International Solar Energy Research Center Konstanz

MoBiDiG: simulations and LCOE

Bifacial WS 2017
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Agenda

- LCOE and motivation
- Hierarchy for energy yield prediction of bifacial modules
- Validation of the simulation model
- Bifacial gain and LCOE sensitivity

Modeling of Bifacial Distributed Gain

Main Assumptions for LCOE Calculation

- Yearly GHI: 1960 kWh/m2 (e.g. Arizona (USA))
- => energy yield (monofacial) first year: 1836 kWh/kWp
- PF = 82%

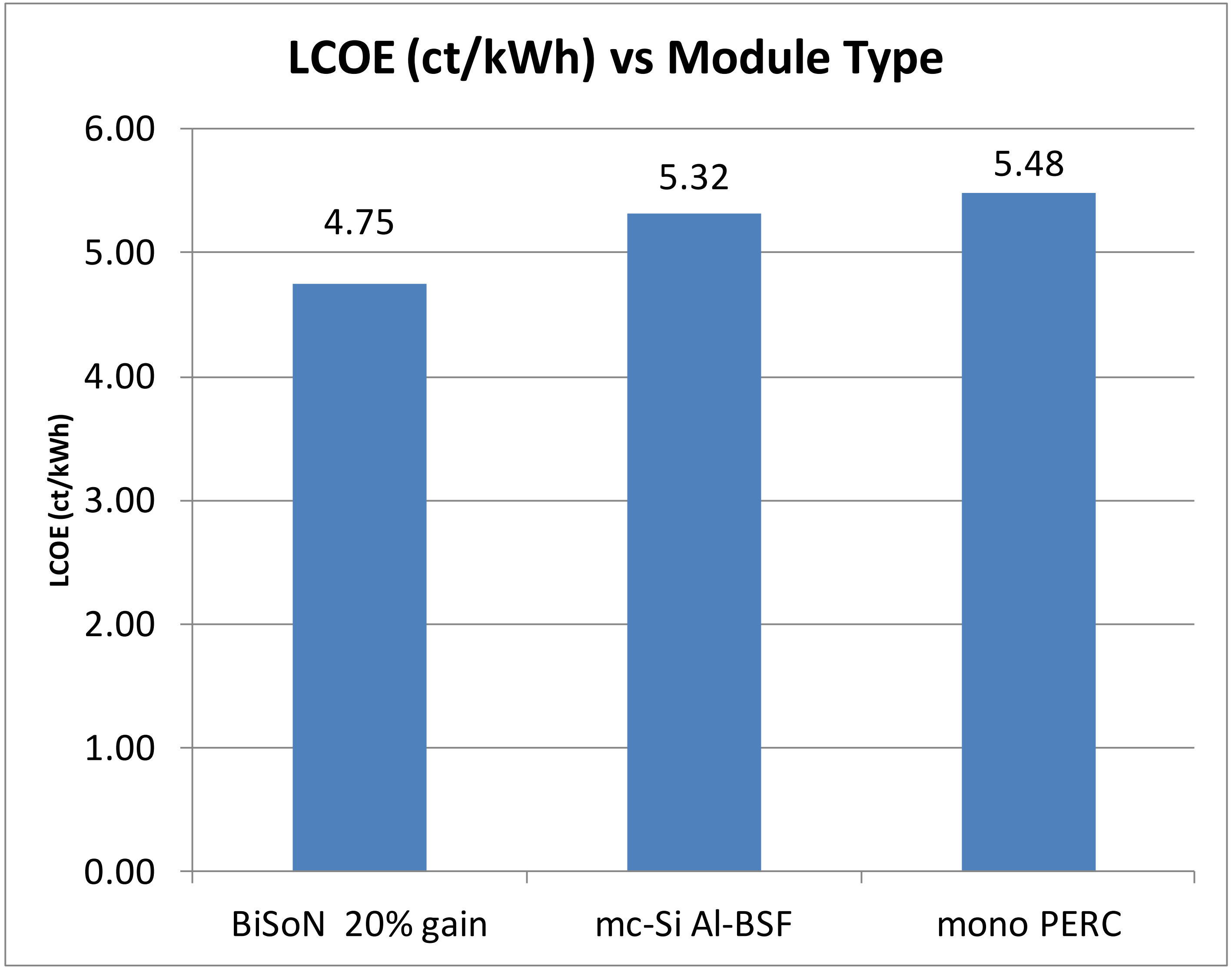
- **Module cost**
  - BiSoN: 0.39 USD/Wp
  - mono PERC: 0.37 USD/Wp
  - mc-Al-BSF: 0.32 USD/Wp

- **Total cost of installed system in USA (fixed tilt, utility scale)**
  - BiSoN: 1.09USD/Wp
  - mono PERC: 1.05 USD/Wp
  - mc-Al-BSF: 1.01USD/Wp

- **Module power (60 cells)**
  - BiSoN (nPERT): 300 Wp (only front side)
  - mono-PERC: 300 Wp
  - mc-Al-BSF: 280 Wp

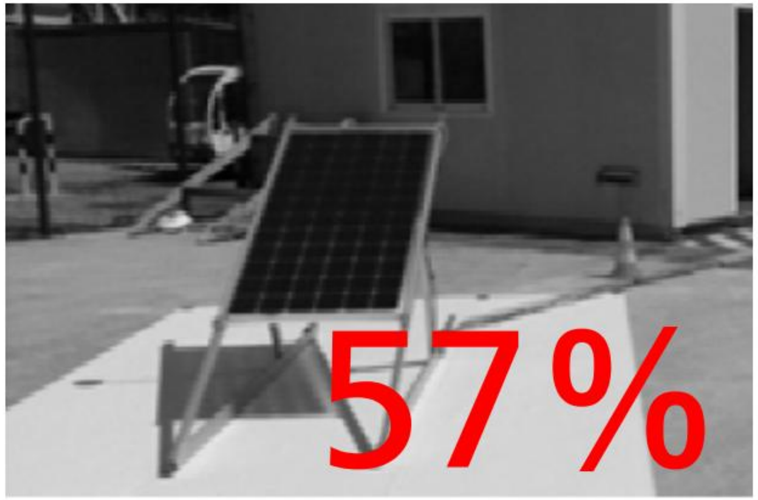
- **Financial parameters**
  - Discount rate / WAAC (weighted averaged cost of capital): 6.5%
  - Economic system lifetime: 25 years

LCOE results: technologies



More than 10% revenue increase from bifacial PV system

Energy Yield Prediction, Bifacial Gain and Challenges



EdF R&D 2014

ISC Konstanz 2014

bSolar 2014

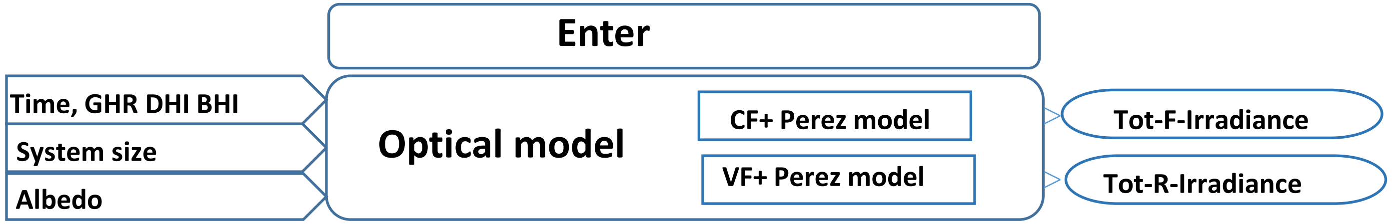
bSolar 2014

LCOE (kWh/$) ?

