REVIEW OF BIFACIAL PV SYSTEMS

J. Libal, R. Kopecek

International Solar Energy Research Center Konstanz

Outline

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- Conclusion

Motivation

Field data regarding the energy yield (kWh/kWp) of bifacial PV systems are very important for the economic evaluation and the bankability of bifacial PV.

(*Also because there is not yet a generally accepted, commercially available simulation tool)*

Thereby, the following requirements have to be met in order to make the data relevant for the above mentioned scope:

- System composed of several module rows, each of them composed by several modules
- Monitoring period > several months, ideally at least 12 consecutive months in order to cover all seasons (varying diffuse light fraction)
- Subsystem with monofacial modules to be monitored simultaneously at the same site as a reference for determination of bifacial gain
- Meteo data (at least irradiance and module temperature) monitored

Definition of „bifacial gain“

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The bifacial gain is the metric that determines - together with the total cost of the installed bifacial PV system – the LCOE (€/kWh) and therefore the economical viability of bifacial PV

Definition of *bifacial gain:*

$$g_{bifacial}\,[\%] = \left(\frac{(e_{bifacial} - e_{monofacial})}{e_{monofacial}}\right) \times 100$$

with

- $e_{bifacial}$: *specific energy yield (kWh/kW$_p$) of the PV system with bifacial modules*
- $e_{monofacial}$: *specific energy yield (kWh/kW$_p$) of the PV system with monofacial modules on the same site, with the same configuration and during the same time period*

Overview of bifacial PV systems

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In the following, a selection of bifacial PV systems and their electrical performance from literature, will be presented and summarized

bSolar - Germany (Geilenkirchen)

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APPLICATION:
Flat rooftop installations, white-coated

Commercial installation, Geilenkirchen, Germany
Monitored by Fraunhofer/ISE
(20cm height above the rooftop, 78% reflectance white roof membrane, 9 months period)
Results (*): Bifaciality Gain of **21.4%**, Cell Effective Efficiency = **22.5%**

- flat roof top with reflective membrane
- ground albedo 78%
- bifacial gain: 21.4%

bSolar – Germany (Berlin)

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APPLICATION:
Flat rooftop installations, covered with white-stone gravel

Commercial rooftop installation, The Technology City of Adlershof, Berlin, Germany
(40cm height above rooftop, 35% reflectance grayish stone roof cover)
Results (*): Bifaciality Gain **11%**, Cell equivalent efficiency = **20.5%**

- flat roof top with greyish stone roof cover
- ground albedo 35%
- bifacial gain: 11%

bSolar – Israel (Eilat-Eilot Desert)

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Test site in the Eilat-Eilot Desert, Israel, supervised by the Arava Outdoor PV Validation Lab, Eilat-Eilot, Israel
(70 cm height above ground, 50% ground reflectance)
Results (*): **17.2%** bifaciality gain vs. German modules, **21.7%** cell equivalent efficiency

- ground mounted with sandy ground
- ground albedo 50%
- bifacial gain: 17.2%

bSolar – Israel (Jerusalem)

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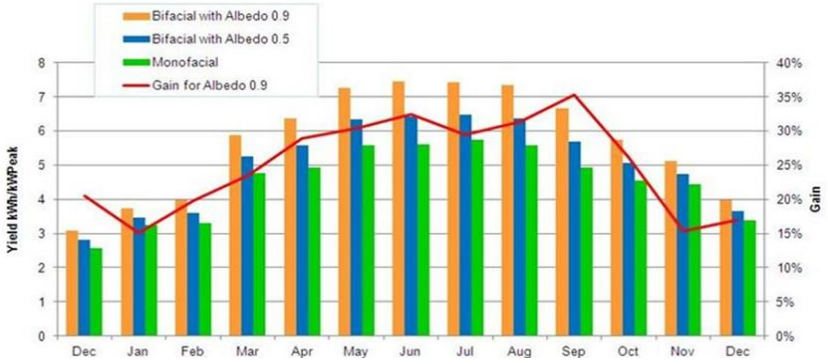
- Solar field of 3x4 modules
- bSolar 170Wp module vs. Suntech 175 Wp module
- Bifaciality gain based on KWh/KWp comparisons
- Site parameters:
  - Ground reflectance (Albedo): ~50%
  - North-South (NS) distance (distance between rows, panel-panel center): 1.5m
  - East-West (WE) distance (panel-panel edge): 0.2m
  - Height (panel lower edge): 0.7m

