bifi PV workshop 2017 Konstanz

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Konstanz, Germany
26 Oktober 2017

Session VII 15:50-16:10

Technical wrap up: are we doing the right things right? Critical summary and outlook for successful bifacial future

Some highlight`s:
It is not complete
and my one personal selection

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TNC Advanced Energy Concepts

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Konstanz, Germany 26 Oktober 2017

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bifiPV workshops from 2012

1) bifiPV 2012 in Konstanz (120 people)

2) bifiPV 2014 in Chambery (80 people)

2,5) bifiPV 2015 in Antofagasta (40 people)

3) bifiPV 2016 in Miyazaki (80 people)

4) bifiPV 2017 in Konstanz (130 people)

all presentations at
https://pvpmc.sandia.gov/pv-research/bifacial-pv-project/

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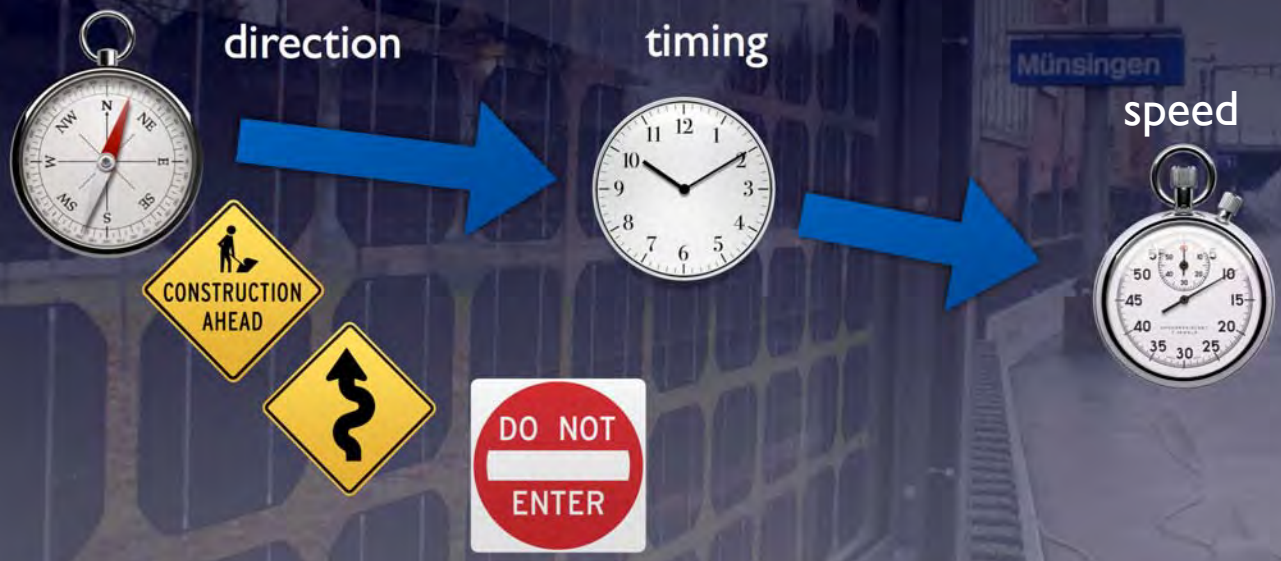
Technical wrap up: are we doing the right things, right?



Thomas Nordmann • TNC Consulting AG • 8706 Feldmeilen/Switzerland
nordmann@tnc.ch • www.tnc.ch

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Are we doing the right things? Are we doing the right right?

Wednesday, 25.10.2017

Session	Presenter, Institution	Topic or Title
Regist		
Openi		
08:30		
Sessio		
Sessio		
Sessio		
Sessio		

Thursday, 26.10.2017

Session V		**Bifacial gain simulations and LCOE calculations**
09:00-09:20	**Joris Libal, ISC Konstanz**	**overview**
09:20-09:35	Bruno Wittmer, PVsyst	Bifacial shed simulations with Pvsyst
09:35-09:50	Lars Kunath, Polysun	Enhanced energy harvest for PV systems using bifacial modules: simulation and model verification
09:50-10:05	Djaber Berrian, ISC Konstanz	MoBiDiG: simulations and LCOE
15 min coffee		
10:20-10:35	Lars Podlowski, PI Berlin	Yield Study on Identical Bifacial Rooftop Systems installed in the USA and in Germany
10:35-10:50	Markus Klenk, ZHAW	Bifarot: an experimental way for LCOE calculation
10:50-11:05	Dimitrij Chudinzow, Uni Stuttgart	Bifacial gain simulations
11:05-11:20	Bas van Aken, ECN	Bifacial PV: hot or cool? Or both!
11:20-11:35	Chris Deline, NREL/SANDIA	Bifacial simulations
25 min coffee		
Session VI		**Measurement- and qualification standards**
12:00-12:20	**Vahid Fakhfouri, Passan**	**overview**
12:20-12:35	Klaus Ramspeck, h.a.l.m.	Measurement techniques for bifacial solar cells
12:35-12:50	Gordon Deans, Aurora	Accurate inline characterization of BSF and emitter fabrication processes for high-volume bifacial cell production
12:50-13:05	Maryline Joanny, INES	Bifacial modules measurement with GE method
70 min lunch		
14:15-14:30	Juan Lopez-Garcia, EC, DG JRC	Temperature coefficients of n-type bicacial silicon PV modules under natural and simulated sunlight
14:30-14:45	Karl Berger, AiT	How to introduce bifaciality within the module type and safety testing procedures
14:45-15:00	Elias Garcia Goma, EternalSun	Single vs double side illumination indoor testing for bifacial performance characterisation
15:00-15:15	Werner Herrmann, TÜV Rheinland Energy	Performance characteristics of bifacial PV modules and power labeling
15:15-15:30	Michael Rauer, ISE	Bifacial Solar Cells under Single- and Double-Sided Illumination: Effect of Nonlinearity in Short-Circuit Current
20 min coffee		
Session VII		**Technical wrap up: are we doing the right things right?**
15:50-16:10	**Thomas Nordmann, TNC**	**Critical summary and outlook for successful bifacial future**
Session VIII		**Bankability**
16:10-16:30	**Andre Richter, Meyer Burger**	**overview**
16:30-17:00	**David Moser, EURAC**	**Moderated podium discussion: how to speed up bifacial future?**

TNC Advanced Energy Concepts

Session I • Systems: reports on large bifacial systems 25 Oktober 2017

Session I		Systems: reports on large bifacial systems
09:00-09:20	**Maryline Joanny, INES**	**overview**
09:20-09:35	Ashok Sinha, Sunpreme	Sunpreme's HCT-based bifacial PV module: a compelling solution for commercial systems
09:35-09:50	Naftali Eisenberg, SolAround	Comparison of different bifacial systems
09:50-10:05	Jason Ni, Yingli	50MWp bifacial system and standards
15 min coffee		
10:20-10:35	Willem Vermeulen, Tempress	400kW bifacial system in EU and comparison with other systems
10:35-10:50	Rob Kreiter, sunfloat	Floating bifacials - reflections on power
10:50-11:05	Andreas Dreisiebener, solarspar	Small vertical E-W oriented modules on rooftop (Swiss)
11:05-11:20	Heiko Hildebrand, Next2sun	3MWp vertical E-W oriented system in Germany
11:20-11:35	Fabrizio Bizzarri, Enel	Innovative (tracked) bifacial PV plant at la silla observatory in Chile

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Rules of tumb of Bifacial gains:

Bifacial gain: fix tilt south/north oriented

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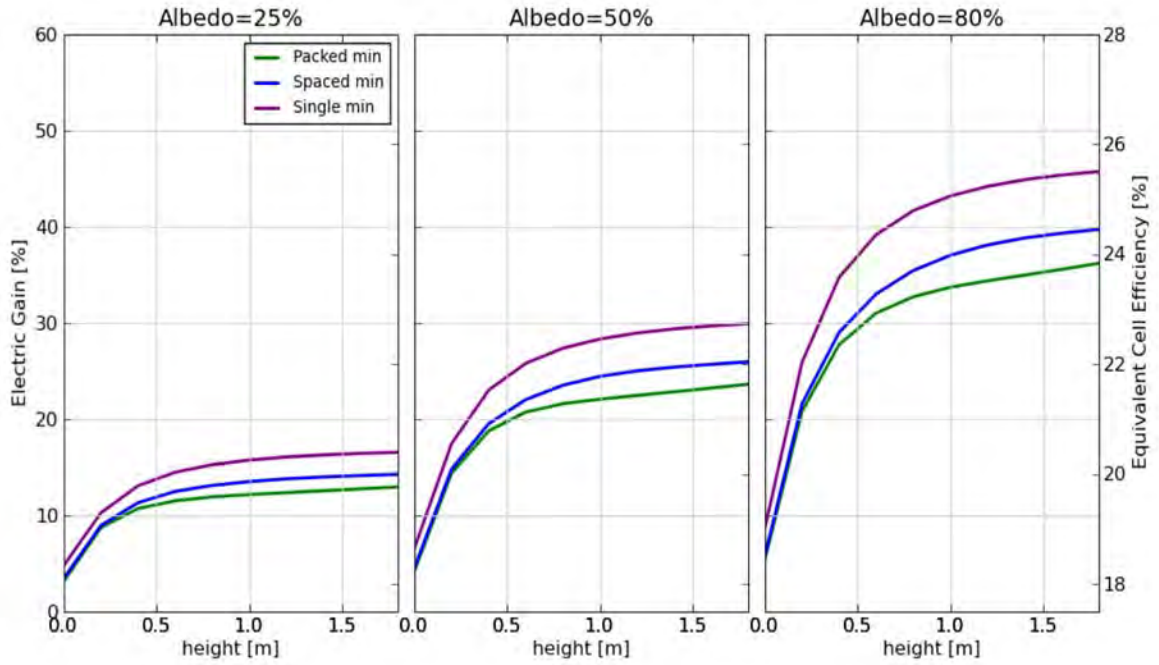


