SOLup

Bifacial Vertical PV System for Flat Roofs

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Solyco Technology GmbH

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We are experts in the field of solar technology since 1996.

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Introduction

- The team is working on bifacial PV products already since 2005. However, in early years we got stuck because of lack of bifacial solar cells
- We are working on vertical bifacial PV since 2016
  - Long-term project because of lack of industry experience
- Vertical bifacial PV is still a niche but it is getting more popular recently:
  - Several publications about the potential
  - Next2Sun (DE): commercial projects for agri-PV
  - Overeasy (NO): start-up for rooftop applications
  - Some special rooftop projects

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From /1/

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From /2/

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From /7/

Energy Yield Studies

Energy Yield Studies

Test site #1: Forst (Germany)

- Vertical bifacial PV with various orientations and 2 albedo factors
- References 10° E-W and 30° south
- Sensors: GHI, DHI, T_{amb}

Test site #2: Tucson AZ (USA)

- Vertical bifacial PV with only high ground albedo
- References: 10° in various orientations
- Sensors: GHI, T_{amb}

Energy Yield Studies

#1: Global annual yield of vertical bifacial east-west vs. monofacial south

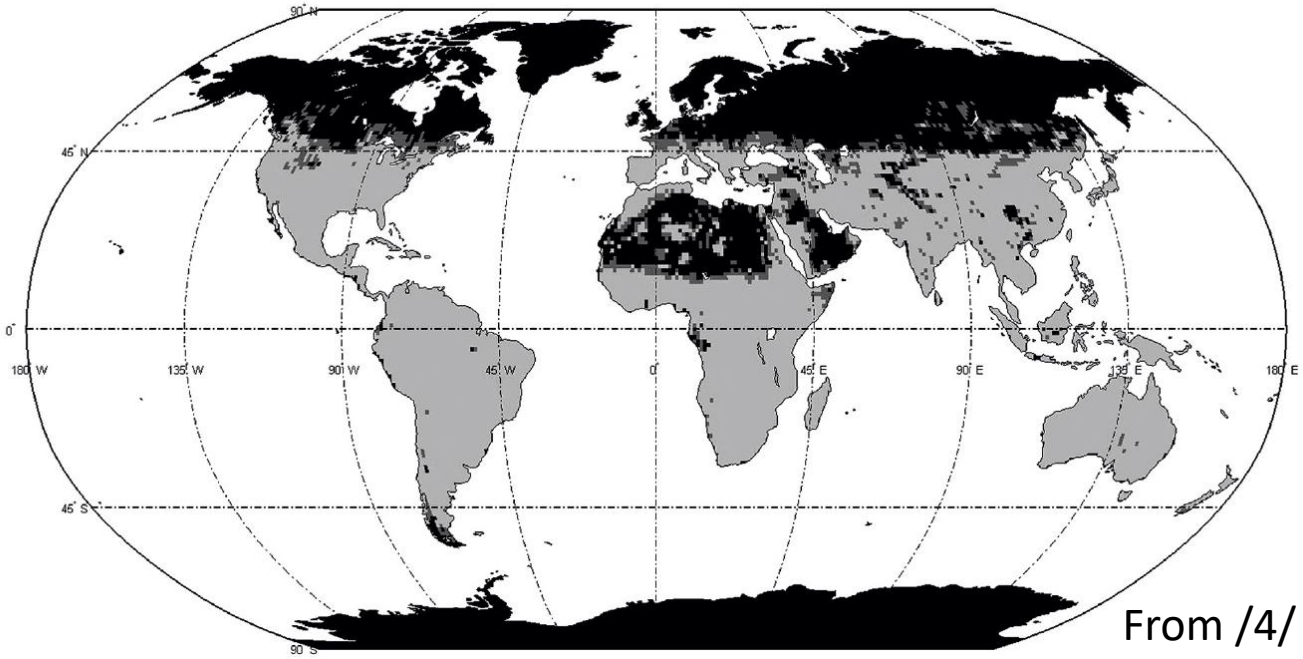
Specific annual energy yield [kWh / kWp]	Technology	bifacial	bifacial	monofacial
	Tilt angle	vertical	vertical	10°
	Albedo	bright	dark	n/a
Tucson (USA); 32.2°N		1,750	-10% -	1,950
Forst (DE); 51.7°N		960 +13%	790 -7%	850

- The relative specific annual yield strongly depends on location (latitude) and albedo
- Bifacial data are for low row spacing (2x module height)