- flat roof top with reflective membrane
- ground albedo 50%
- bifacial gain: 15 %

BIFACIAL bSOLAR VS. MONOFACIAL MODULE

Monthly and Yearly Gain

Annual gain measured (Albedo 50%) : 15%
Annual gain calculated (Albedo 90%) : 26%



PVGS – Japan (Kitami)

- small ground mounted with grass
- estimated ground albedo 23%
- bifacial gain: 14.6%

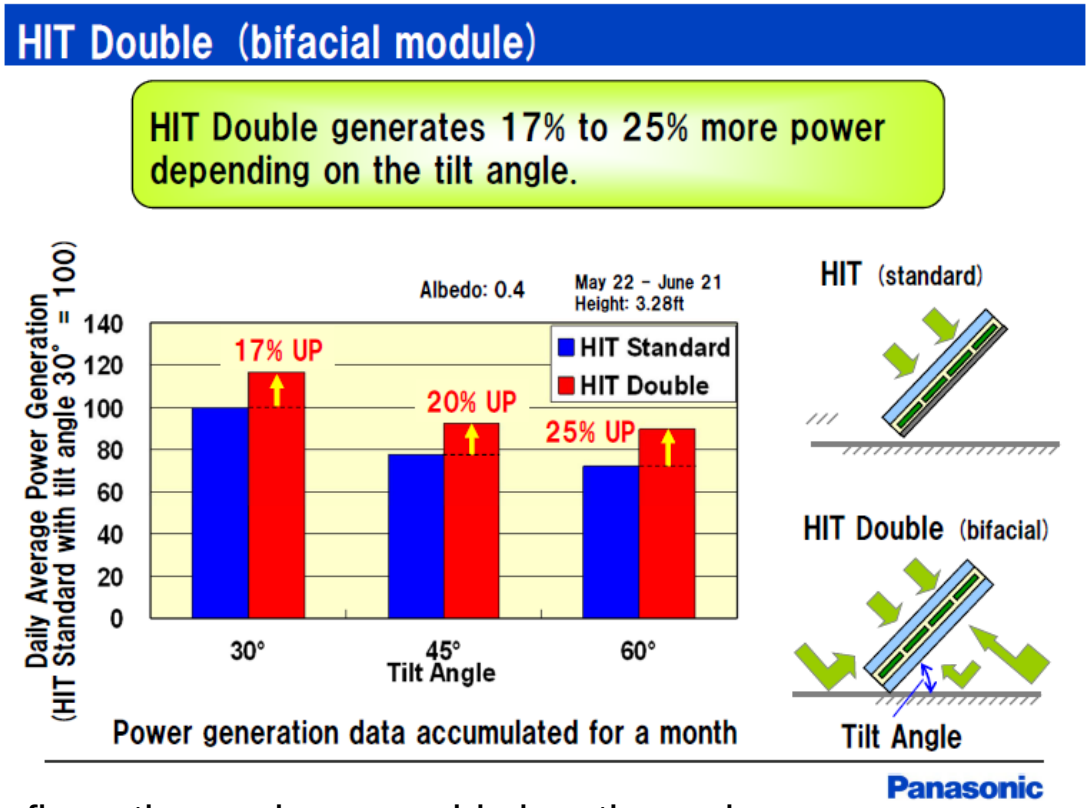
- small ground mounted with scallop shells
- estimated ground albedo 50%
- bifacial gain: 20.6%

ISC Konstanz – Egypt (El Gouna)

- **single bifacial module** with one neighbouring monfacial reference module
- ground mounted with desert sand
- estimated ground albedo 30%
- bifacial gain: 22.3%

.(C.Comparotto et al., BIFACIAL N-TYPE SOLAR MODULES: INDOOR AND OUTDOOR EVALUATION, EUPVSEC 2014, Amsterdam)