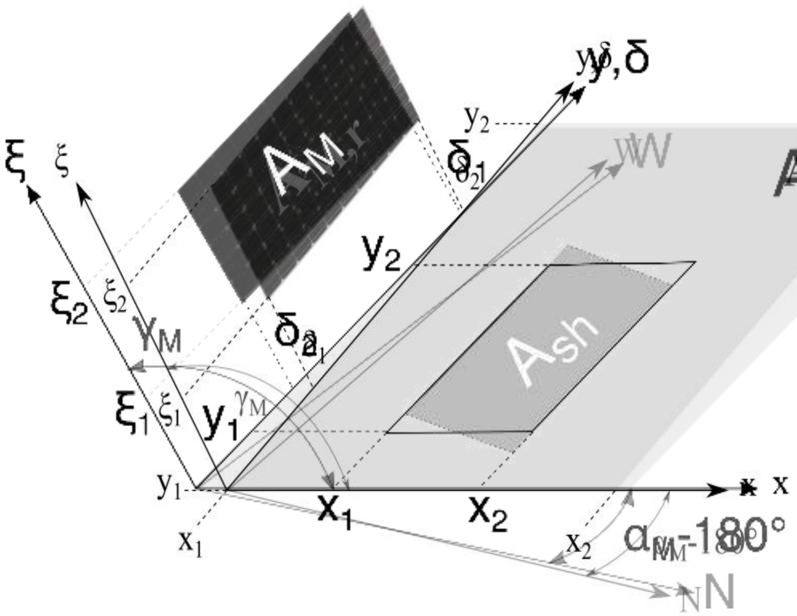
factors influencing rear side power output:

- latitude and longitude
- Height
- Albedo
- Diffuse irradiance factor
- Tilt
- number of neighboring modules
- row-to-row distance
- bifaciality factors
- rear irradiance inhomogeneity.
- Structures, frame and frameless
- …+Electrical and thermal model

Hierarchy for Energy Yield Prediction of Bifacial Systems

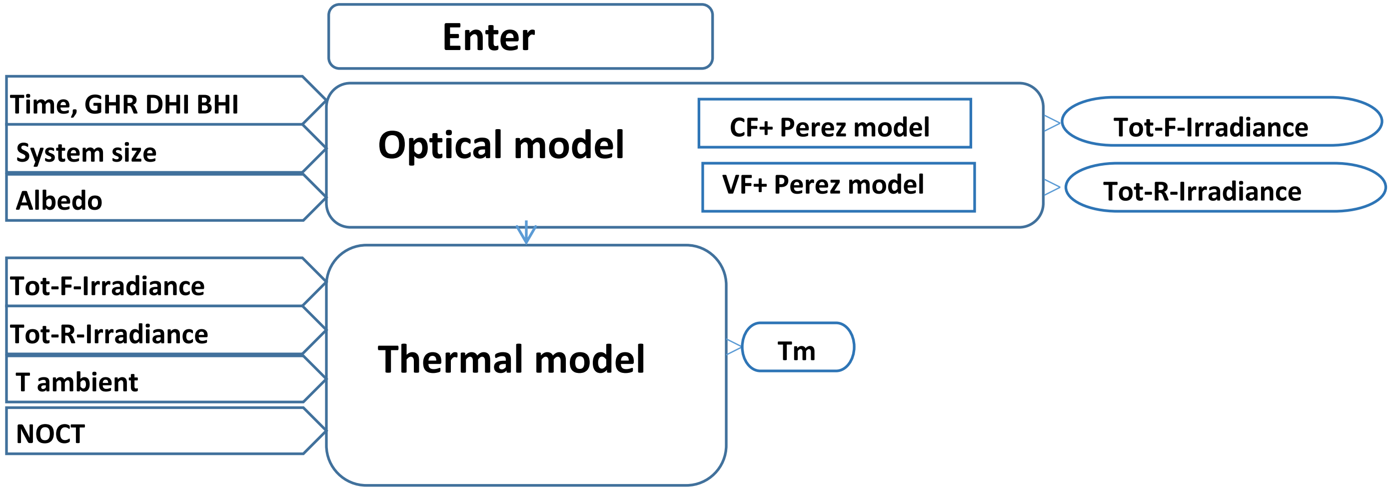


$$I_{POA} = \text{Direct irr} + \text{Ground reflected irr} + \text{Sky Diffuse irr}$$



$$I_{refl,r} = \alpha\ GHI\ F_{A_{nsh} \rightarrow A_M} + \alpha\ DHI\ F_{A_{sh} \rightarrow A_M}$$