from bSolar > now SolAround

HOKUTO Solar power plant

Over a period of 32 months, an energy yield over 1,200 kWh/kW per year is obtained

- **Location:** Asahikawa, Japan

PVG Solutions

西山坂田電気㈱

- **System:**
  1,25 MWp
  5 320 modules
  40° South, fixed tilt
  Elevation: 1,5 m min
  Albedo ≈ 20% bare soil to 90% snow
- **Module:**
  PVGS EarthON 60
  254 Wp STC
- **Operation:**
  December 2013

1,25 MWp

www.pvgs.jp

The bifacial gain is considered to be over 20%

[3] Naoki Ishikawa, Satoshi Nishiyama, 3rd BifiPV Workshop, Japan, 2016

The rear side produces more energy due to higher albedo and accelerates the snow melting on the front side due to rear irradiance (thermalization effect).

Session I Systems: reports on large bifacial systems

The world wide bifacial PV tour by Maryline Johnny • ines France

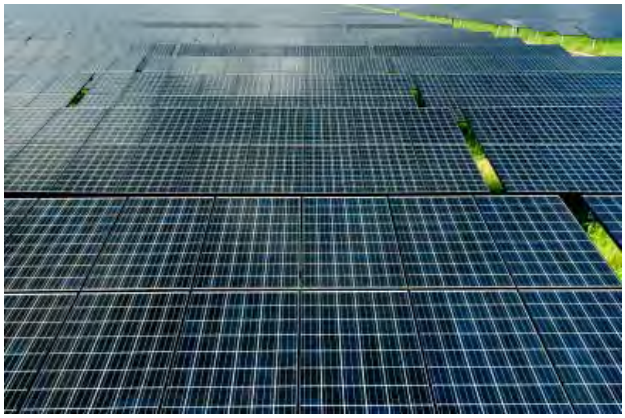
YINGLI connects 50 MW PV project in Shanxi Province, as part of TOP RUNNER programme launched by China's National Energy Administration (NEA)

The project is estimated to produce more than 80 GWh of electricity per year, enough to power about 37,000 homes

- **Location:** Datong City, China
- **System:**
  50 MWp
  186 120 modules
  Elevation: n.a.
  Albedo = grass
- **Module:**
  Yingli TwinMAX 60
  285 Wp STC
- **Operation:**
  Since June 2017

50 MWp

www.yinglisolar.com



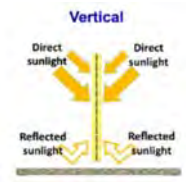
[See J.Ni today talk]

The world wide bifacial PV tour by Maryline Johnny • ines France

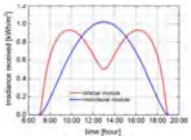
GEOGRAPHICAL MAPPING OF THE PERFORMANCE OF VERTICALLY INSTALLED BIFACIAL MODULES

this adds up to an expected gain (>10-20%) through reduced soiling and resulting cleaning costs

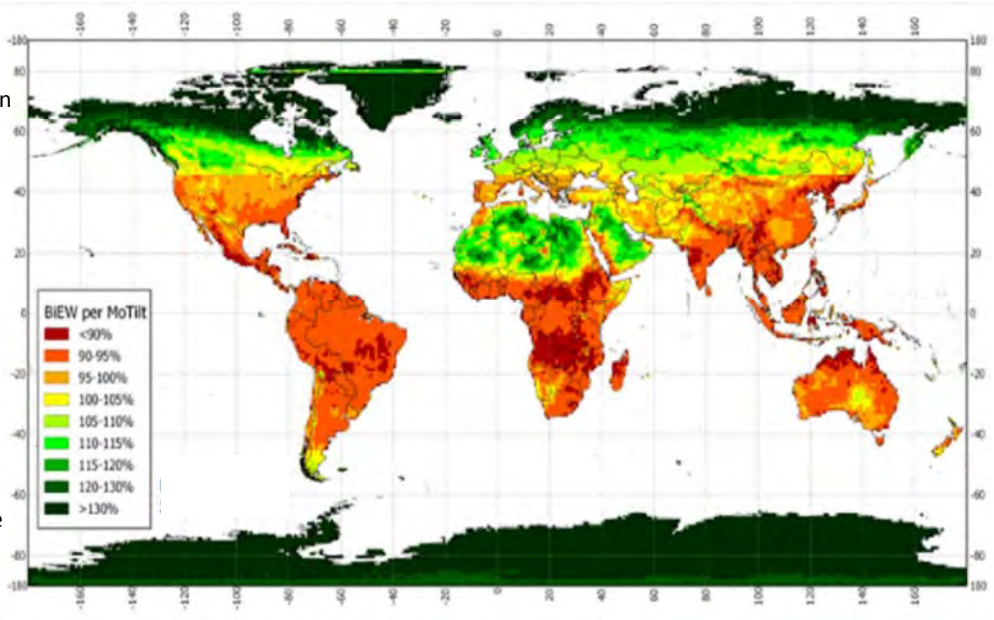
BIFACIAL VERTICALLY MOUNTED SYSTEMS - SIMULATION



- 15% to 20% gain of vertical EW bifacial over tilted monofacial in high albedo sunbelt,



- Northern regions can obtain performance gain and avoid snow coverage



eric.gerritsen@cea.fr

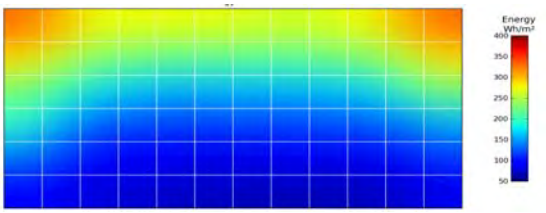
Vertical bifacial E/W versus monofacial N/S tilted (tilt=latitude angle)
(annual kWh performance simulation based on world irradiation and albedo map)

[9] Eric Gerritsen, Masakazu Ito, EUPVSEC, Munchen, Germany, 2016

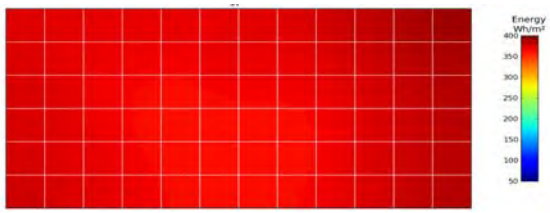
Session 1 Systems: reports on large bifacial systems

