This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 792059

June. 22nd. 2022

6. Performance analysis

Yield simulation at design phase

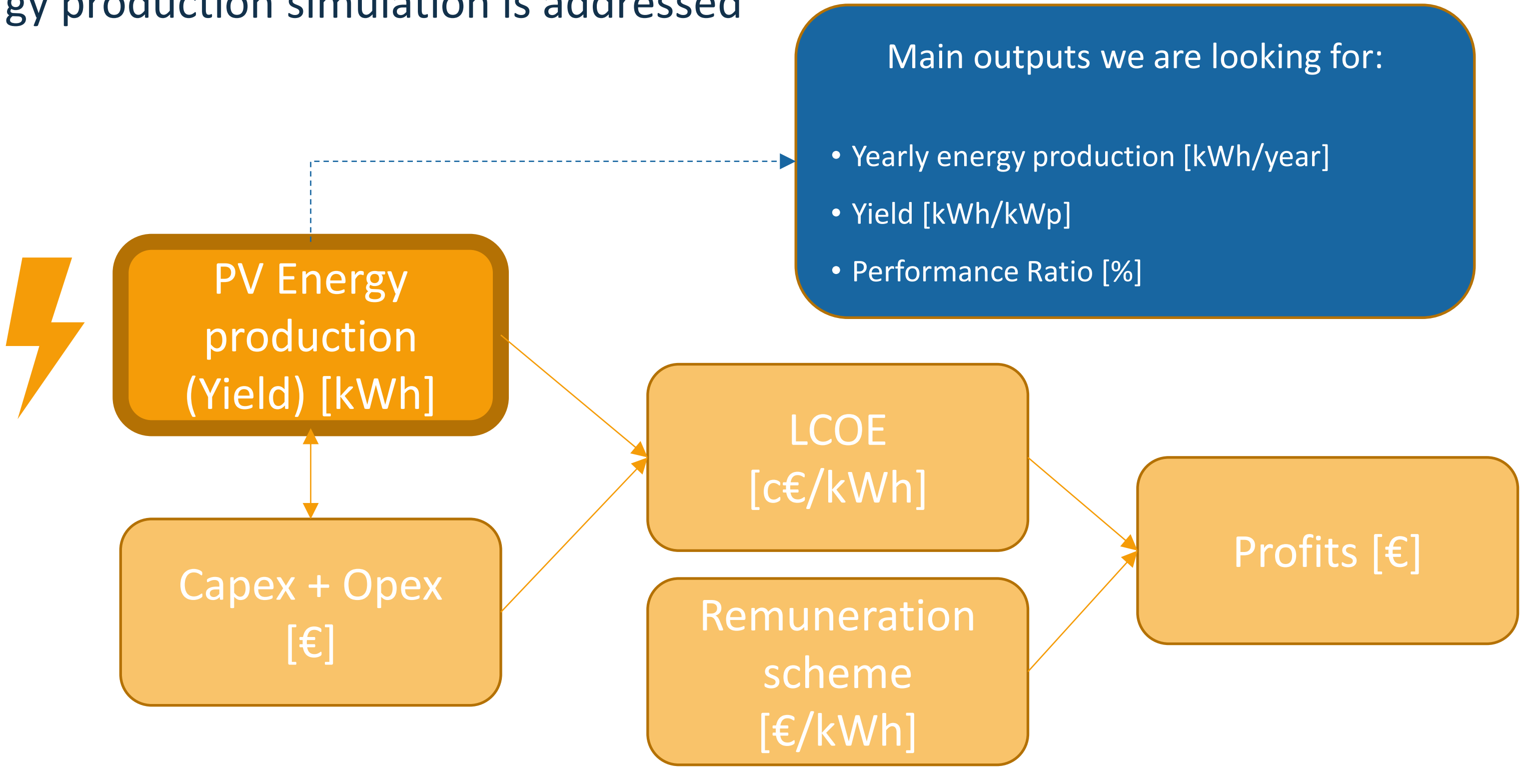
Daniel Valencia-Caballero
GOPV Summer School. Catania

GLOBAL OPTIMIZATION OF INTEGRATED PHOTOVOLTAIC SYSTEM FOR LOW ELECTRICITY COST

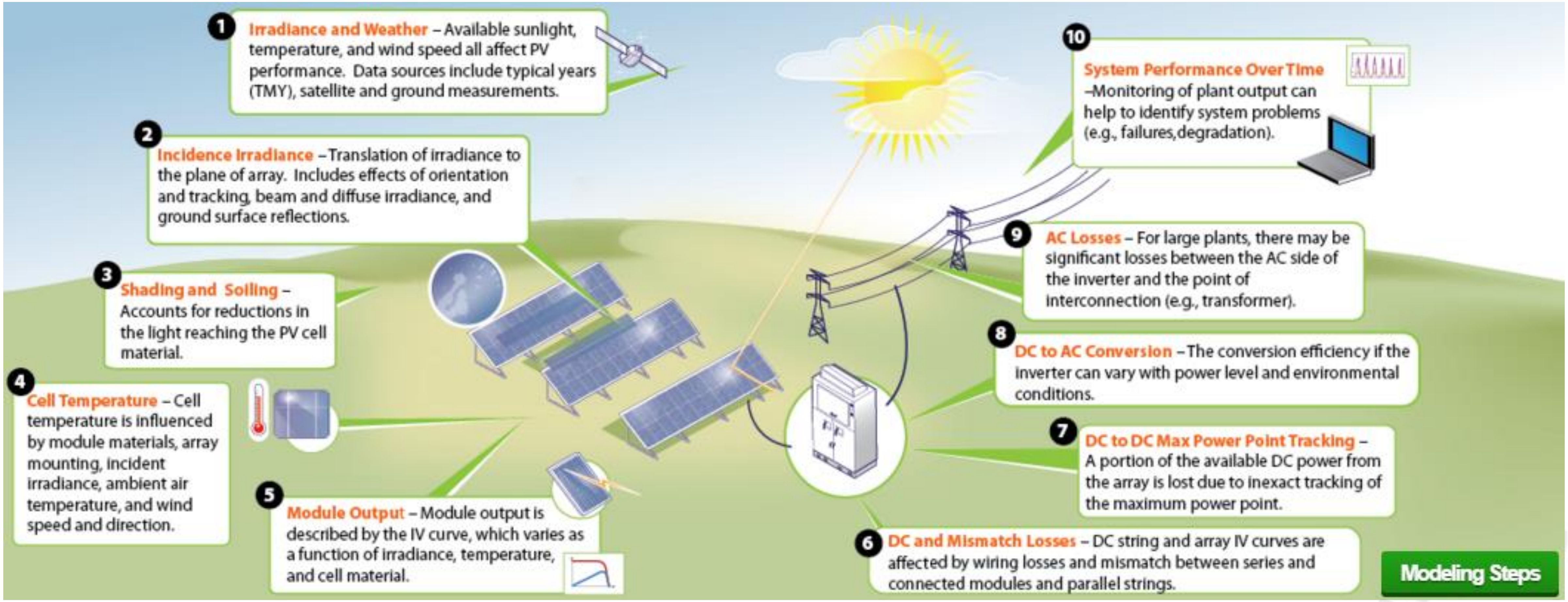
co-organized with

THE PURPOSE

- The purpose (normally) is getting an economic profitability of the PV installation
- Here, only PV energy production simulation is addressed

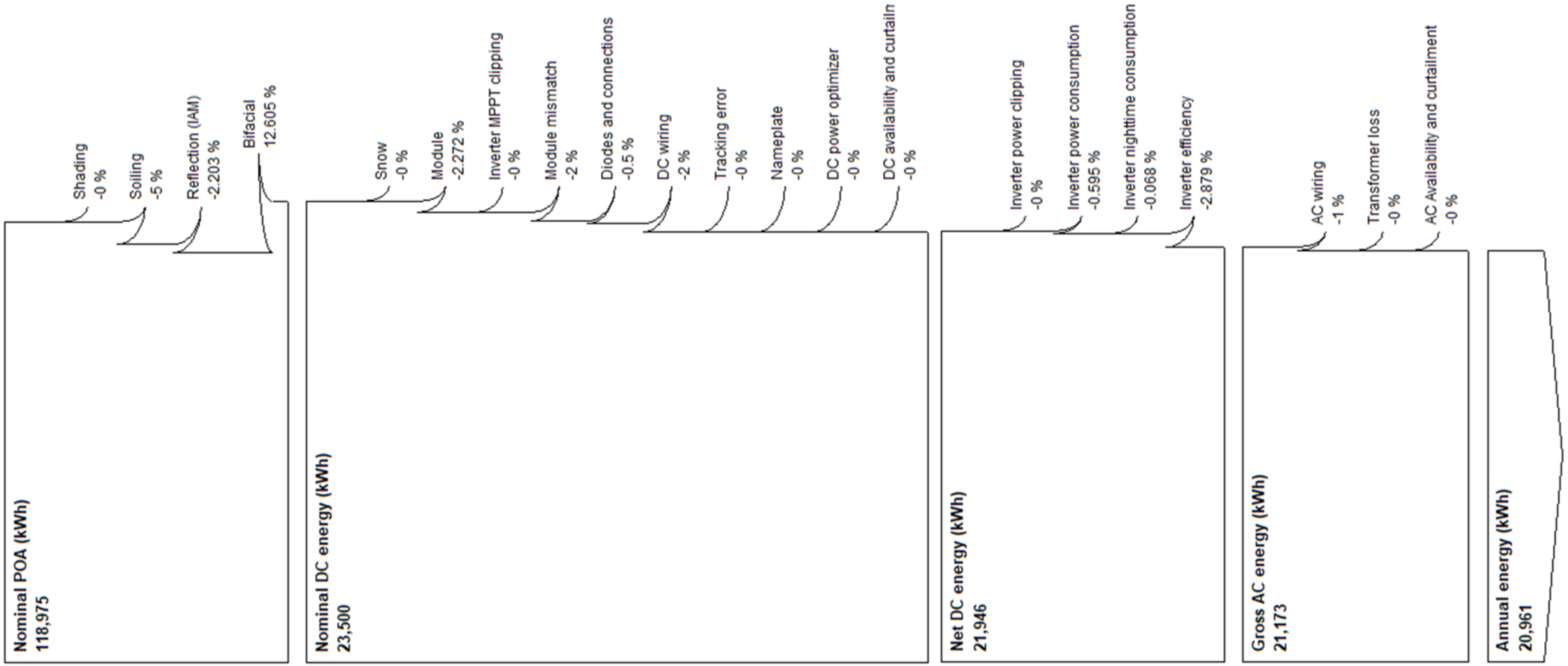


FROM SUN RADIATION TO AC ELECTRICITY



Moser D. et al. "Uncertainties in Yield Assessments and PV LCOE," Nov. 2020. IEA-PVPS T13.
https://pvpmc.sandia.gov/

