Enhanced energy yield for PV systems using bifacial modules: simulation and model verification

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polysun®
SIMULATION SOFTWARE

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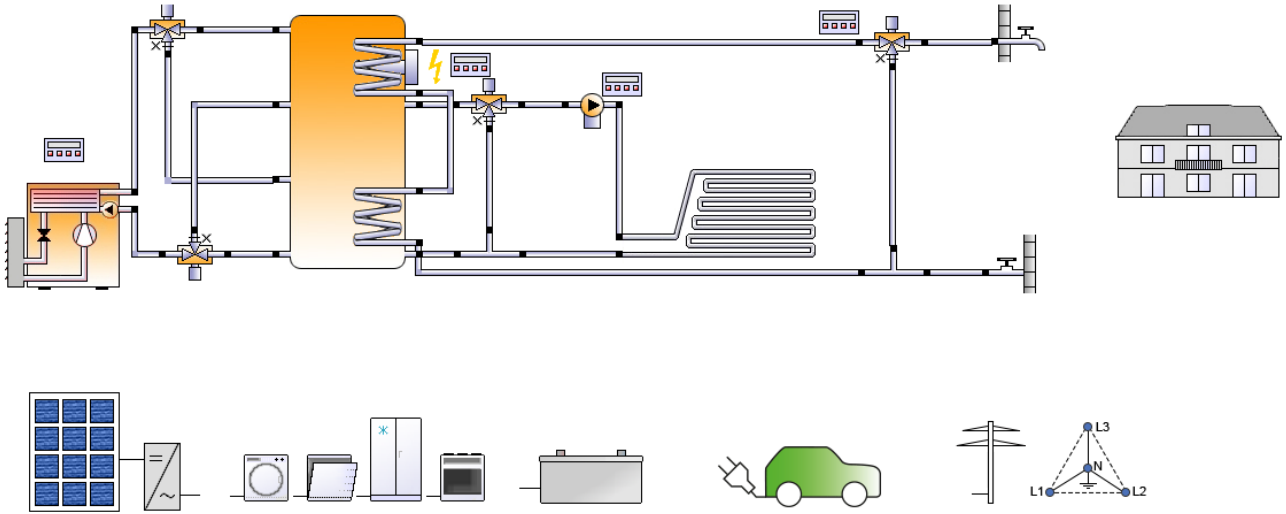
1. Polysun – Planning and Design Tool for Renewable Energy Systems

- Dynamic time step simulation (time steps 1 s to 12 min)
- Simulation time 1 year (plus preliminary simulation)
- Physical models for the components (PV modules, batteries, …)
- Modular set up of systems and control strategies
- Research and development in cooperation with several Universities (ETH, HSR, FHNW, ZHAW…)

1. Polysun – Planning and Design Tool for Renewable Energy Systems

- Focus on the system and not only on components!



2. Enhanced energy yield – Energy Boost

- Characterization through bifaciality coefficient (B)
- B is roughly 65 % (SunModule Bisun SW 275 duo) to 80 %

