PVSYST
PHOTOVOLTAIC SOFTWARE

Simulating Bifacial Fixed Tilt and Tracking Systems with PVsyst

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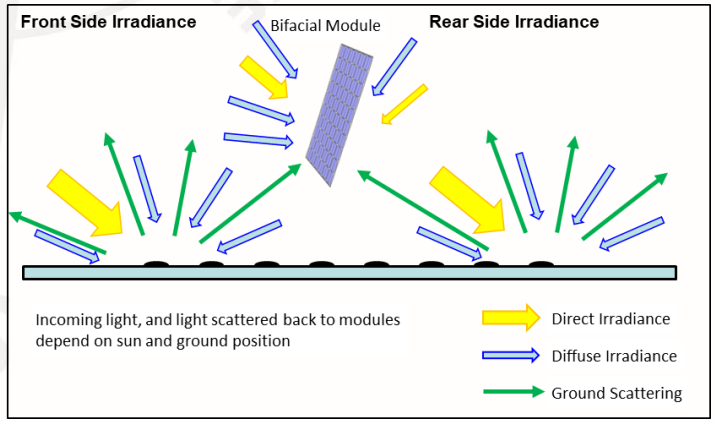
Introduction

Irradiance on Bifacial PV Module



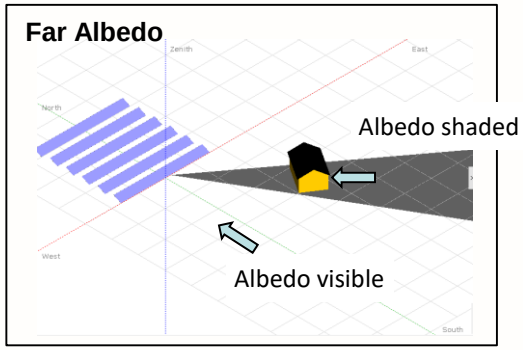
Assumptions for bifacial calculation

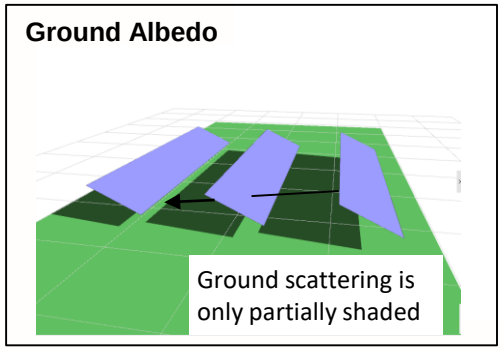
- Sky irradiance is direct and diffuse **(Sky diffuse is isotropic)**
- Direct and sky diffuse irradiance contribute to ground illumination
- Irradiance from sky and ground scattering contribute to front and rear irradiance
- Only ground scattering is considered (no reflection from neighbor rows)
- **The ground reflection is isotropic (Lambertian Surface)**
- Non-uniform illumination of backside is neglected at this stage (added later as empirical mismatch factor)

Far Albedo is not the same as Ground Albedo

- **Far Albedo (of transposition model)**
  Reflections from ground that is far away.
  Obstacles shade albedo for given azimuth.