from /3/

Energy Yield Studies

World map of where vertical bifacial PV can be beneficial over „normal“ PV

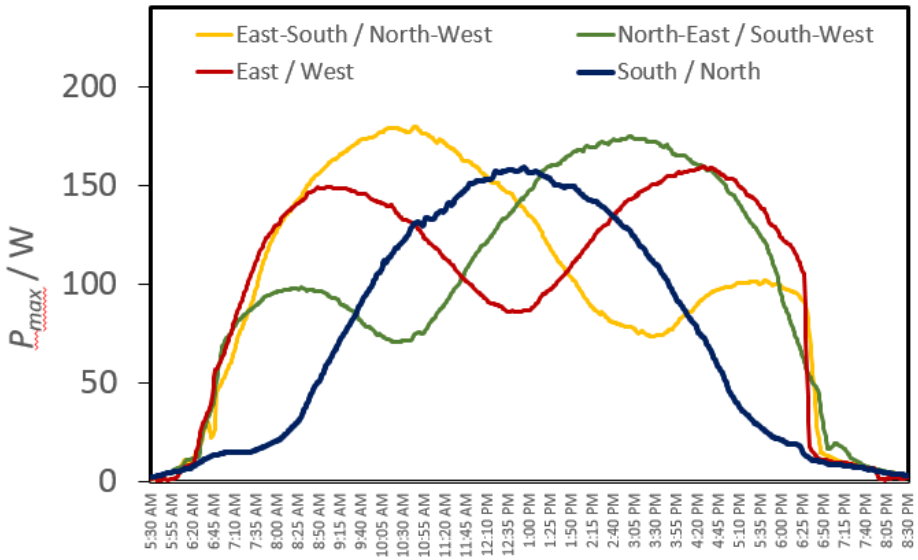


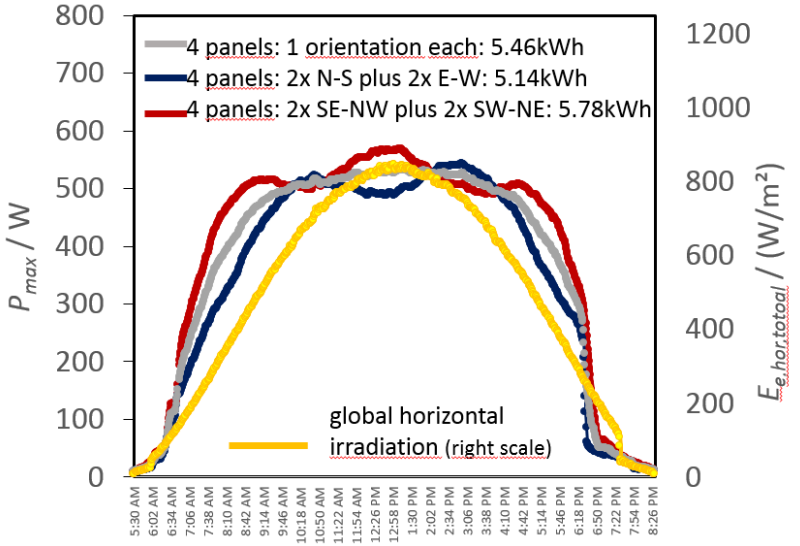
From /4/

- The relative specific annual yield strongly depends on location (latitude) and albedo

