
# Simulation of PV Systems with PVsyst

## PEARL PV Conference
## 14.-15. March 2022
## Twente University, Enschede, Netherlands

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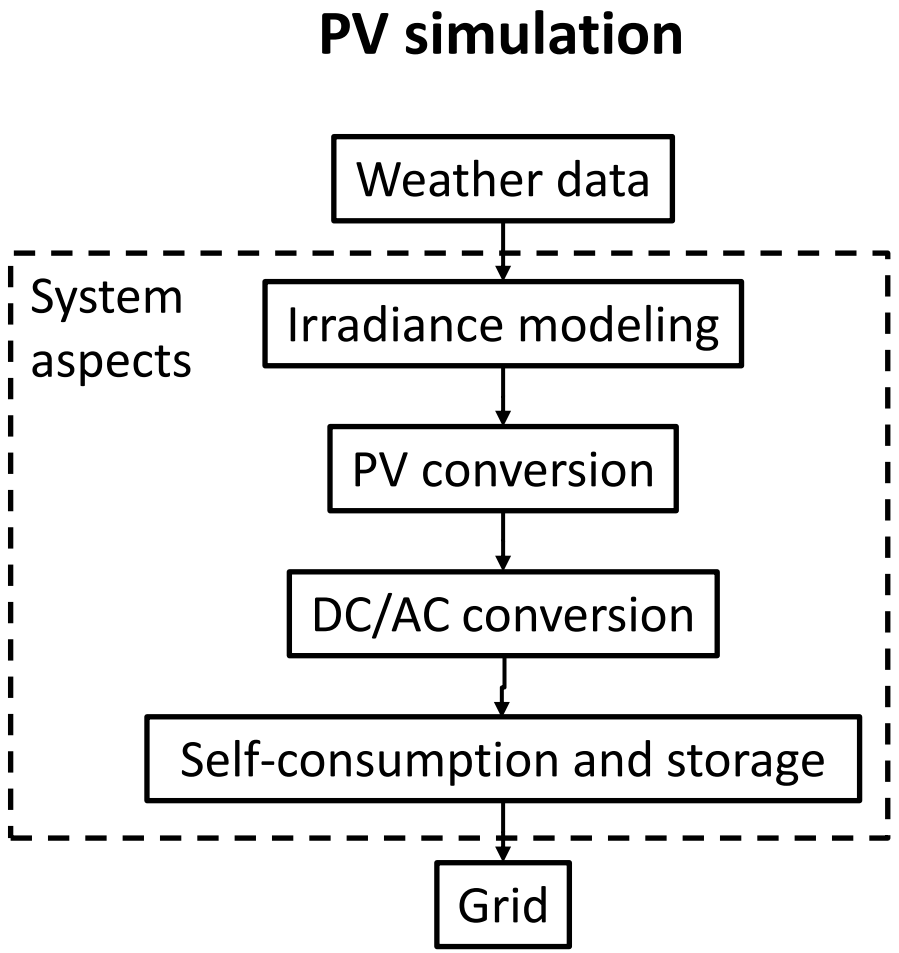
PVsyst SA, Switzerland

# Outline

- **Introduction**
- **PV Simulation aspects**
  - Weather input data
  - Modeling of PV Systems
- **Simulation results**
  - Advanced analysis with detailed PVsyst results
  - Comparison with measured data
  - Simulation uncertainties
- **Summary and Outlook**



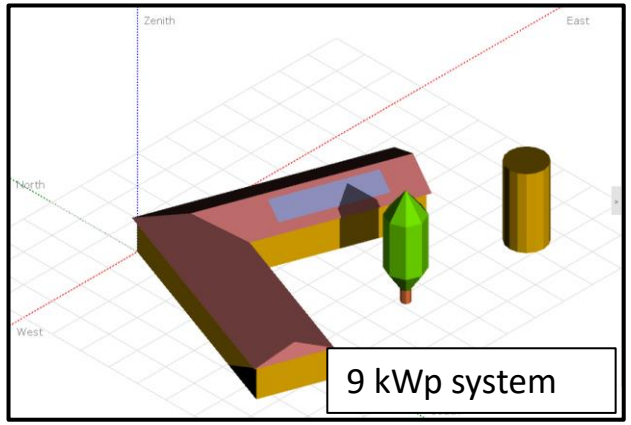
# Types of PV Systems in PVsyst


Grid-connected


Stand-Alone

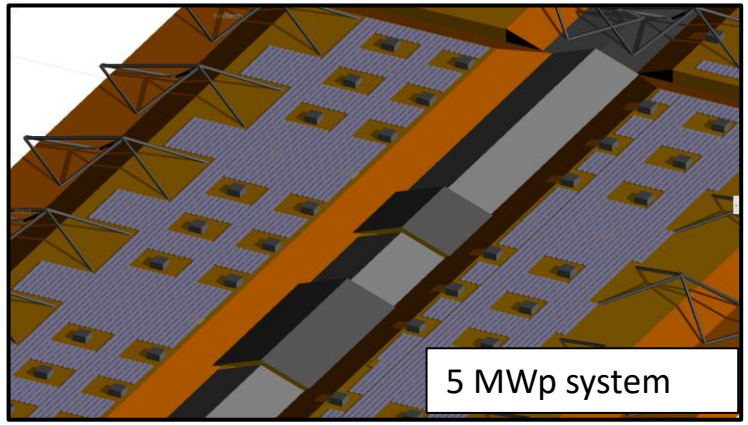

Pumping

Residential



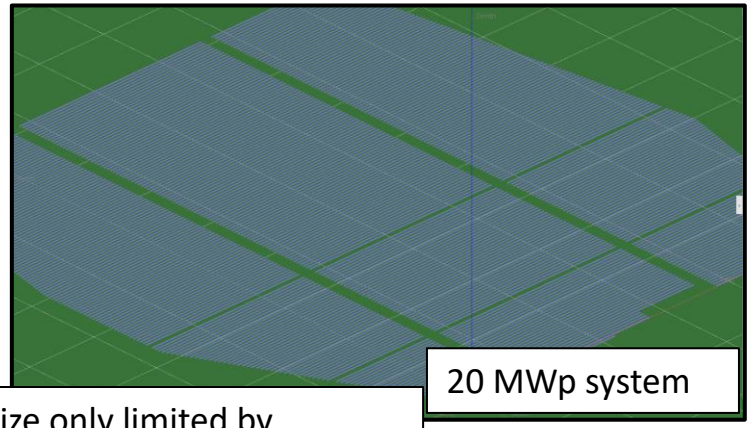

9 kWp system

Commercial



5 MWp system

Utility



20 MWp system

Size only limited by simulation/modeling time and computer memory

# Weather Data

## Sources

- Built-in
  - Metonorm 8.0
  - PVGIS API
  - NSRDB API
  - Solcast API
- External files
  - > 15 formats are recognized by PVsyst
- Custom data (text files)
  - New formats
  - Custom measured data

| Variables | |
|---|---|
| **Global horizontal irradiance** | **GHI** |
| **(Diffuse horizontal irradiance)** | **(DHI)** |
| **Ambient temperature** | **Tamb** |
| Global incident irradiance (PoA) | GlobInc |
| Wind speed | Windvel |
| Relative humidity / Precipitable water | RelHum/PrecWat |
| Linke turbidity | Linke |

### Data quality checks

Most useful for custom data import
Detects errors in timestamps and unrealistic data


## Transposition

Default is Perez-Ineichen model (Hay model optional)

