Bifacial PV world 2018

Technology, applications and economics

Radovan Kopecek and Joris Libal

International Solar Energy Research Center (ISC), Konstanz, GERMANY

bifi PV workshop 2018 Denver

JOLYWOOD 中来股份 · LONGi Solar · Soltec · SUNPREME Premium Bifacial Thin Film Solar · naturblau +++ branding for longevity

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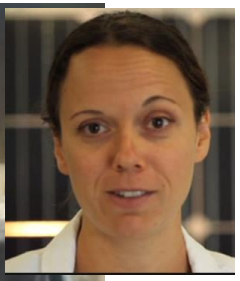

W E L C O M E

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W E L C O M E

Workshops series from ISC Konstanz

International Solar Energy Research Center Konstanz

Metallisation WS from 2008

>> next in **May 2019 in Konstanz**

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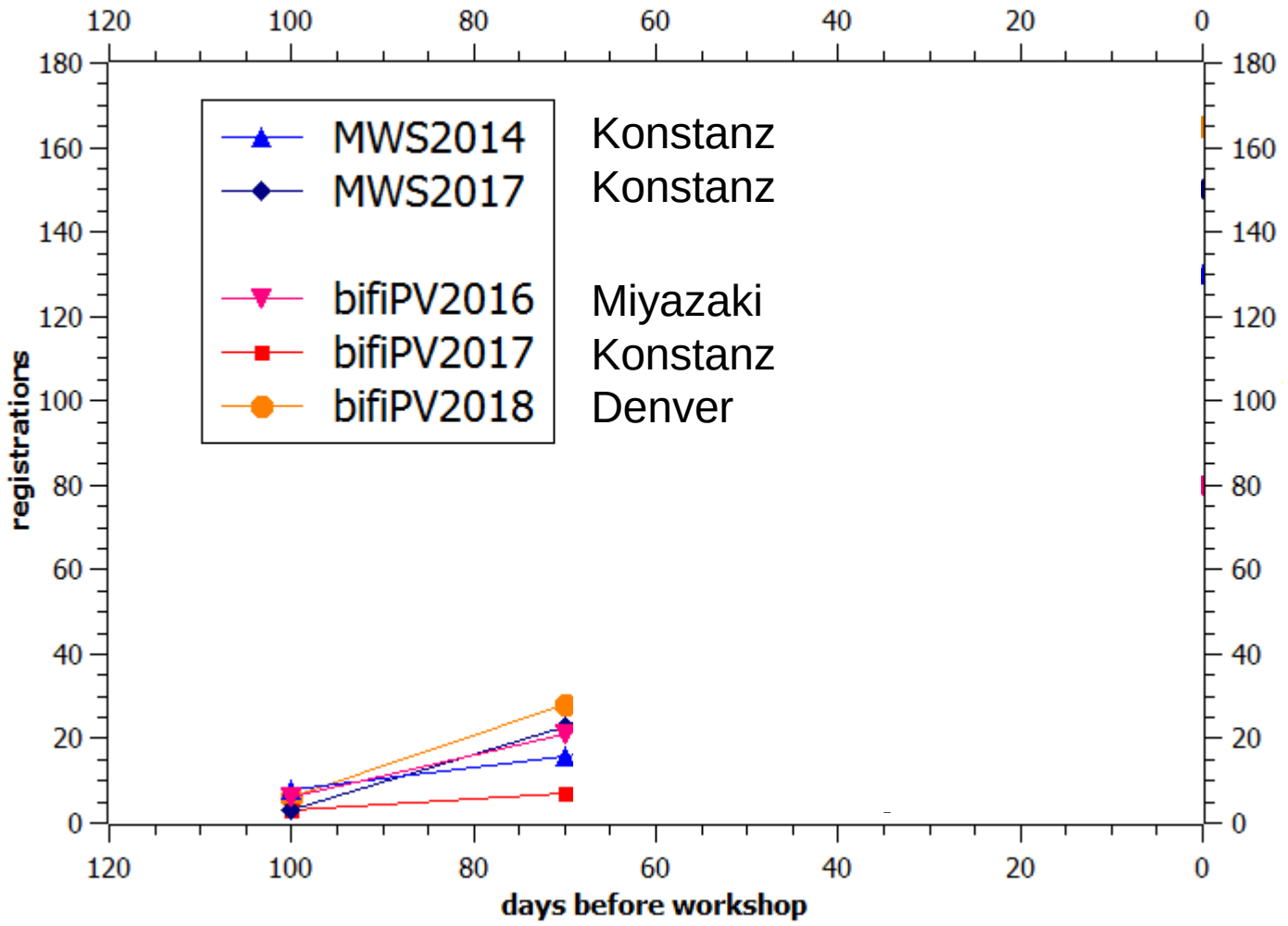
bifiPV WS from 2012