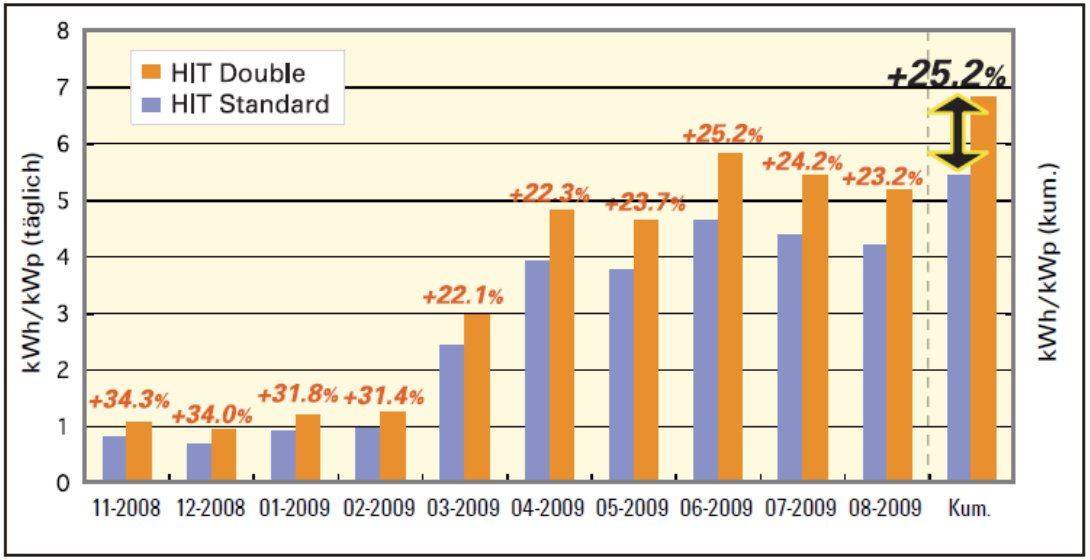
Sanyo - Panasonic



- configuration and geographic location unknown
- ground albedo: 40%
- bifacial gain: 17% (for 30% tilt angle)

(E. Maruyama, "Recent Technological Progress of High-efficiency HIT Solar Cells", PV Japan Tokyo, 24-26.07.2013)

Sanyo - Panasonic



Module type	HIT® Standard	HIT Double®
Leistung der Anlage	2,10 kWp	2,00 kWp
Reflexionsrate des Untergrunds	64%	
Höhe der Montagestruktur	30 cm	
Winkel der Module	Neigungswinkel 20°, Ausrichtung: Süden	
Zeitraum der Messungen	11 2008 – 08 2009	
Installationsort	Geilenkirchen	
Messeinrichtung	Unter Aufsicht des Fraunhofer Instituts	
Installation	Pohlen Solar GmbH	

- small rooftop system
- ground albedo: 64%
- bifacial gain: 25.2%

(Sanyo module datasheet “HIT double 205”, 10/2009)

PVGS/Nishiyama – Hokuto (Japan)