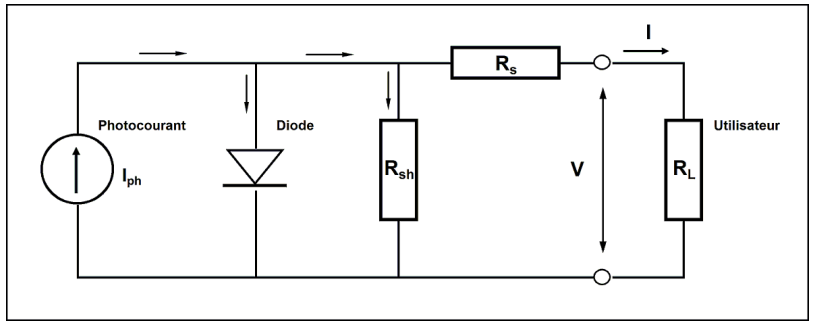
**Horizontal plane** → **Tilted plane (PoA)**

**GHI+DHI** →
- Direct
- Circumsolar
- Diffuse Isotropic
- *(Horizon Band)*
- *(Far Albedo)*

} Irradiance components used in the simulation

# Modeling of PV Modules

## Single diode model

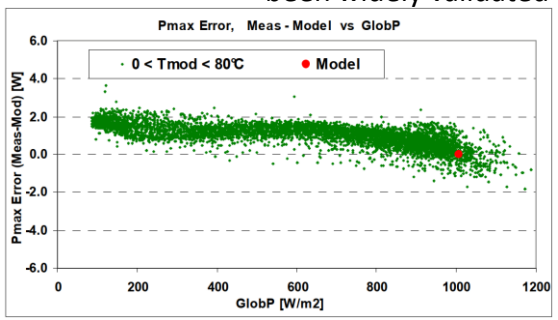



Describes the PV cells for any irradiance and temperature conditions

Each type of PV module is described by a set of parameters for this model

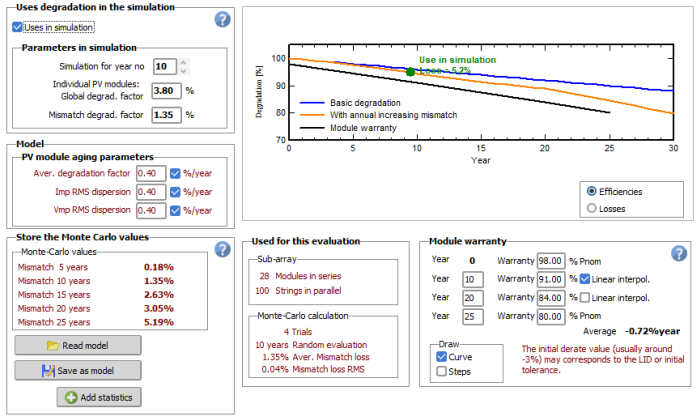
Users can add their own PV modules

The single diode model has been widely validated



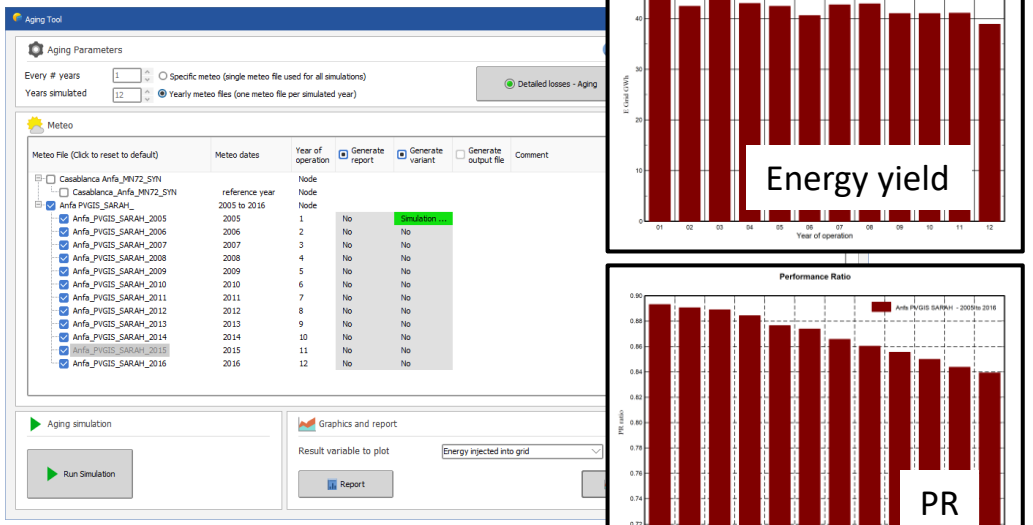

*A. Mermoud, T. Lejeune*,
**Performance assessment of a simulation model for PV modules of any available technology**, 2010

## Aging model



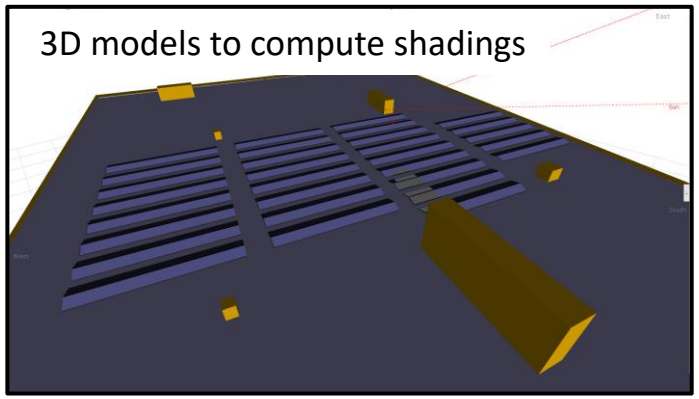

Global power degradation (yearly decrease of power generation)
Increasing mismatch due to individual module aging

Multi-year simulations:

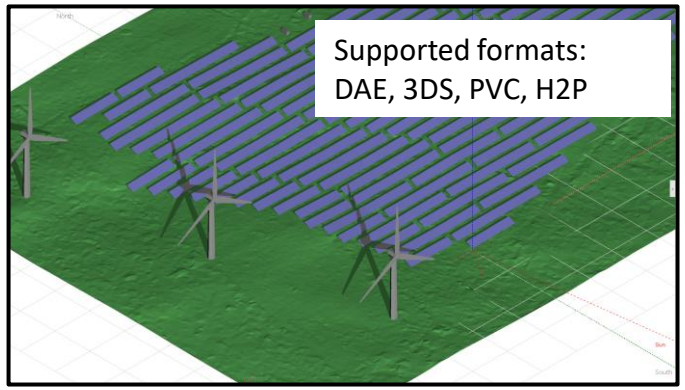


# Shadings Losses

## ‘Linear’ shading losses (irradiance loss)



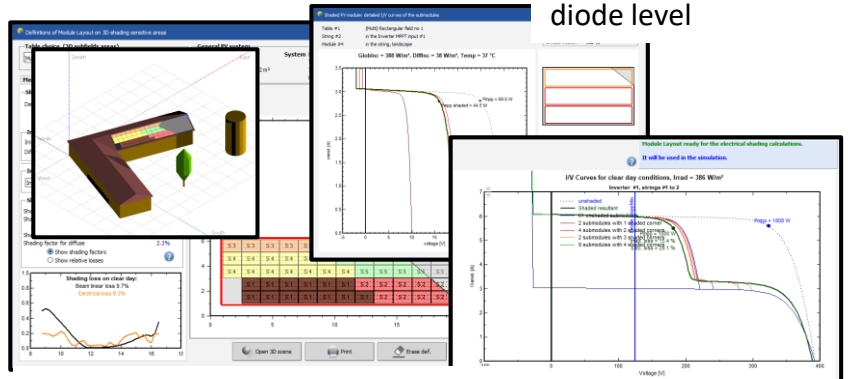

Import 3D models from other software tools




## ‘Electrical’ shading losses

Detailed analysis of electrical mismatch (Module Layout)