>> next in **2019 in ???**

Registrations



Registrations

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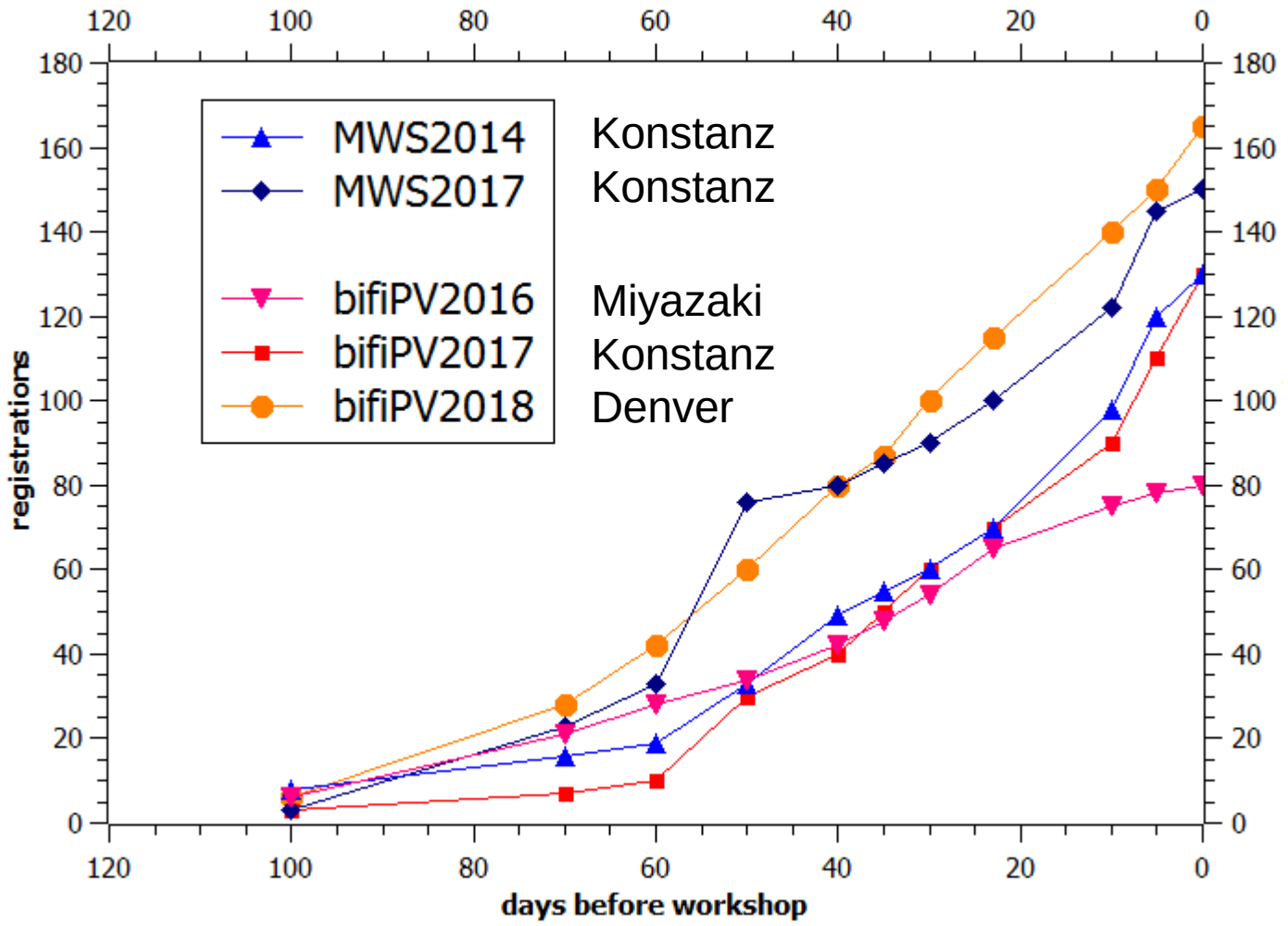