Hierarchy for Energy Yield Prediction of Bifacial Systems



$$T_{module} = T_{ambient} + \frac{NOCT - 20^{\circ}C}{800\ W/m2}\, G\ (W/m^2)$$

NOCT is the nominal cell temperature.
G is the total irradiance on POA

J. R. G. Ross and Smokler, M. I., **"Flat-Plate Solar Array Project Final Report"**, pp. 86-31, 1986.

Hierarchy for Energy Yield Prediction of Bifacial Systems

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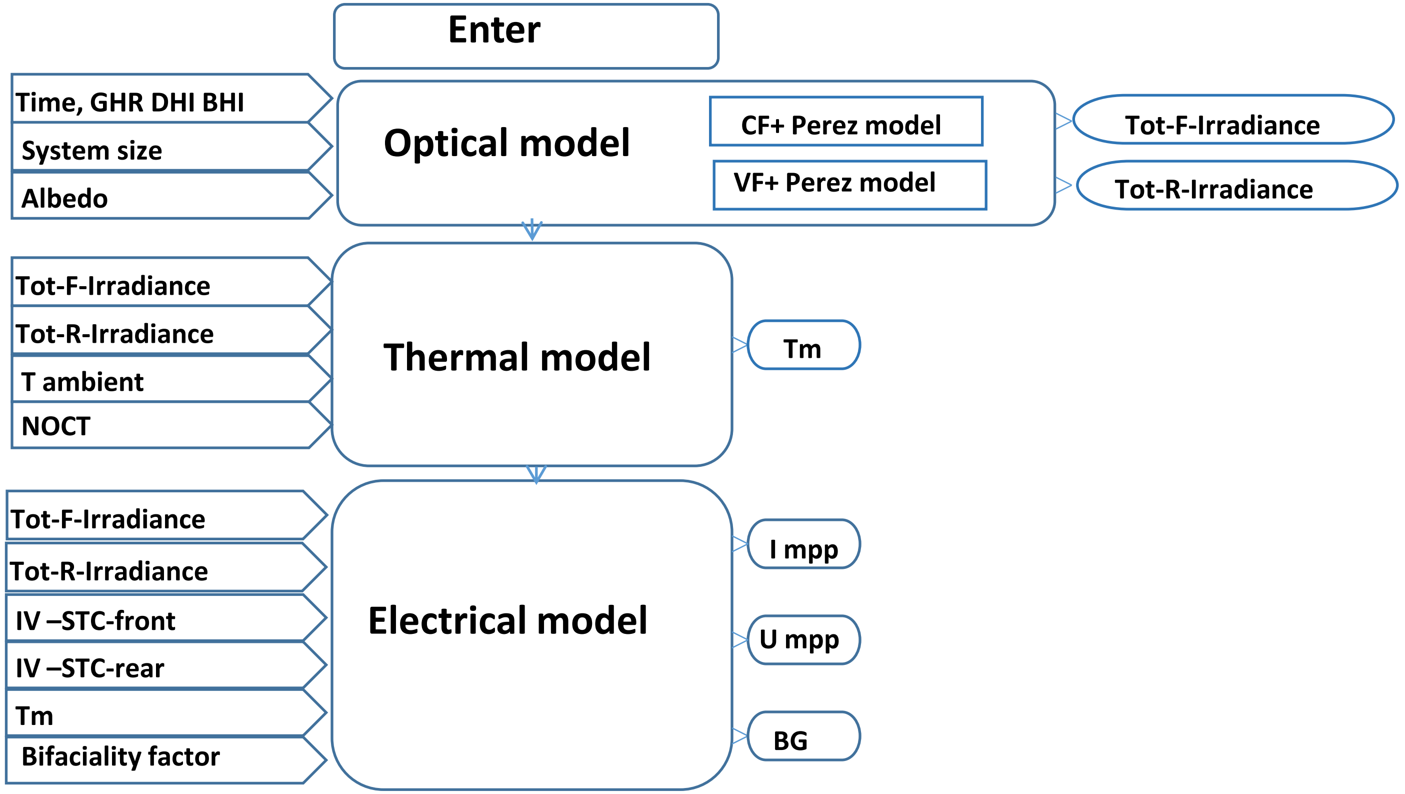
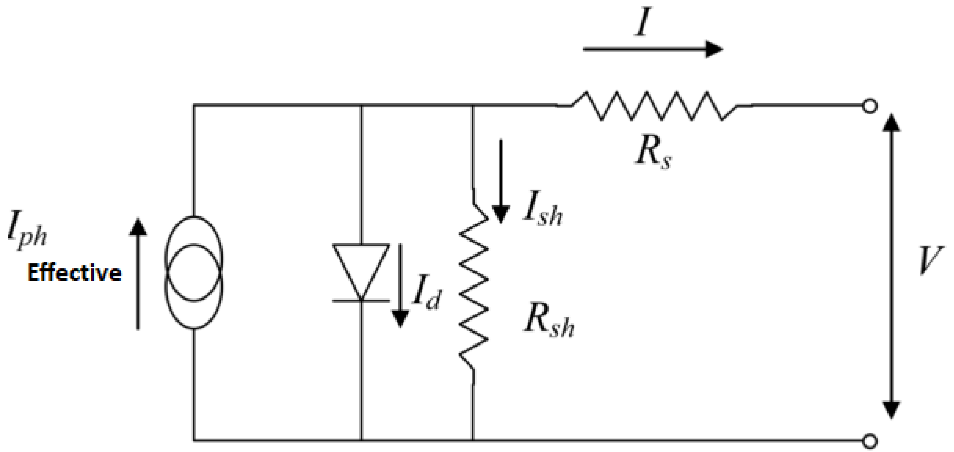


$$I_{ph\_effective} = I_{sc\text{-}f0} \frac{(E_{front} + \beta E_{rear})}{E_0}$$



Jai Prakash et al., “Electrical characterization method for bifacial photovoltaic modules”, Sol. Energy Mater Sol. Cells., 2014

Hierarchy for Energy Yield Prediction of Bifacial Systems

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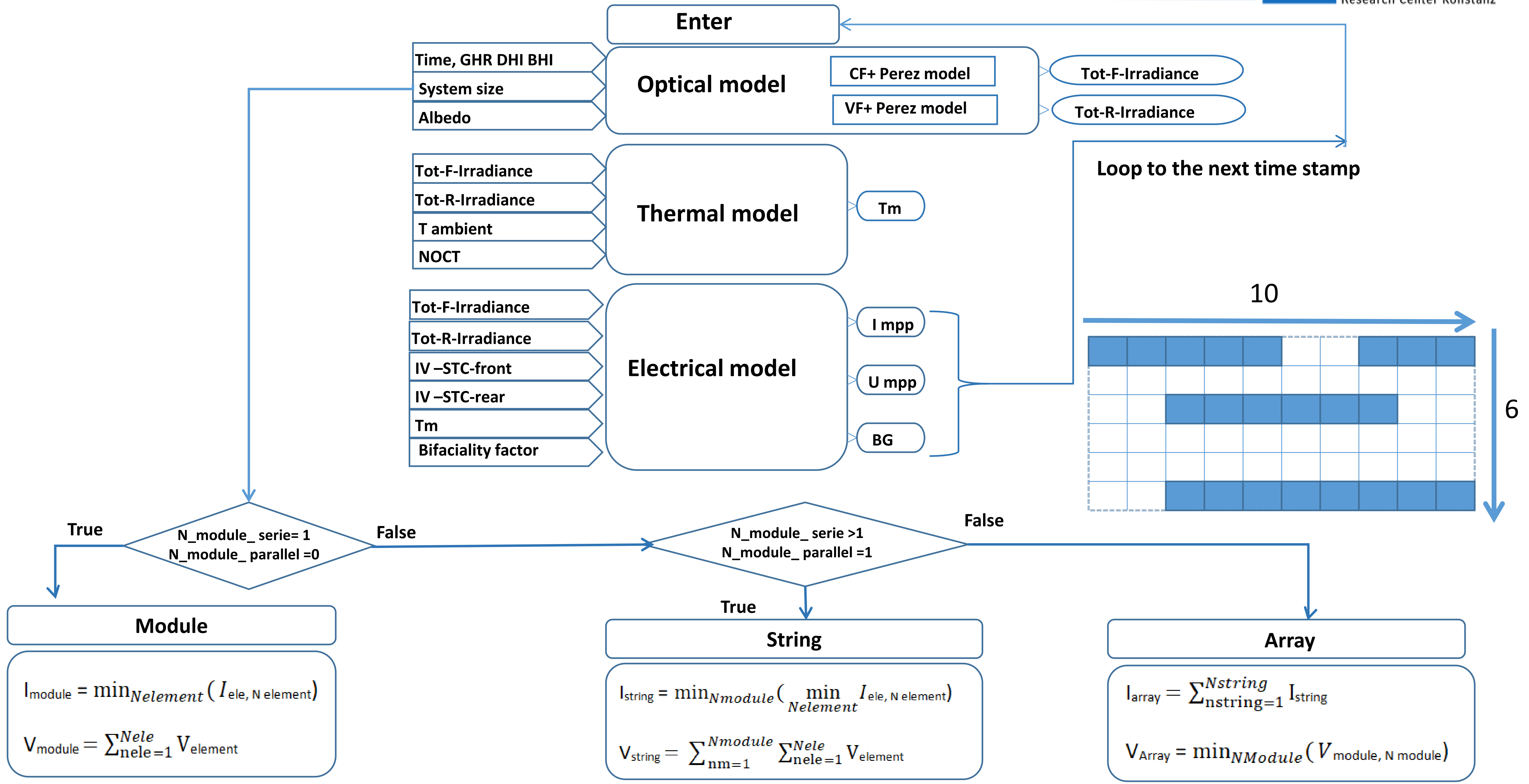