FROM SUN RADIATION TO AC ELECTRICITY



FROM SUN RADIATION TO AC ELECTRICITY

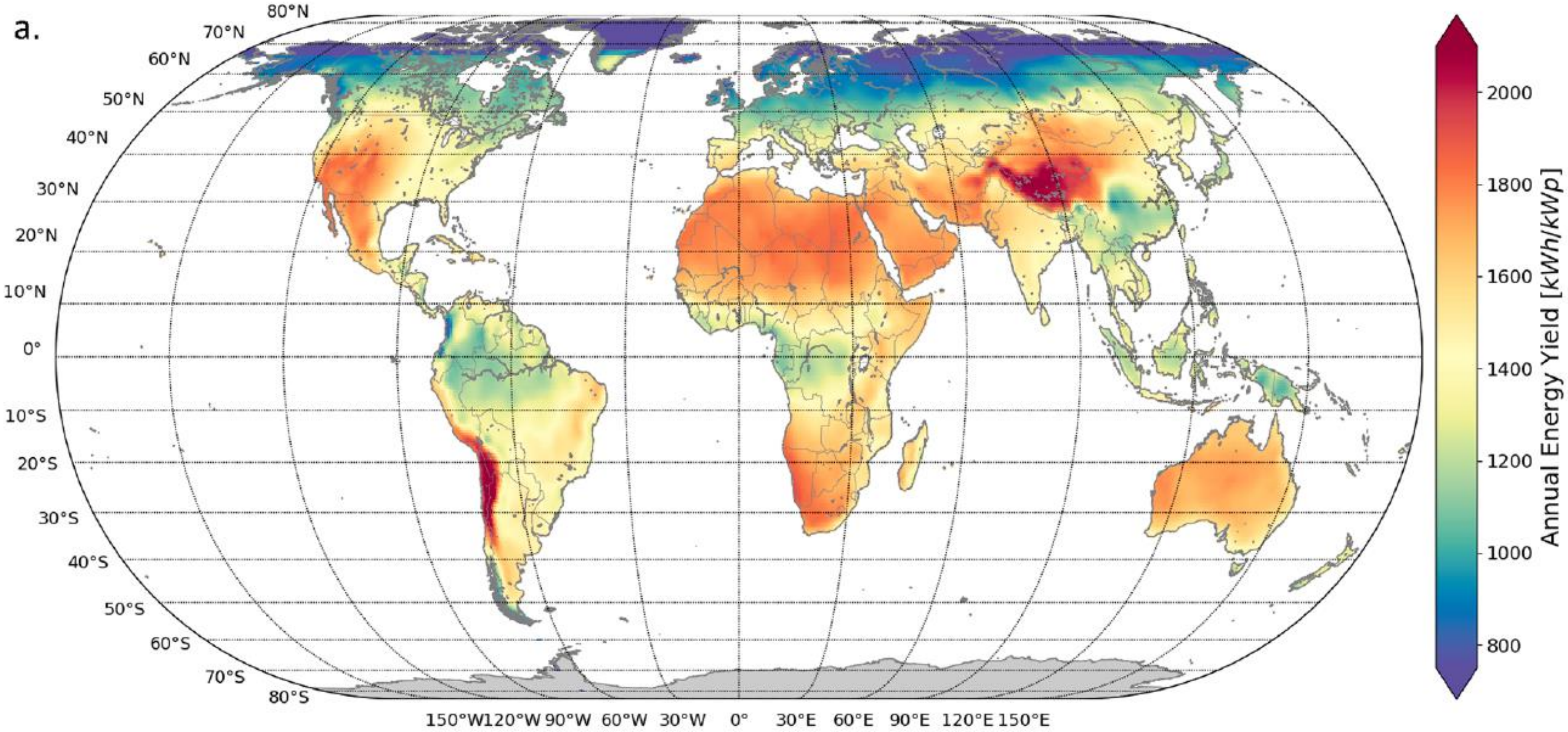
- Example of gains/losses along each modelling step and the related uncertainty.
- Typical output tables or diagrams in yield assessment show the contribution. Rarely the uncertainty is provided.
- The starting point of PR = 100 is considered after applying the horizon shading as this become the annual insolation seen by the PV modules
- Note that radiation in [kWh/m^2] and electricity in [kWh/kWp] give comparable numbers.
- Uncertainty equal to 6.5 % is the result of the sum of the root mean square error of the relative uncertainty of each step.

Annual values	uncertainty	value	gains/loss	PR
	%	kWh/m^2	%	%
global irradiation on horizontal plane	4.0	1248		
irradiation on module plane	2.5	1448	16.0	
shading				
horizon shading	0.5	1445	-0.2	100.0
row shading	2.0	1422	-1.7	98.3
object shading	3.0	1422	0.0	98.3
soiling	0.5	1414	-0.5	97.9
deviations from STC				
reflection losses	0.5	1376	-2.7	95.2
	%	kWh/kWp	%	%
spectral losses	0.5	1363	-1.0	94.3
irradiation-dependent losses	0.8	1342	-1.5	92.9
temperature-dependent losses	1.0	1309	-2.5	90.5
mismatch losses	0.5	1298	-0.8	89.8
DC cable losses	0.5	1287	-0.8	89.1
inverter losses	1.5	1272	-1.2	88.0
inverter power limitation	0.5	1272	-0.1	88.0
additional consumption	0.5	1270	-0.1	87.9
AC cable losses low voltage	0.5	1265	-0.4	87.5
Transformer medium voltage	0.5	1253	-0.9	86.7
AC cable losses medium voltage	0.5	1252	-0.1	86.6
Transformer high voltage	0.0	1252	0.0	86.6
total	**6.5**	**1252**		**86.6**

Example done by Fraunhofer ISE

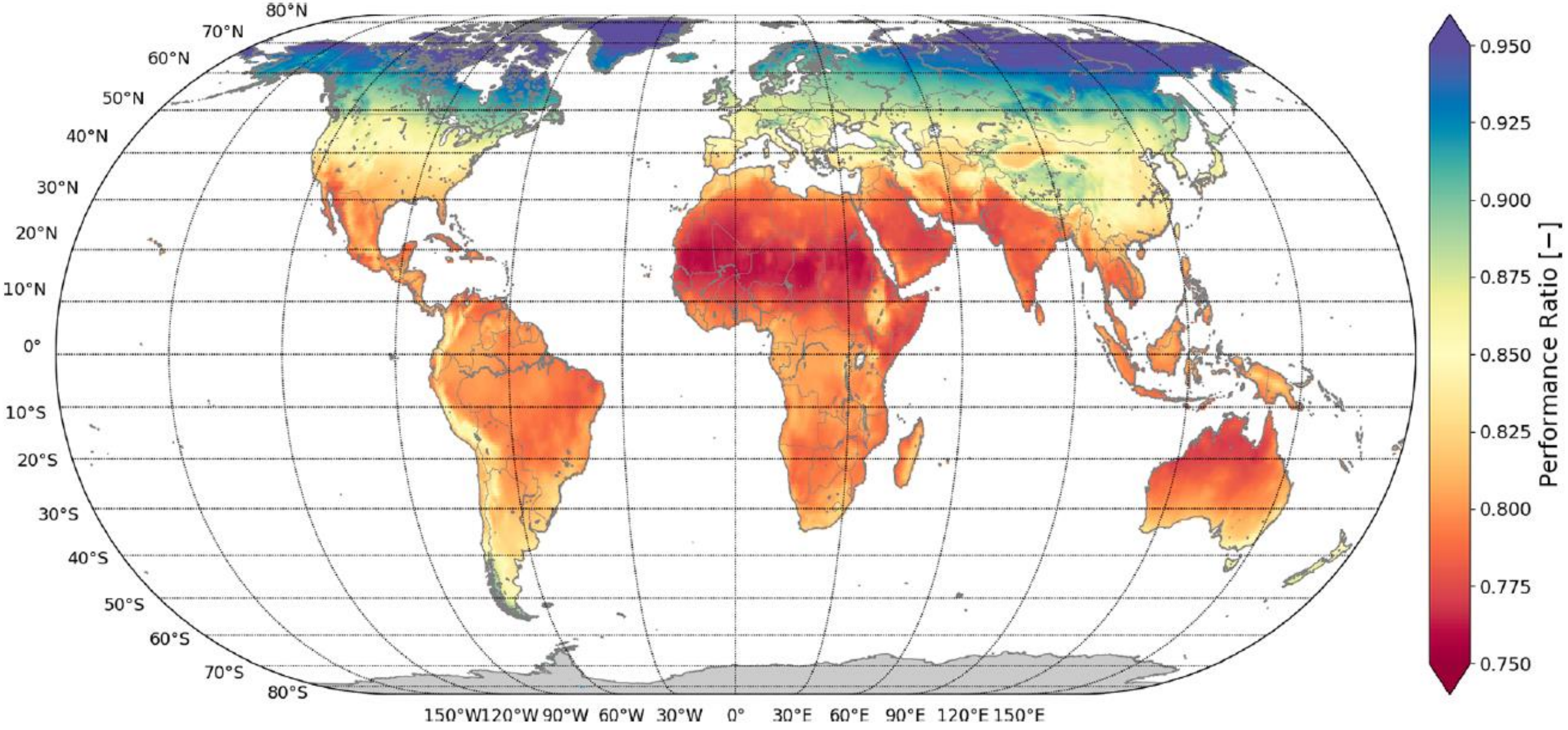
Moser D. et al. "Uncertainties in Yield Assessments and PV LCOE," Nov. 2020. IEA-PVPS T13.

ENERGY YIELD



J. Ascencio-Vásquez et al. "Methodology of Köppen-Geiger-Photovoltaic climate classification and implications to worldwide mapping of PV system performance," Solar Energy, vol. 191, pp. 672–685, Oct. 2019, doi: 10.1016/j.solener.2019.08.072.

THE PERFORMANCE RATIO



J. Ascencio-Vásquez et al. “Methodology of Köppen-Geiger-Photovoltaic climate classification and implications to worldwide mapping of PV system performance,” Solar Energy, vol. 191, pp. 672–685, Oct. 2019, doi: 10.1016/j.solener.2019.08.072.

IMPORTANCE OF YIELD

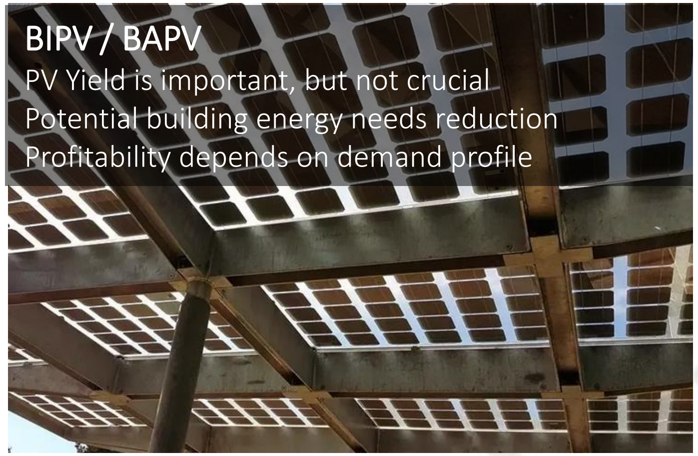
- Yield assessments (YA) and Long-Term Yield Predictions (LTYP) are a prerequisite for business decisions on long term investments into photovoltaic (PV) power plants.
- They should be provided with a related exceedance probability
- A **reduction in the uncertainty** of the energy yield can lead to a stronger business case.
- The main challenge in YA and LTYP relates to the trustworthiness of site-specific information
- The YA is **not only about the software** used; it is **mainly about the user.**
- There are always personal experience and assumptions: irradiance database selection and site adaptation, degradation/PLR assumption, total modelling uncertainty, soiling and far/near shading, …

Moser D. et al. "Uncertainties in Yield Assessments and PV LCOE," Nov. 2020. IEA-PVPS T13.

PV APPLICATIONS

SAM
PVGIS
SISIFO
PVSYST
HelioScope
archelios PRO
pvDesign
PVcase
PV*SOL

BIMsolar
Solarius PV
aurora



Images from Soltec, BayWa r.e., Huaneng Group, Onyx Solar

PV SOFTWARE FOR EACH APPLICATION

PVSYST

- The reference in the market for big PV projects and bankability analysis
- Very detailed descriptions
- Confidence has been earned over time via repetition, experience, and accrued knowledge

PVGIS

- Useful to get meteo data of Europe and Africa
- Useful for first design and simple simulations

HelioScope

- Uses the same core as PVsyst for energy modeling.
- Unlike Pvsyst, it features an intuitive graphical user interface with Google Earth and SketchUp integration.