INFLUENCE OF PANEL ELEVATION ON BACK IRRADIANCE

NON UNIFORMITY OF BACK IRRADIANCE VS. PANEL ELEVATION



Elevation 8 cm



Elevation 108 cm

Measured back side irradiance for a 30° tilted stand alone module

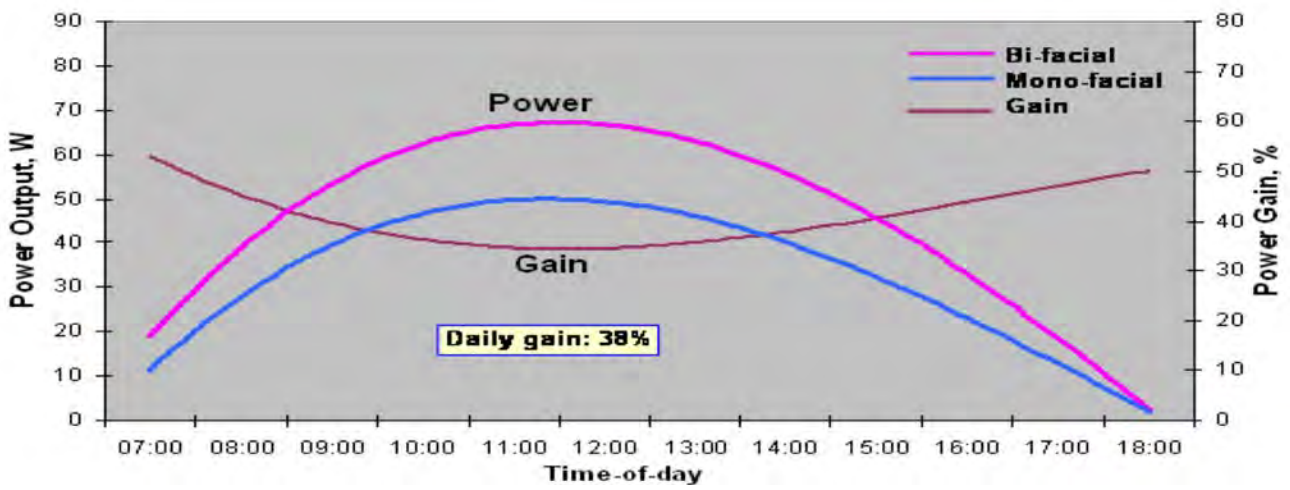
Albedo: 0.55
Global Irradiation: 1006 W/m²
Diffuse Irradiation: 111 W/m²
Panel size: 80x160 cm²

Naftali Eisenberg

Session 1 Systems: reports on large bifacial systems

INFLUENCE OF WEATHER CONDITIONS ON GAIN

HOURLY DEPENDANCE OF ENERGY OUTPUT FOR MONO AND BIFACIAL MODULES IN A FIELD



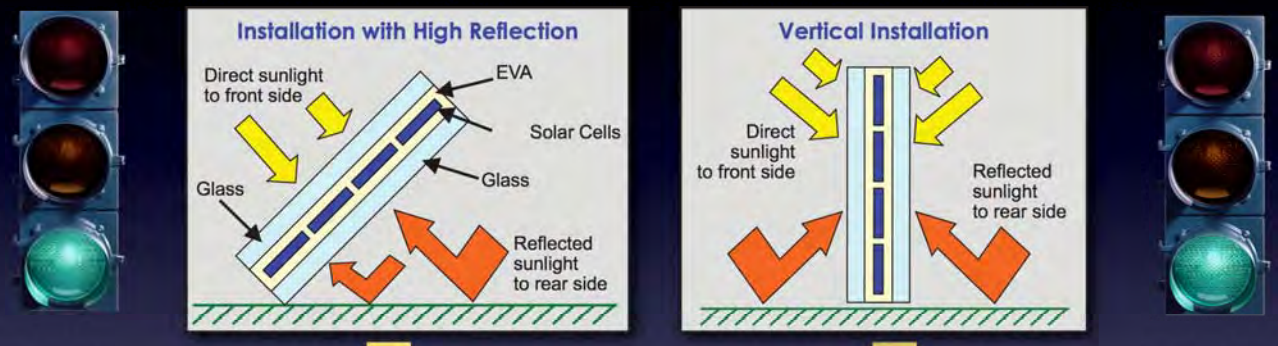
SolAround

Naftali Eisenberg

Monitoring for sunny day with diffused/global radiation ratio: 11 % at noon
Monitoring for cloudy day with diffused/global radiation ratio: 88 % at noon

Session 1 Systems: reports on large bifacial systems

My findings: The two main concepts of bifacial PV systems!



- More albedo ➜ higher yield
- ➜ +10 … +30% [kWh/kWp]
- How to compensate the extra BOS cost?
- Dos it allow lower energy cost?
- For utility type of installation!
- Fedd in in grid level 1 or 3!

- ± 100% yield [kWh/kWp]
- Extended field of application S ➜ E-W
- Noon peak shaving
- «rectangle» solar power production
- True dual use of function and cost
- Sound barriers, agricultural PV, BIPV?

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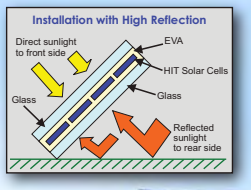
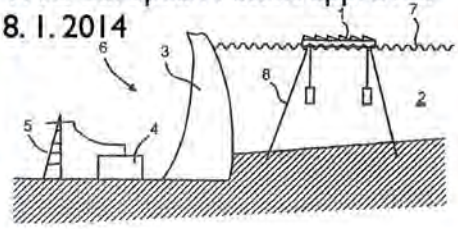
Why Solar PV on artificial Hydropower Lakes?