Outdoor Data vs. Simulated Energy Yield

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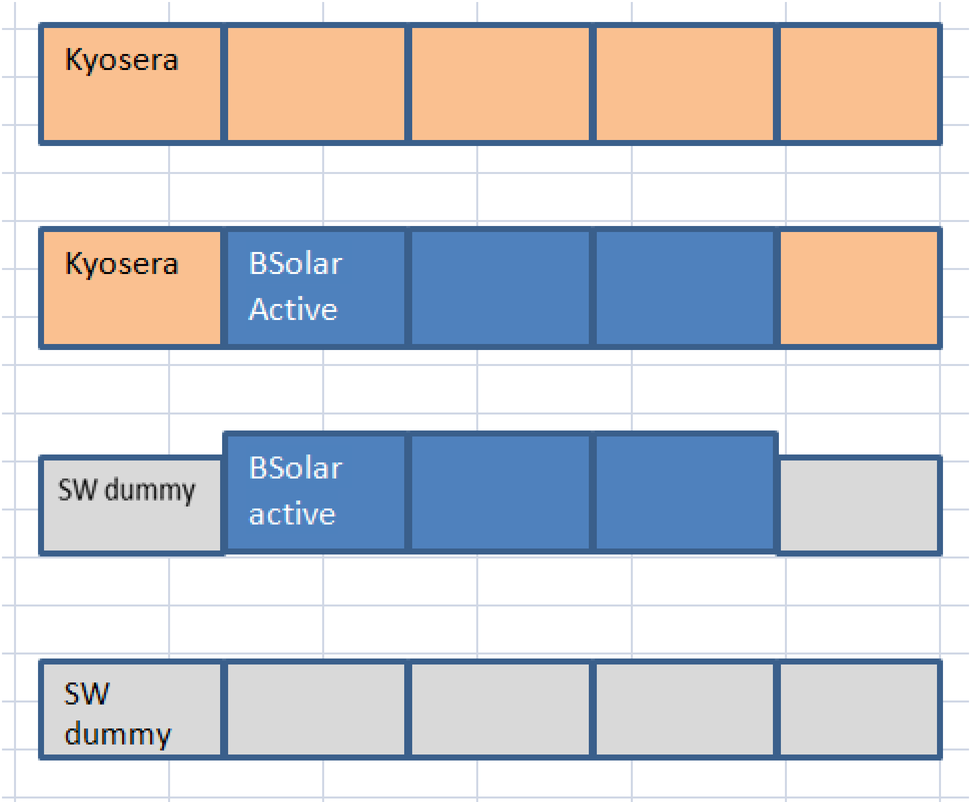
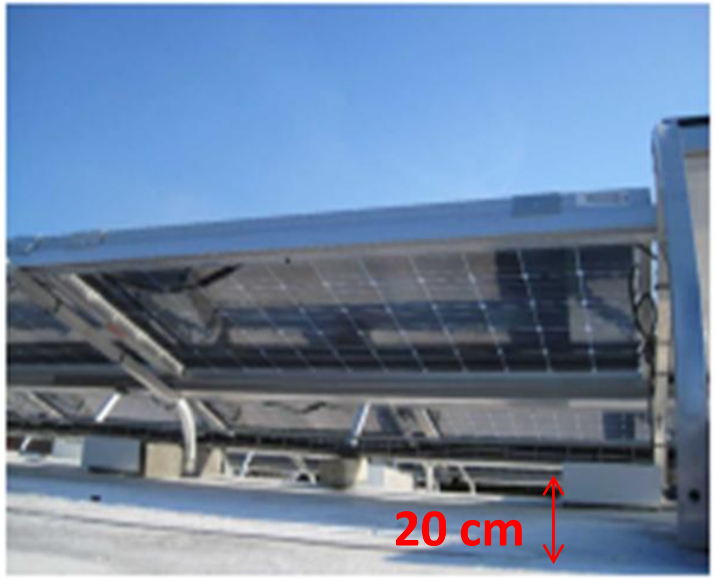
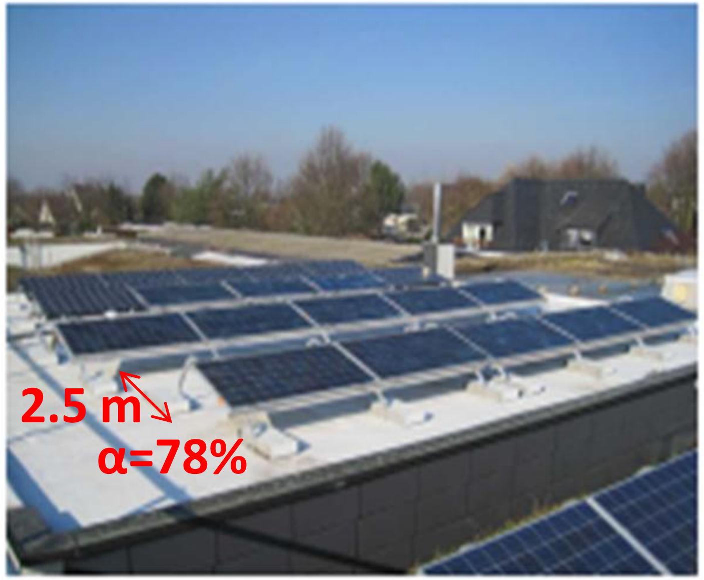
bSolar Test System at Geilenkirchen, Germany