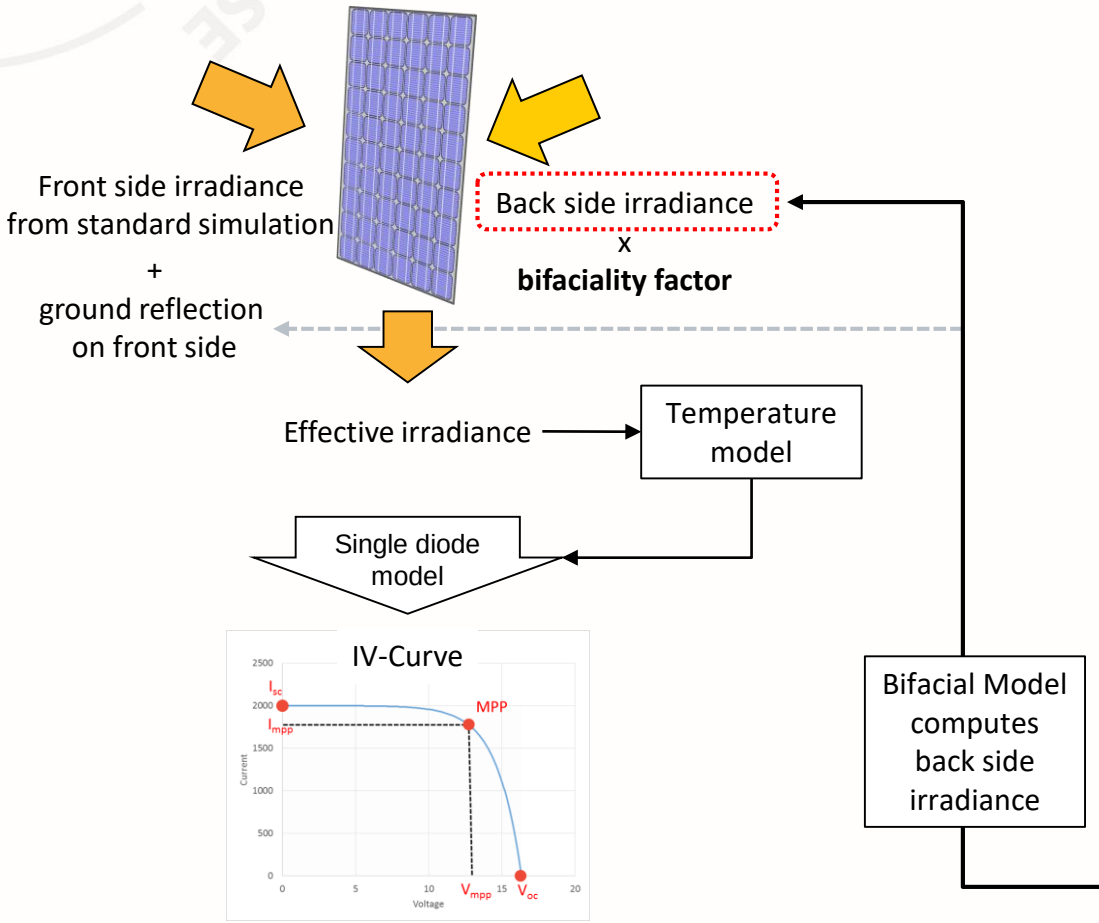
- **Ground Albedo (for bifacial simulations)**
  Light scattered back from ground underneath PV modules.
  Calculated with view factors.