SAM

- Probably the best option among free software
- Complete options and accurate
- Most financiers do not accept SAM energy models in lieu of PVsyst reports

BIMsolar

- Developed for BIPV, it uses a ray-tracing engine to calculate irradiance.
- Possible to import 3D files of buildings or other objects
- Compatible with BIM format

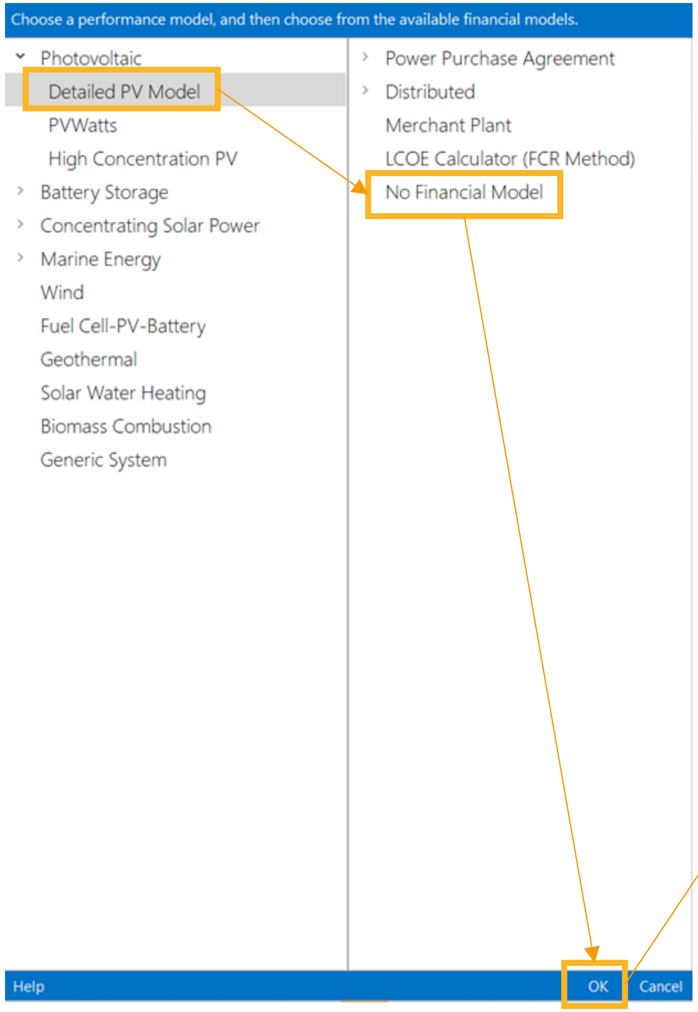
MODELING STEPS

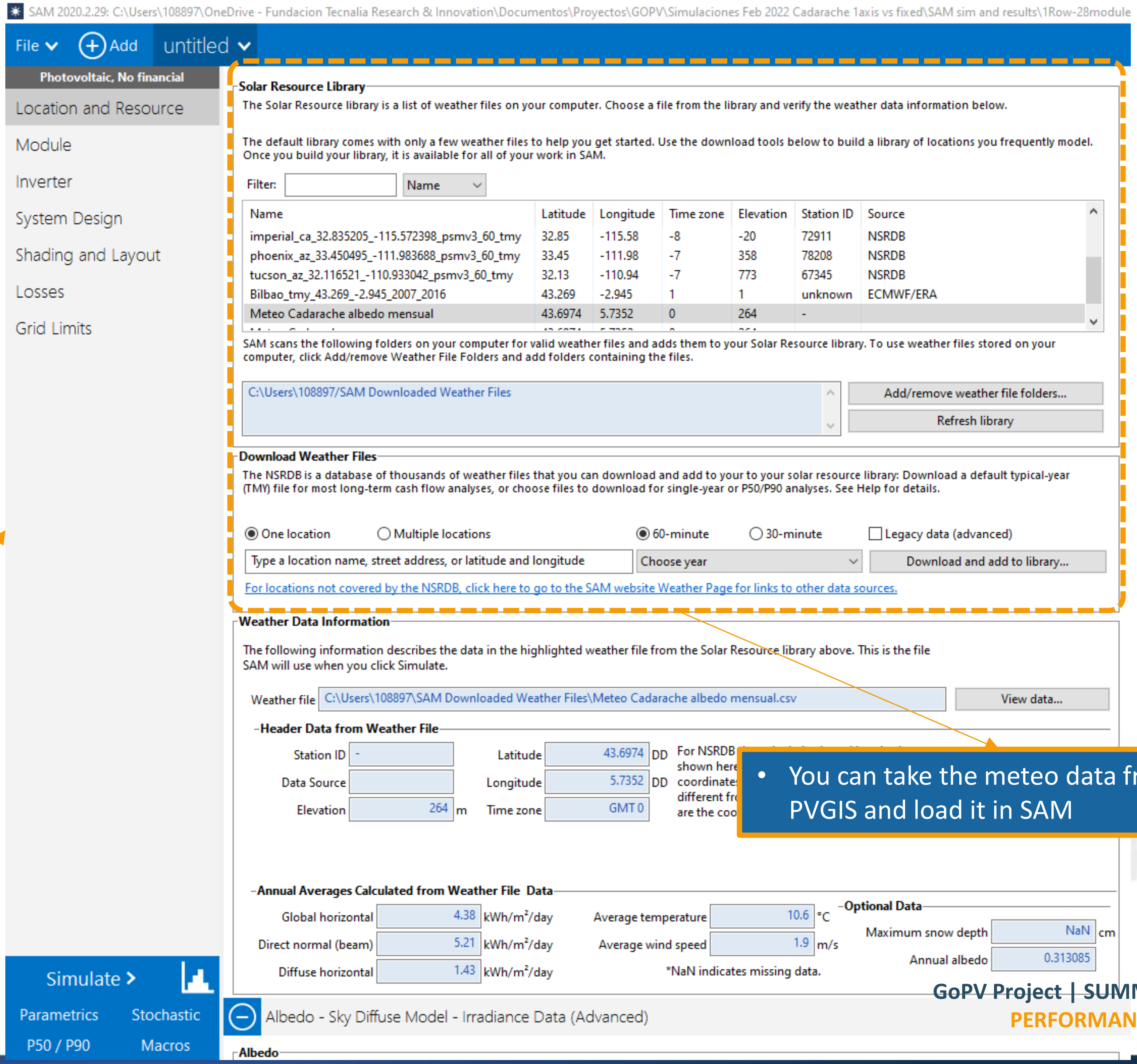
Example with SAM

Example done by Fraunhofer ISE

Moser D. et al. "Uncertainties in Yield Assessments and PV LCOE," Nov. 2020. IEA-PVPS T13.

MODELING STEPS – METEO DATA





- You can take the meteo data from PVGIS and load it in SAM

THE IMPORTANCE OF RADIATION DATA

- Prediction of weather in a particular place is the most difficult process.
- The selected **radiation model may provide variation up to ±4%** in the simulated output.
- Overall **uncertainty of the energy yield** to fall in a range between **5 and 11%.** The **main source of uncertainty is related to the insolation** estimation.
- For comprehensive analysis of big PV plants:
  - High-quality long-term ground-based measurements have been are rare.
  - Site adaptation techniques combine **short-term measured data (about 1 year) and long-term satellite estimates**.
  - Assuming a strong correlation, the strengths of both data sets are captured and the uncertainty in the long-term estimate can be reduced.
  - Root mean square errors for satellite-based irradiation reported in literature are situated between 4 % to 8 % for monthly and 2 % to 6 % for annual irradiation values.
- Solar irradiation at the Earth's surface is not stable over time for all locations on earth.
- An increase in the average irradiance has been suggested. In Germany, about 1,1%/year

[1] Sekhar et al. 2017. "Performance Simulation of a Grid Connected Photovoltaic Power System Using TRNSYS 17." IOP Conference Series: Materials Science and Engineering 263 (November): 062078. https://doi.org/10.1088/1757-899X/263/6/062078
[2] Müller, Björn, and Klaus Kiefer. 2019. "Long-Term Trends of in-Plane-Irradiance, Energy Yield and Performance for PV Systems." In 29th International Photovoltaic Science and Engineering Conference. Xi'an.
[3] Moser D. et al. "Uncertainties in Yield Assessments and PV LCOE," Nov. 2020. IEA-PVPS T13.

THE IMPORTANCE OF RADIATION DATA

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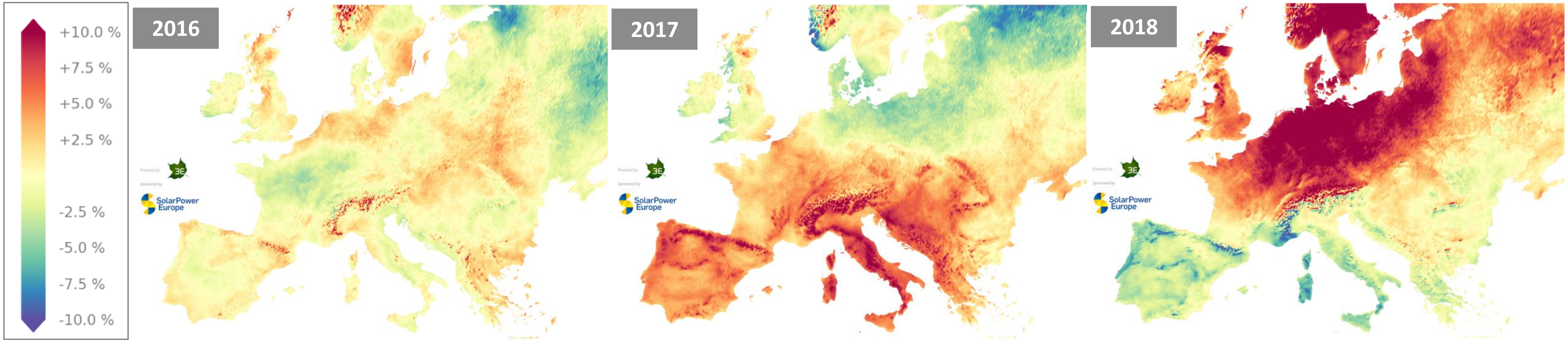