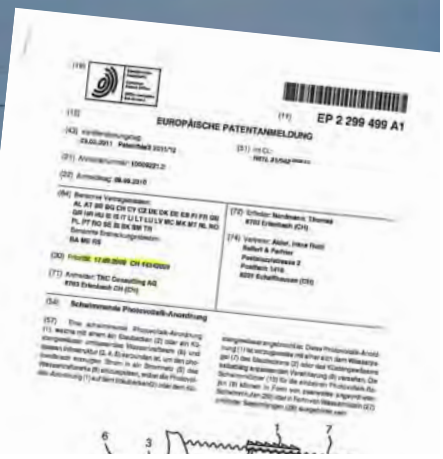


Waterlily™

120 km²

TNC European Patent approved
8. 1. 2014

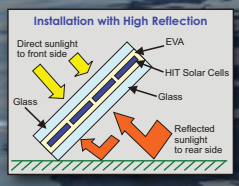


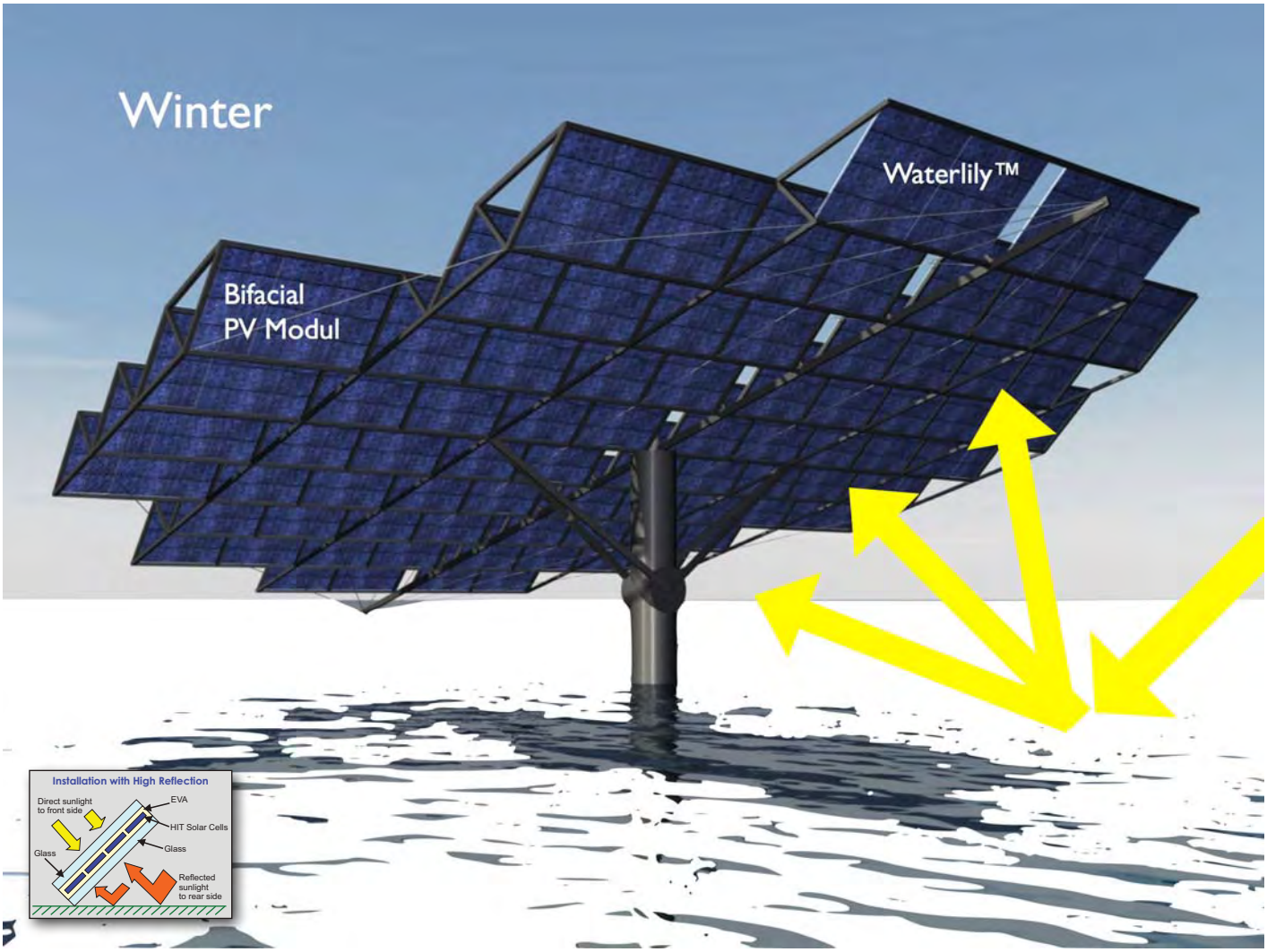


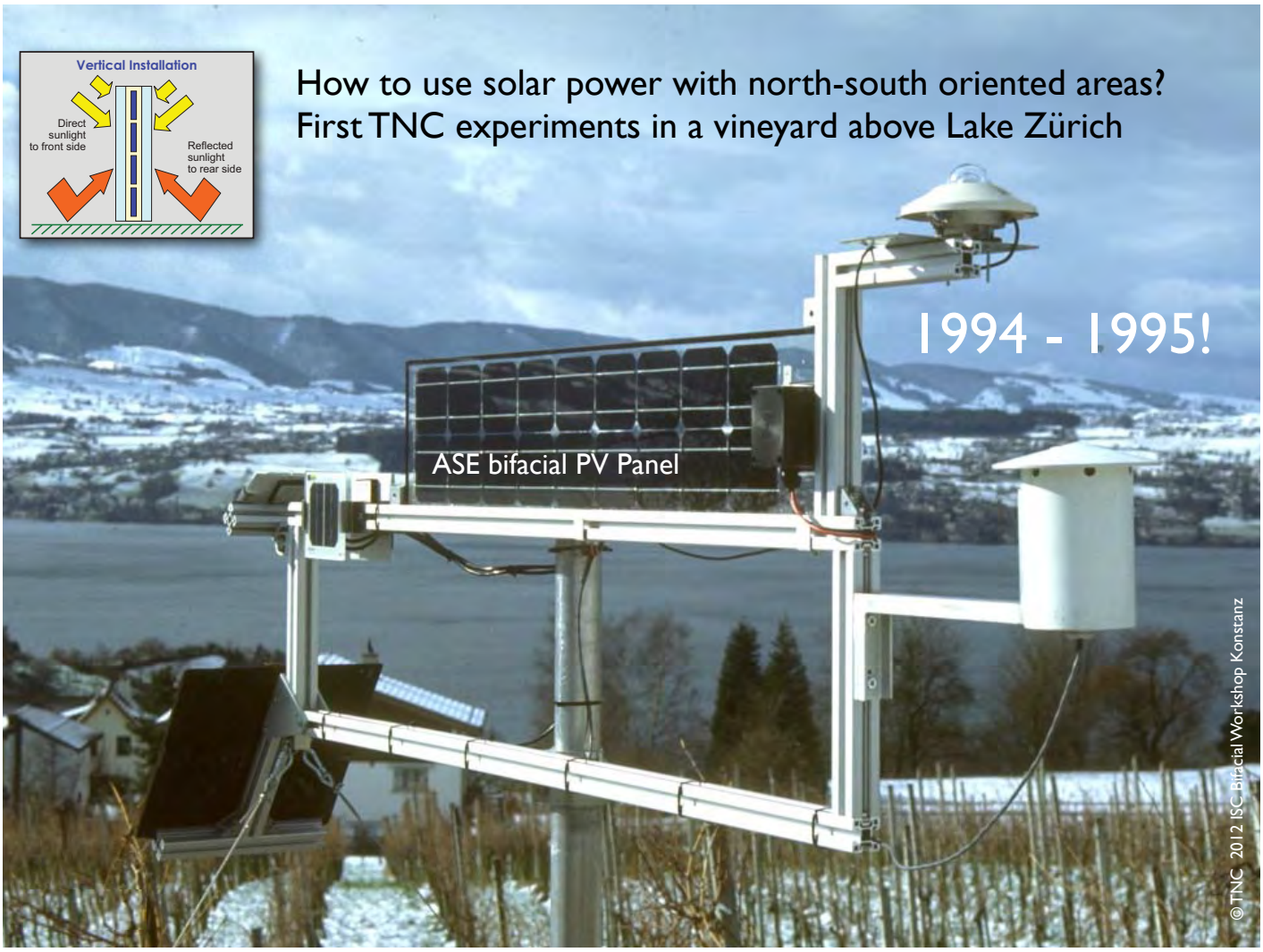
Summer

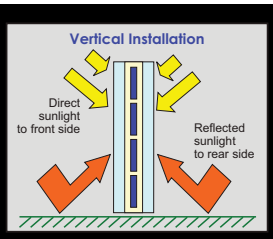
Waterlily™

Bifacial
PV Modul

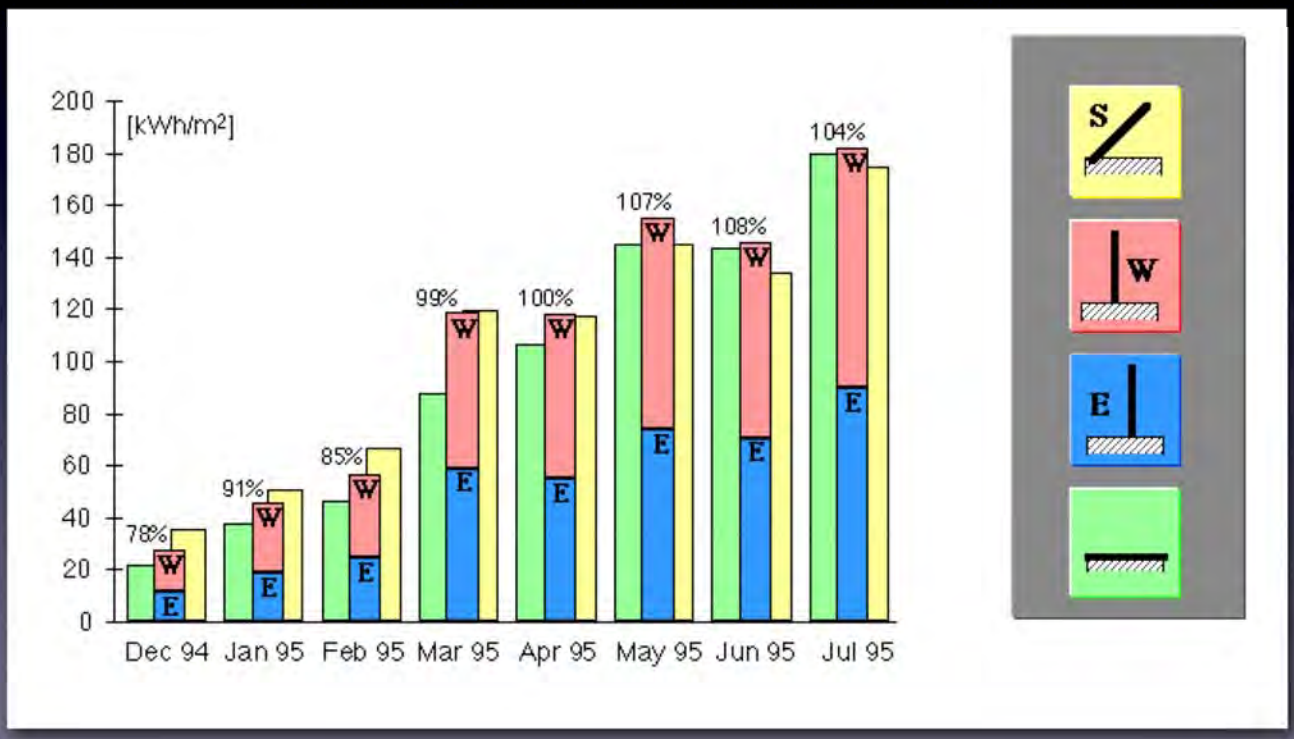



Winter
Waterlily™
Bifacial
PV Modul
Installation with High Reflection
Direct sunlight to front side
EVA
HIT Solar Cells
Glass
Glass
Reflected sunlight to rear side


Vertical Installation
Direct sunlight to front side
Reflected sunlight to rear side
How to use solar power with north-south oriented areas?
First TNC experiments in a vineyard above Lake Zürich
1994 - 1995!
ASE bifacial PV Panel
©TNC 2012 ISC Bifacial Workshop Konstanz