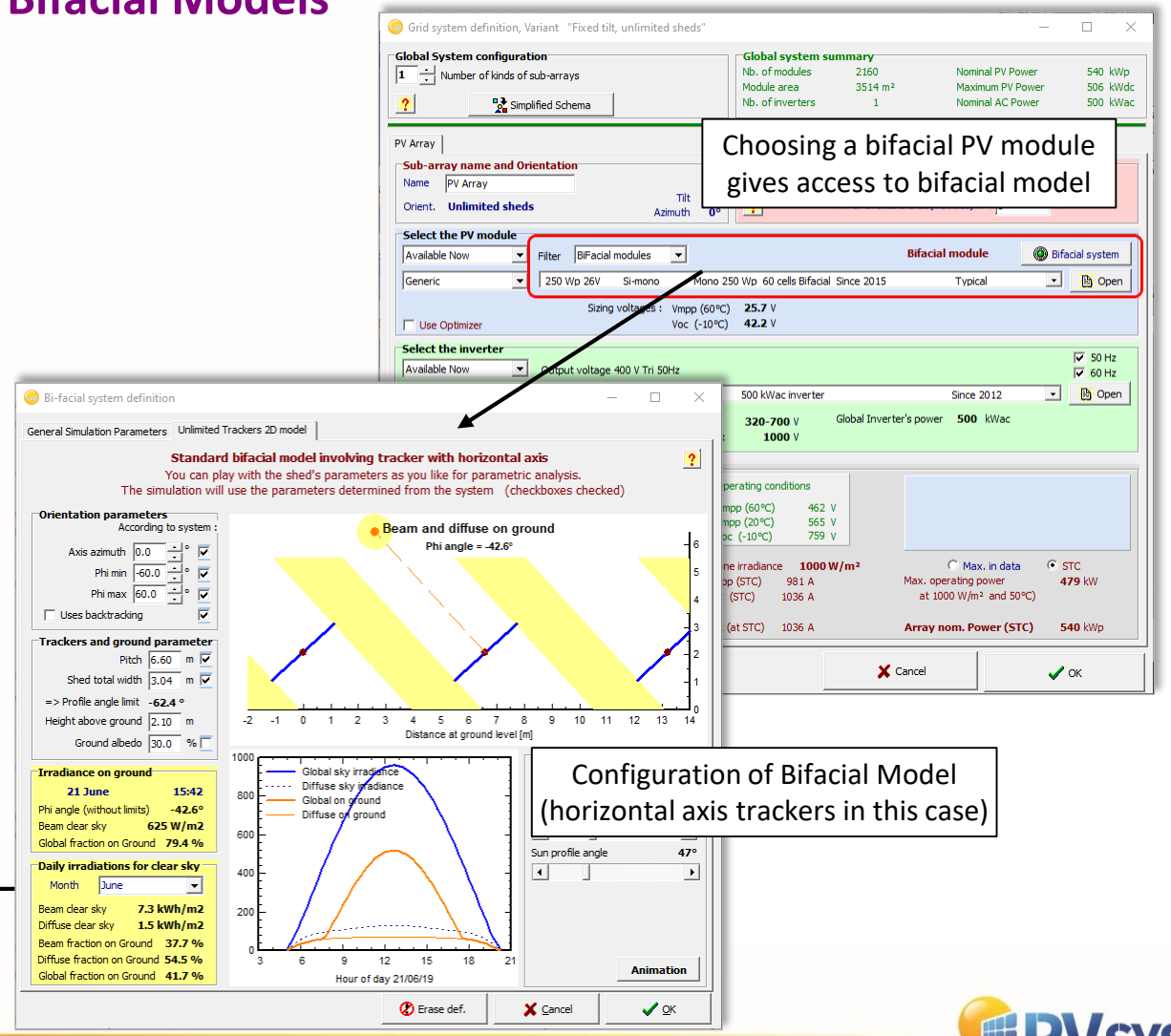


Using the Bifacial Models in PVsyst

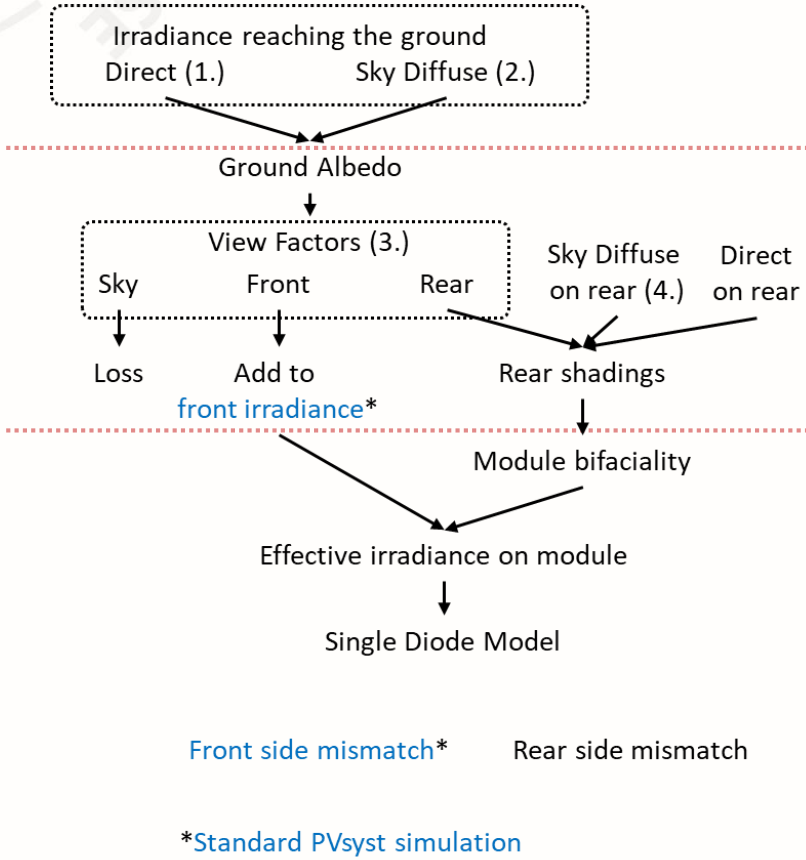
Bifacial PV Module



Bifacial Models



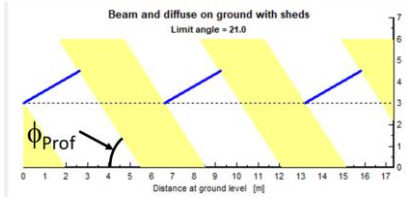
2D View Factor Model



IAM losses are also included in View Factors

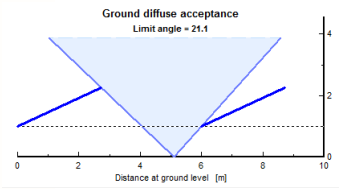
Irradiance on Ground

1. Ground Acceptance of direct light



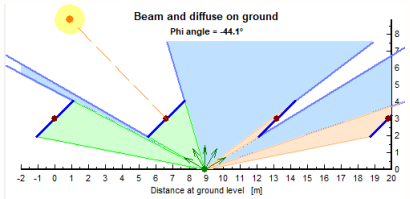
The sun profile angle is the sun height in the 2D projection

2. Ground acceptance of diffuse light



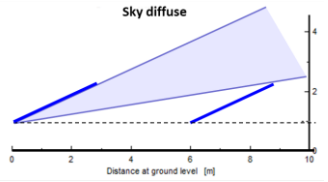
Irradiance on Module

3. View factors