https://solardata.3e.eu/maps/solarindex

THE IMPORTANCE OF RADIATION DATA

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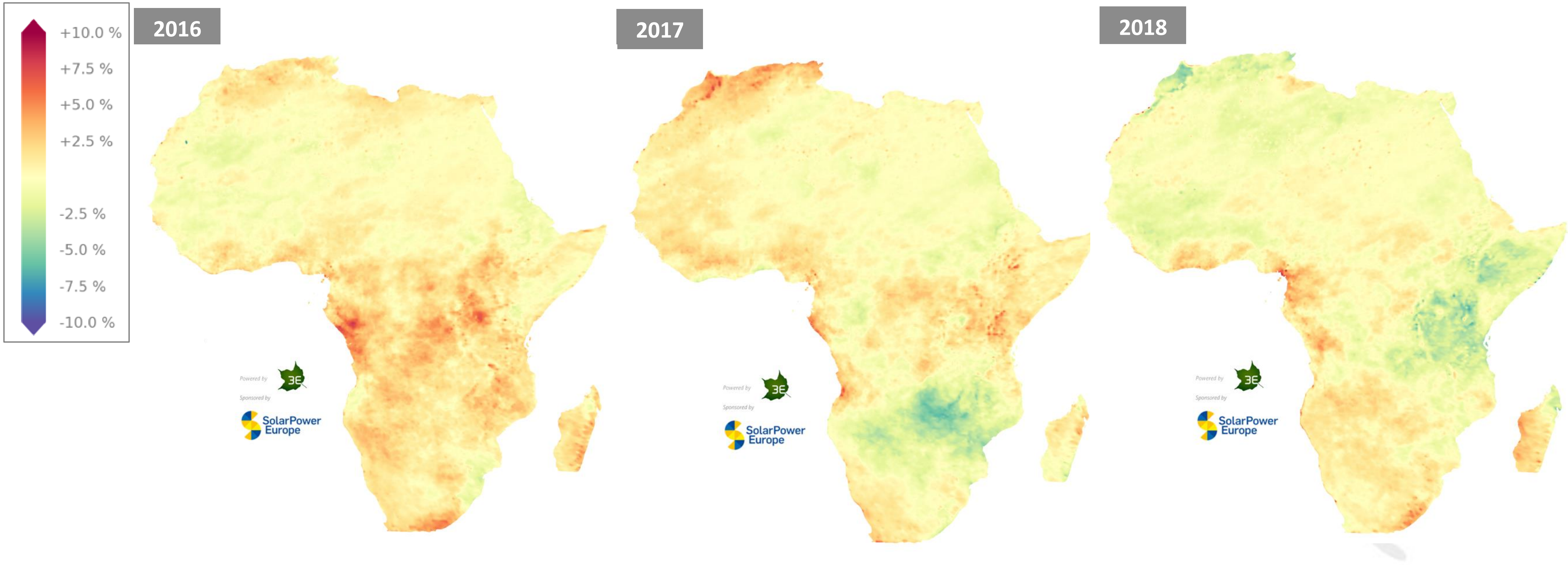

https://solardata.3e.eu/maps/solarindex

EXAMPLE IN SAM – PV MODULE

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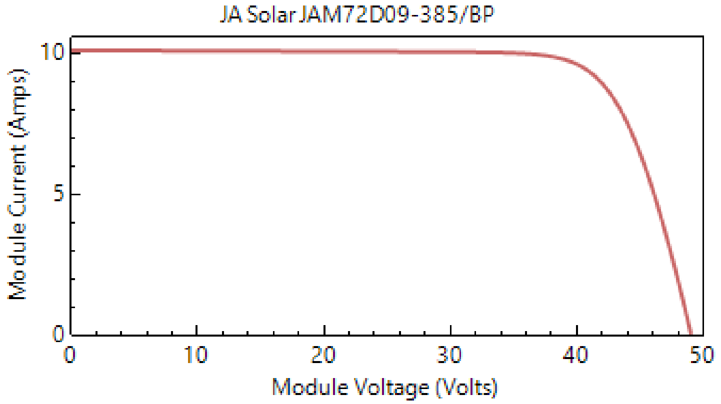
- Normally there is a module database.
- PAN files is a standard file format for PV modules information.
- It can be also defined from manufacturer datasheets.
- It is becoming common the characterization by independent parties.

Filter: [ ] Name

Name	Technology	Bifacial	STC	PTC	A_c	Length	Width	N_s	I_sc_ref	V_oc_ref	I_mp_ref	V_mp_ref	alpha_sc	I
JA Solar JAM72S01-370/PR	Mono-c-Si	0	370.041000	343.600000	1.880000			72	9.910000	48.180000	9.380000	39.450000	0.004162	-
JA Solar JAM72D09-375/BP	Mono-c-Si	1	374.768000	348.200000	1.970000			72	9.970000	48.500000	9.440000	39.700000	0.004088	-
JA Solar JAM72S01-375/PR	Mono-c-Si	0	375.240000	348.400000	1.880000			72	9.980000	48.450000	9.440000	39.750000	0.004192	-
JA Solar JAM72S09-375/PR	Mono-c-Si	0	375.315000	349.400000	1.940000			72	10.060...	48.500000	9.550000	39.300000	0.003823	-
JA Solar JAM72D09-380/BP	Mono-c-Si	1	380	353	1.970000			72	10.030...	48.800000	9.500000	40	0.004112	-
JA Solar JAM72S01-380/PR	Mono-c-Si	0	380.285000	353.200000	1.880000			72	10.050...	48.710000	9.500000	40.030000	0.004221	-
JA Solar JAM72S09-380/PR	Mono-c-Si	0	380.160000	354.200000	1.940000			72	10.120...	48.800000	9.600000	39.600000	0.003846	-
JA Solar JAM72D09-385/BP	Mono-c-Si	1	384.865000	357.700000	1.970000			72	10.090...	49.100000	9.550000	40.300000	0.004137	-

Module Characteristics at Reference Conditions

Reference conditions: Total Irradiance = 1000 W/m2, Cell temp = 25 C



	Value	Unit	Temperature coefficients	Unit		Unit
Nominal efficiency	19.5363	%				
Maximum power (Pmp)	384.865	Wdc	-0.362	%/°C	-1.393	W/°C
Max power voltage (Vmp)	40.3	Vdc				
Max power current (Imp)	9.6	Adc				
Open circuit voltage (Voc)	49.1	Vdc	-0.270		-0.133	V/°C
Short circuit current (Isc)	10.1	Adc	0.041	%/°C	0.004	A/°C

Bifacial Specifications

☑ Module is bifacial

Transmission fraction: 0.013 (0-1)

Bifaciality: 0.7 (0-1)

Ground clearance height: 2.3 m

EXAMPLE IN SAM – TEMPERATURE MODEL

- Here there are two model for calculating the PV module operating temperature. In general, this models works fine with the appropriate coefficients
- It is important to select the proper mounting configuration of the models, as the module temperature will impact the final PV production results

Temperature Correction

(●) Nominal operating cell temperature (NOCT) method
( ) Heat transfer method

See Help for more information about CEC cell temperature models.

NOCT method parameters

Mounting standoff	Ground or rack mounted
Array height	One story building height or lower

Heat transfer method parameters

Mounting configuration	Rack	Rows of modules in array	1
Heat transfer dimensions	Module Dimensions	Columns of modules in array	10
Mounting structure orientation	Structures do not impede flow underneath module	Temperature behind the module	20 °C
Module width	1 m	Space between module back and roof surface	0.05 m
Module length	1.97 m		

Physical Characteristics

Material	Mono-c-Si	Module area	1.970 m²	Number of cells	72

Additional Parameters

T_noct	45.1 °C	I_L_ref	10.096 A	R_s	0.333449 Ohm
A_ref	1.83448 V	I_o_ref	2.37927e-11 A	R_sh_ref	563.182 Ohm

The model assumes a reference bandgap voltage Eg_ref = 1.121 eV, and temperature coefficient for bandgap of -0.0002677 eV/K.

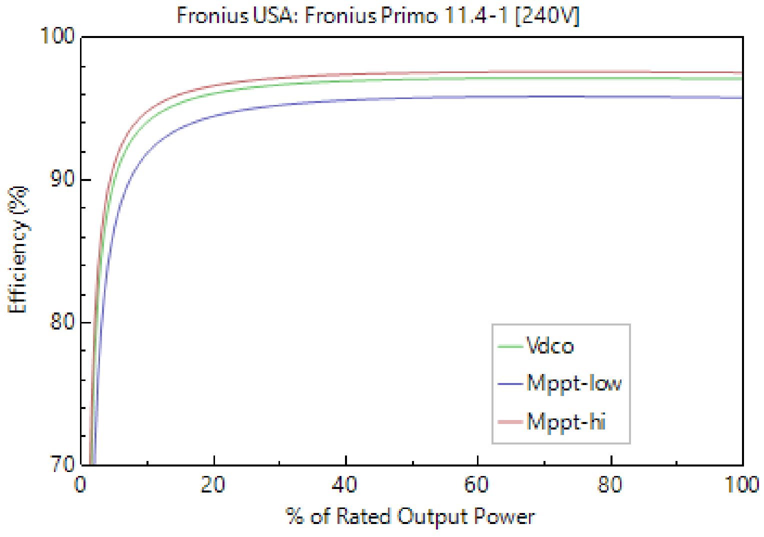
EXAMPLE IN SAM – INVERTER SELECTION

- Normally there is an inverter database.
- OND files is a standard file format for inverters information.
- It can be also defined from manufacturer datasheets.
- It is becoming common the characterization by independent parties.
- **Inverter power (AC power) is normally lower than DC power** for optimizing the inverter cost and efficiency
- Normally DC/AC power is 1.2 for monofacial, and 1 for bifacial.

Filter: Name

Name	Paco	Pdco	Pso	Pnt	Vac	Vdcmax	Vdco	Mppt_high	Mppt_low	C0	C1	C2	C3
Fronius USA: Fronius Primo 10.0-1 [208V]	9995	10292.20...	36.211...	2.998500	208	800	660	800	100	-4.2756...	-0.000029	-0.000759	-0.00
Fronius USA: Fronius Primo 10.0-1 [240V]	9995	10295.99...	44.270...	2.998500	240	800	655	800	100	-7.9973...	-0.000028	-0.000619	0.000
Fronius USA: Fronius Primo 11.4-1 [208V]	11...	11743.89...	36.851...	3.420000	208	800	660	800	240	-4.7172...	-0.000032	-0.000730	-0.00
Fronius USA: Fronius Primo 11.4-1 [240V]	11...	11738.66...	49.129...	3.420000	240	800	660	800	240	-6.6822...	-0.000033	-0.000724	-0.00
Fronius USA: Fronius Primo 12.5-1 [208V]	12...	12891.54...	43.310...	3.750000	208	800	665	800	260	-6.7086...	-0.000033	-0.001410	-0.00

Efficiency Curve and Characteristics



Number of MPPT inputs	1	
CEC weighted efficiency	96.922	%
European weighted efficiency	96.540	%

Datasheet Parameters

Maximum AC power	11400	Wac
Maximum DC power	11738.7	Wdc
Power consumption during operation	49.129	Wdc
Power consumption at night	3.42	Wac
Nominal AC voltage	240	Vac
Maximum DC voltage	800	Vdc
Maximum DC current	17.7859	Adc
Minimum MPPT DC voltage	240	Vdc
Nominal DC voltage	660	Vdc
Maximum MPPT DC voltage	800	Vdc