First TNC Solar bifacial PV irradiation measurements 1994/95



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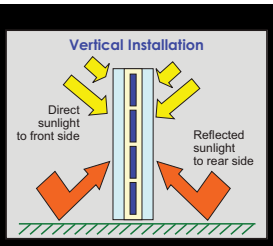
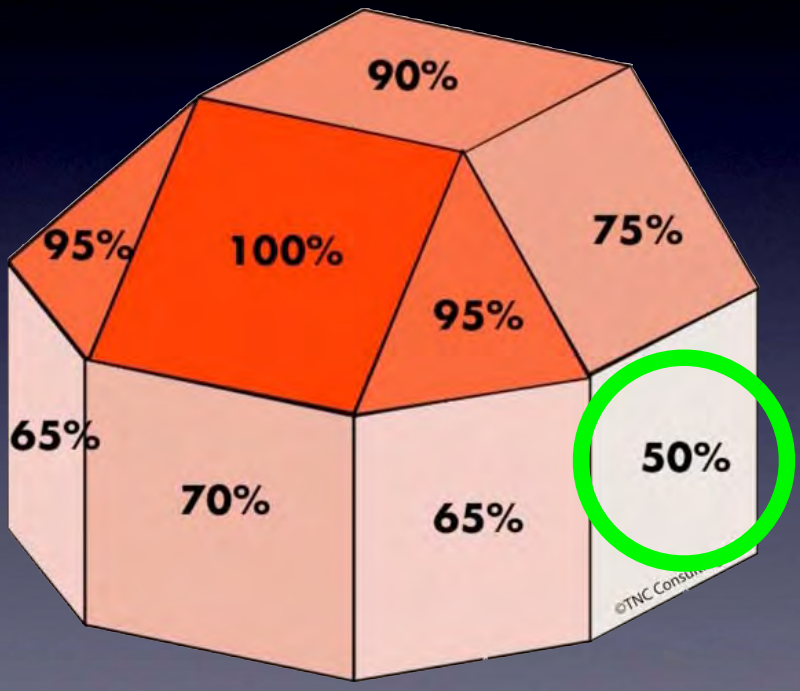


Why is the sky is tolerant to PV?

+ 50% →



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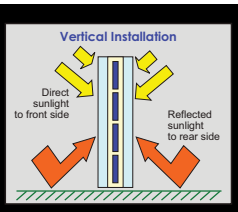
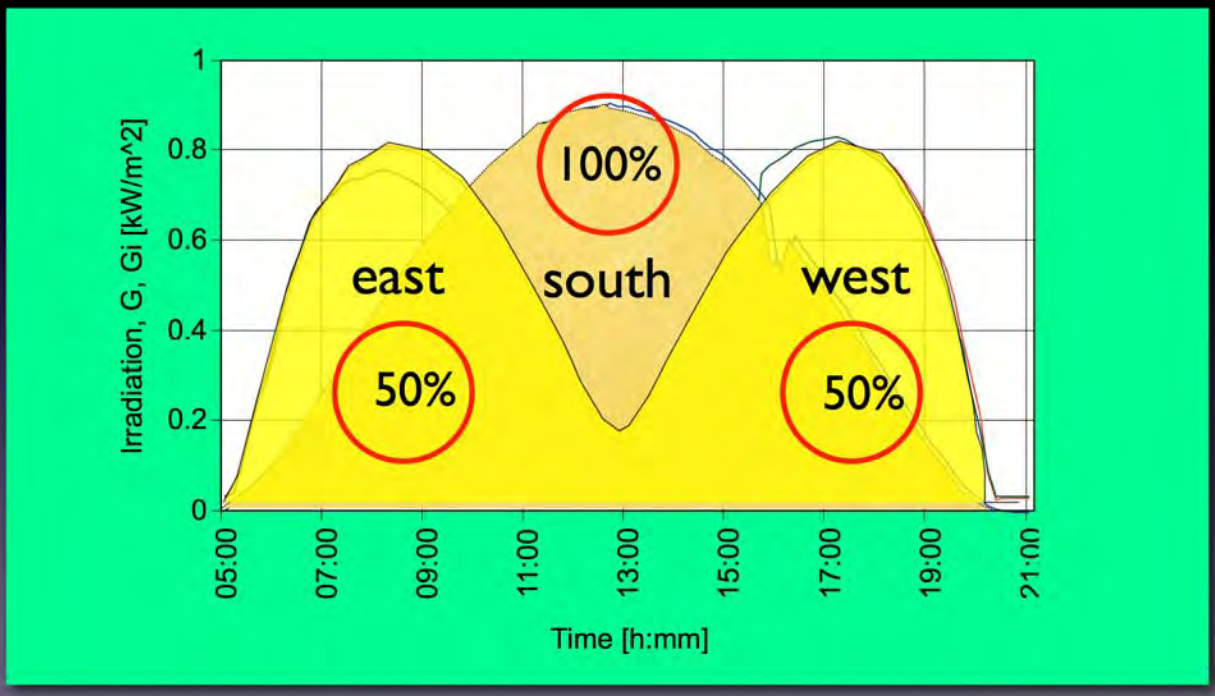


Typical daily curves for Solar irradiation and power



Irradiance GI is the sum of irradiance on the eastfacing and west-facing sides.

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December 2008
2000
TNC Advanced Energy Concepts
©TNC 2017 bifi PV Workshop Konstanz


How to use solar power with north-south oriented areas?
…Vineyard for photosynthesis since the 6th century!
©TNC 2012 ISC Bifacial Workshop Konstanz

Session II • Solar Cells: industrial bifacial calls for production

25 Oktober 2017

Session II		Solar Cells: industrial bifacial cells for production
12:00-12:20	**Ingrid Romijn, ECN**	**overview**
12:20-12:35	Thorsten Dullweber, ISFH	Bifacial PERC+ solar cells: status of industrial implementation and future perspectives
12:35-12:50	NN, Jolywood	nPERT bifacial technology
12:50-13:05	Lev Kreinin, SolAround	pPERT as an alternative
13:05-13:20	Andreas Teppe, RCT	mcPERCT

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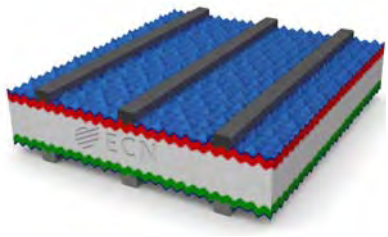
Commercial bifacial solar cells

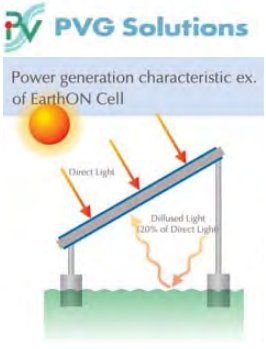
- 2000: Bifacial HIT cells from Sanyo in production
→ Symmetric metallization for thin wafers



- 2004 - 2008: large scale PV industry takes off….
→ With monofacial cells and modules

- 2010: Yingli commercializes ECNs n-Pasha cells[1]
→ Applied in monofacial modules

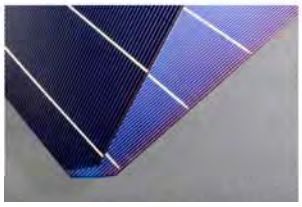
- 2011: PVGS starts with EarthOn technology[2]
→ Applied in bifacial modules



1: A.R. Burgers, 26th EUPVSEC, Hamburg, Germany (2011)
2: S. Goda, 11th CSPV, Hangzhou, China (2015)