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

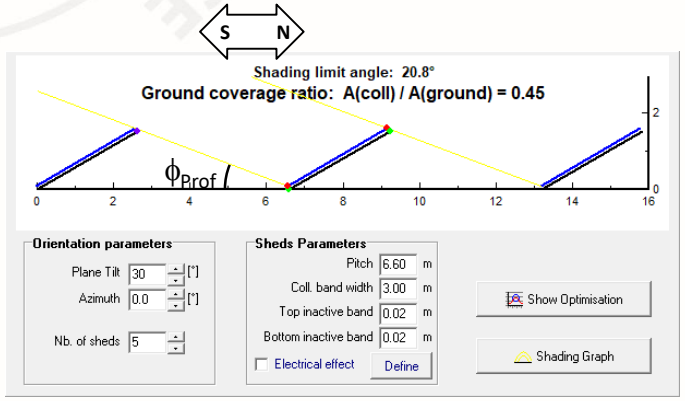
4. Sky diffuse and direct on back side



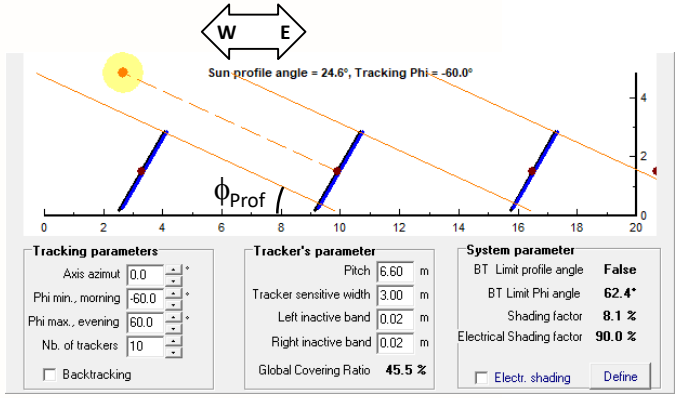
2D-Model neglects border effects at the row ends
⇒ suited for long regular rows

Using the Bifacial Models in PVsyst

Rows with fixed orientation



Horizontal Single Axis trackers

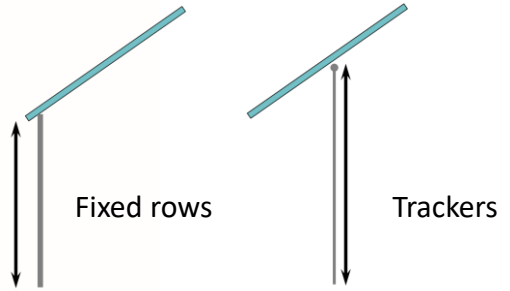


Simulation Parameters specific for Bifacial Systems

- **Ground Albedo**
  (yearly or monthly values)
- **Mounting Height**
- Module bifaciality factor
- Row transparent fraction
- Structure shading factor
- Mismatch loss factor