Sandia Coefficients

C0	-6.68228e-07	1/Wac
C1	-3.3e-05	1/Vdc
C2	-0.000724	1/Vdc
C3	-0.000765	1/Vdc

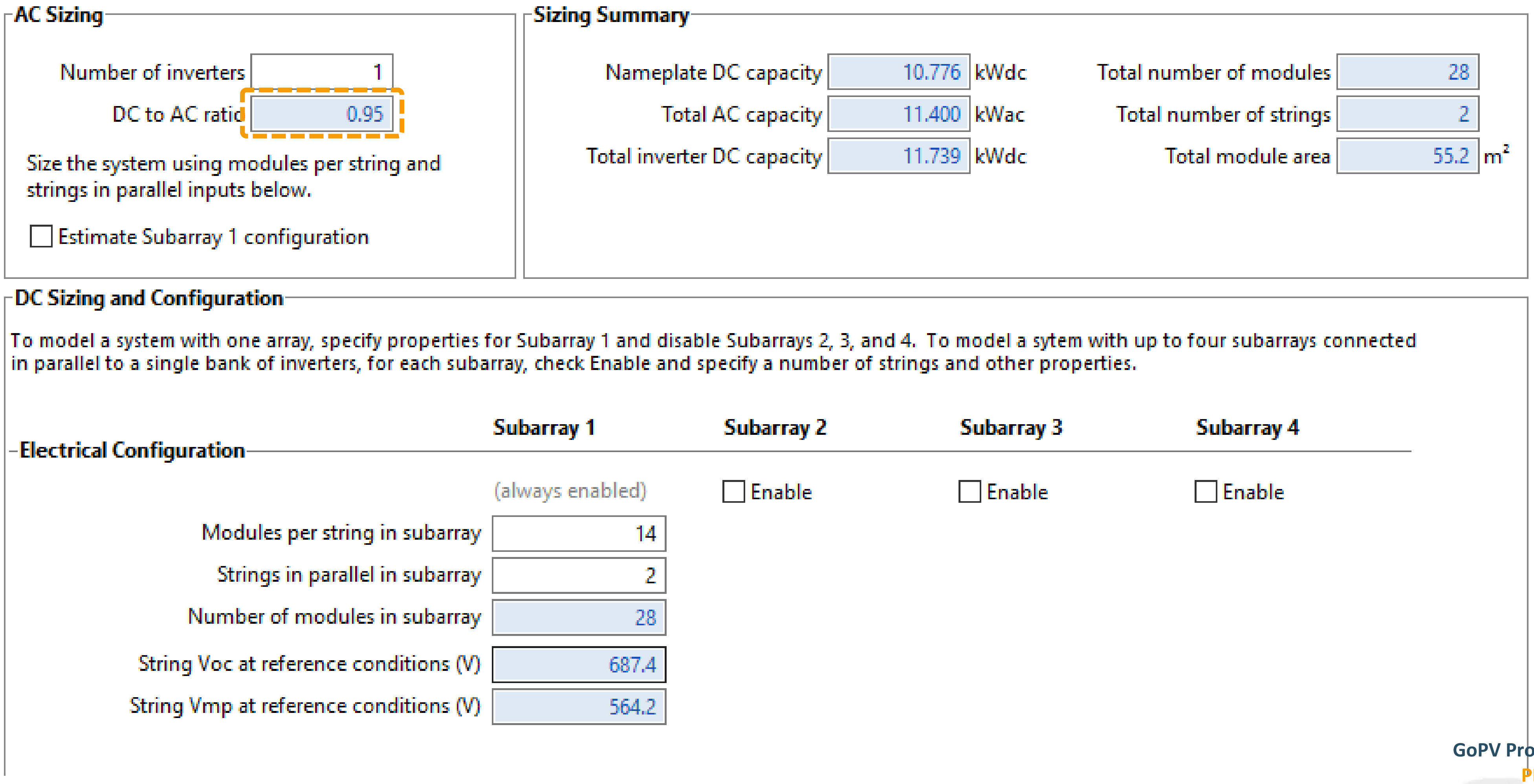
Note: If you are modeling a system with microinverters or DC power optimizers, see the Losses page to adjust the system losses accordingly.

CEC Information

CEC name: Fronius USA: Fronius Primo 11.4-1 [240V]   CEC type: Utility Interactive   CEC date

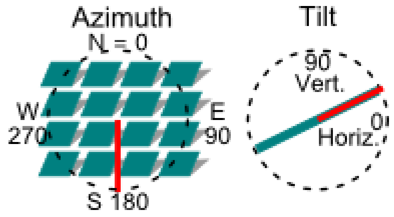
EXAMPLE IN SAM – ELECTRICAL CONFIGURATION

- DC – AC ratio is normally 1.2 for monofacial installations. About 1 for bifacial due to extra production of rear side



EXAMPLE IN SAM – ORIENTATION

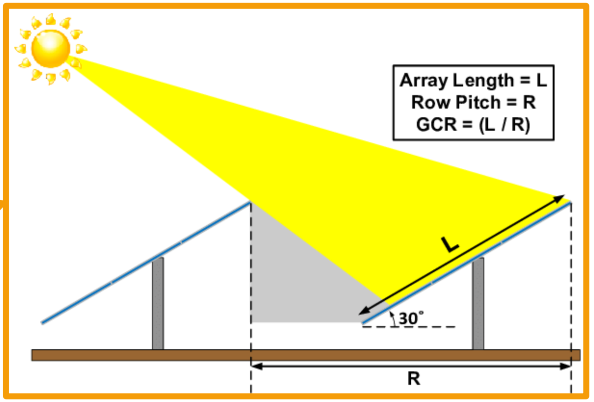
Tracking & Orientation



- ○ Fixed
- ◉ 1 Axis
- ○ 2 Axis
- ○ Azimuth Axis
- ○ Seasonal Tilt

☐ Tilt=latitude

Tilt (deg)	0
Azimuth (deg)	180
Ground coverage ratio (GCR)	0.35
Tracker rotation limit (deg)	55
Backtracking	☑ Enable



Ground coverage ratio is used (1) to determine when a one-axis tracking system will backtrack, (2) in self-shading calculations for fixed tilt or one-axis tracking systems on the Shading page, and (3) in the total land area calculation. See Help for details.

Electrical Sizing Information

Maximum DC voltage	800.0	Vdc
Minimum MPPT voltage	240.0	Vdc
Maximum MPPT voltage	800.0	Vdc

Voltage and capacity ratings are at module reference conditions shown on the Module page.

No system sizing messages.

EXA

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External Shading

External shading is shading of beam and diffuse incident irradiance by nearby objects such as trees and buildings. Shading losses apply in addition to any soiling losses on the Losses page.

3D Shade Calculator

Automatically generate shade data from a drawing of the array and shading objects.

Open 3D shade calculator...

Shade Loss Tables

Edit and import shade data. Data may be entered by hand, imported from shade analysis software and devices, or generated by the 3D shade calculator.

Subarray 1	Subarray 2	Subarray 3	Subarray 4
Edit shading...	Edit shading...	Edit shading...	Edit shading...

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	None	None	None	None

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

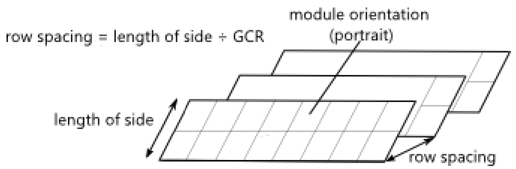
The product of number of modules along side and bottom and number of rows should be equal to the number of modules in subarray.

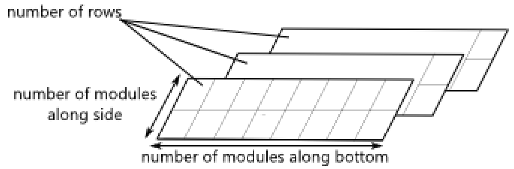
Module orientation	Landscape	Portrait	Portrait	Portrait
Number of modules along side of row	2	0	0	2
Number of modules along bottom of row	14	0	0	9

Calculated System Layout

Number of rows	1	NaN	NaN	0
Modules in subarray from System Design page	28	0	0	0
Length of side (m)	2.15297	0	0	3.66005
GCR from System Design page	0.35	0.25	0.25	0.3
Row spacing estimate (m)	6.15135	0	0	12.2002

Module aspect ratio	1.7	
Module length	1.83003	m
Module width	1.07649	m
Module area	1.97	m^2



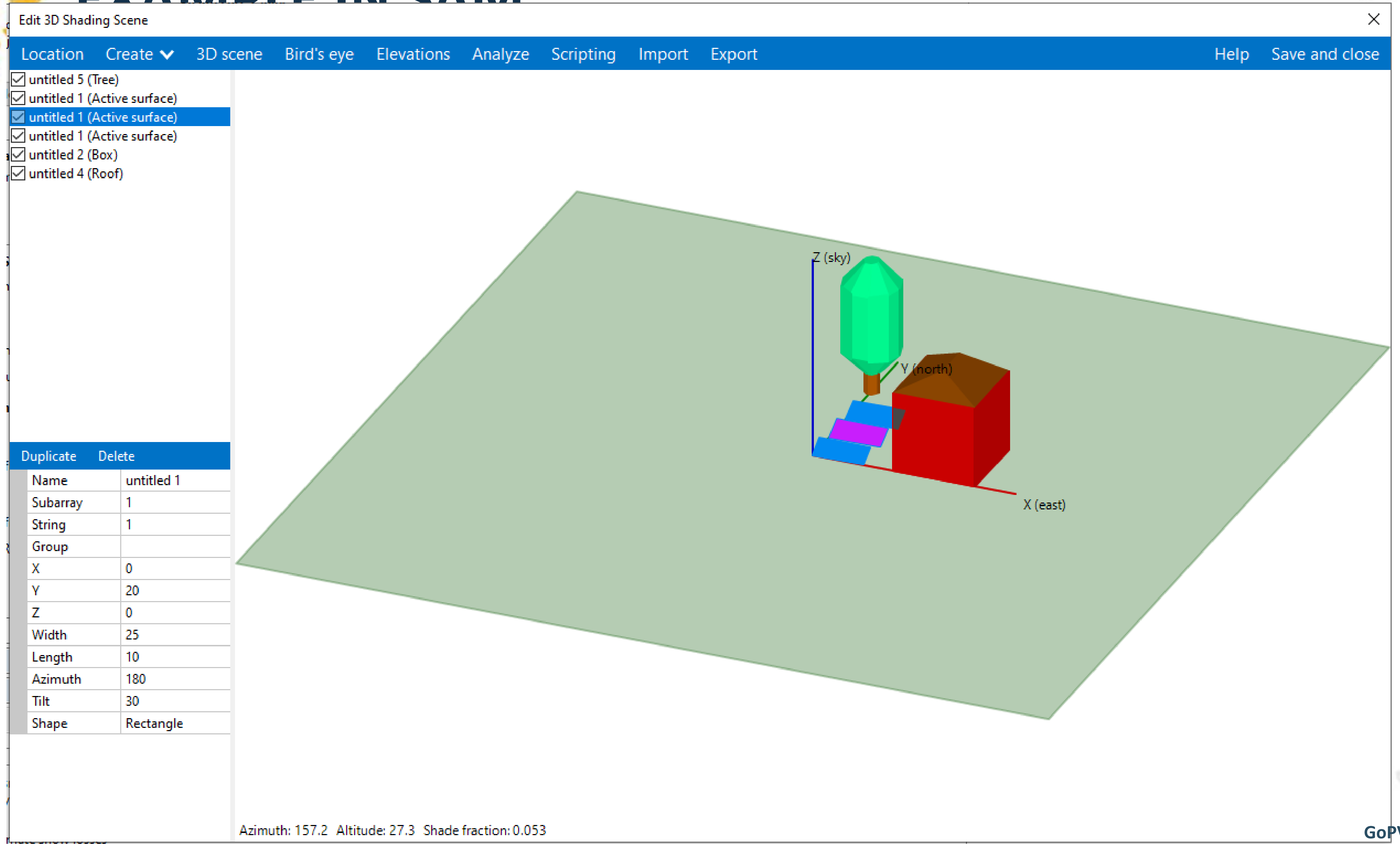


Snow Losses

Snow losses are caused by snow covering the array. When your weather file includes snow depth data, SAM can estimate losses due to snow. Losses are calculated for each subarray.

☐ Estimate snow losses

EXAMPLE IN SAM



EXAMPLE IN SAM – SOILING AND DC LOSSES

- Soiling is an uncertainty which strongly depends on the environment of the system, raining conditions, etc.
- In **medium-rainy climates** (like middle of Europe) and in residential zones, this is **usually low** and may be neglected (less than 1%)
- **Common values are:**
  - 5% for regions with long dry seasons
  - 2% for regions with year-round rain
- O&M costs are in part dictated by the frequency of cleaning required
- In bifacial, soiling on rear side is normally 10 times lower than in front side.

Irradiance Losses

Soiling losses apply to the total solar irradiance incident on each subarray. SAM applies these losses in addition to any losses on the Shading and Snow page.