Energy Yield Studies

#2: Daily energy production characteristics for different orientations

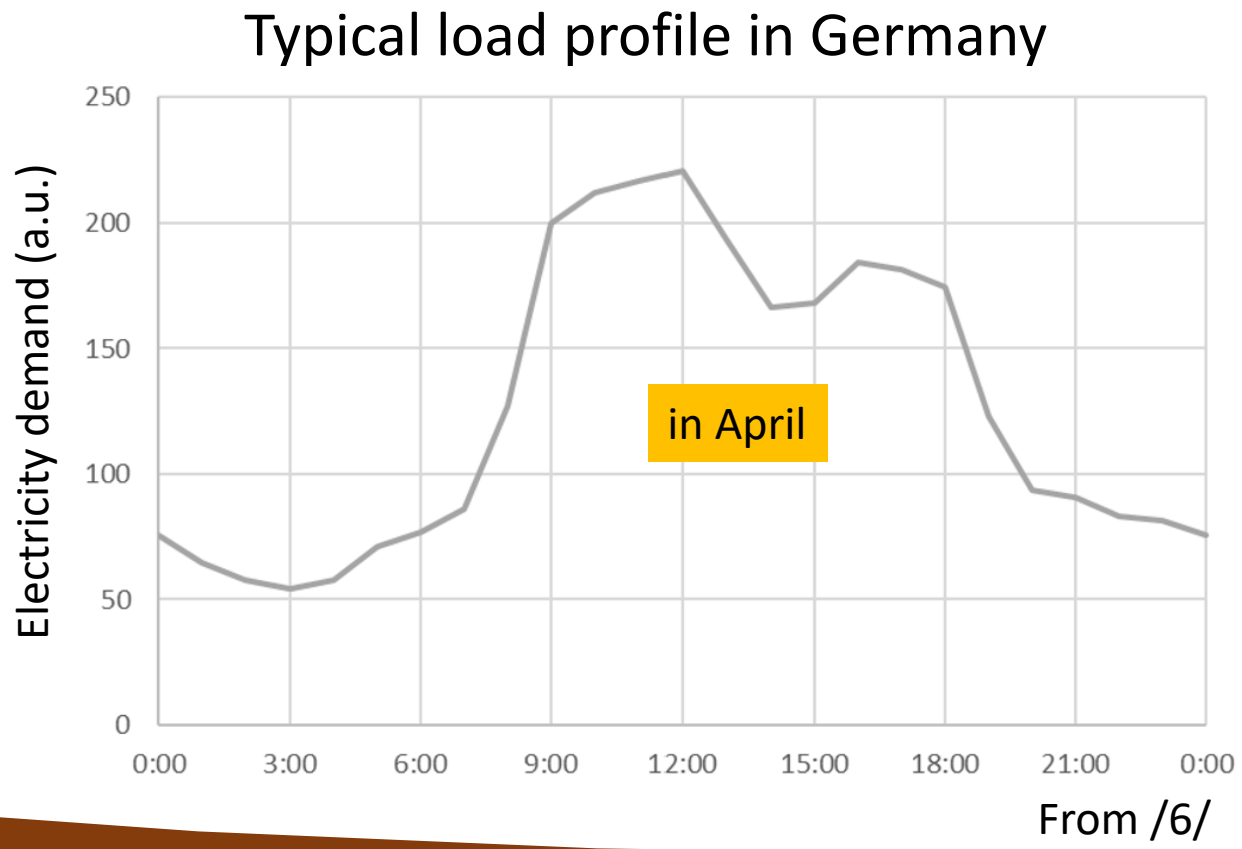




- The daily energy production curve strongly varies with module orientation
- By combining different orientations a stable energy production during the day can be achieved. From /5/.