Ground Type	Albedo
Worn Asphalt	0.12
Bare Soil	0.17
Green Grass	0.25
Desert sand	0.40
New concrete	0.55
Fresh snow	0.8-0.9

Mounting Height

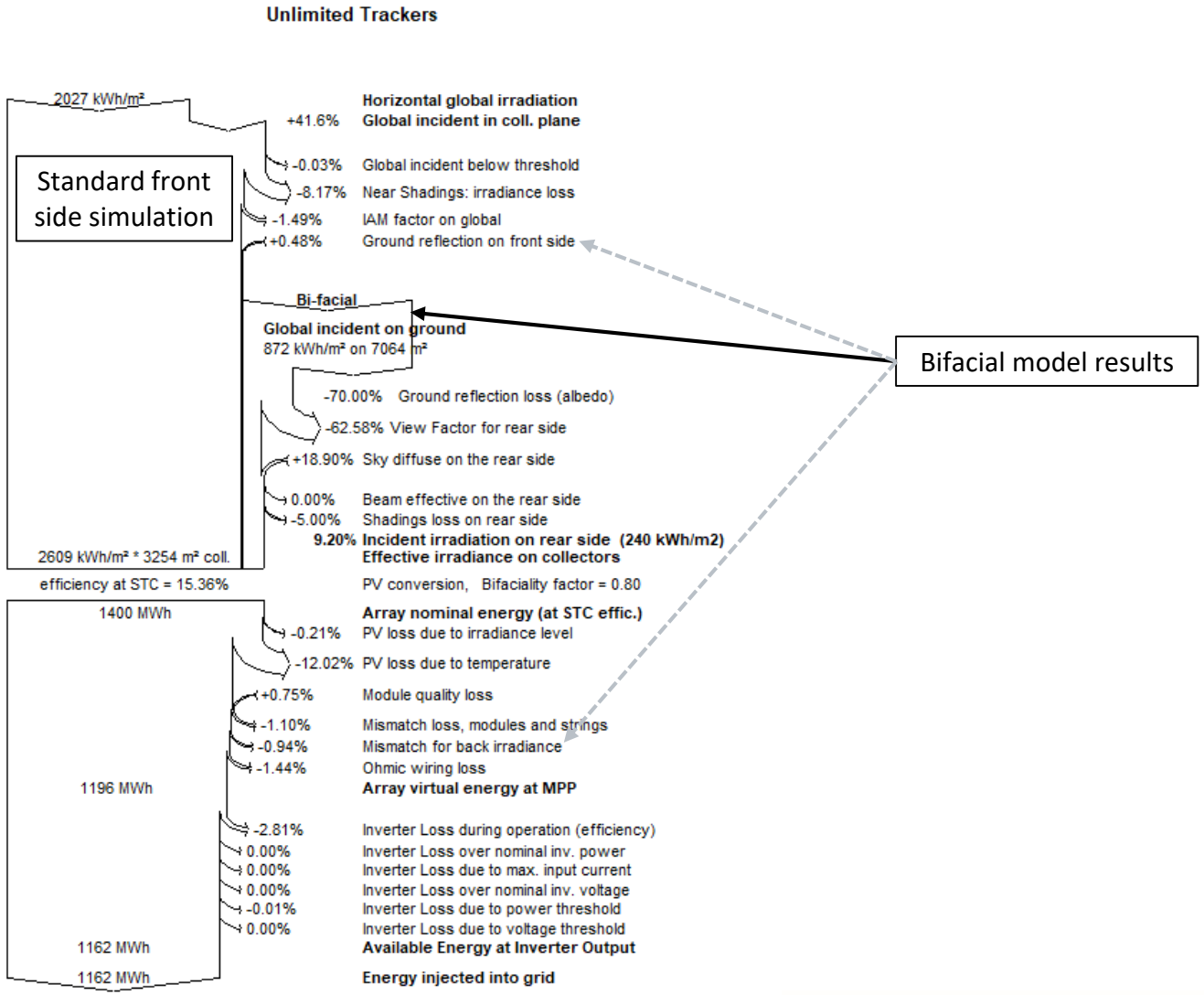


Bifacial Simulation and Results

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
- Mismatch for back irradiance