	Subarray 1	Subarray 2	Subarray 3	Subarray 4
Monthly soiling loss	Edit values...	Edit values...	Edit values...	Edit values...
Average annual soiling loss	5	5	5	5
Bifacial modules only				
Average annual rear irradiance loss due to soiling, mismatch, or external shading (%)	0	0	0	0

DC Losses

DC losses apply to the electrical output of each subarray and account for losses not calculated by the module performance model.

Module mismatch (%)	2	2	2	2
Diodes and connections (%)	0.5	0.5	0.5	0.5
DC wiring (%)	2	2	2	2
Tracking error (%)	0	0	0	0
Nameplate (%)	0	0	0	0
DC power optimizer loss (%)	0	All four subarrays are subject to the same DC power optimizer loss.		
Total DC power loss (%)	4.440	4.440	4.440	4.440

Total DC power loss = 100% * [1 - the product of (1 - loss/100%)]

Default DC Losses

Apply default losses to replace DC losses for all subarrays with default values.

Apply default losses for: Central inverters | Microinverters | DC optimizers

- Between 0,01%-3%. Industry consensus is 2%

https://www.pvsyst.com/help/soiling_loss.htm
https://ratedpower.com/blog/soiling-losses/
https://www.aurorasolar.com/blog/understanding-pv-system-losses-part-3-soiling-snow-system-degradation/
E. Grau Luque et al. Effect of soiling in bifacial PV modules and cleaning schedule optimization. Energy Conversion and Management. Oct 2018.

EXAMPLE IN SAM – AC & TRANSMISSION LOSSES

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AC Losses

AC losses apply to the electrical output of the inverter and account for losses not calculated by the inverter performance model.

AC wiring | 1 | %

> Potential losses between inverters and transformers (AC cabling resistance, ...)

Transformer Losses

The transformer loss model is intended for distribution or substation transformers in large PV systems. Losses apply to the electrical output of the inverter and assume a power factor of 1. The transformer capacity is equal to the total inverter AC power rating.

Transformer no load loss | 0 | % Transformer load loss | 0 | %

> - In big PV plantas there are transformers to increase the Voltage
> - This data should be taken from transformers datasheet

Transmission Losses

Transmission losses apply to the system generated power output.

Transmission loss | 0 | %

System Availability

System availability losses reduce the system output to represent system outages or other events. Availability losses may be applied either on the DC or AC side of the system.

DC Losses

Edit losses...
Constant loss: 0.0 %
Hourly losses: None
Custom periods: None

AC Losses

Edit losses...
Constant loss: 0.0 %
Hourly losses: None
Custom periods: None

THE AVAILABILITY

- PV power plant effective availability
  - Availability of our power plant because is working properly
  - Availability of the grid to accept power
- O&M contractor guaranteed availability values typically are 99% or higher
- Availability is between 92% and 99.5%, typically 99 % ±1 %
- Unavailability has decreased over time, possibly based on improved O&M protocols
- Plants in areas with constrained grids can have availabilities below 90%

Figure 14: Statistical indicators of mean monthly unavailability of 533 PV plants in 2019 (majority installed in Belgium, Germany and Switzerland)

"Market Notices - Update to system strength requirements in North Queensland, Market Notice 76455 CONSTRAINTS,"Jul. 27, 2020. https://aemo.com.au/Market Notices
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K. Hunt, A. Blekicki, and R. Callery, "Availability of utility-scale photovoltaic power plants," in *2015 IEEE 42nd Photovoltaic Specialist Conference (PVSC)*, Jun. 2015, pp. 1–3, doi: 10.1109/PVSC.2015.7355976.
M. García, J. A. Vera, L. Marroyo, E. Lorenzo, and M. Pérez, "Solar-tracking PV plants in Navarra: A 10 MW assessment," Progress in Photovoltaics: Research and Applications, vol. 17, no. 5, pp. 337–346, 2009, doi: 10.1002/pip.893.
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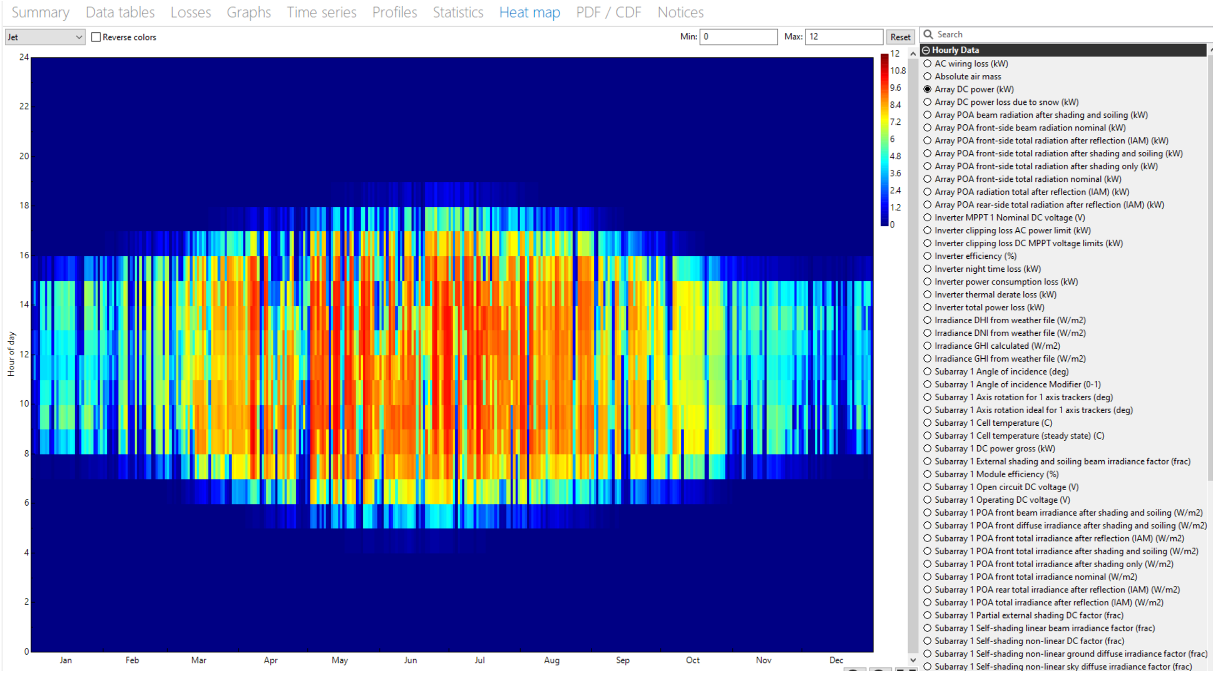
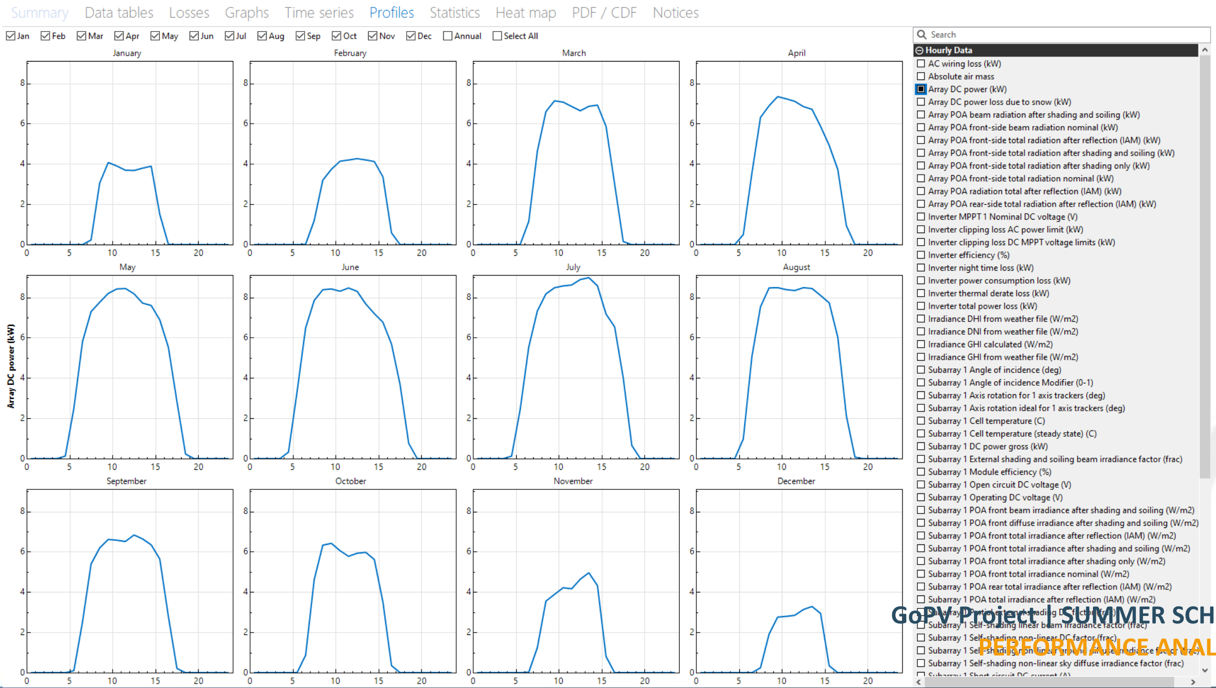
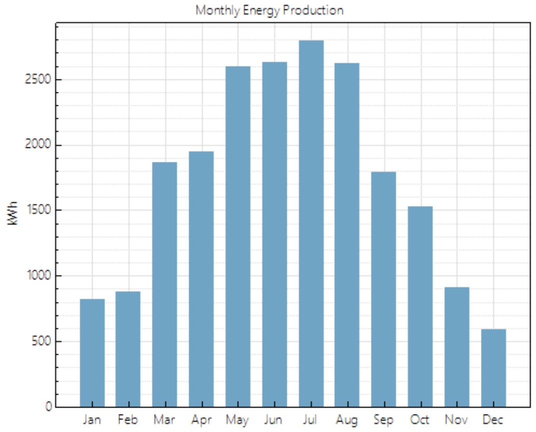
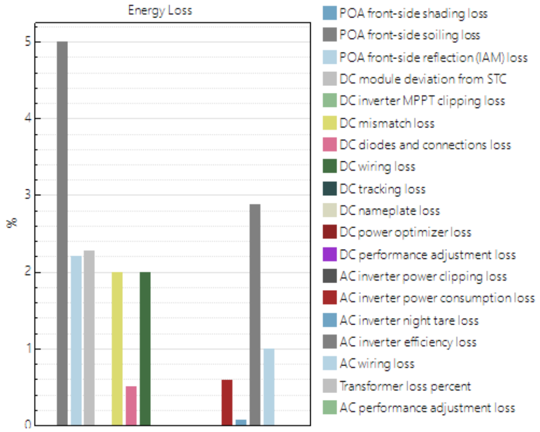
EXAMPLE IN SAM – RESULTS

Metric	Value
Annual energy (year 1)	20,961 kWh
Capacity factor (year 1)	22.2%
Energy yield (year 1)	1,945 kWh/kW
Performance ratio (year 1)	0.90