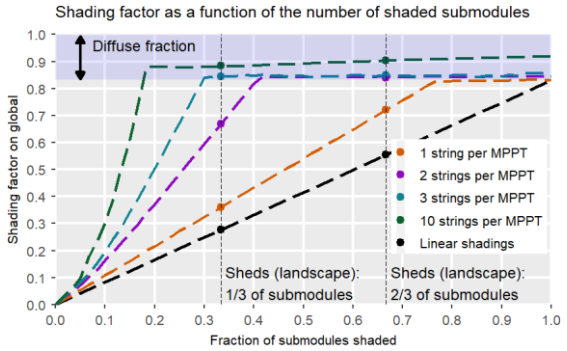
Calculated on bypass diode level



Systems > 5 MW become hard to work with

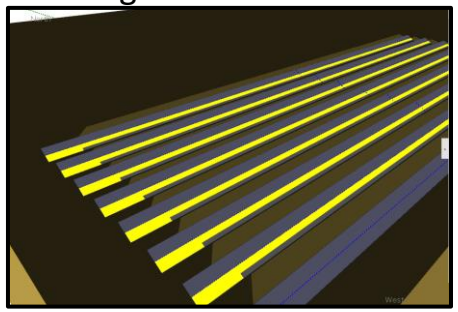
## Simplified calculation for electrical shading losses

treat partially shaded strings as a whole

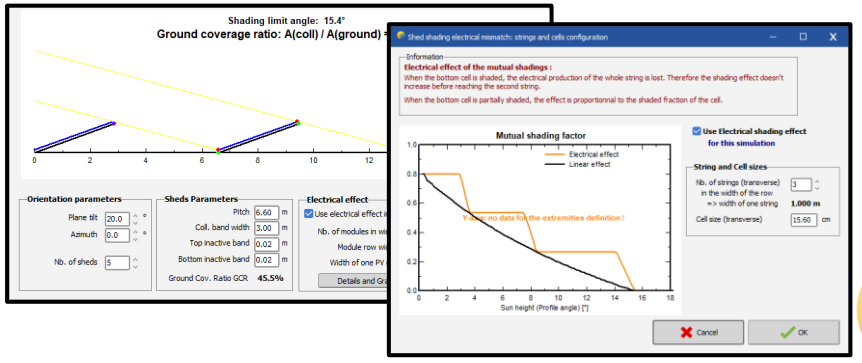



Partially shaded strings loose a **fixed fraction** of the PV generation coming from **direct** sunlight

String partitions in 3D drawing:



‘Unlimited’ sheds/trackers:
Simplified shading calculations based on 2D cross section

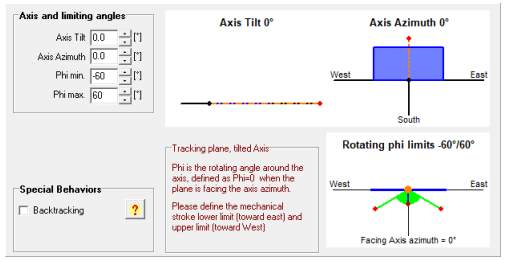



*M. Oliosi, B. Wittmer, A. Mermoud* ,
**Analysis of Electrical Shading Effects in PV Systems**, EUPVSEC Proceedings, 2021

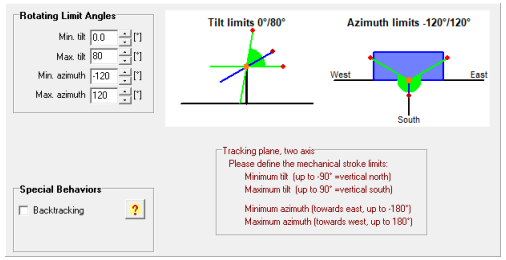
# Tracking Systems

## Common trackers

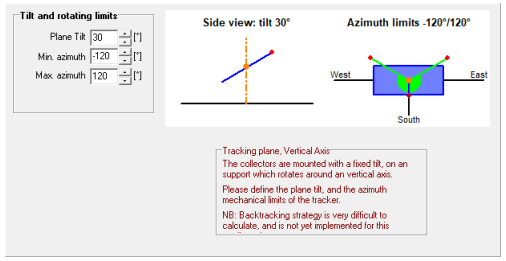
Horizontal or tilted axis




Dual axis

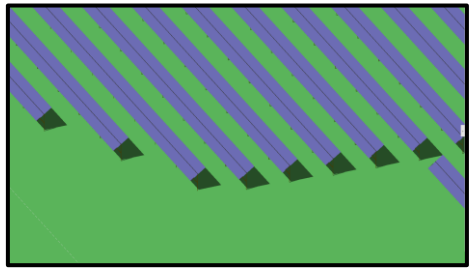


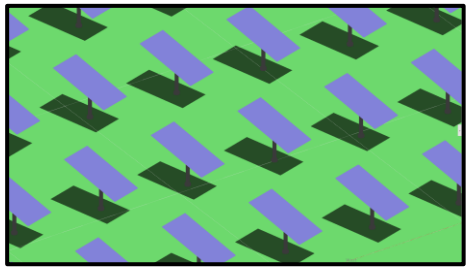

Vertical axis

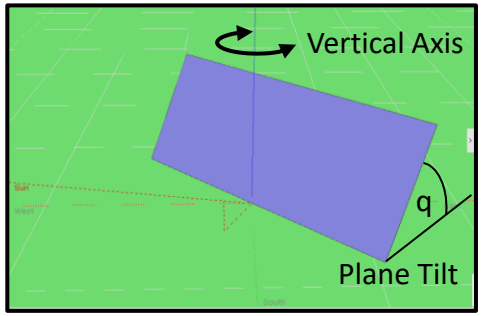



A few more exotic tracking systems are also available in PVsyst

## 3D Representations



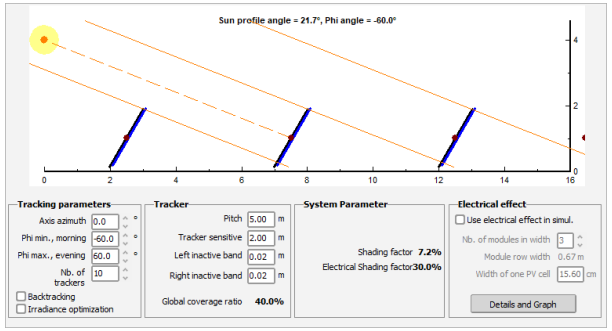





To get a correct simulation of the shading losses, a 3D model of the PV trackers is necessary