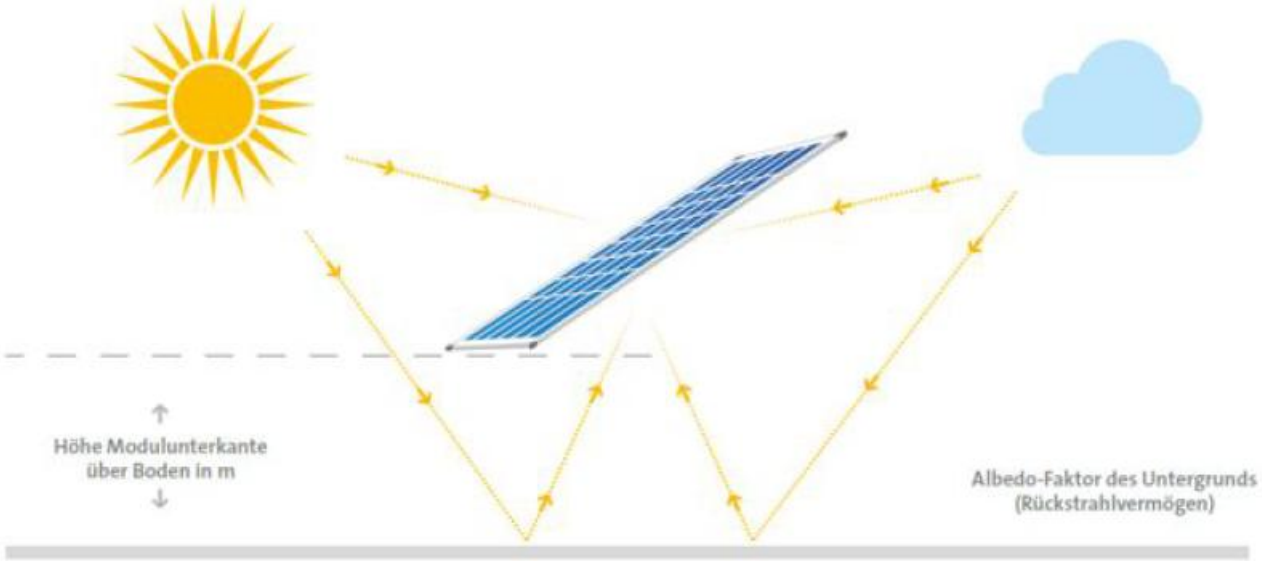
$$B = \frac{P_{mpp,rear}}{P_{mpp,front}} \qquad (1)$$

3. Energy Boost Calculation

- Comparison to an identical monofacial system – Energy Boost (EB)
- Depending on geometry of the racking system (row pitch, mounting height, tilt angle, orientation), albedo of the underground, location of the system, climate, …

$$EB = \frac{E_{bifacial}}{E_{monofacial}} \qquad (2)$$

3. Energy Boost Calculation



3. Energy Boost Calculation

- Albedo (albedo is defined as the ratio of irradiance reflected to the irradiance received by a surface)

Testfläche	Albedo
Rasen	23%
Verwitterter Beton	16%
Weiße Farbe auf verwittertem Beton 1 Anstrich / mehrere Anstriche (Abbildung 6 A)	63% / 89%
Weißer Kies (Abbildung 6 B)	27%
Weißes Trapezblech	56%
Graues Trapezblech	32%
Weiße Dachbahn	80%