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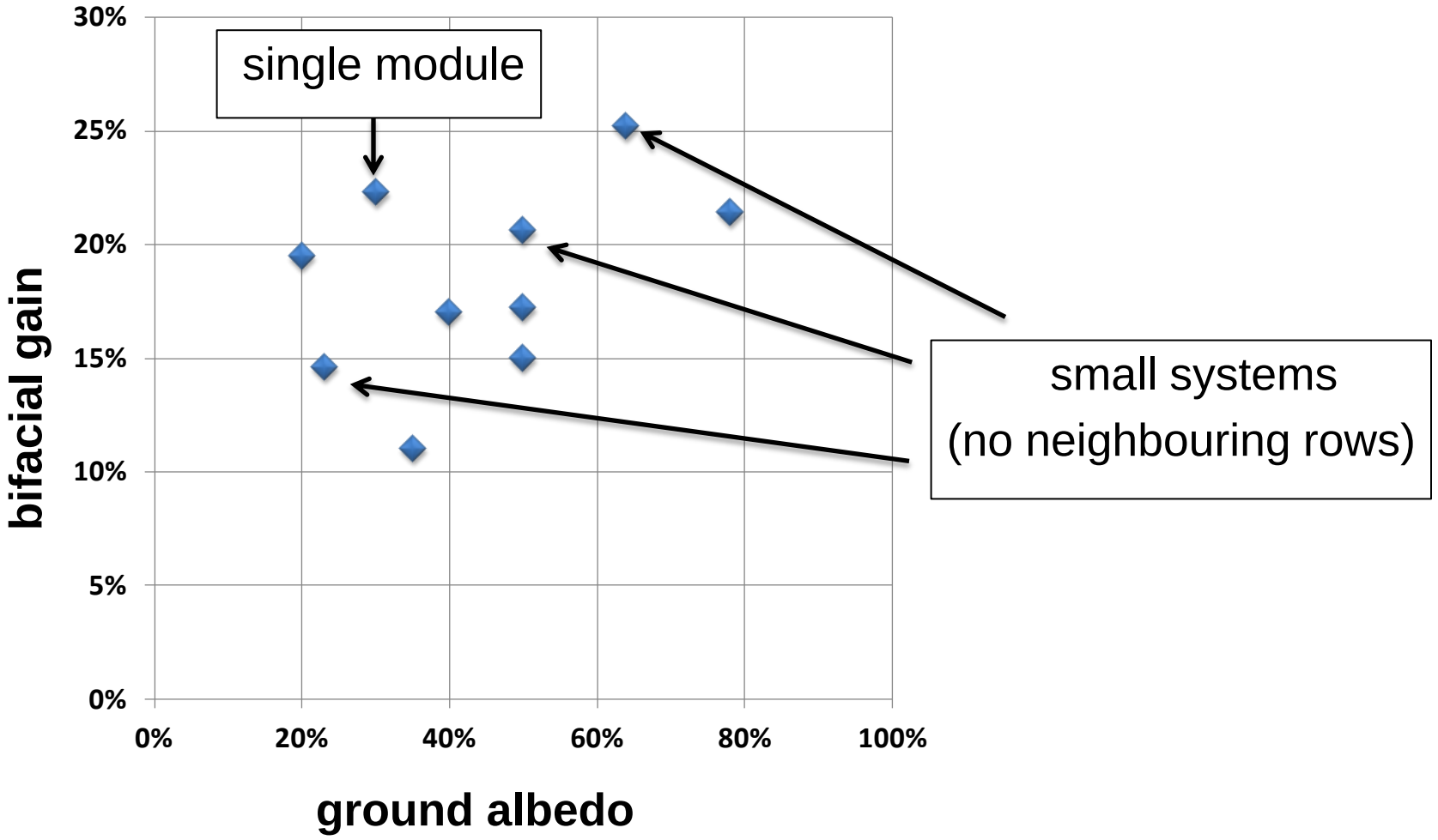
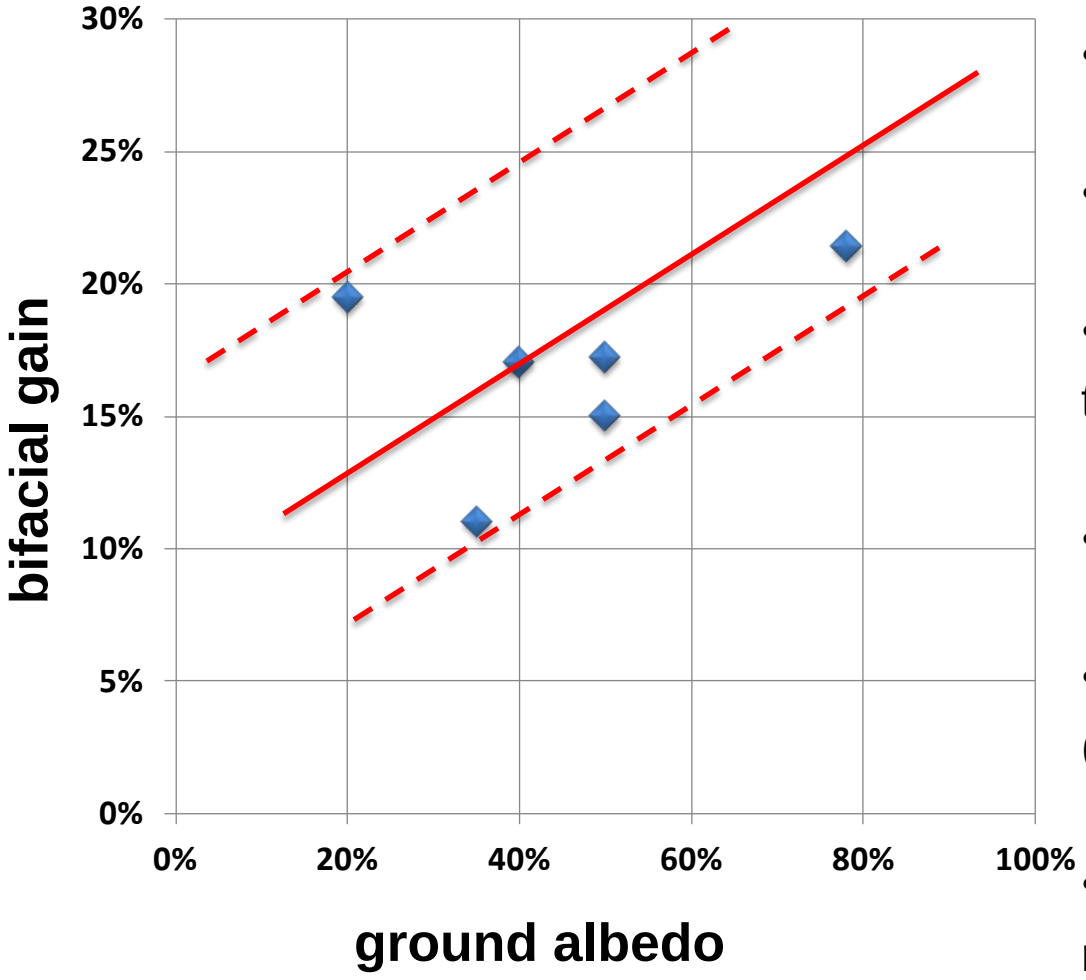
- system size 1.25 MW
- ground albedo (estimated): 20 %
- bifacial gain: 19.5%