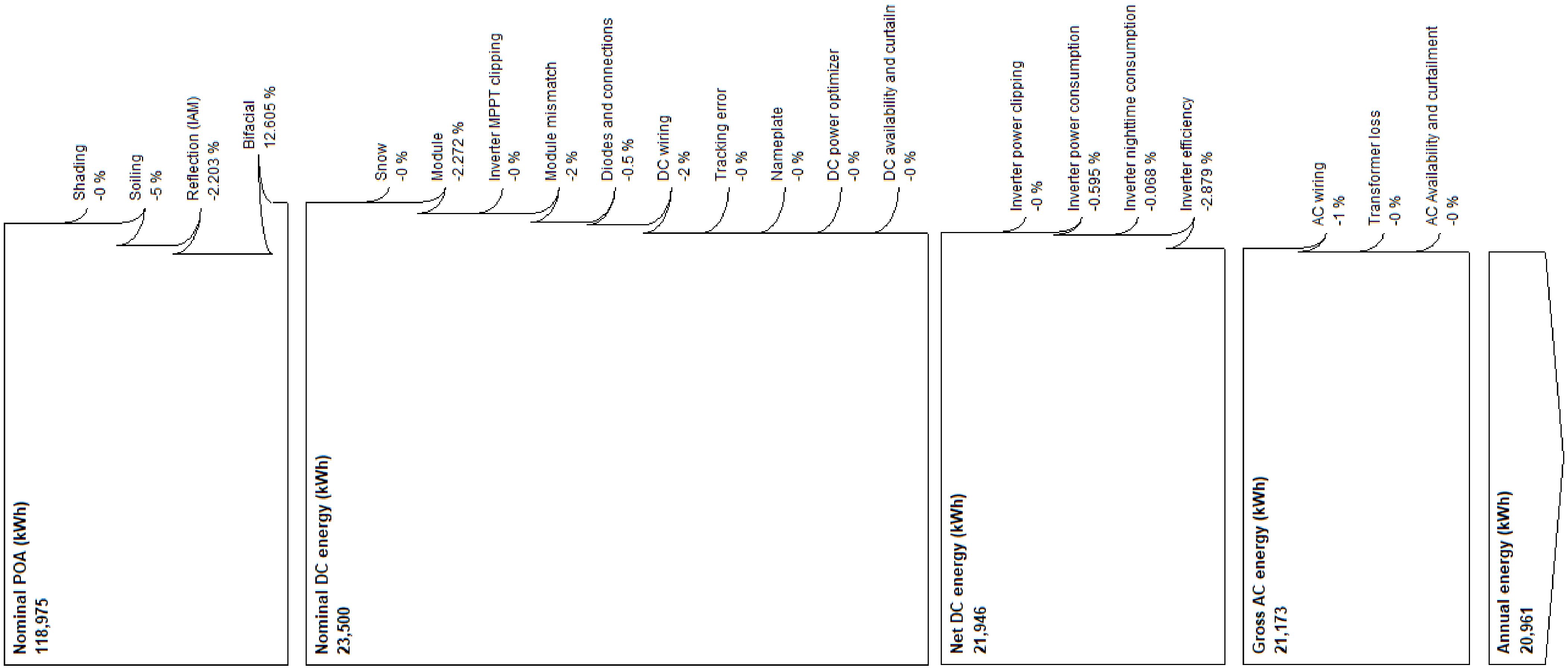








EXAMPLE IN SAM - RESULTS



GLOBAL OPTIMIZATION OF INTEGRATED PHOTOVOLTAIC SYSTEM FOR LOW ELECTRICITY COST

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 792059

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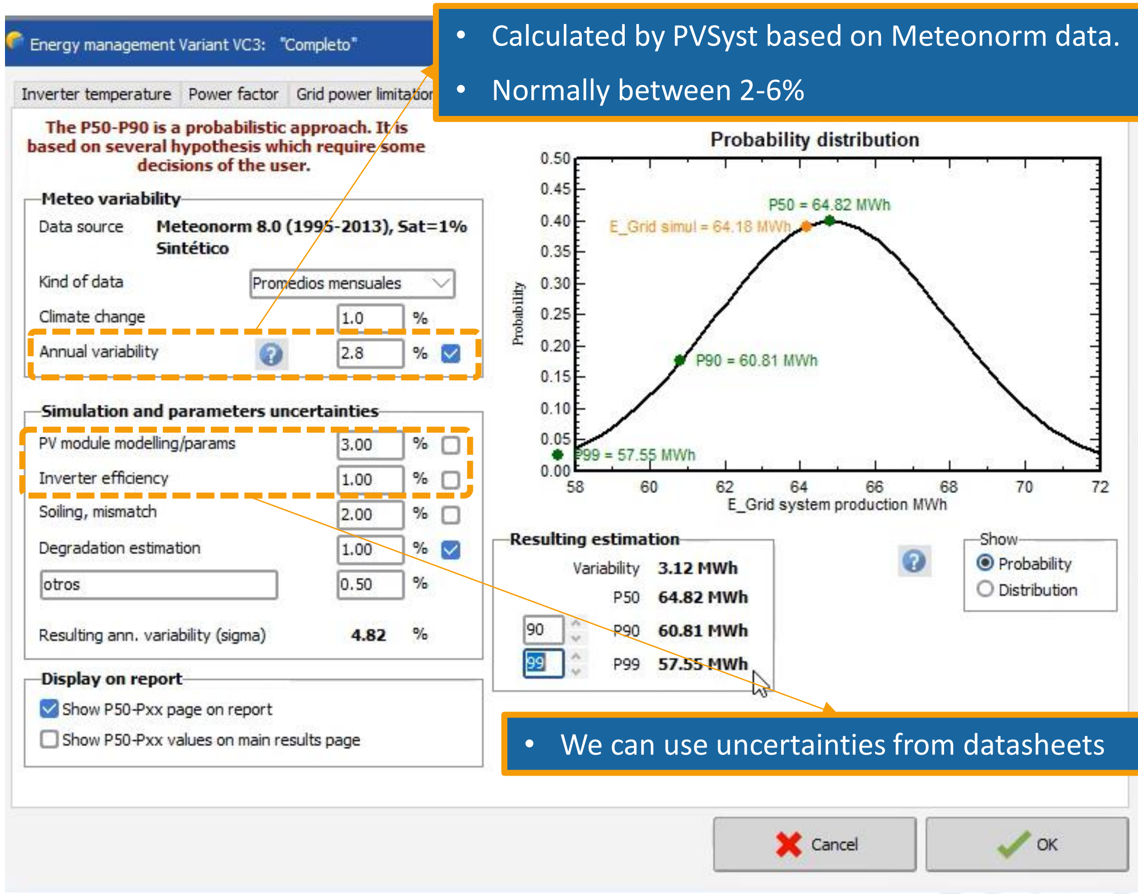
EXTRA INFORMATION

Moser D. et al. “Uncertainties in Yield Assessments and PV LCOE,” Nov. 2020. IEA-PVPS T13.

ANALYSIS P50-P90-PXX

- Probability analysis of having a minimum yearly production.
- P90 data is the minimum PV production that we will get with 90% probability.
- Mainly required by banks and investment firms.
- Main contribution will be the uncertainty and variability of the meteo data. But other uncertainties should be considered.
- It is also used in wind farms. Not specific of PV.
- TMY weather files includes 1-year hourly data choosing ”typical” months to represent the long-term properties. TMY files are not valid for P50-P90 analysis.
- It is required several years weather data to ensures that the performance prediction accounts for potential worst-case years.



- Calculated by PVSyst based on Meteonorm data.
- Normally between 2-6%

- We can use uncertainties from datasheets

A. Dobos, P. Gilman. P50/P90 Analysis for Solar Energy Systems Using the System Advisor Model. 2012 World Renewable Energy Forum. https://www.nrel.gov/docs/fy12osti/54488.pdf

HOW MANY YEARS OF METEO DATA?

- Uncertainty in yield assessment can be reduced by decreasing uncertainty of irradiation.
- The more years of irradiation data, more uncertainty reduction
- Reference scenario is defined for the case of 20 years of satellite data on the horizontal plane (20 y sat GHI DiffHI)
- P90 values which could be up to 20 % higher for the case with reduced uncertainty

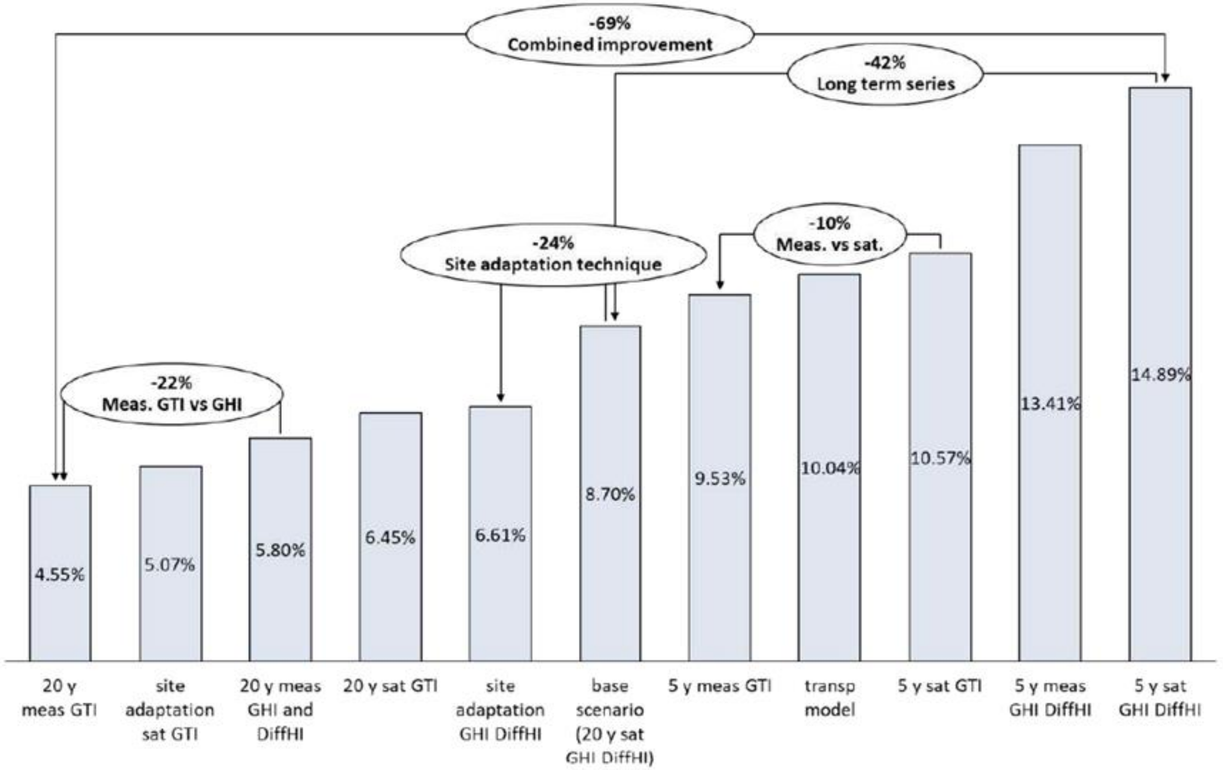


Figure 16: Reduction of uncertainty in case of improvement of the quality of irradiation source. Taken from [47], courtesy of Eurac Research

Moser D. et al. "Uncertainties in Yield Assessments and PV LCOE," Nov. 2020. IEA-PVPS T13.