Current commercial bifacial cells

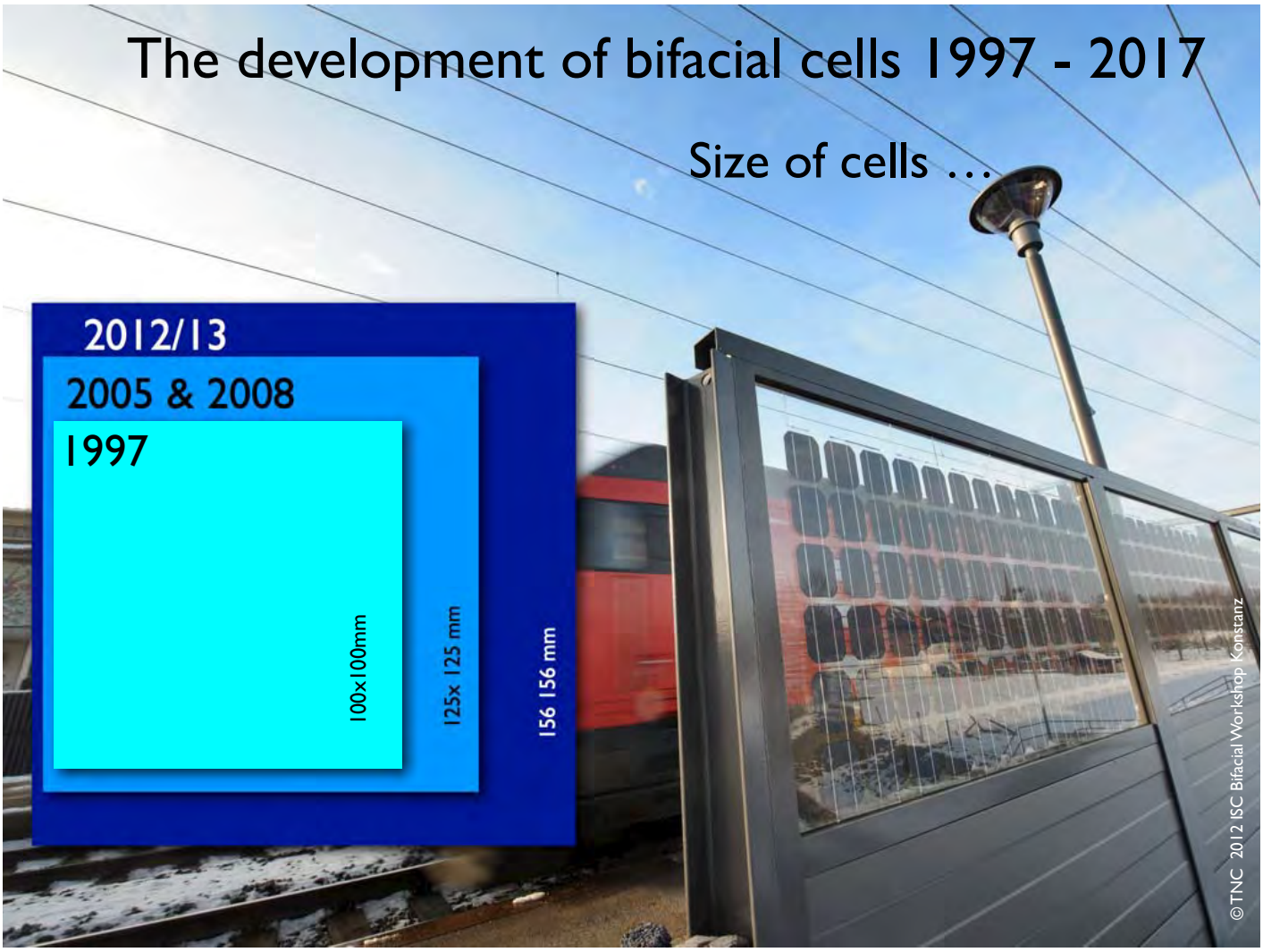
Selection of PV companies working on different bifacial cell technologies[1]								
technology	Eta	bifi						
HJ	22 – 23.5%	>95%	Sunpreme	3sun	Hanergy	Panasonic	Jinergy	
n-PERT	21 - 22%	>90%	Jolywood	Yingli	Adani	Linyang	Trina	LG
p-PERT	19 - 20%	>85%	SolAround	NSP	Shanxi Lu'An			
p-PERC+	21 - 22%	70%	SolarWorld	JA Solar	LONGi	Trina		



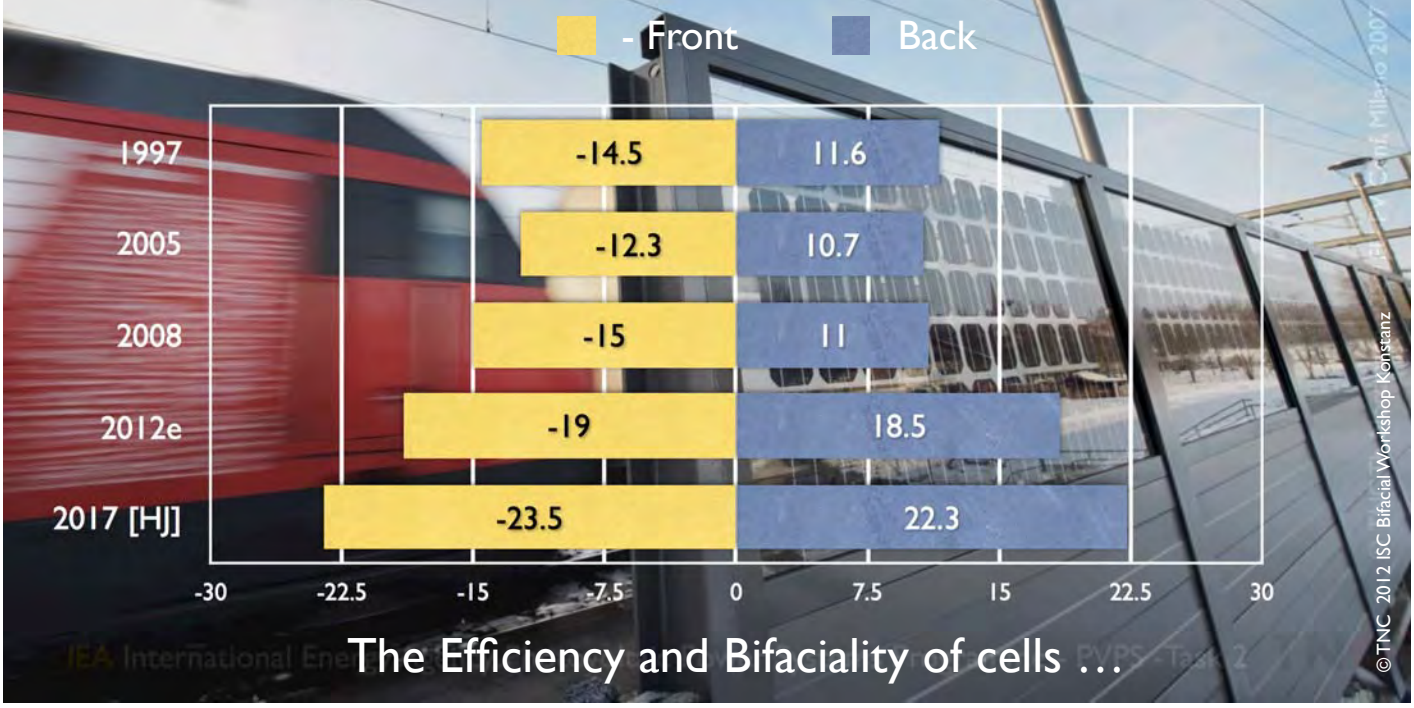
ecn.nl

27

1: S. Chunduri, M. Schmela, Bifacial Solar Module Technology, 2017 Edition, TaiyangNews



The development of bifacial PV cells 1997 - 2017



The Efficiency and Bifaciality of cells …

Bifacial cells predictions for the future

- First in appearance in ITRPV ro2017ap of 2015
- Bifacial cells become more and more prominent in the PV world

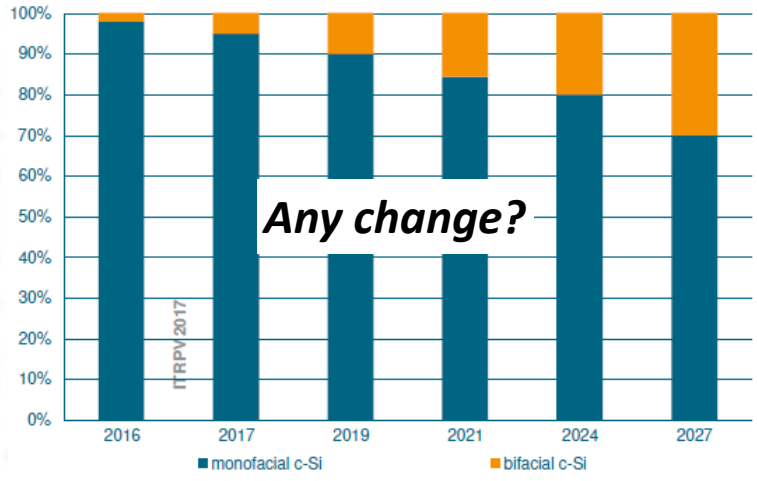
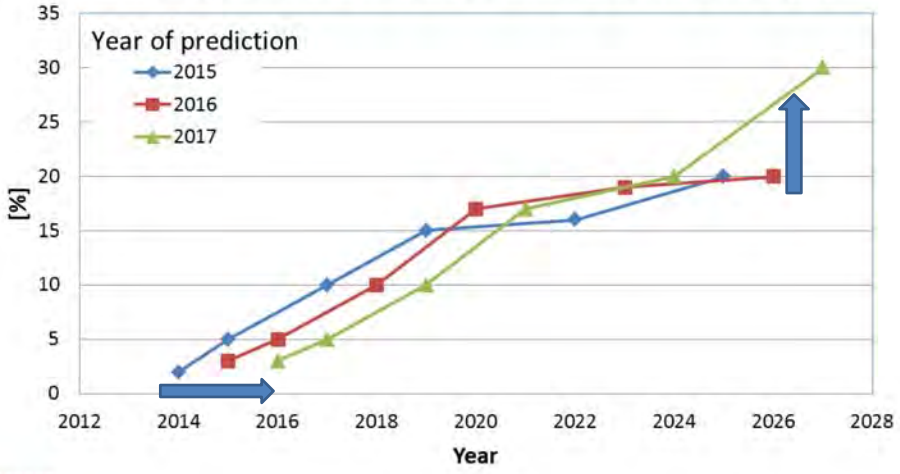


Fig. 29
Worldwide market shares for bifacial cell technology.