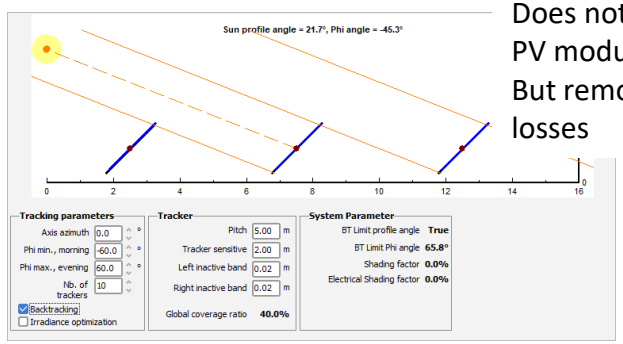
## Astronomic tracking

Minimizes angle of incidence




## Backtracking

Avoids mutual row shadings

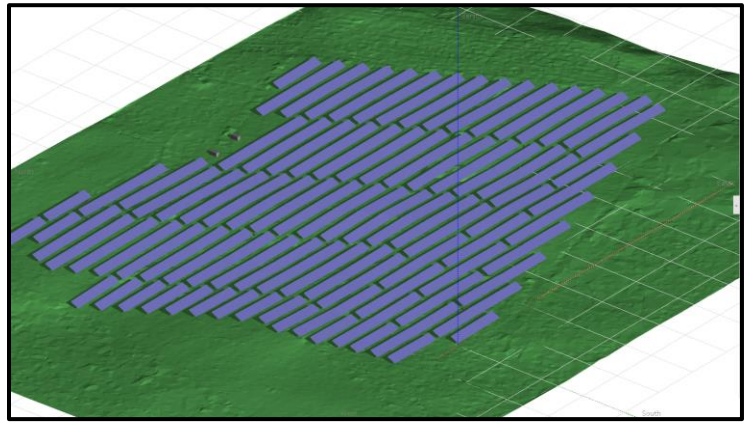



Does not increase irradiance on PV modules

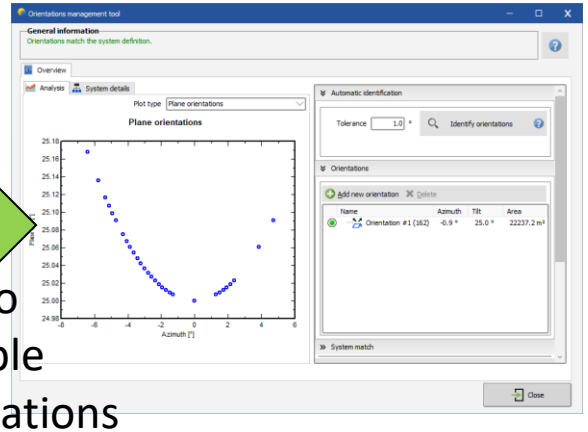
But removes electrical shading losses

# Non-flat topologies

PV Systems on non-flat topology

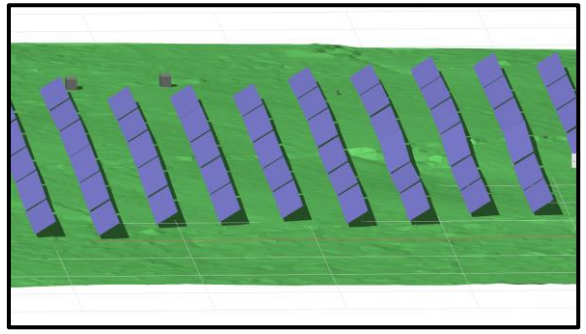


lead to multiple orientations

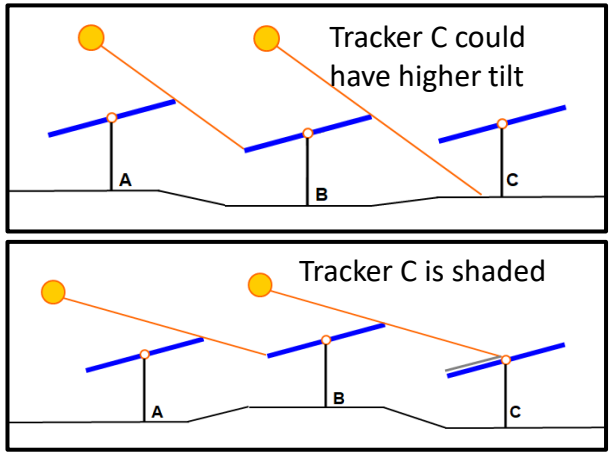



The orientations are averaged for the transposition calculation
All detail is conserved for the shading calculations (important for electrical shadings)

Trackers can also be simulated on topology:



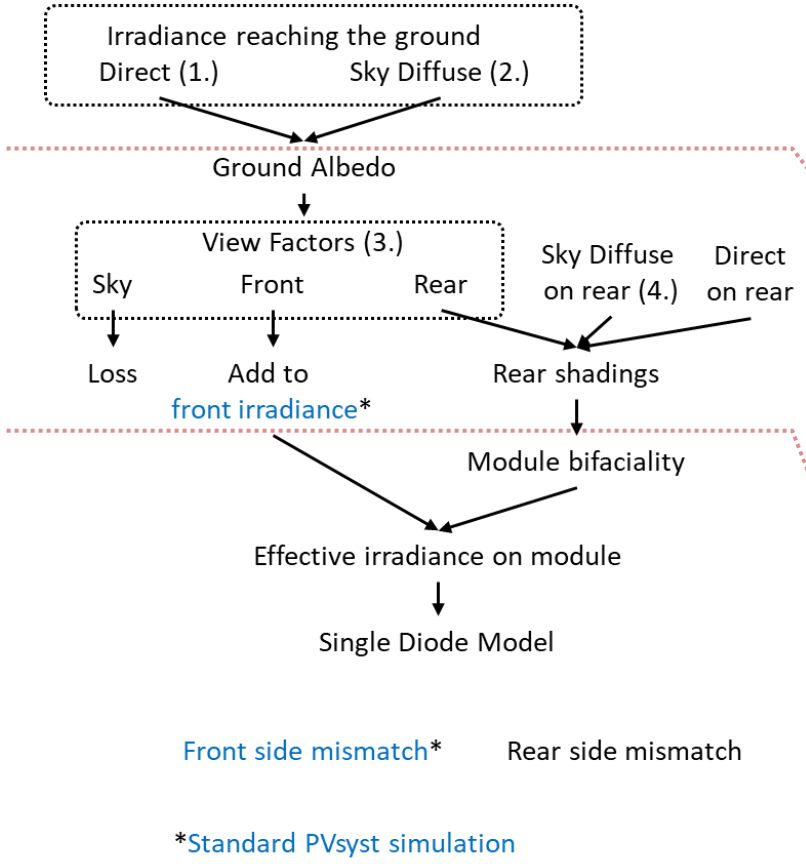
but backtracking is problematic:




Trackers need to have individual positions
There is no unique solution to this problem