Energy Yield Studies

#3: Optimization of daily energy production for grid load characteristics

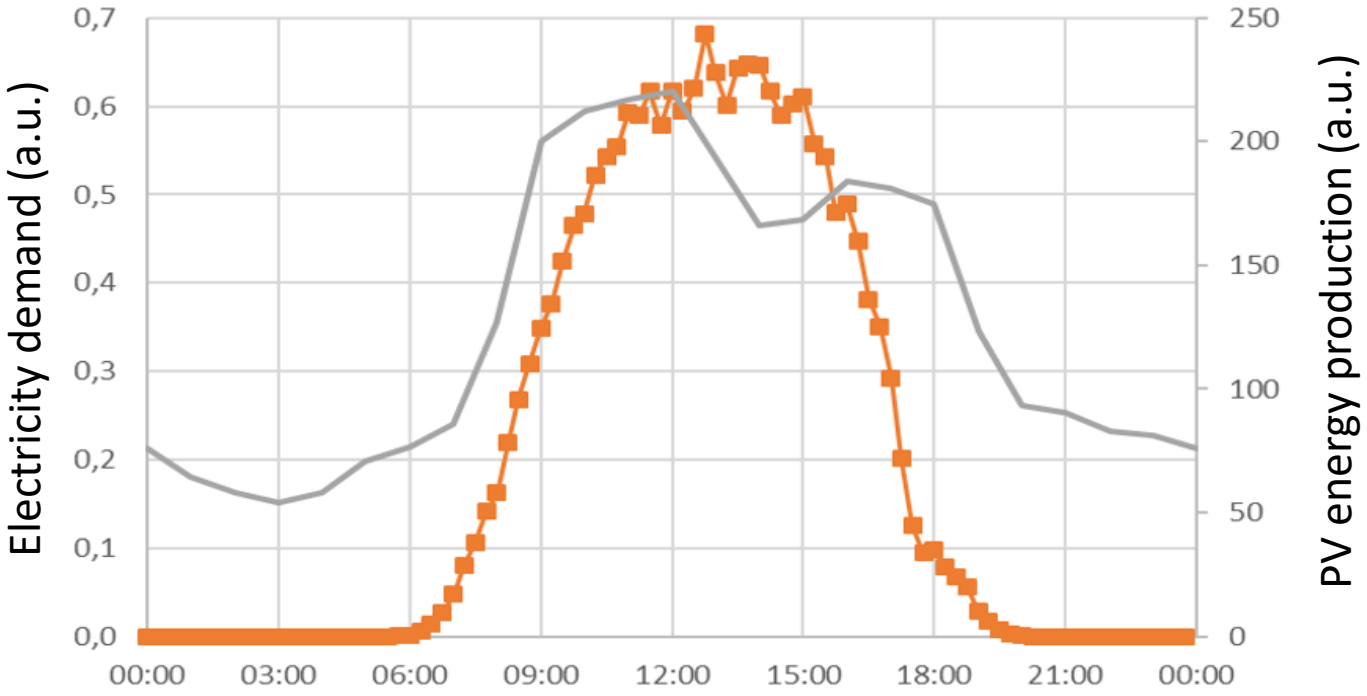


From /6/

Energy Yield Studies

#3: Optimization of daily energy production for grid load characteristics

Typical load profile in Germany



Normal south-oriented PV system

Production peak does not match with demand

Energy Yield Studies

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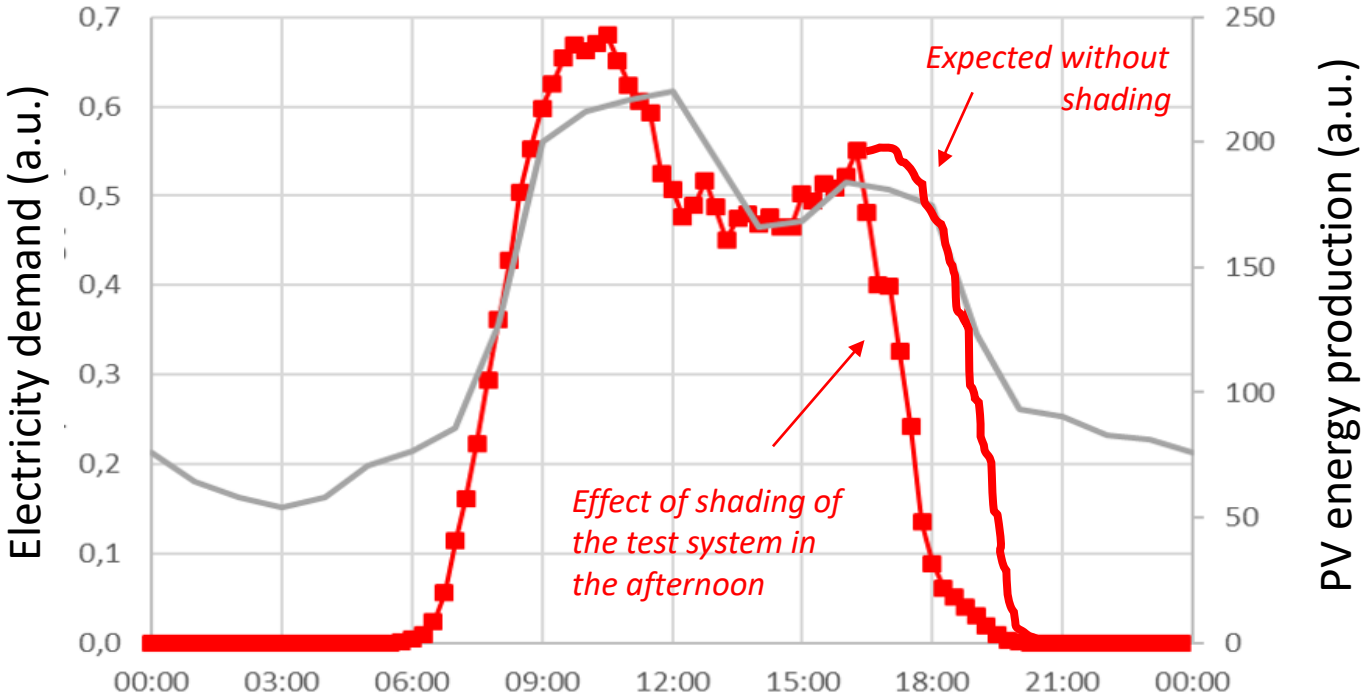


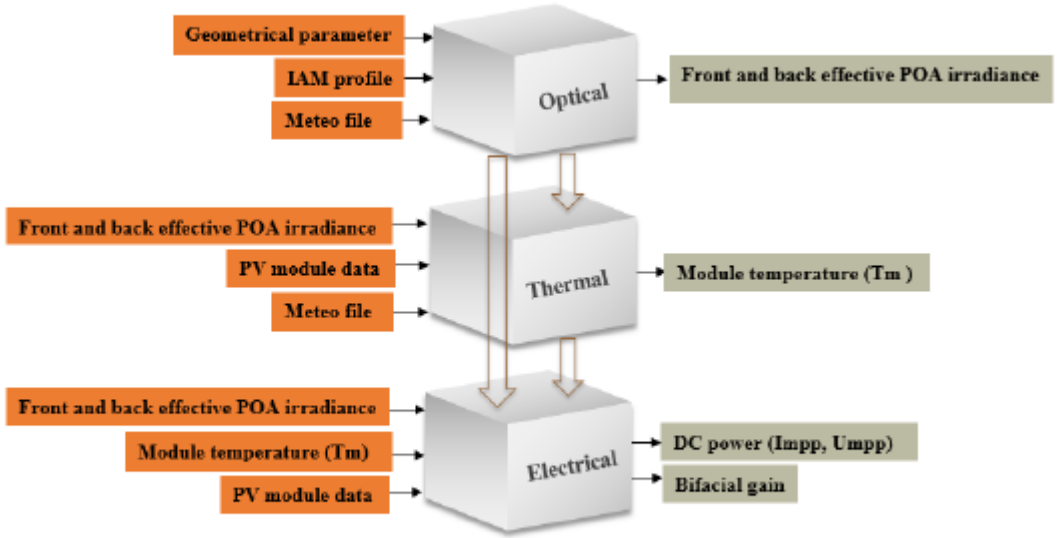
Vertical bifacial PV system (50% NE-SW + 50% E-W)

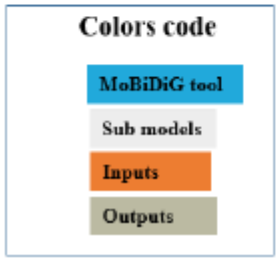
The energy production curve does match the demand very well
→ higher value of PV energy

Simulation

Simulation

- **MoBiDiG**[1]:
  Simulations tool of ISC for calculation of energy production of bifacial systems