THE TERRAIN

- Uneven terrain represent both a construction and yield assessment challenge

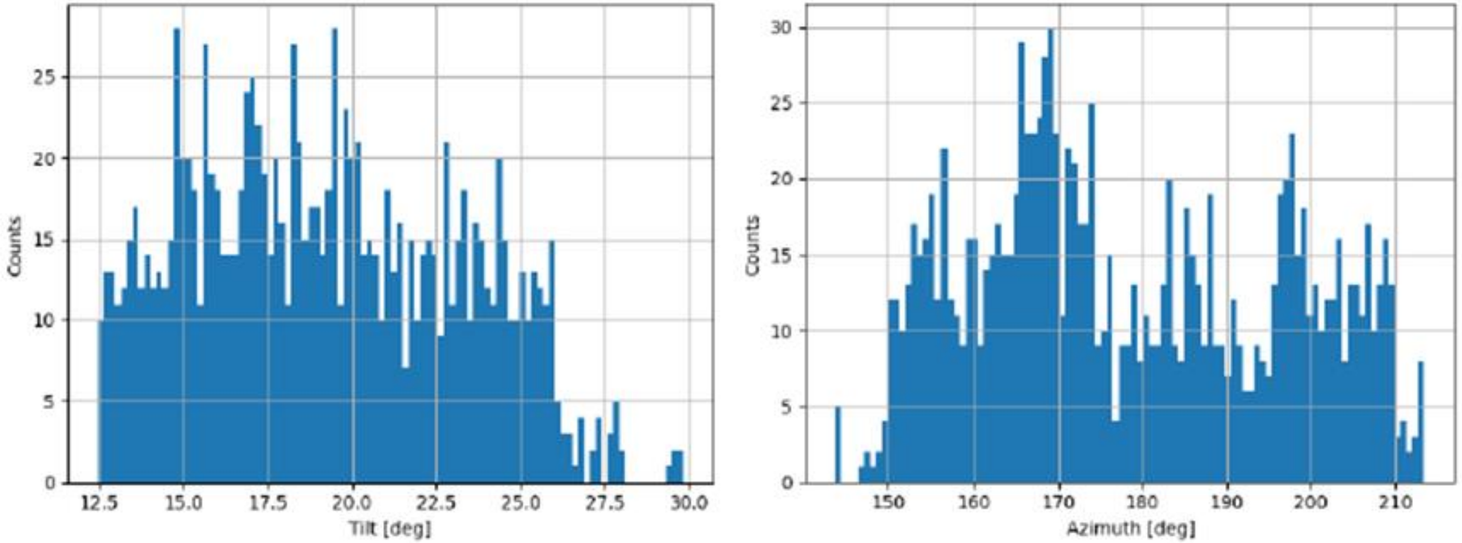
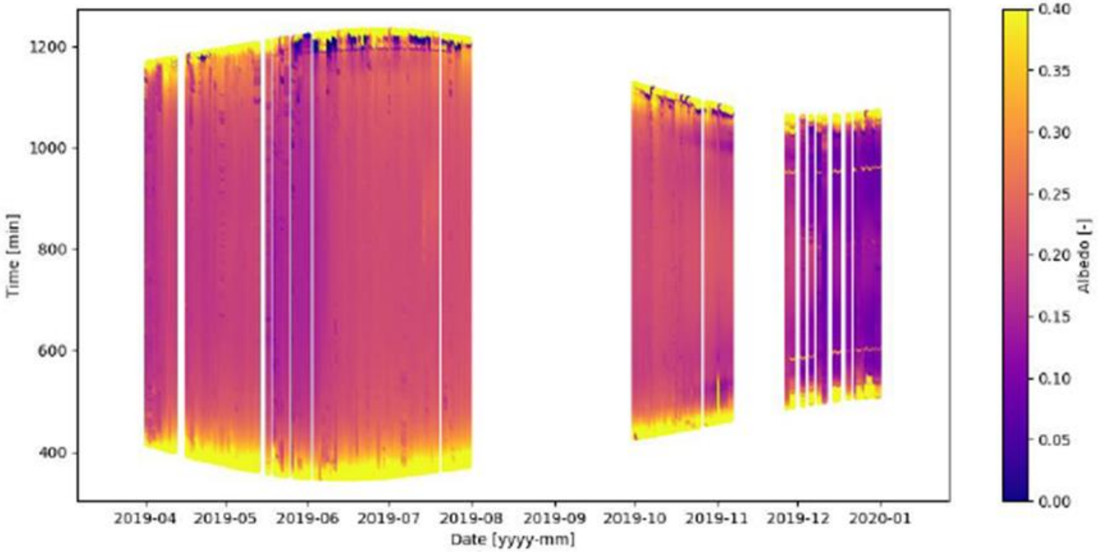


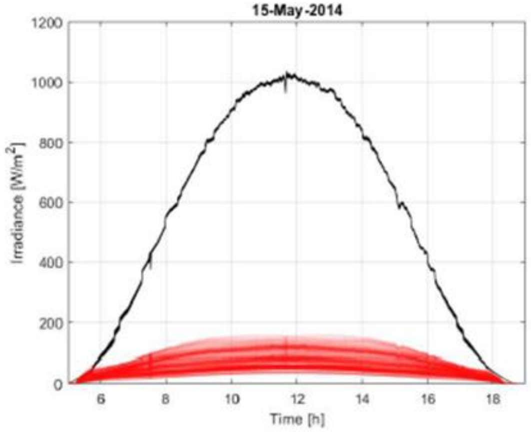
Figure 13 - Distribution of mounting structure tilt (left) and azimuth (right) angles for a PV system installed on a site characterized by uneven terrain

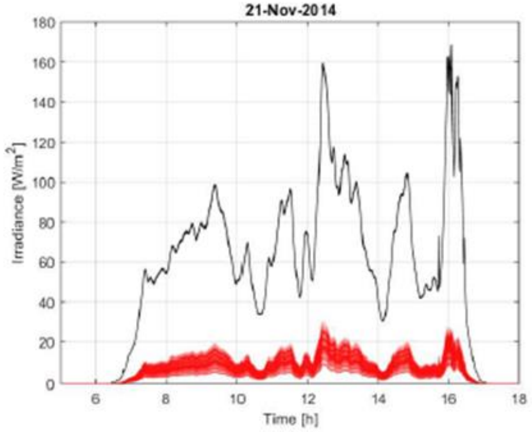
Moser D. et al. "Uncertainties in Yield Assessments and PV LCOE," Nov. 2020. IEA-PVPS T13.

THE BIFACIAL CASE

- Challenge of calculating rear side irradiance
- Two main approaches: ray tracing and view factor
- Published errors compared to in-plane irradiance measurements range from 5 % to 40 % showing that both methods have high accuracy potential if appropriately implemented.
- Challenging task to obtain such measurements as albedo
- Albedo variations:
  - intra-day due to anisotropic ground reflectivity
  - seasonal variations due to changing vegetation, ground moisture or snow cover
- Albedo difference of 0.1 results in an approx. 1 % bifacial gain difference
- Non-uniform rear irradiance is inevitable in bifacial PV systems







Moser D. et al. "Uncertainties in Yield Assessments and PV LCOE," Nov. 2020. IEA-PVPS T13.

THE FLOATING PV CASE

- Two benefits: mitigation of land-use conflicts and improved energy performances
- Lack of simulation tools specific to the FPV
- Most installers/researchers are still using conventional simulation tools that do not account for the PV-water interaction and cooling effect caused
- The temperature model should be changed
- There are temperature models depending on whether the FPV system is on a lake/river or on seawater

Huaneng Group. Yellow Sea Number One.

N. Manoj Kumar et al. "Advancing simulation tools specific to floating solar photovoltaic systems – Comparative analysis of field-measured and simulated energy performance," Sustainable Energy Technologies and Assessments, vol. 52, p. 102168, Aug. 2022, doi: 10.1016/j.seta.2022.102168.

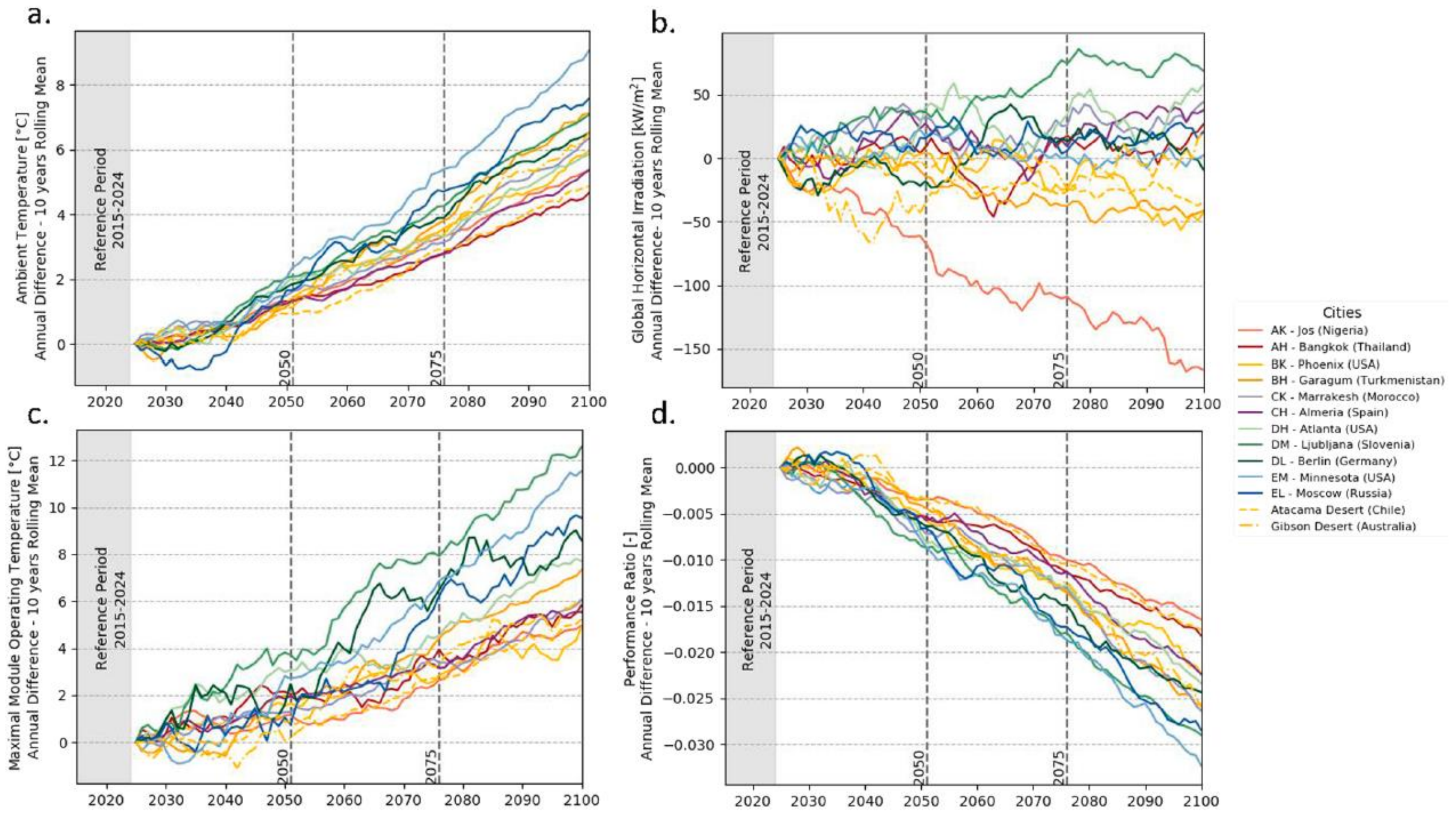
THE AGRI-PV CASE

- Two targets: electricity production + crop production
- This application is still under study
- Impact of lower irradiance received by the crops?
- Potential protection of the crops by the PV modules (hailstorms)?
- Optimal inclination/tracking of the PV modules
- Performance depends on the type of plants/crops
- No specific software currently available
- Currently, common PV tools are being used.

BayWa r.e.

METEO INPUTS AND CLIMATE CHANGE

- Growing number of publications is using data from global climate models (GCM's) for predictions in years 2050 or 2100.
- They can predict either higher and lower irradiation depending on locations, but in general higher temperatures that impacts the PR.
- The regional analysis and more realistic PV performance modelling including uncertainties need further exploration.



J. Ascencio-Vásquez et al. "Methodology of Köppen-Geiger-Photovoltaic climate classification and implications to worldwide mapping of PV system performance," Solar Energy, vol. 191, pp. 672–685, Oct. 2019, doi: 10.1016/j.solener.2019.08.072.

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