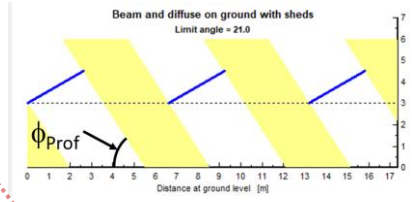
# Bifacial 2D Model in PVsyst

Bifacial calculation steps



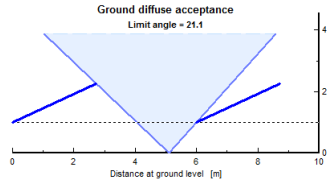

**Irradiance on Ground**

1. Ground Acceptance of direct light



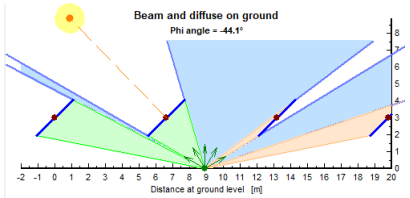

The sun profile angle is the sun height in the 2D projection

2. Ground acceptance of diffuse light



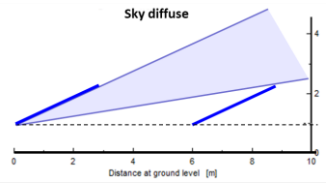

**Irradiance on Module**

3. View factors



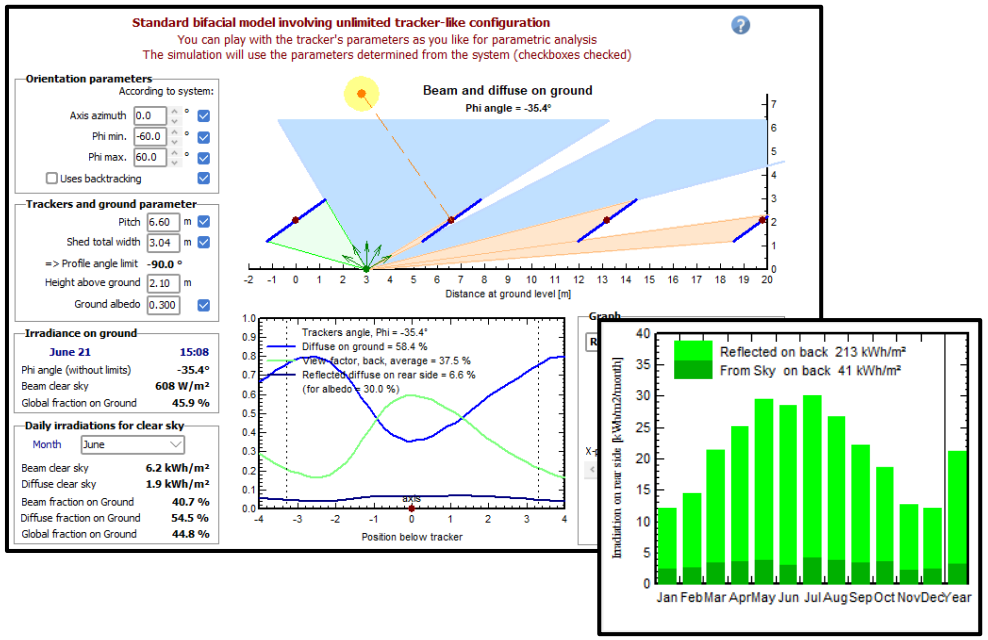

Integrate over all ground points and the back side of the module

4. Sky diffuse and direct on back side

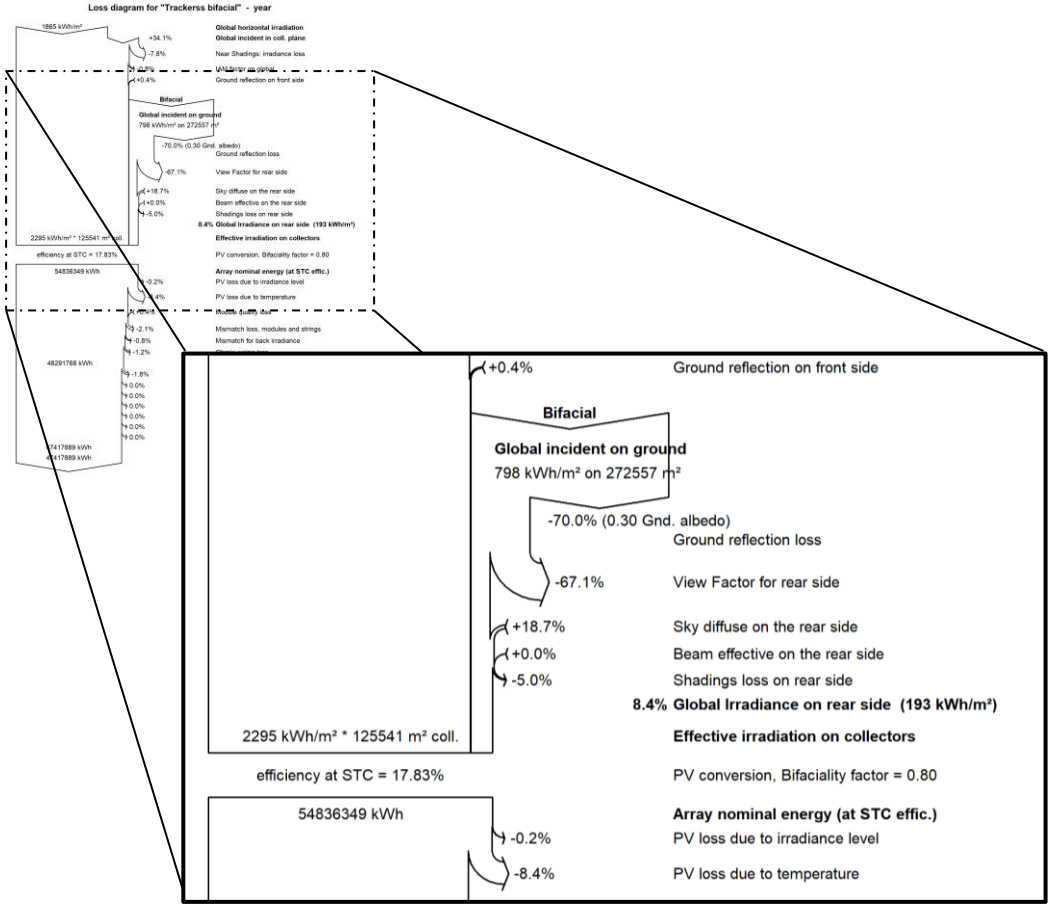


# Bifacial Simulations

## Tool to visualize bifacial model




## Additional irradiance flow in simulation results

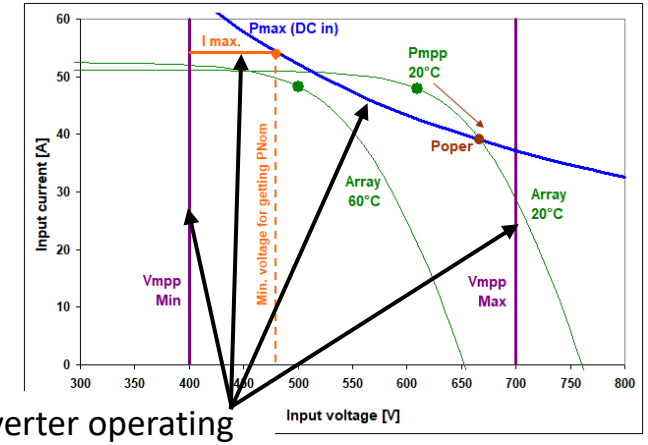



With current model:
Fixed tilt rows and rows with trackers can be modeled

Development:
Generalize the bifacial simulation to work with any 3D drawing

# MPPT and Inverter modeling

## Operating point




Inverter operating limits

A valid operating point is searched on the string IV-curve

Different losses:
Power limit
Voltage limits
Current limit
Conversion efficiency

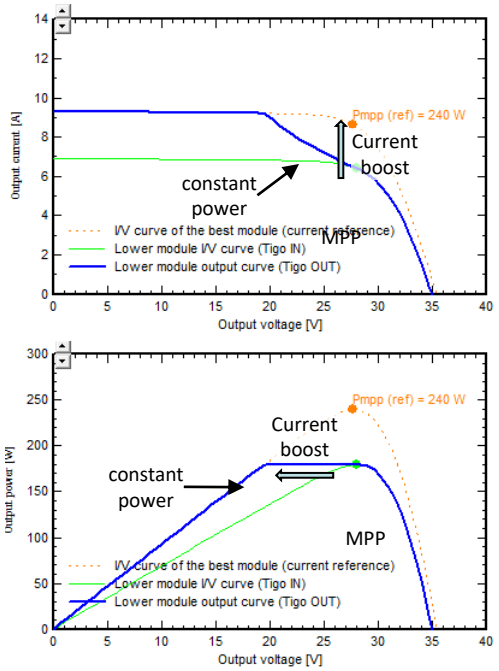
**Additional inverter features**:
Reactive power (power factor)
Temperature behavior
Multiple MPPT (string inverters)
Grid limitation

Users can also add their own inverters

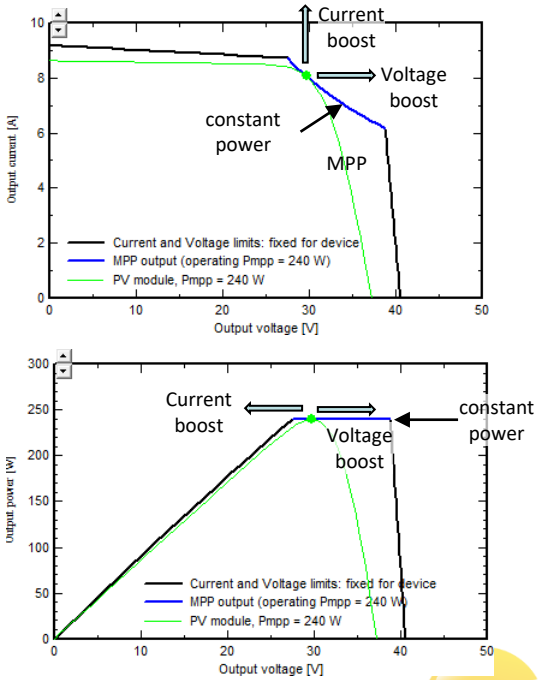
## Power optimizers

Need specific implementations
(4 brands so far, 5th in preparation)