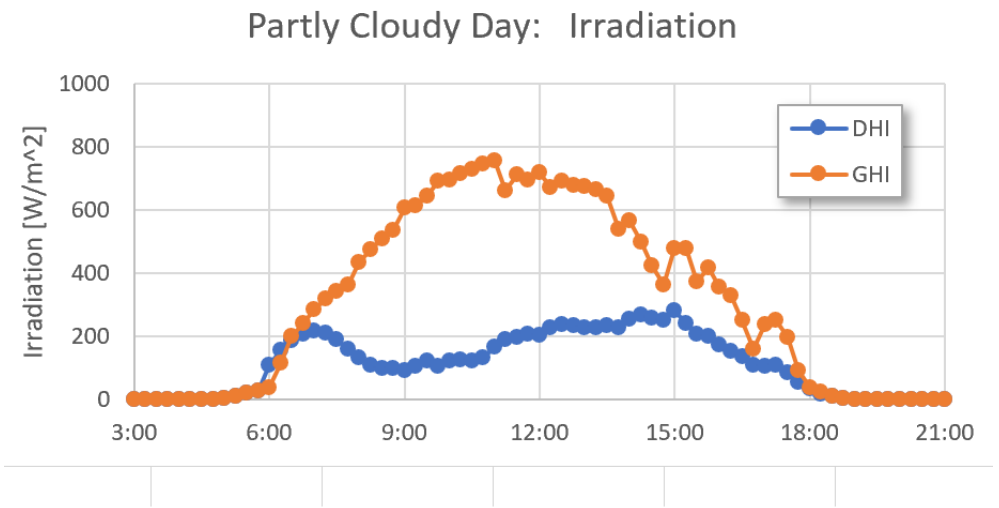


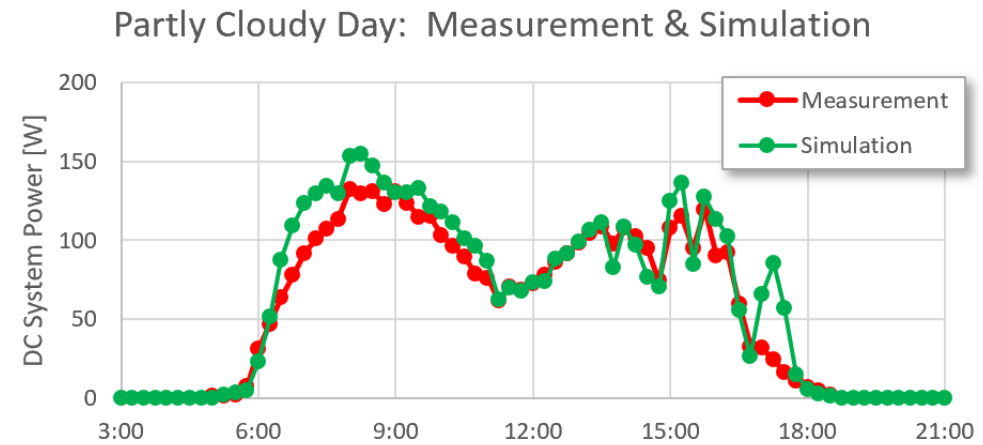


- Got optimized for vertical systems
- Consideration of the self-shading
- applying 3D and 2D view-factor modelling, as well as ray-tracing

1: Modeling of Bifacial Distributed Gain

Simulation





- ISC ran a comparison of MoBiDiG prediction with our test site data for 1 year
- As a result MoBiDiG is now able to simulate also vertical bifacial PV systems

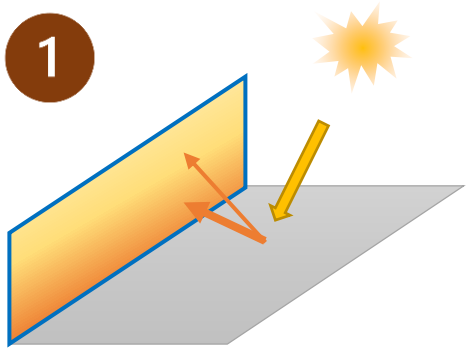
Module design considerations

Module design considerations

(1) The albedo leads to an inhomogeneous light intensity on the module

(2) Calculation by using “View-Factor”-method

1



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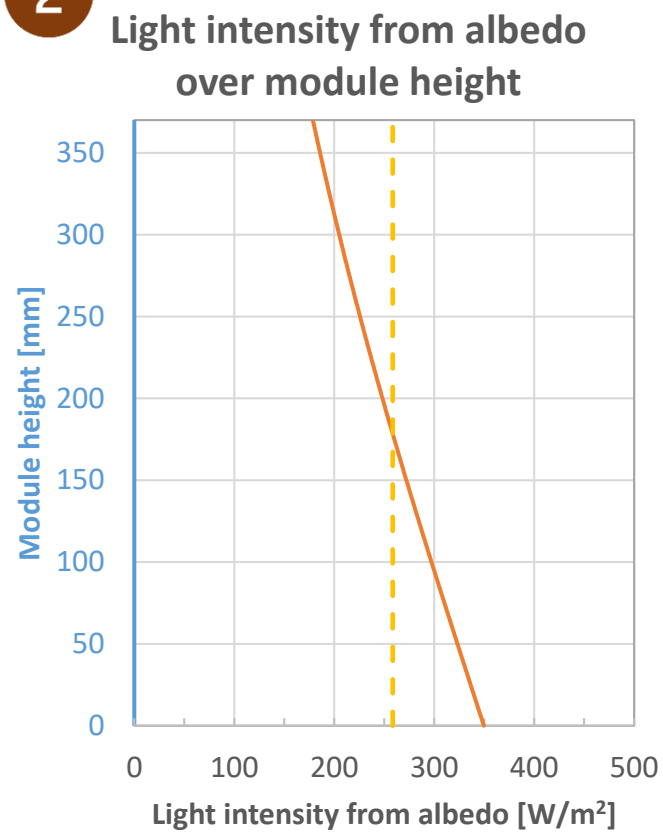