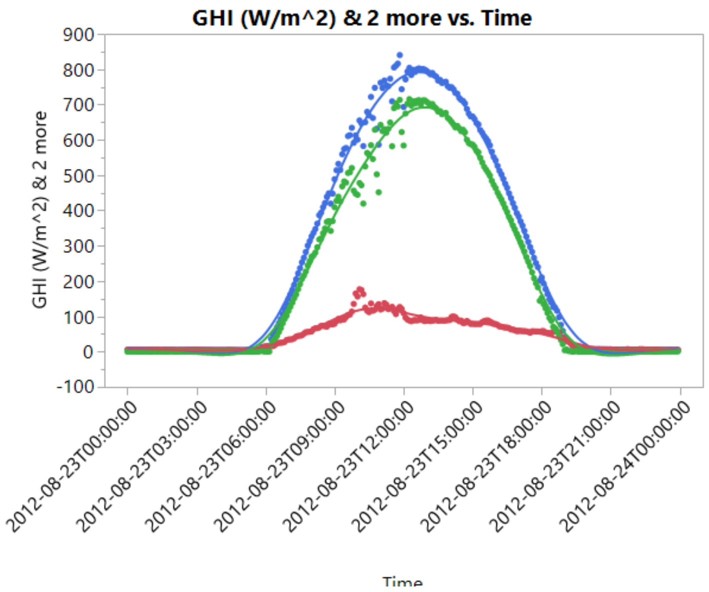


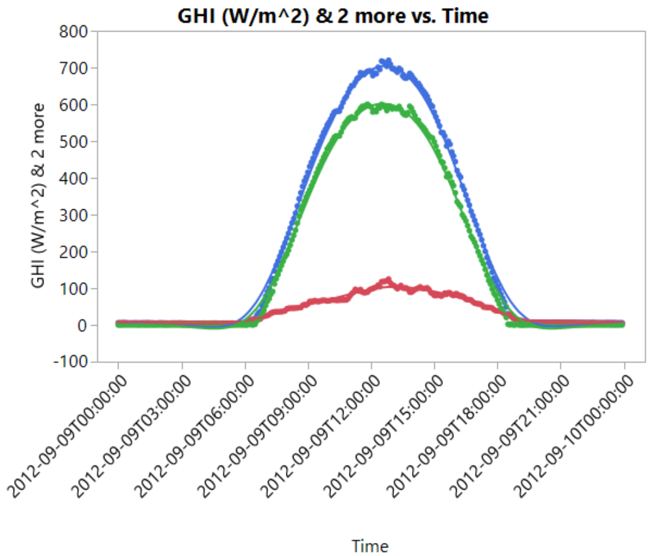


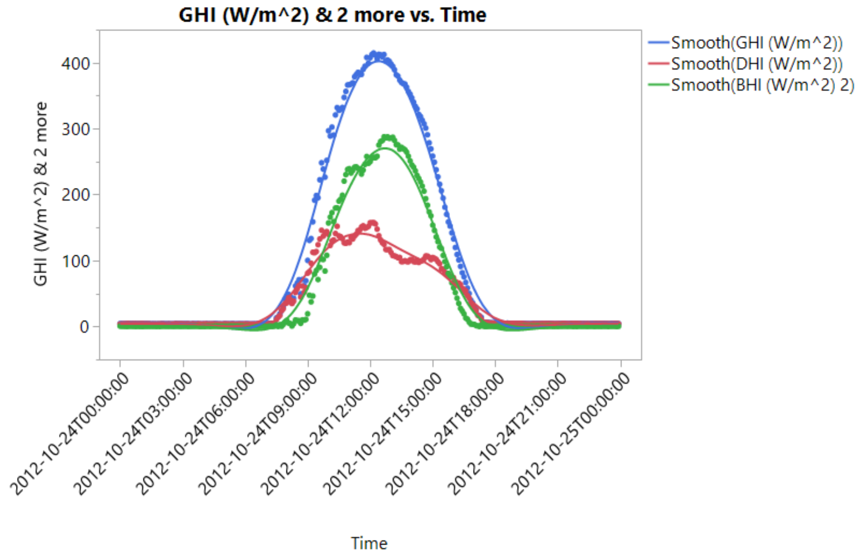


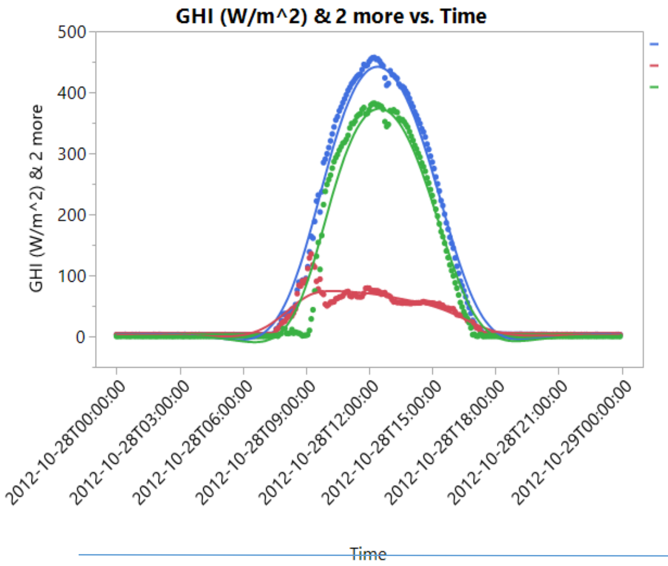
Azimuth – 145°
Tilt – 30°
6 Bifacial modules
7 Standard modules
7 Dummy modules