'Buck-only'
Current boost




Full optimizer
Current & Voltage boost

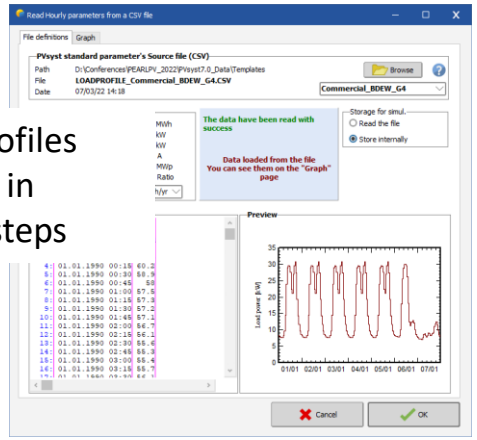


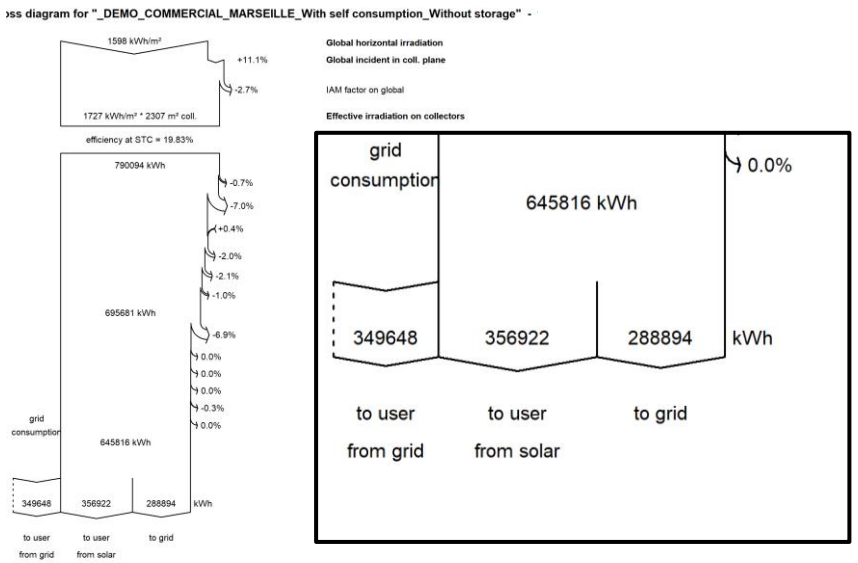

: Module IV curve
: Optimizer Output

# Self-consumption and Storage

## Load profiles

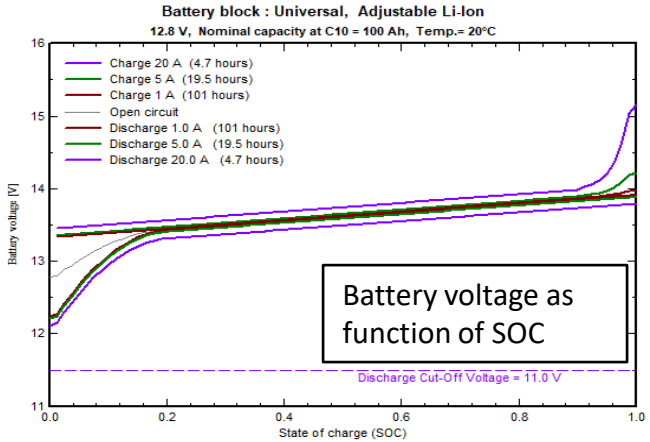
Load profiles defined in hourly steps




## Battery models

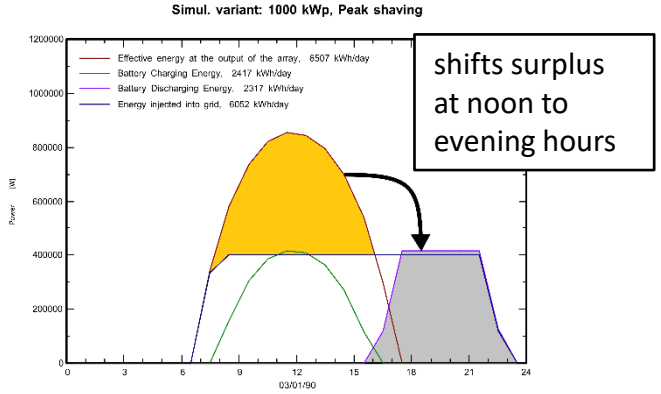
Lithium Ion and Lead Acid



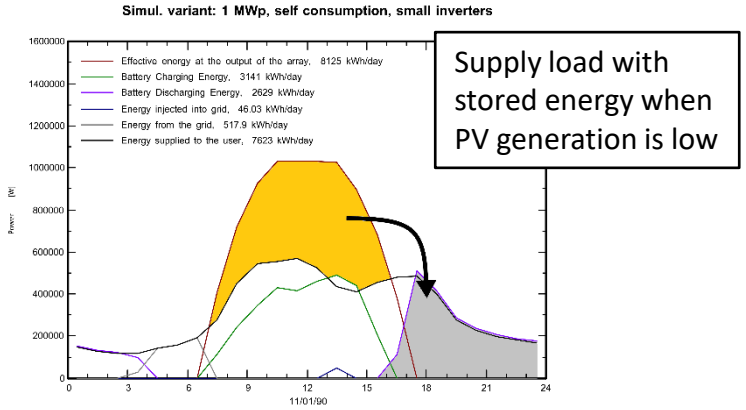

## Dispatch strategies

The battery regulation algorithms are based on SOC

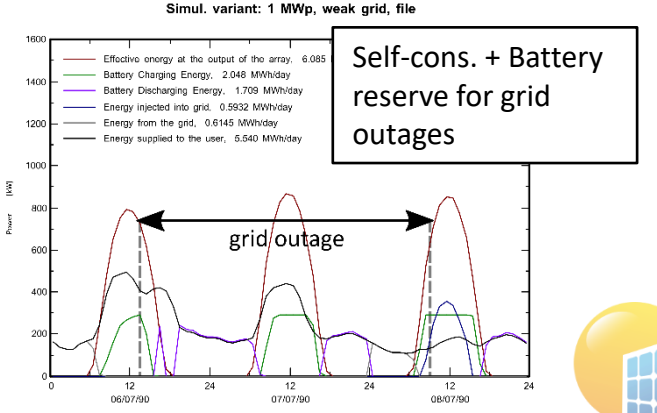
### Peak shaving (injection limitation)




