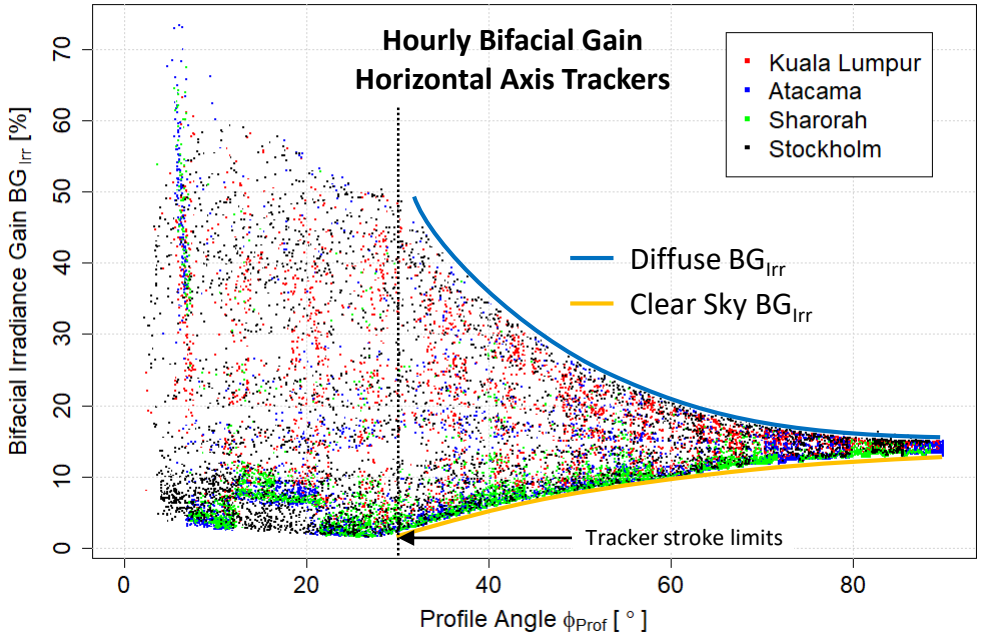

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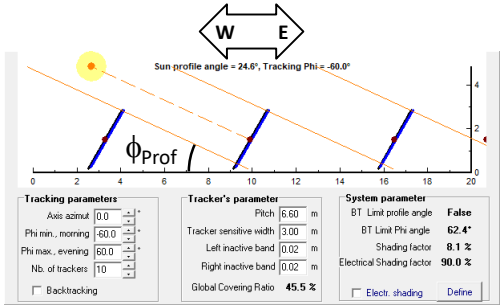
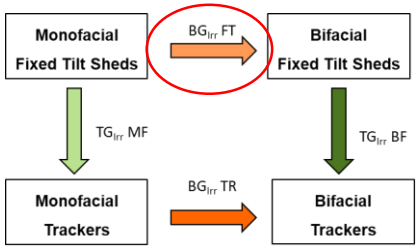
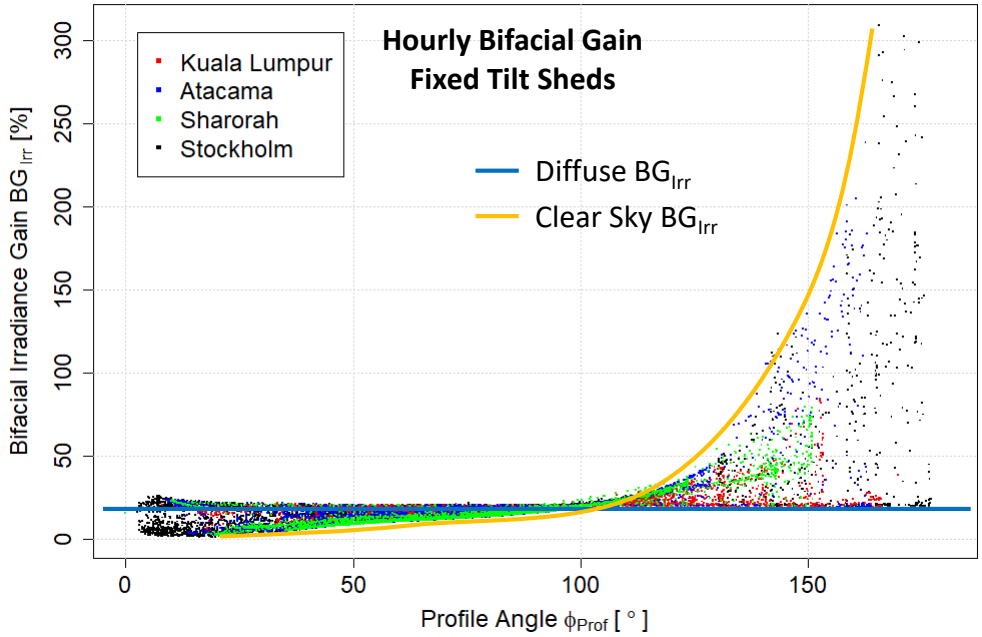


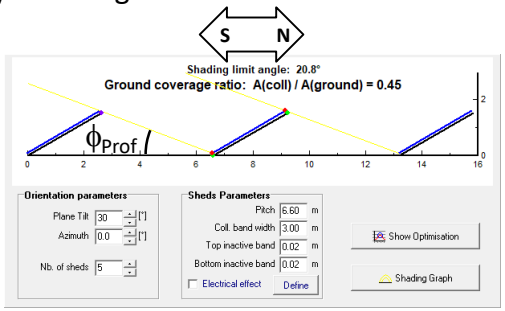
Bifacial Gain in different Climates (Fixed Tilt)

Site	Stockholm	Sharorah	Atacama	Kuala Lumpur
Latitude	59.35	17.5	-23.42	3.12
Diff/Glob	49.5%	26.1%	28.6%	58.9%
GlobEff	1384	2375	2327	1384
GlobGnd	474	1282	1214	924
GlobBak	137	327	313	251
BG_{Irr} FT	**12.5%**	**13.8%**	**13.5%**	**18.2%**





With fixed tilt sheds, the two gain curves intersect.
There is no general rule for the yearly bifacial gain.



Summary and Outlook

- **Summary**
  - Bifacial model for horizontal axis trackers was implemented in PVsyst
  - Detailed simulations and parametric studies are possible
  - Bifacial gain for trackers is smaller than for fixed tilt sheds
  - Diffuse contributions have higher BG in trackers than clear sky conditions
- **Open Questions, Next Steps**
  - Validation against measurements
  - Model the mismatch due to non-uniform irradiance on back side
  - Bifacial model for vertical fixed tilt installations
  - General bifacial model based on near shading 3D drawing