Bifacial cells predictions for the future

- Introduction slower then expected, but prediction becomes

ITRPV prediction bifacial cells world market share [%]



Critical summary and outlook for successful bifacial future 25 Oktober 2017

Session III		Modules: bifacial module concepts
14:30-14:50	**Hartmut Nussbaumer, ZHAW**	**overview**
14:50-15:05	Anna Battaglia, 3sun	Si HJ bifacial modules: an innovative industrial perspective towards more efficient PV energy generation
15:05-15:20	Thomas Soederstroem, MB	The real power of bifacial HJT Smart Wire Connection Technology
15:20-15:35	David Dassler, FhG CSP	Bifacial gain simulations of modules and systems under desert conditions
15:35-15:50	Jai Prakash, SERIS	Shingled bifacial Photovoltaic modules
15:50-16:05	Milica Mrcalica, DSM	Advanced layers for bifacial modules

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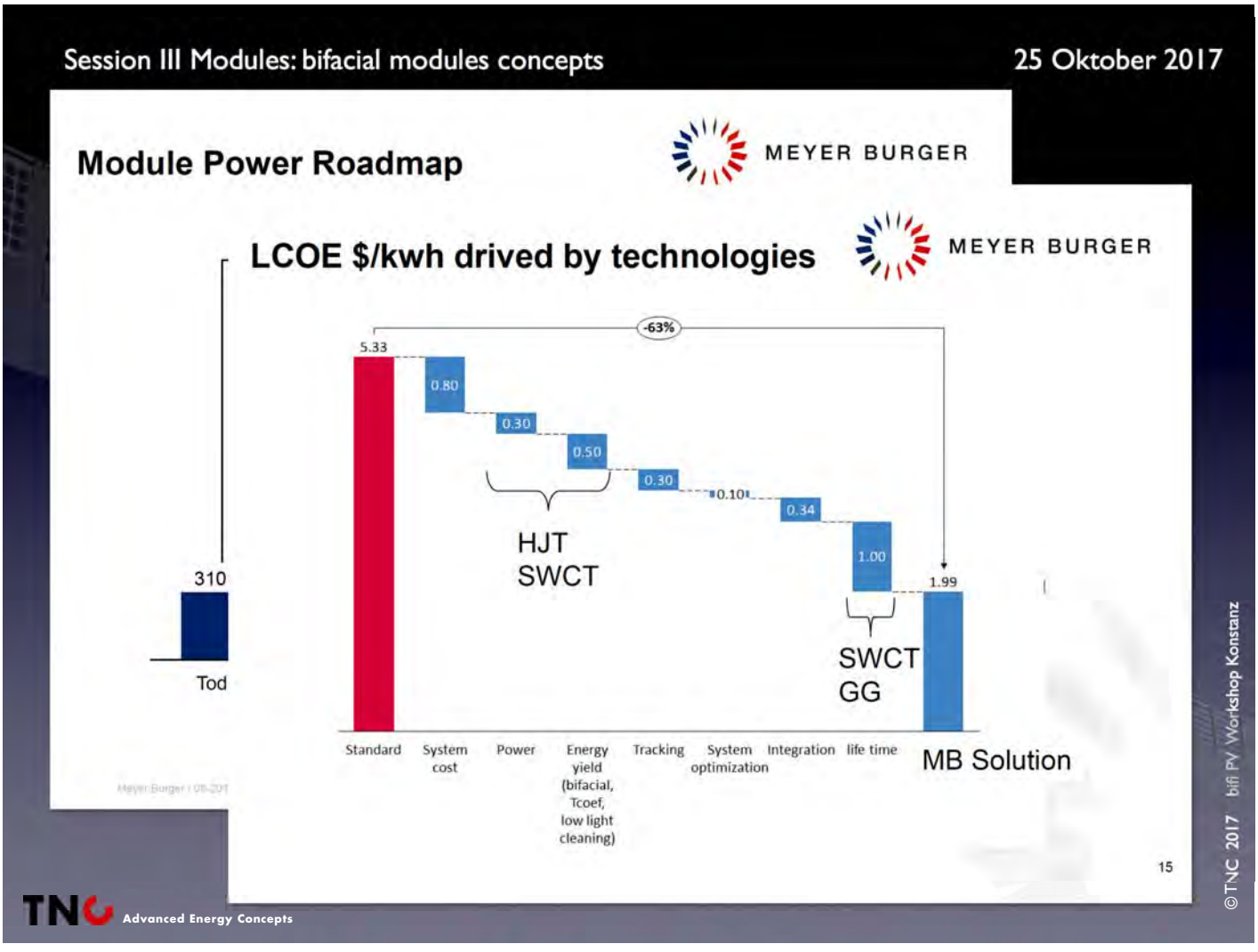
Comparison

Company	Technology	Rated Module Efficiency STC	Speciality
Trina Solar	p-type Mono PERC, G/G	18%	
Meyer Burger	HJT, Mono, G/G	19.1%	Smart Wire, TPO encapsulant
LG Electronics	n-type Mono, G/BS	18.3%	Multiwire, Transparent BS
Yingli Green Energy	n-type Mono PERT, G/G	17.6%	Half cells 5BB
SolarWorld	p-type Mono PERC G/G	17.3%	Reflecting coating
Sunpreme	HJT Mono, G/G	19.1%	Large 96 cell modules

List incomplete!

Current «industrial standard» for bifacial modules:
Glas/Glas: 2.5/2.5 mm, 60 cells, EVA encapsulant, 5BB technology, *p-type PERC*,
3 Bypass diodes, JB at the edge not shading the cell area, Efficiency 17-18% at STC



Session IV

Discussion about Technology:
What is needed to develop for bifacial technology? with the crystal ball

25 Oktober 2017

- Ashok Sinha von Sunpreme
- Rob Kreiter from sunfloat
- Fabrizio Bizzarri from Enel
- Liuyong from Jolywood
- Heiko Hildebrand von next2sun

- Glas-Glas PV modules will become mainstream!
- Thin glas will surpass «Tedlar» as back sheet, also economical!
- Most PV modules will be Bifacial!

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Critical summary and outlook for successful bifacial future

26 Oktober 2017

Season V • Bifacial gain simulations and LCOE calculations

Session V		Bifacial gain simulations and LCOE calculations
09:00-09:20	**Joris Libal, ISC Konstanz**	**overview**
09:20-09:35	Bruno Wittmer, PVsyst	Bifacial shed simulations with Pvsyst
09:35-09:50	Lars Kunath, Polysun	Enhanced energy harvest for PV systems using bifacial modules: simulation and model verification
09:50-10:05	Djaber Berrian, ISC Konstanz	MoBiDiG: simulations and LCOE
		oftop Systems installed in the USA and in Germany
		OE calculation

Beauty Contest:
- PVsyst
- Polysun
- MoBiDiG

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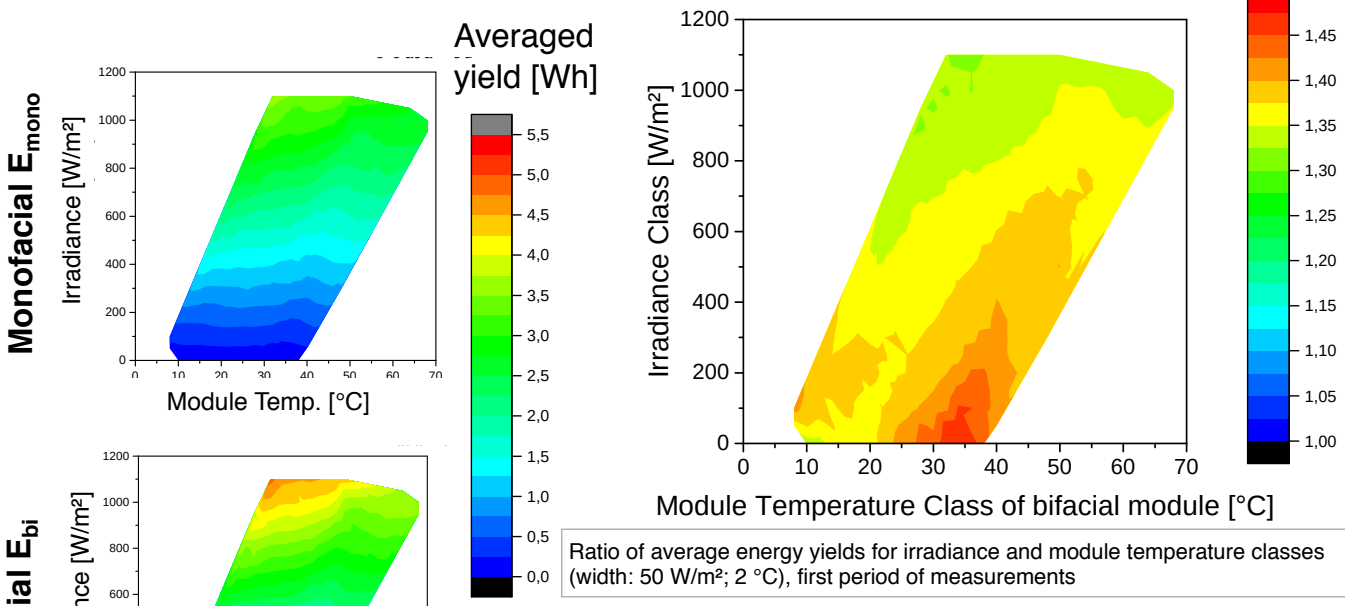
Bifacial gain simulations of modules and systems under desert conditions