(http://www.nishiyama-s-denki.co.jp/)

Summary of bifacial gain vs. albedo



Summary of bifacial gain vs. albedo



Other important factors:

- climate (diffuse light, snow)
- installation height of modules
- distance between modules (row-to-row and within the rows)
- module inclination
- rear side efficiency of modules (bifaciality)
- design of modules and mounting racks (rear side shading)

Albedo of various ground typologies

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surface	albedo
Dry dark soil	0.13
Grass	0.17-0.28 (avg. 22.5)
Dry sand	0.35
Dune sand	0.37
Old snow	0.4 - 0.7
Fresh snow	0.75 to 0.95

- **Most** ground surface typologies show an Albedo of **over 20 %**
- When installation site is **selected explicitely for bifacial PV, 30% or more** can be found.
- Using methods for **enhancing ground reflectivity** (covering the ground with white sand, scallops shells or reflective painting or sheets), **40% to 90%** ground albedo can be achieved.

Summary

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• For suitable installation sites and system configurations**, large bifacial PV systems produce 15% to 20% more kWh per year** compared to monofacial PV systems with the same nominal (front side) peak power, installed at the same site.

• If special measures are taken, e.g:

  • artificially increasing the ground albedo (white sand, gravel or white paintings or coatings) and

  • increasing slightly the installation height of the modules over the ground (usually, less than 1.5 m are sufficient → see presentations about simulations at this workshop),

  over 30% bifacial gain is expected even for large bifacial systems

In General: more field data regarding the energy yield of large bifacial PV systems is required in order to confirm the above statements !

Outlook – recent bifacial systems

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TRACKED BiSoN Farm in Chile: **Enel** in "La Silla"

Total Systems size (monofacial + bifacial):

1.7MWp

Outlook – recent bifacial systems

MegaCell:

- **2.5 MWp** ground mounted
- location: Hormiga (Chile)
- installed, waiting for grid connection

Sunpreme:

- **12.8 MWp** ground mounted
- location: eastern US
- installed

→ **more field data on bifacial gain of utility scale systems to come very soon !**

nPV WS: April 5/6, 2017 in Freiburg

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Announcement: nPV WORKSHOP April 5/6 2017 in Freiburg, Germany

npworkshop Freiburg 2017

Organizers: Fraunhofer ines, ISC, ISFH, imec, ECN, csem

Imprint

Main | nPV Chairman´s Message | Abstracts | Program | Registration | Sponsoring | Freiburg | Previous nPVs

Dear PV-scientists,

because of its great success we will for the 7th time organise the nPV workshop with the participation of scientists and industry from all around the world. As last time, we will connect it to the Silicon PV conference allowing the visitors to combine both events. The nPV workshop will take place from

April 5-6, 2017 in Freiburg, Germany.

The first day is dedicated to scientific n-type presentations and is a combined day with Silicon PV conference. The second day is the "industry day" with invited talks dealing with well known n-type wafer, solar cells and module technologies from e.g. Panasonic and Sunpower as well as with emerging technologies from e.g. LG Electronics, Solar City, Hyundai and Sunpreme.

Arthur Weeber (ECN) Stefan Glunz (FH ISE) Radovan Kopecek (ISC) Delfina Munoz (INES) Joachim John (IMEC) Jan Schmidt (ISFH) Matthieu Despeisse (csem)

www.nPV-workshop.com

hosted and organized by: Fraunhofer ISE, ECN, PSE projects in solar energy

linked to: SiliconPV 2017