### Self consumption

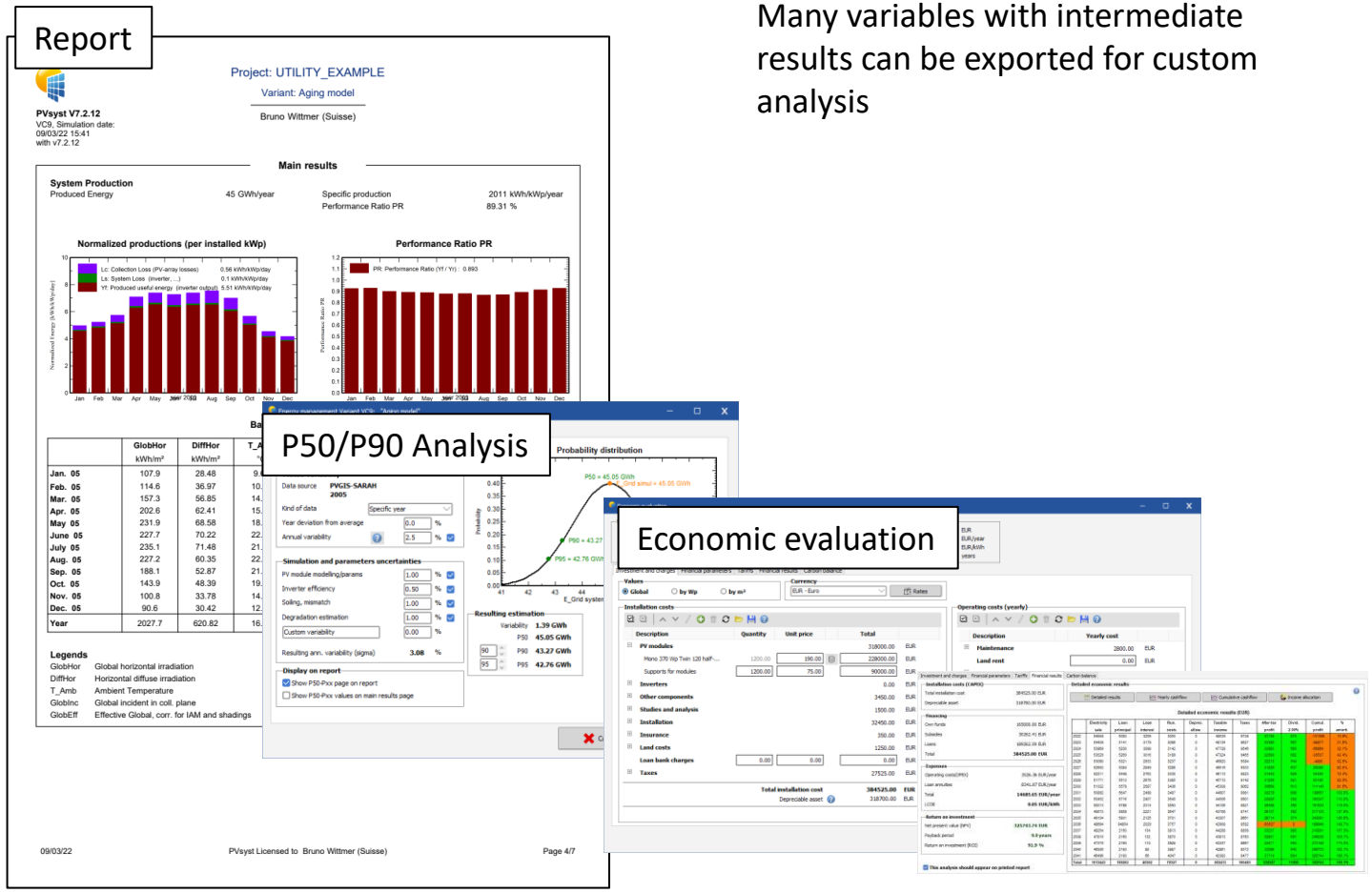



### Weak grid



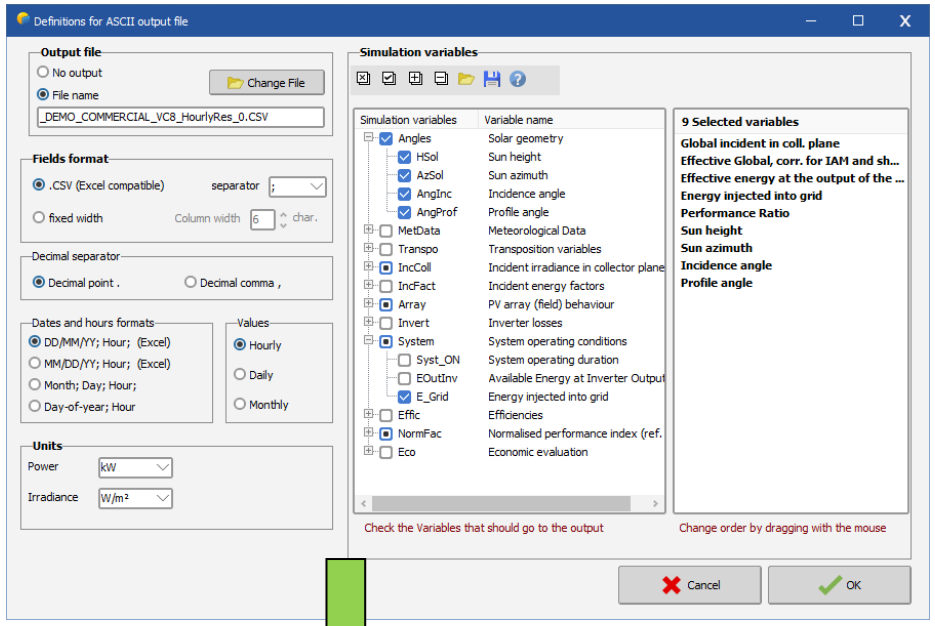
# Simulation Results

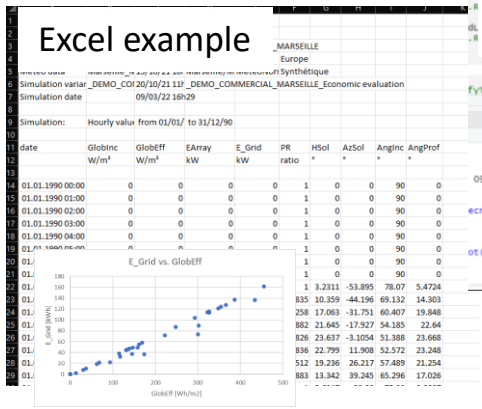
## Comprehensive results

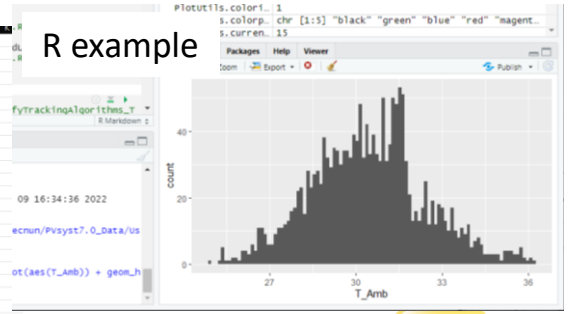



## Hourly result files

Many variables with intermediate results can be exported for custom analysis



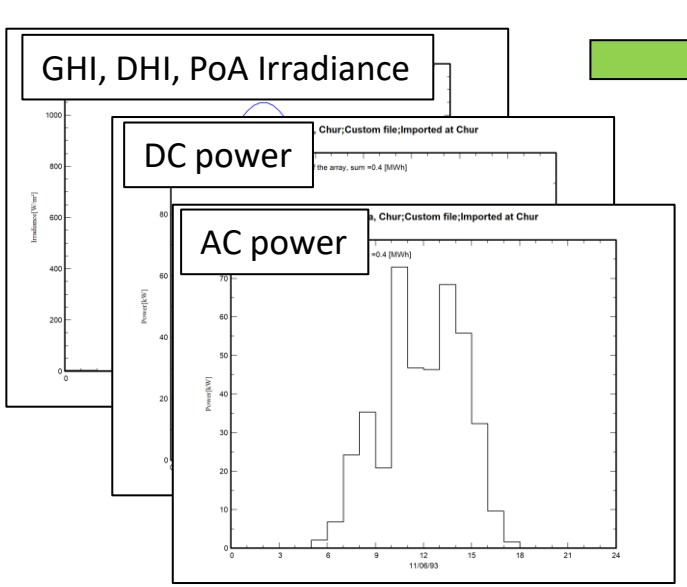



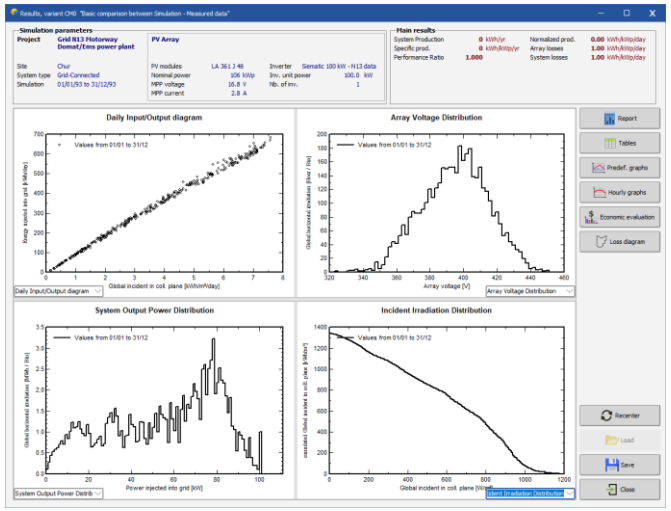
# Comparison with measured data

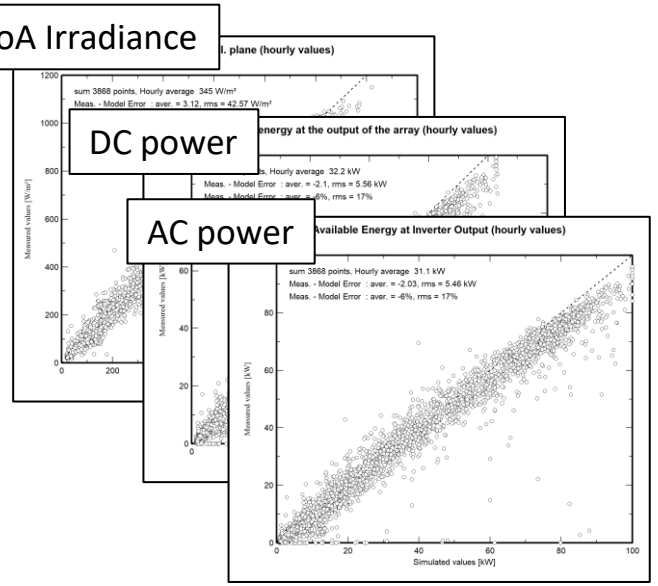
Import weather and monitoring data

Execute simulation

Comparison plots






## Published validations

Validation should be done on hourly data!


*H. Nussbaumer, G. Janssen, D. Berrian, B. Wittmer, M. Klenk, T. Baumann, F. Baumgartner, M. Morf, A. Burgers, J. Libal, A. Mermoud*,
**Accuracy of simulated data for bifacial systems with varying tilt angles and share of diffuse radiation**, Solar Energy, Volume 197, 2020

*B. Wittmer, A. Mermoud, T. Schott* ,
**Analysis of PV Grid Installations Performance, Comparing Measured Data to Simulation Results to Identify Problems in Operation and Monitoring**, EUPVSEC Proceedings, 2015

*A. Mermoud, T. Lejeune*,
**Performance assessment of a simulation model for PV modules of any available technology**, 2010, available at www.pvsyst.com/scientific-publications/

*A. Mermoud, R. Durot*,
**Installation Photovoltaïque de l'Ecode d'Aïre: Analyse des données de fonctionnement, comparaisons avec le logiciel PVsyst**, 2009 , available at www.pvsyst.com/scientific-publications/

# Simulation uncertainties

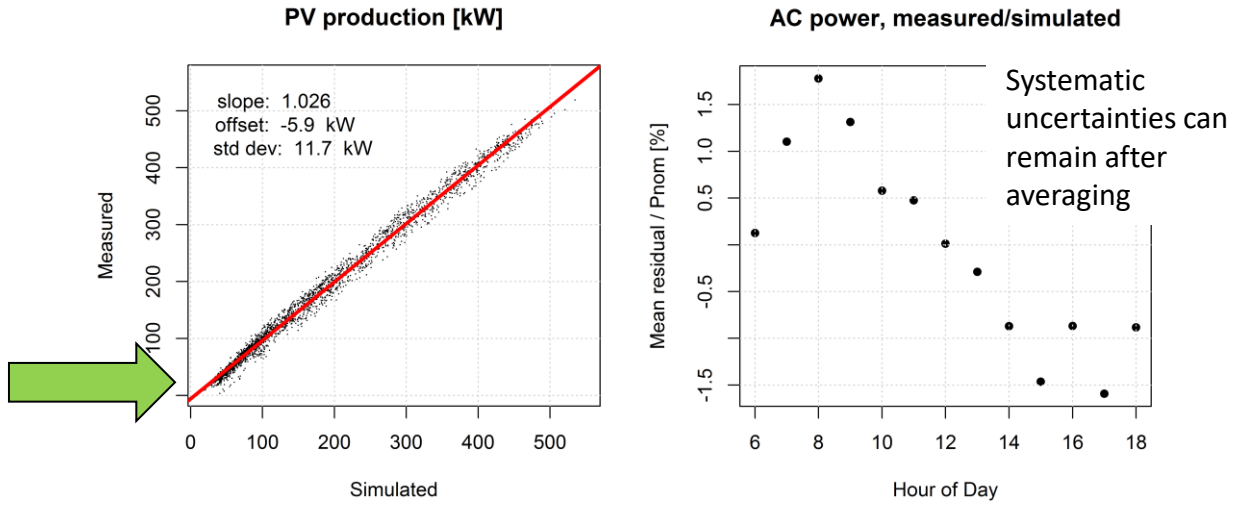