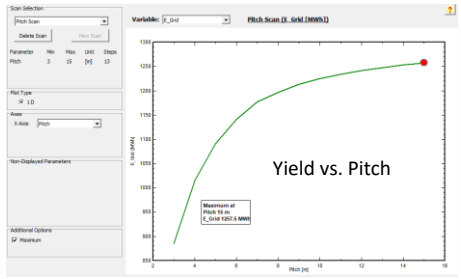
IAM losses are included in View Factors

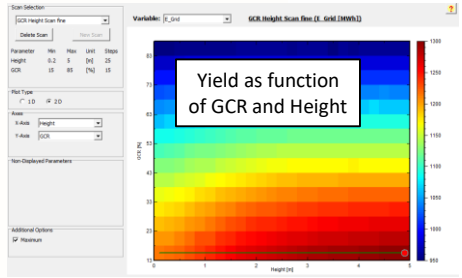


Studying Bifacial Behavior with PVsyst

Optimization Tool

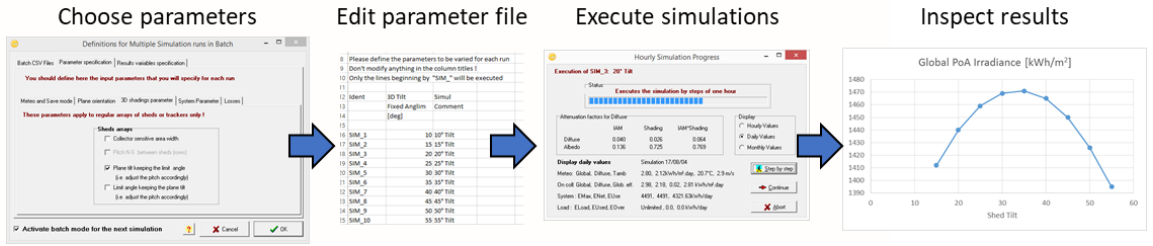
Allows quick parametric scans to optimize Irradiance or Yield