Bifacial PV systems: best reported

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Bifacial PV systems: best reported

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Bifacial PV systems: mostly shown

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Bifacial PV systems: largest fixed tilt

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Bifacial PV systems: largest rooftop

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Bifacial PV systems: largest tracked

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中来股份 JOLYWOOD JA SOLAR Trinasolar LONGi Solar

Bifacial PV systems: largest vertical

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Bifacial PV systems: largest vertical

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10+% bifacial energy gain

Ökostrom Saar regenerative Energien

Next 2 Sun

2 MWp

Bifacial applications (from LinkedIn)

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Will Zhang
Jolywood -Sales Manager &Technical Supporting
2w

BIPV application with double glass bifacial modules. Looks very nice ...see more

Will Zhang
Jolywood -Sales Manager &Technical Supporting
2d

@Bifacial
@N-type
BIPV application with bifacial modules. ...see more

Bifacial applications (from LinkedIn)

International Solar Energy Research Center Konstanz

Bifacial applications (from LinkedIn)

International Solar Energy Research Center Konstanz

Will Zhang
Jolywood -Sales Manager &Technical Supporting
4d

@N-type @Bifacial
Fishing matched with PV solar plant. This is the largest fishing PV solar systems all over the world.

Will Zhang
Jolywood -Sales Manager &Technical Supporting
1w

@Bifacial double glass module
@N-type
@Different applications like floating system/ground plant with tracke ...see more

Bifacial applications (from LinkedIn)

International Solar Energy Research Center Konstanz

History and future of PV, PERC, bifi

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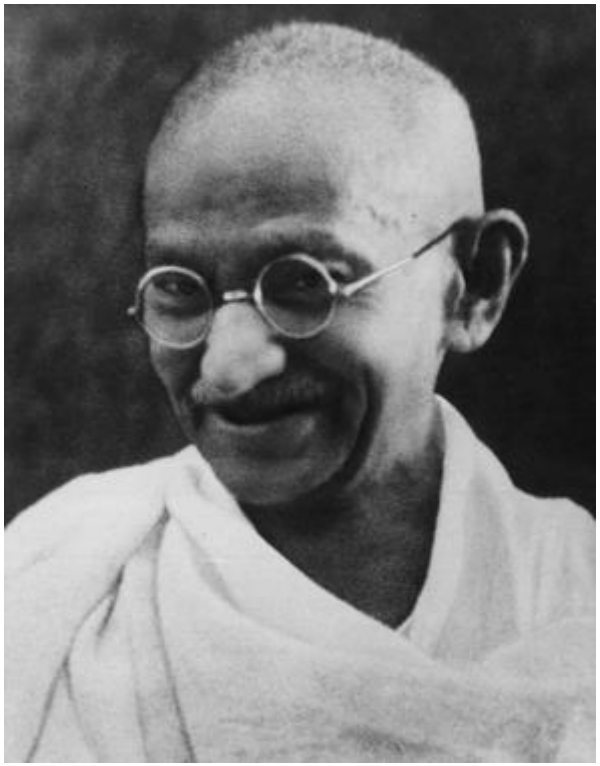

First they ignore you then they laugh at you then they fight you and then you win.