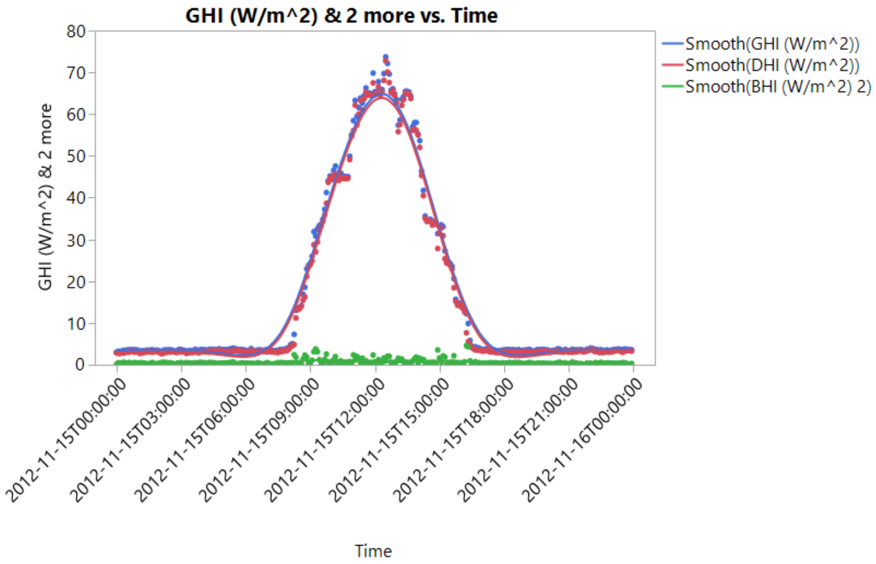
Irradiance Data (5 min, GHI, DHI, BHI), Inputs