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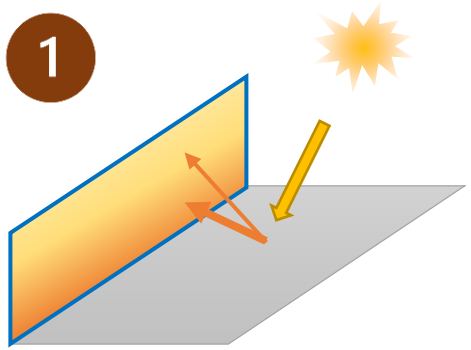
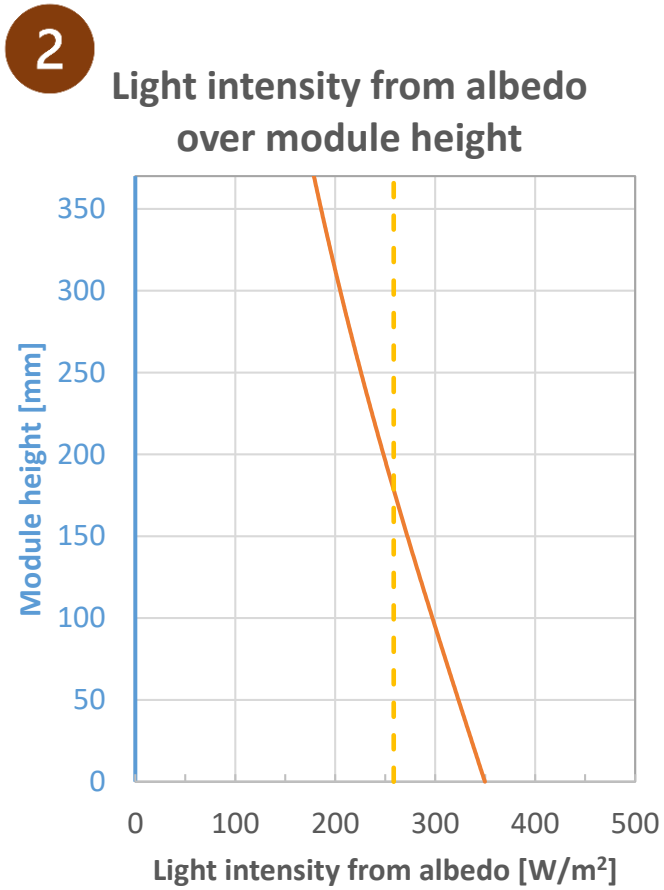




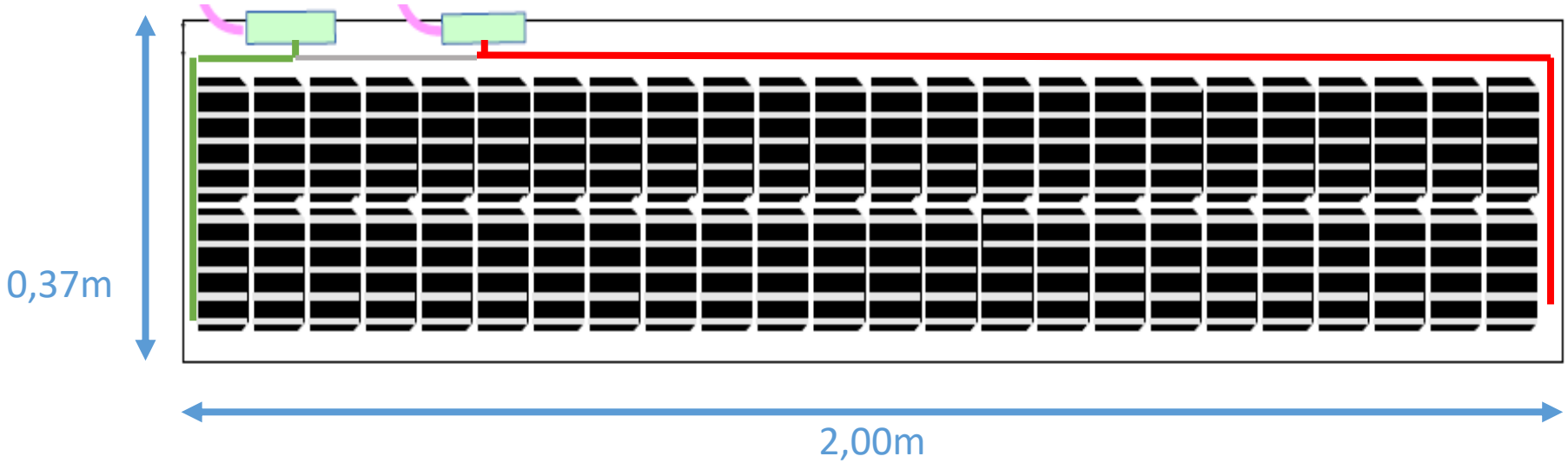
(3) The module must be pretty flat in order to minimize the wind load

(4) The module should be reasonably large in order to minimize manufacturing costs and racking and cabling efforts

(5) Solar cells must have high bifacial coefficient

Module design considerations

Resulting module design *)