History and future of PV, PERC, bifi

International Solar Energy Research Center Konstanz

2000	2003	2006	2009	2012	2015	2018	2021	2024	2027

History and future of PV, PERC, bifi

International Solar Energy Research Center Konstanz

2000	2003	2006	2009	2012	2015	2018	2021	2024	2027

PV against other energy sources (total installations)

0%	0%	0%	0%	0.1%	0.5%	1-2%	4%	6%	8%

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History and future of PV, PERC, bifi

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PERC against Al-BSF (market share)

0%	0%	0%	0%	0%	5%	50%	70%	100%	100%

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History and future of PV, PERC, bifi

International Solar Energy Research Center Konstanz

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PERC against Al-BSF (market share)

0%	0%	0%	0%	0%	5%	50%	70%	100%	100%

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Bifacial against Monofacial (total installations)

0%	0%	0%	0%	0%	0.1%	0.3%	5%	10%	40%

First they ignore you then they laugh at you then they fight you and then you win.

Bifacial book

International Solar Energy Research Center Konstanz

Bifacial Photovoltaics: Technology, applications and economics

Editors: Radovan Kopecek and Joris Libal

Bifacial Photovoltaics: Technology, applications and economics provides an overview of the history, status and future of bifacial PV technology with a focus on crystalline silicon technology, covering the areas of cells, modules, and systems. In addition, topics like energy yield simulations and bankability are addressed. Illustrations are in full color.

Bifacial photovoltaic (PV) modules are able to utilize light from both sides and can therefore significantly increase the electric yield of PV power plants, thus reducing the electricity cost and improving profitability. Bifacial PV technology has a huge potential to reach a major market share, in particular when considering utility scale PV plants. In combination with simple tracking technology the total energy output of a PV power plant can be boosted to up to 50% compared to standard monofacial fixed tilt systems at about 10-20% additional costs. In addition different application fields are waiting for bifacial modules such as facades, car-ports, green-houses and other glass-intensive structures. Accordingly, bifacial PV is currently attracting increasing attention from involved engineers, scientists and investors.

Publication date: October 2018

Retail price: £115 / $150

Hardback: 300pp

ISBN: 978-1-78561-274-9

Product code: PBPO107

Bifacial book

ISC International Solar Energy Research Center Konstanz

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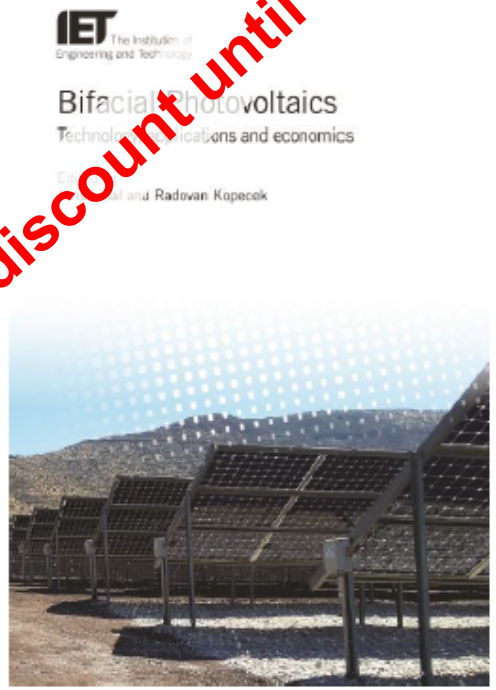

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Use offer code "BIFACIAL" to get 20% discount until 10 Oct 2018