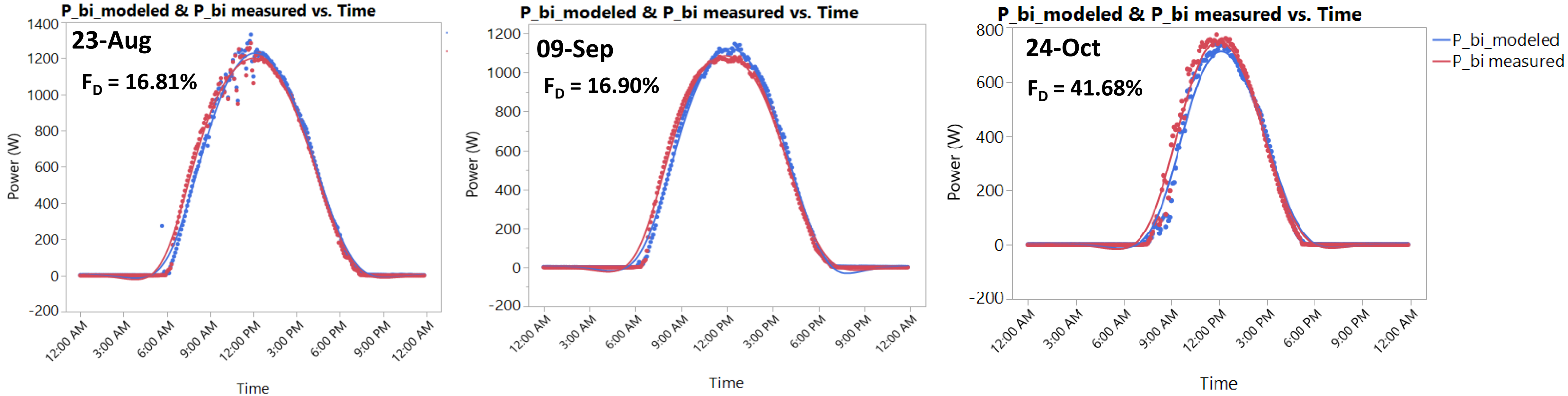


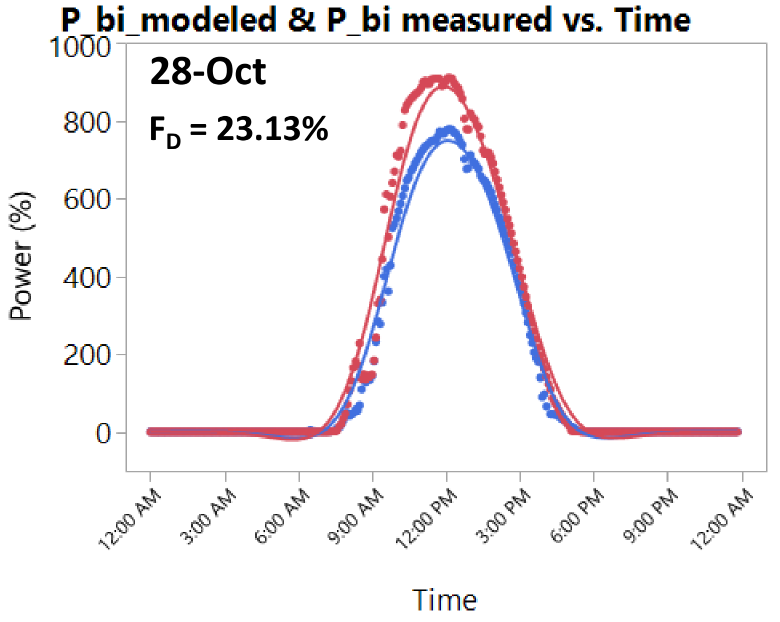


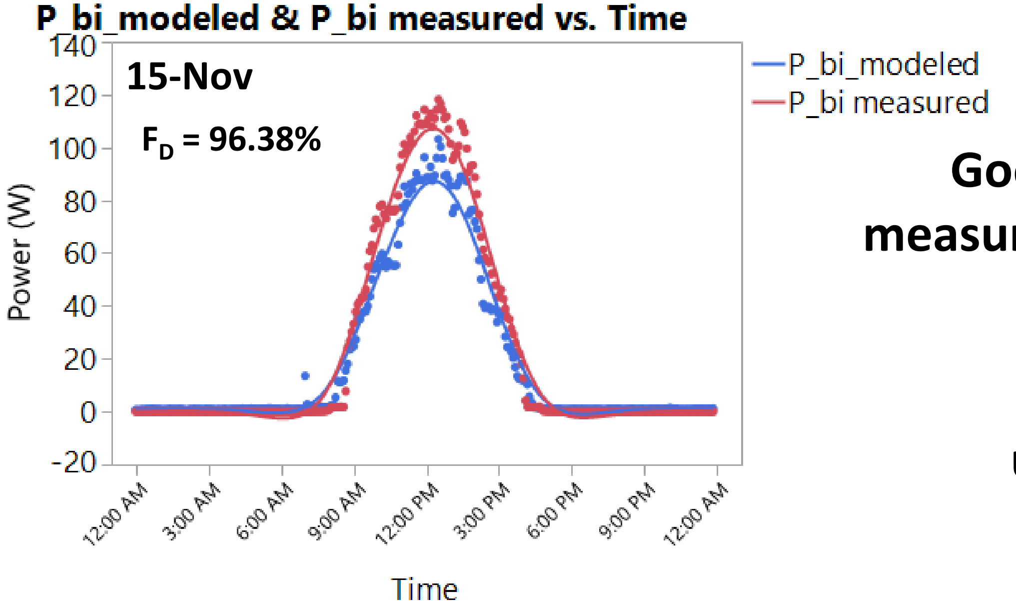




Daily Bifacial String Power Modeled Vs. Measured







Good correlation between measured and simulated power at high irradiance

Good trend, but underestimation at low irradiance

Accumulated Results Modeled Vs. Measured

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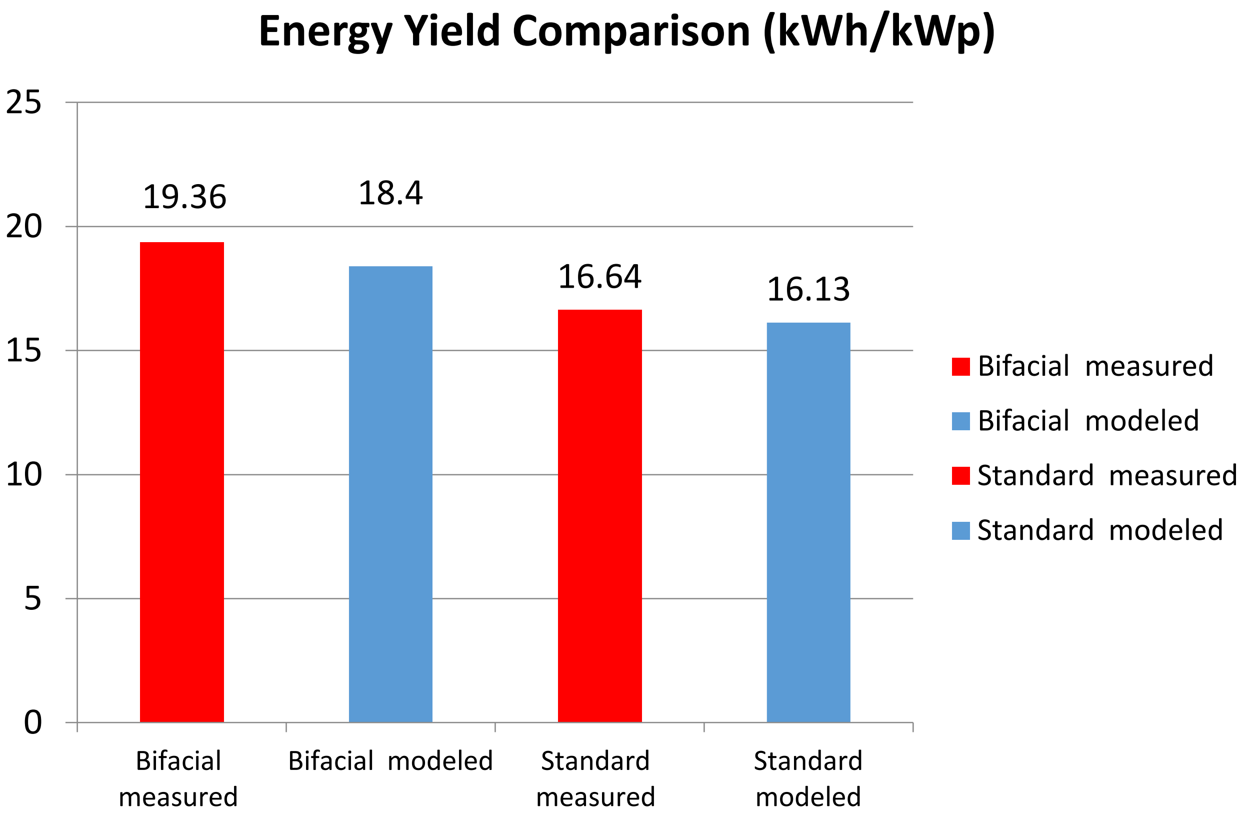
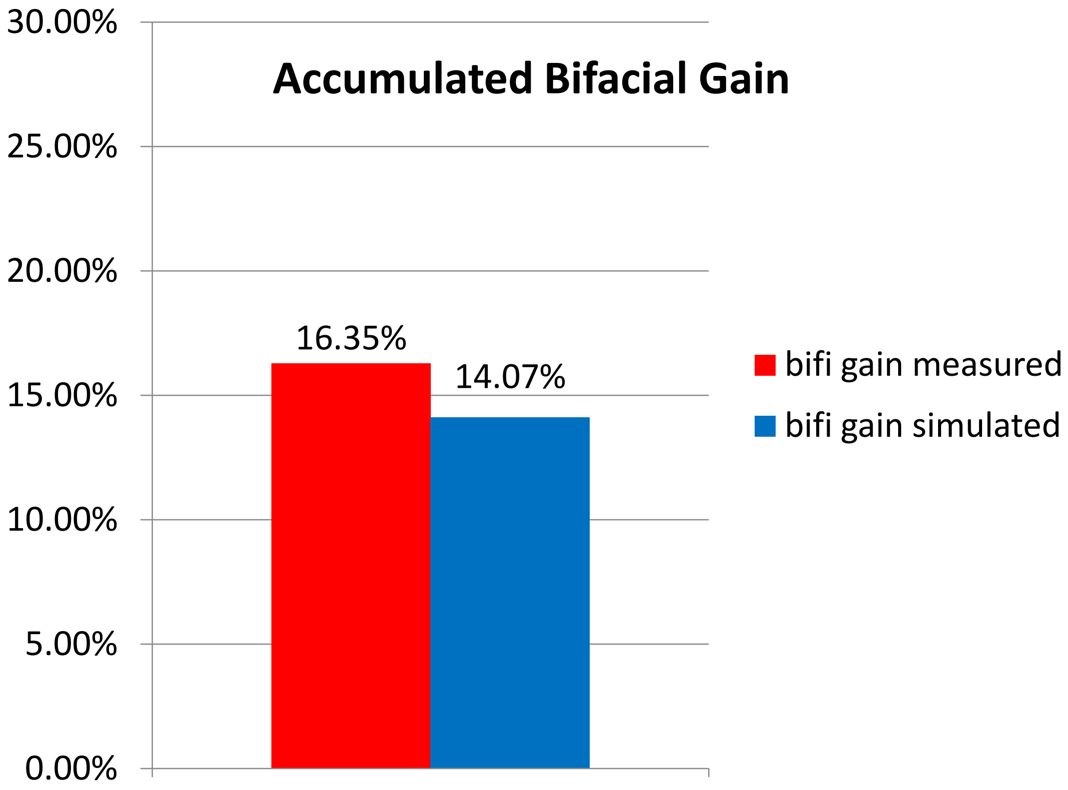
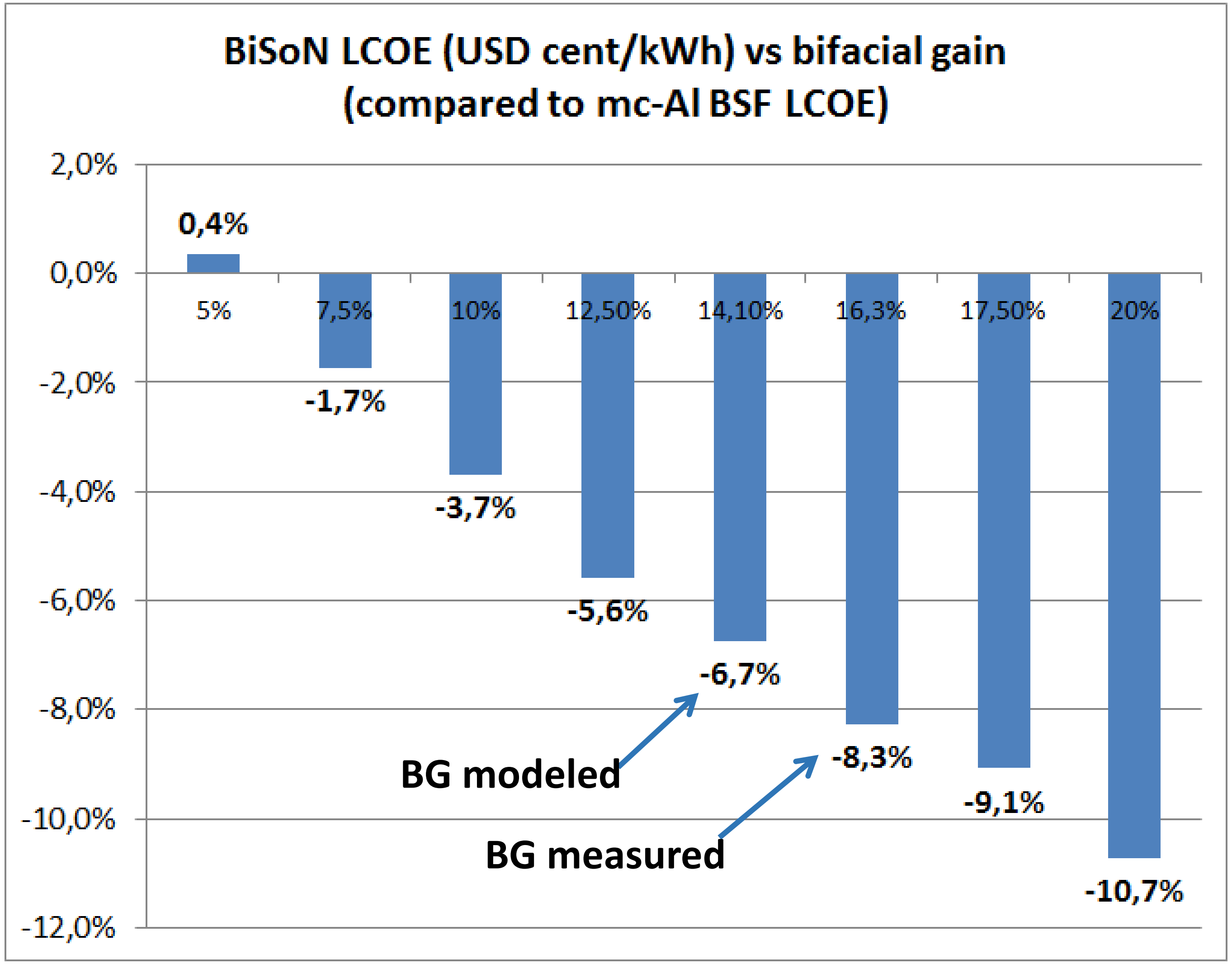