- The module contains just 2 rows of strings. Module height is approx. 40cm
- Both strings contains ½cut cells and are connected in parallel in order to tolerate inhomogenuous irradiation
- Module height:length ratio is 1:5 … 1:6

*) module design is IP-protected

System design challenges

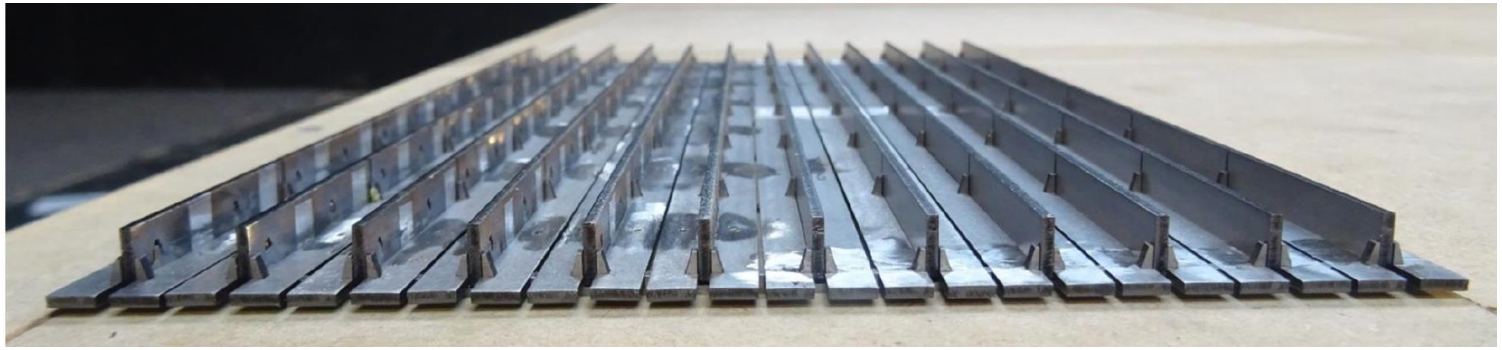
System design challenges

- Module mounting structure
  - Modules can only be fixed at the outer edges
  - Flat roofs very often only have limited load reserve which can be utilized for the solar systems → system must be light-weight
- Cabling
  - The power per module is fairly low, so many cables per kWp
  - Cables cannot be hidden behind the module (UV; rain; …)
- Wind load
  - The system is very prone to wind load
- What is the ideal row spacing?
  - More distance between rows means more kWh/kWp but less kWh per roof

System design challenges

#1: Wind tunnel testing

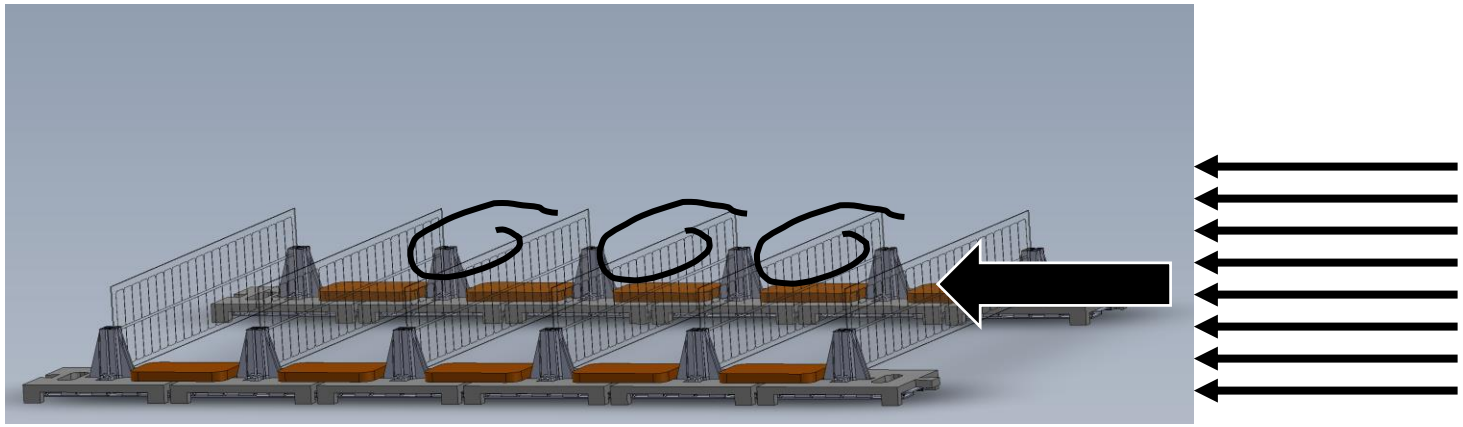
- We followed the standard procedure which also most manufacturers of „normal“ racking systems are using
  - A small-scale modell of the system is tested on various positions on a (small-scale) building



System design challenges

#1: Wind tunnel testing result

- There are pretty strong forces which are pushing towards the front rows of the modules → in case of ballasting heavy weight is required
  → or you have to mechanically fix the systems to the roof
- There are some turbulences behind the front rows
- There are no uplift forces