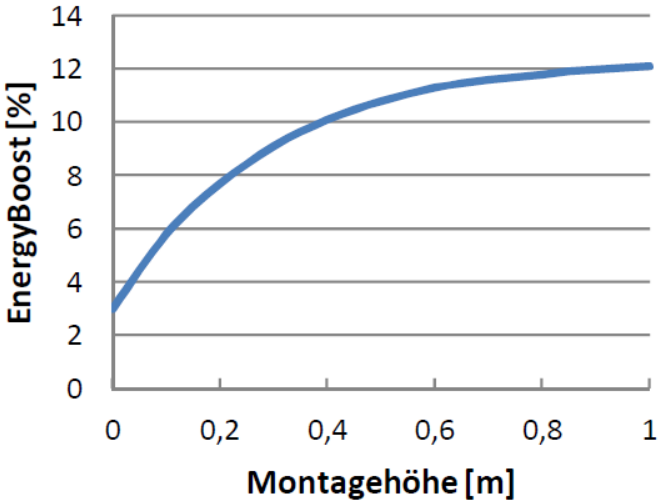
OTTI 2016

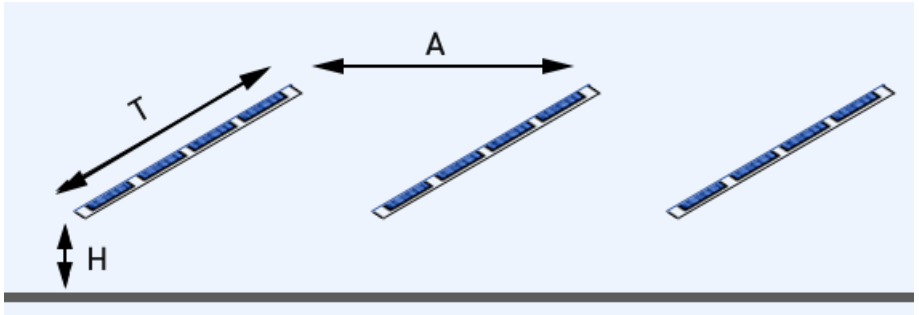
Surface	Typical albedo
Fresh asphalt	0.04[4]
Open ocean	0.06[5]
Worn asphalt	0.12[4]
Conifer forest (Summer)	0.08,[6] 0.09 to 0.15[7]
Deciduous trees	0.15 to 0.18[7]
Bare soil	0.17[8]
Green grass	0.25[8]
Desert sand	0.40[9]
New concrete	0.55[8]
Ocean ice	0.5–0.7[8]
Fresh snow	0.80–0.90[8]

Wikipedia

3. Energy Boost Calculation

- Mounting height (always height of the first module over the ground)





3. Energy Boost Calculation

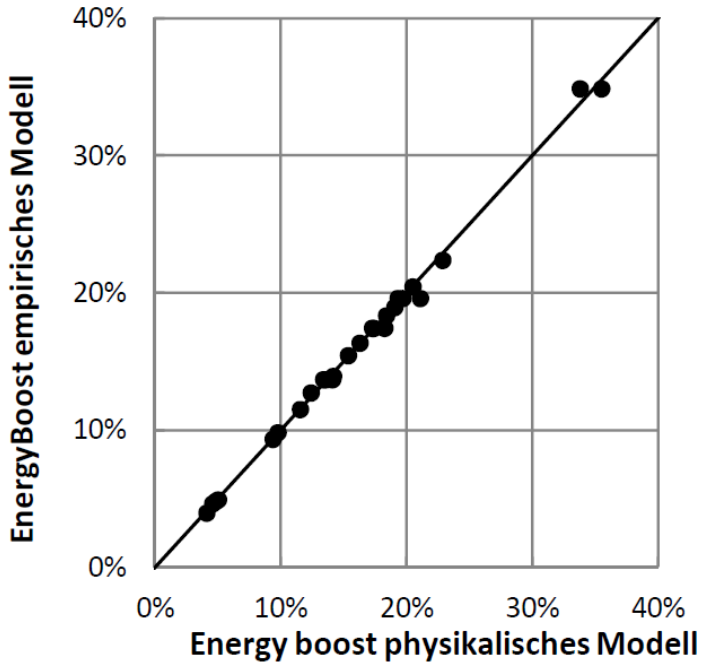
- Cooperation with Fraunhofer ISE
- Physical model for reverse-raytracing
- a, b, c are parameters of the empiric model, s is a correction factor for shading effects (through racking system)

$$EB = Albedo \cdot Bifacialität \cdot s \cdot \left[a \cdot \left(1 - \frac{1}{\sqrt{A}} \right) \cdot \left(1 - e^{-\frac{b \cdot H}{A}} \right) + c \cdot \left(1 - \frac{1}{A^4} \right) \right]$$