Energy yield prediction of bifacial system is 4.9% underestimated compared to measured data

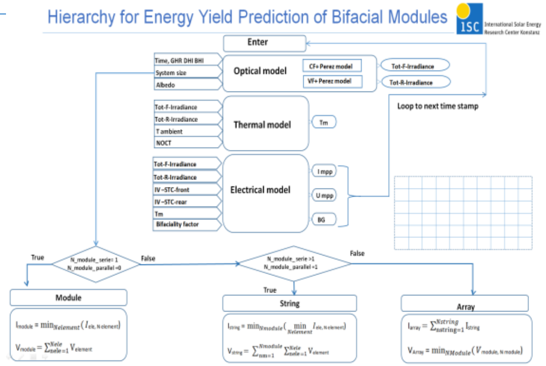
Bifacial Gain and LCOE Sensitivity

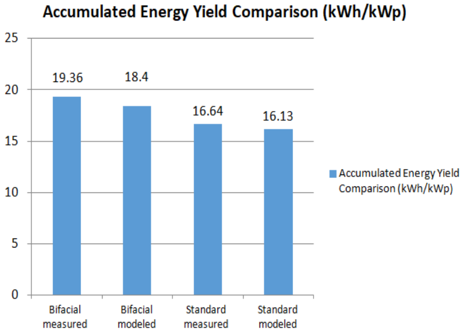


±2.5% absolute difference in predicted bifacial gain can decide on the profitability of Bifacial system.

Prediction of bifacial gain with high accuracy is needed

Summary and Future Work

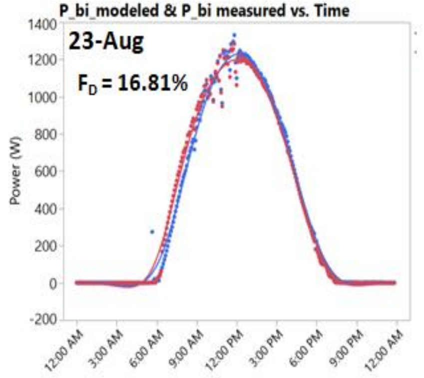




- ISC has developed MoBiDiG bifacial energy yield prediction
- The model has been validated with measured data at string level

on daily and hourly basis.

- Deviation of 4.9% (rel.)on the accumulated energy yield is recorded from only for 5 extreme
- days

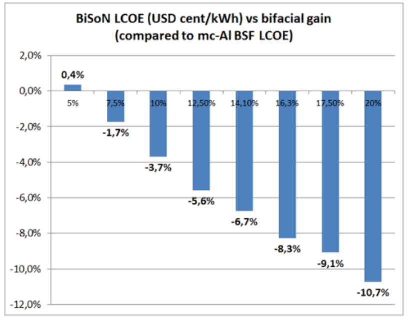


- We have shown that for our scenario LCOE is ±2.5% (absolute) sensitive to bifacial gain

Future goals

- Long term validation (several months to a completed year) also for different geographic locations
- ISC Cooperates with ZHAW/IEFE for a comparative analysis between BIFAROT

approach and ISC's simulation model.



• Thank you for your attention!

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