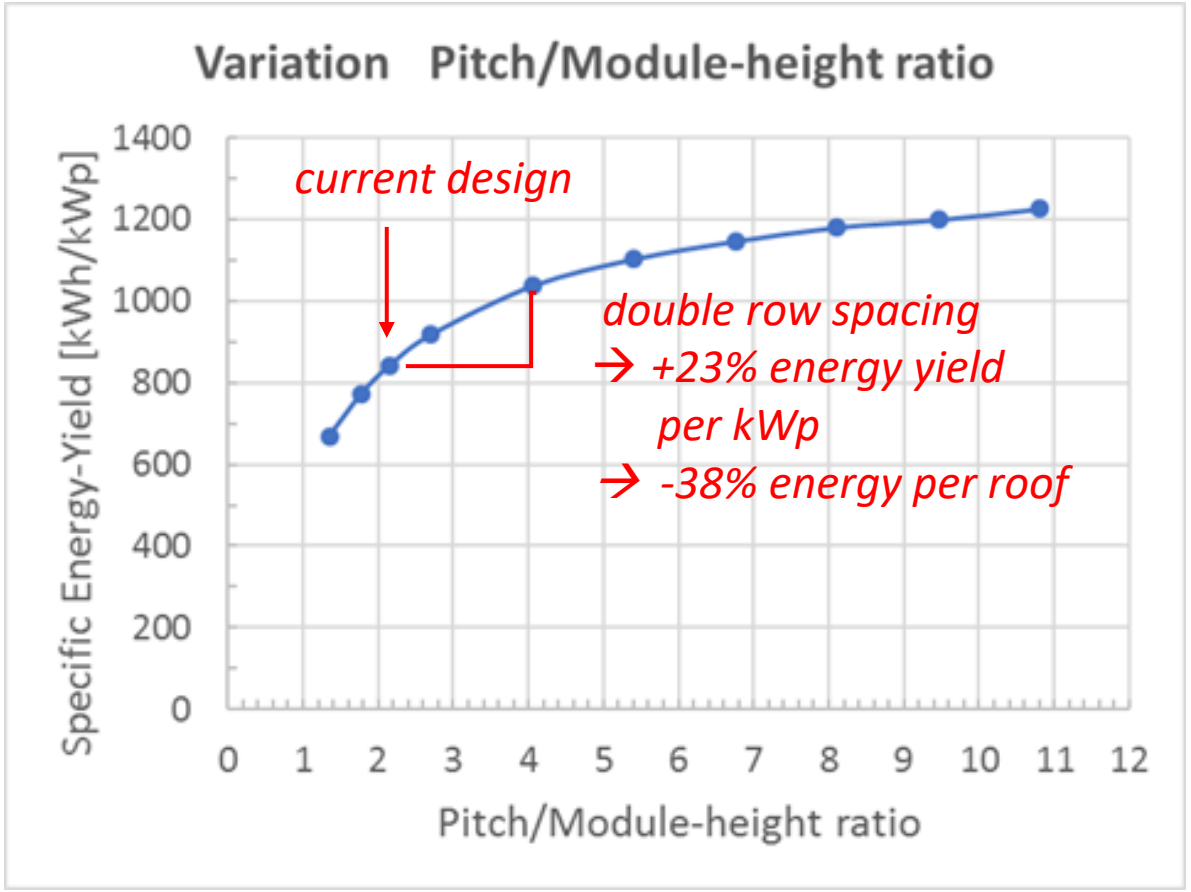
System design challenges

#2: Row spacing

- The distance between the rows has a strong impact on the annual yield because of self-shading

Simulations data:

- Location: Berlin
- Albedo 60%
- GHI: 900 kWh/m²
- Orientation: E-W



Marketing aspects

- Such vertical bifacial PV rooftop system is very unusual so it needs a lot of explanations
- There is no industry experience with such systems. No external reference can be given. You will not get bank financing for such projects.
- The annual energy production depends on many variables
  - You need tons of field data as a reference
  - You need to configure in detail an energy yield predicton tool
- The cost of the PV module will be higher than for a standard module
- Extensive wind load studies will be required in order to convince statical engineers to sign off for a building permit

After 5 years of work on such system we think that marketing is the real challenge (not so much developing a good technical solution).

Special applications

- Regions with many snow days

- No immediate power loss with snow
- Snow leads to ideal albedo properties

- Green roofs

- Best solution for combining PV and green roofs

Summary

- Bifacial vertical PV systems can be very interesting, e.g. in combination with green roofs
- Energy yield per Wp can be very high – depending on albedo and row spacing and location on earth. However, the energy yield per area is always less than for a conventional east-west system
- The daily energy production characteristics can be tuned to best meet the daily demand curve → the value of energy may be higher
- The design of the racking system is a real challenge (wind, cabling, ballasting, …)
- MoBiDiG is now suitable to make good energy yield predictions

Next step:

- Get a better understanding of customer acceptance and market potential (project with *University of Applied Science HTW Berlin*)

Thank you for your attention !

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ZIM Zentrales Innovationsprogramm Mittelstand

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References

/1/ www.next2sun.de

/2/ https://www.youtube.com/watch?v=5bsAUBVJ_eI

/3/ L. Podlowski et al., 36. PV-Symposium 2021

/4/ S. Guo et al., https://doi.org/10.1016/j.energy.2013.08.040

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/6/ Repräsentative VDW Lastprofile, VDEW, Frankfurt/Main 1999

/7/ www.reech.ch