$$a = 1{,}03 \qquad b = 8{,}69 \qquad c = 0{,}12 \qquad s = 0{,}95$$

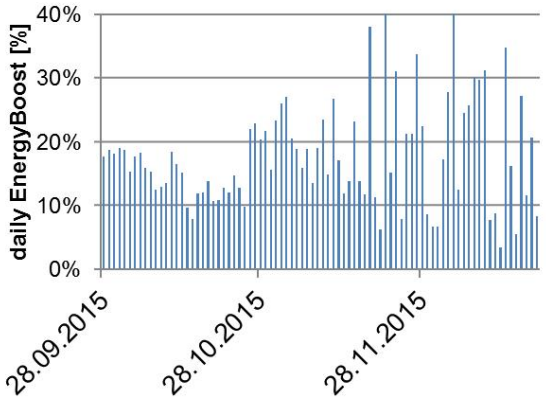
$$A = \frac{\text{Reihenabstand}}{\text{Tischbreite}} \qquad H = \frac{\text{Montagehöhe}}{\text{Tischbreite}}$$

4. Validation of the model

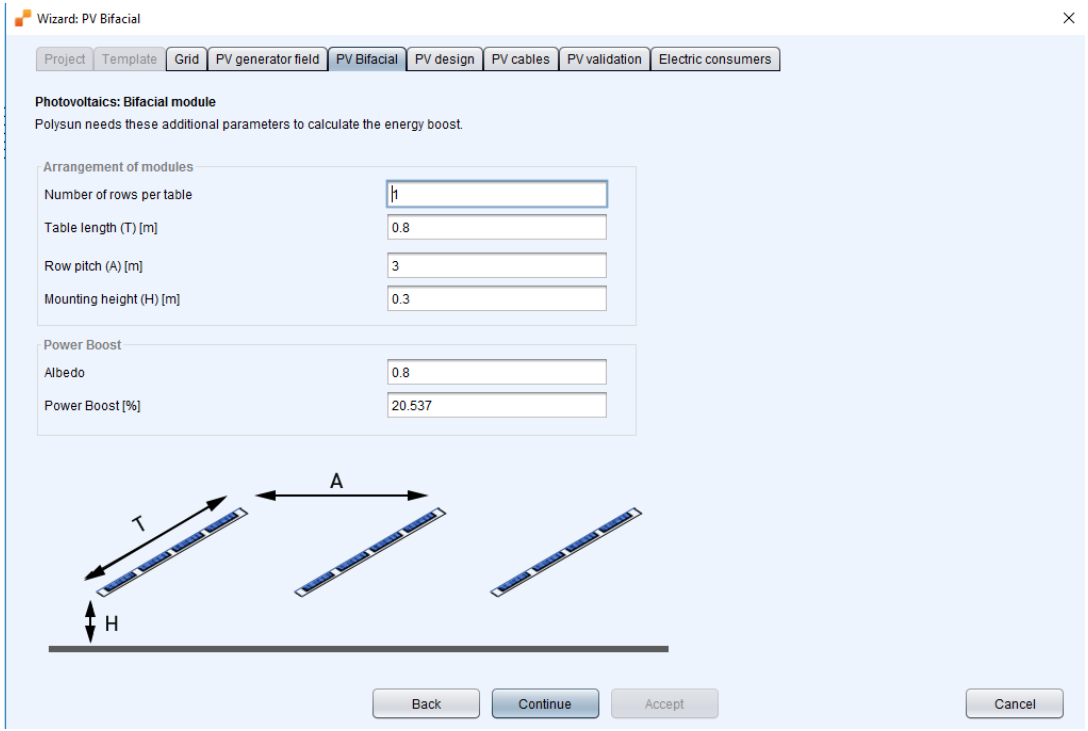


4. Validation of the model

Euskirchen, Germany	
Size	3.2 kW - 12 x SW 270 duo modules with Enphase inverters (shaded)
Mounting	Landscape, 15° tilt, 20° azimuth, 30 cm above ground
Albedo	80% (white roof covering foil)
Expected Energy Boost	21.8%
Measured Energy Boost	20.9% (28.09. – 20.12.)



5. Bifacial modules in Polysun



6. Conclusions

- Energy surplus of up to 25 % through bifacial technology (compared to monofacial)
- Empirical model on basis of reverse ray tracing simulations for energy boost estimation
- Validation in different pilot test system installations