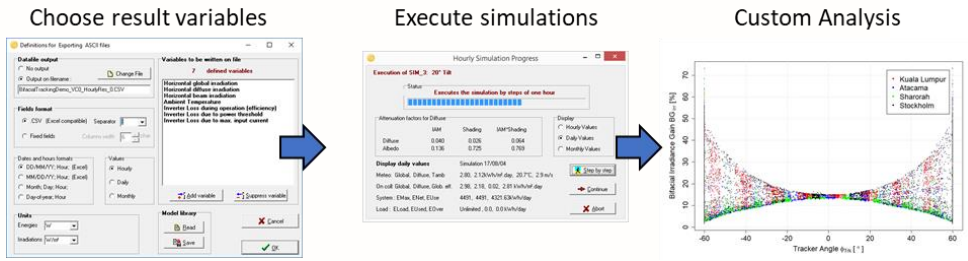
Batch Mode

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



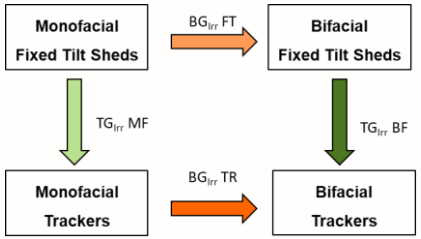
Hourly Results

Simulation results in hourly steps for ≈ 100 different variables



Impact of Parameters on Bifacial Gain

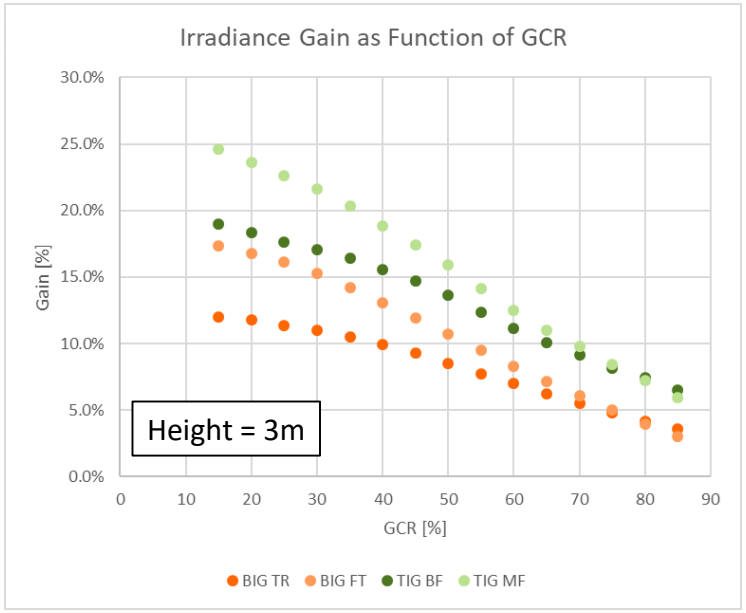
Parameters used here:
Site: Albuquerque NM, 35.05°N, 106.62°W, 1614m ASL
Weather data: Meteonorm 7.1, typical year
Geometry: Pitch=6.6m, Width 3m, GCR 45%, Height 3m
Ground albedo 30%



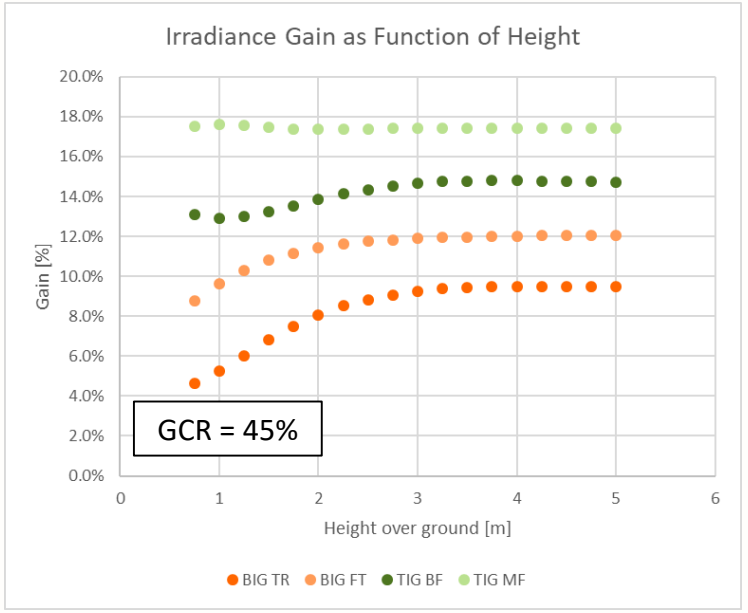
Bifacial Irradiance Gain

Tracker Irradiance Gain

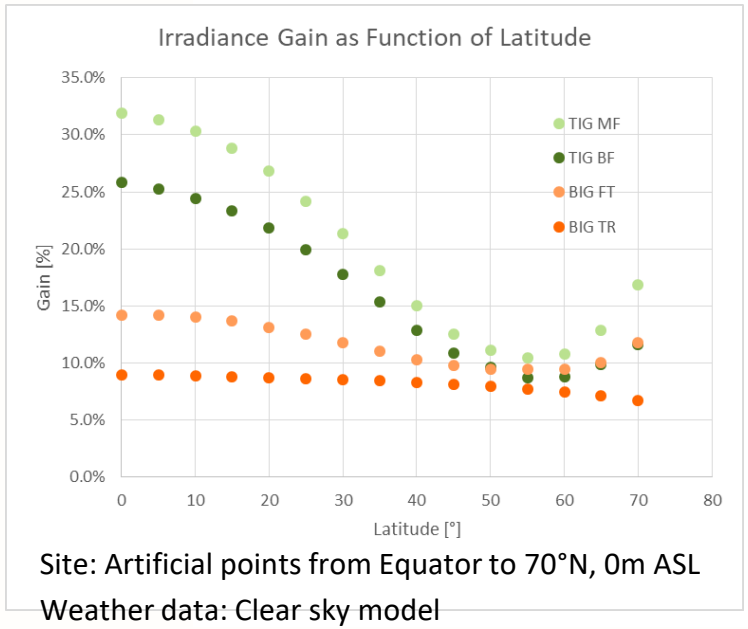
Ground Covering Ratio GCR:



Height over Ground:



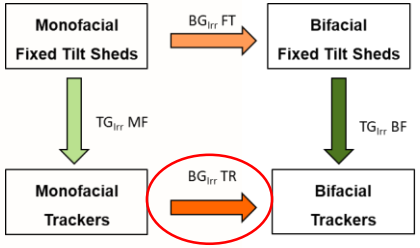
Different Latitudes:

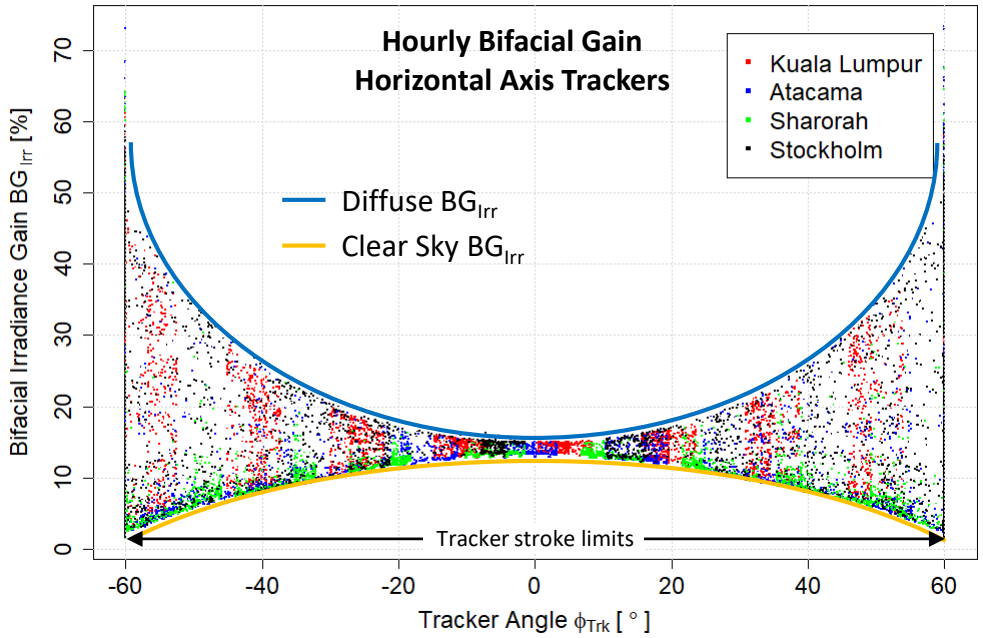


Site: Artificial points from Equator to 70°N, 0m ASL
Weather data: Clear sky model

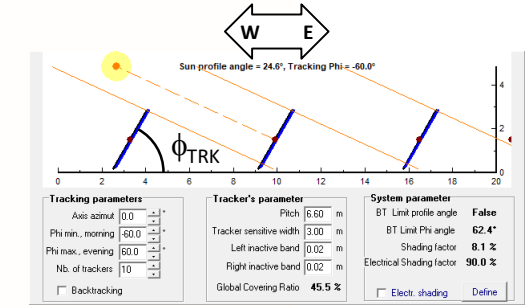
Bifacial Gain in different Climates (Trackers)

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



Summary and Outlook

- Summary
  - Bifacial model for fixed orientation sheds and horizontal axis trackers is implemented in PVsyst
  - 2D View factor approach is well suited for long and regular rows
  - Vertical bifacial simulations are possible
  - Batch Mode allows detailed parametric studies

- Outlook
  - Model the mismatch due to non-uniform irradiance on back side
  - General bifacial model based on near shading 3D drawing

Collaborative validation article with ZHW Zurich, ECN/TNO (NL), ISC Konstanz
'*Accuracy of Simulated Data for Bifacial Systems with Varying Tilt Angles and Share of Diffuse Radiation*'
to be published in *Solar Energy*