(3) Energy yield evaluation

$$\text{Factor} = \frac{E_{bi}}{E_{mono}}$$



Ratio of average energy yields for irradiance and module temperature classes (width: 50 W/m²; 2 °C), first period of measurements

- Bifacial: Shift of absolute yield upwards
- Almost constant energy yield levels with rising temperatures until 800 W/m²
- Bifaciality up to 45% for moderate module temp.

David DASSLER
Hochschule Anhalt
Anhalt University of Applied Sciences
Fraunhofer CSP

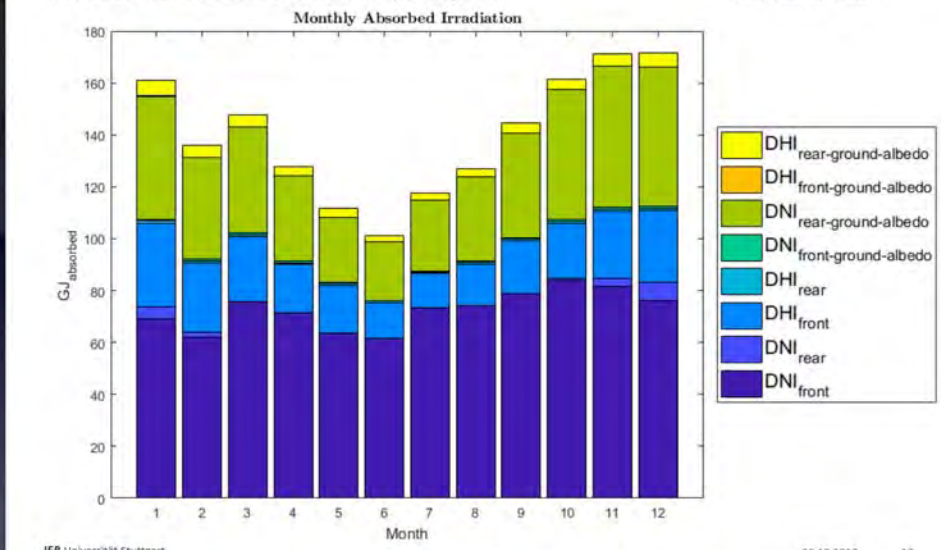
Season V • Bifacial gain simulations and LCOE calculations

26 Oktober 2017

Monthly absorbed irradiation

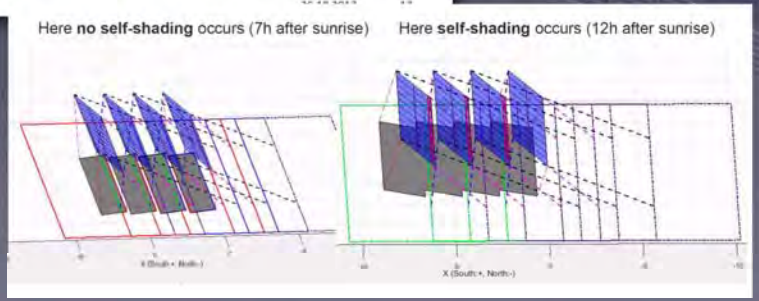
Slope=25°, elevation= 3.5m, row spacing=4m

University of Stuttgart
IER Institute of Energy Economics and Rational Energy Use



Dimitrij Chudinzow

Now we understand the bifacial shading albedo DNA!



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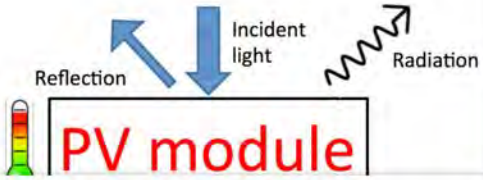
Bas Van Aken ecn.nl

Now we understand the thermal heat balance of (bifacial) modules

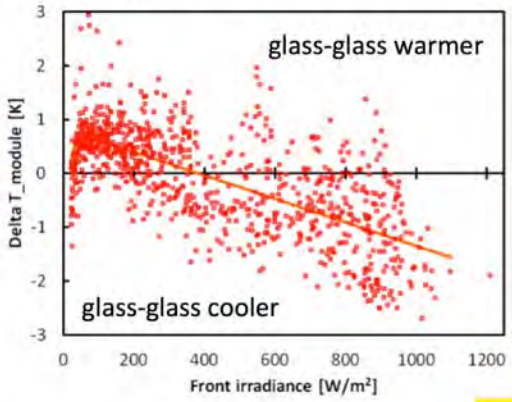
Heat balance

- Light
  - Reflected / transmitted
  - Absorbed
- Conversion



Bifacial gain in current/power does not lead to significant heating of bifacial modules

- At low irradiance, bifacial gain leads to limited extra warming of modules
- At high irradiance, bifacial modules become cooler



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Session VI		Measurement- and qualification standards
12:00-12:20	**Vahid Fakhfouri, Passan**	**overview**
12:20-12:35	Klaus Ramspeck, h.a.l.m.	Measurement techniques for bifacial solar cells
12:35-12:50	Gordon Deans, Aurora	Accurate inline characterization of BSF and emitter fabrication processes for high-volume bifacial cell production
12:50-13:05	Maryline Joanny, INES	Bifacial modules measurement with GE method

IEC BiFi standard method at a glance

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	Analogy: T° coefficients	Measurement	D
Laboratory	Determination of α, β, κ	Bifaciality measurement	R
		Bifacial gain determination	R
Production	$Pmax_{DUT,T^\circ}$ measurement $Pmax_{STC}$ (calculated)	STC measurement	P

Conclusion

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- IEC 60904-1-2: I-V measurement of BiFi devices
  - Standard project in a very advanced stage
  - Reproducible method to assess bifacial devices and to value the bifacial gain
  - No requirement for new measurement equipment in PV productions
- BiFi measurement challenges
  - Uniformity of irradiance on the rear-side (outdoor, double-side illumination)
  - Bare cells contacting and temperature measurement (double-side illumination)
  - Background compensation (achievable)

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14:15-14:30	Juan Lopez-Garcia, EC, DG JRC	Temperature coefficients of n-type bicacial silicon PV modules under natural and simulated sunlight
14:30-14:45	Karl Berger, AiT	How to introduce bifaciality within the module type and safety testing procedures
14:45-15:00	Elias Garcia Goma, EternalSun	Single vs double side illumination indoor testing for bifacial performance characterisation
15:00-15:15	Werner Herrmann, TÜV Rheinland Energy	Performance characteristics of bifacial PV modules and power labeling
15:15-15:30	Michael Rauer, ISE	Bifacial Solar Cells under Single- and Double-Sided Illumination: Effect of Nonlinearity in Short-Circuit Current

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Seven Conclusions

2012 2017

- Monday
  The combined irradiation for this bifacial PV plant was 98-01 about 4 % higher!! than on a south facing optimal oriented surface. → Sufficient light on vertical N/S!
- Tuesday
  An improvement of PR from 55% to 61% due to higher overall efficiency of the new modules and closer matching of the nominal to the effective efficiency of the new cells.
- Wednesday
  A shift of PR from 61% to 67% due to improved MPP tracking of the two new inverters.
- Thursday
  Bifacial PV plants overcome „look to the south“ dilemma of solar power

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Seven Conclusions (II):

2012 2017

- Friday
  We need industrial bifacial cell production lines to match the market price of PV modules today.
- Saturday
  The multi-functional bifacial PV noise barrier modules can fully substitute conventional glass noise barrier elements and save costs. Noise barrier infrastructure can partially substitute BOS of bifacial PV plants.
- Sunday
  - Glas-Glas PV modules will become mainstream!
  - Thin glas will surpass «Tedlar» as back sheet, incl. economical
  - Most PV modules will be Bifacial

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