**Systematic simulation uncertainty**
Idealizations in describing the system
From **models** and their **parameters**:
Uncertainties in transposition models,
Single diode model describing PV modules,
Idealized geometry,
etc.
Estimated overall yearly uncertainty around 1% - 3%

**Differential comparisons**
Compare only a single aspect like geometry or string topology:
uncertainty can become < 1%

**Weather**:
- Differences between data providers
- Annual variability
- Long-term trends

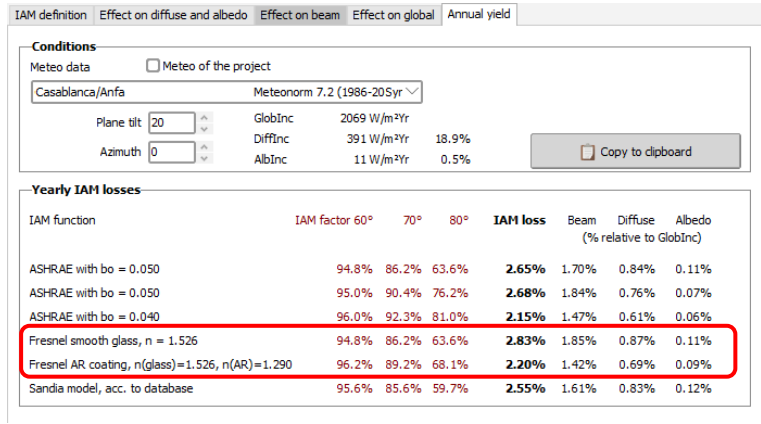
Estimated uncertainty: 3% - 15%

Example of a comparison for a 500 kWp system




Systematic uncertainties can remain after averaging

Example of comparison of different PV module cover glasses



# Summary

- **Large variety of systems can be simulated in PVsyst**
  Grid-connected, Standalone, Pumping
- **From small residential PV systems up to utility scale**
- **Complex shadings, bifacial systems, trackers, self-consumption, storage**
- **Many details can be described in the simulation, including PV module aging**
- **Components like PV modules, inverters and batteries can be added by user**
- **Weather data from many different sources can be imported**
- **Simulation results**
  - Comprehensive reports
  - Plots and tables
  - Detailed hourly result files for further analysis
  - Direct comparison to measured data

# Developments

- Agri-PV extensions
- Floating PV
- Improvement of bifacial models (based on 3D drawing)
- Orientations -> more flexibility
- Sub-hourly data
- Single Line diagram for PV system
- Validations on measured systems
- Tandem perovskite PV modules
- Operate PVsyst simulations from command line