Bifacial history

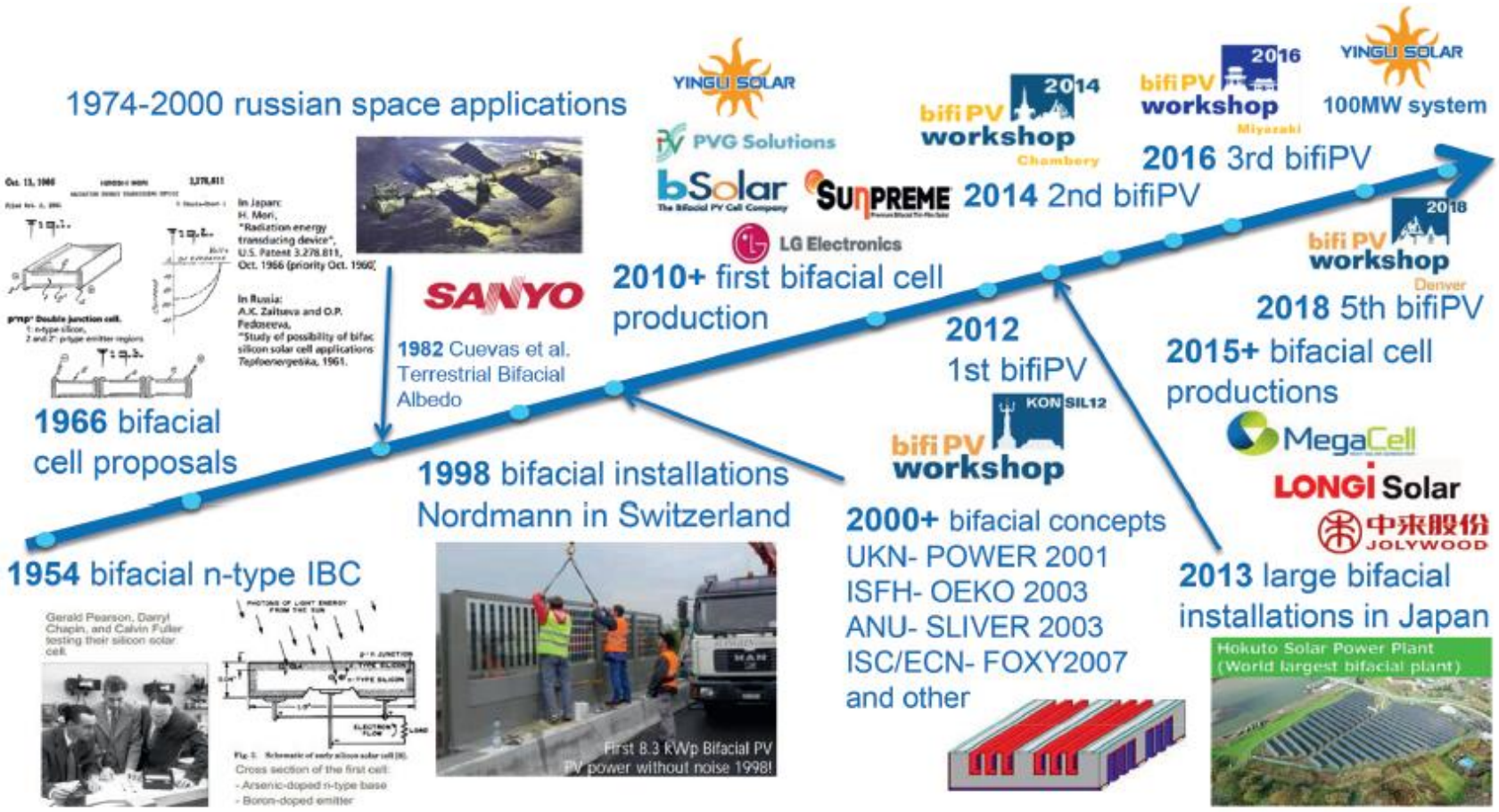

Figure 1.4 Bifacial history in few pictures

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Bifacial history

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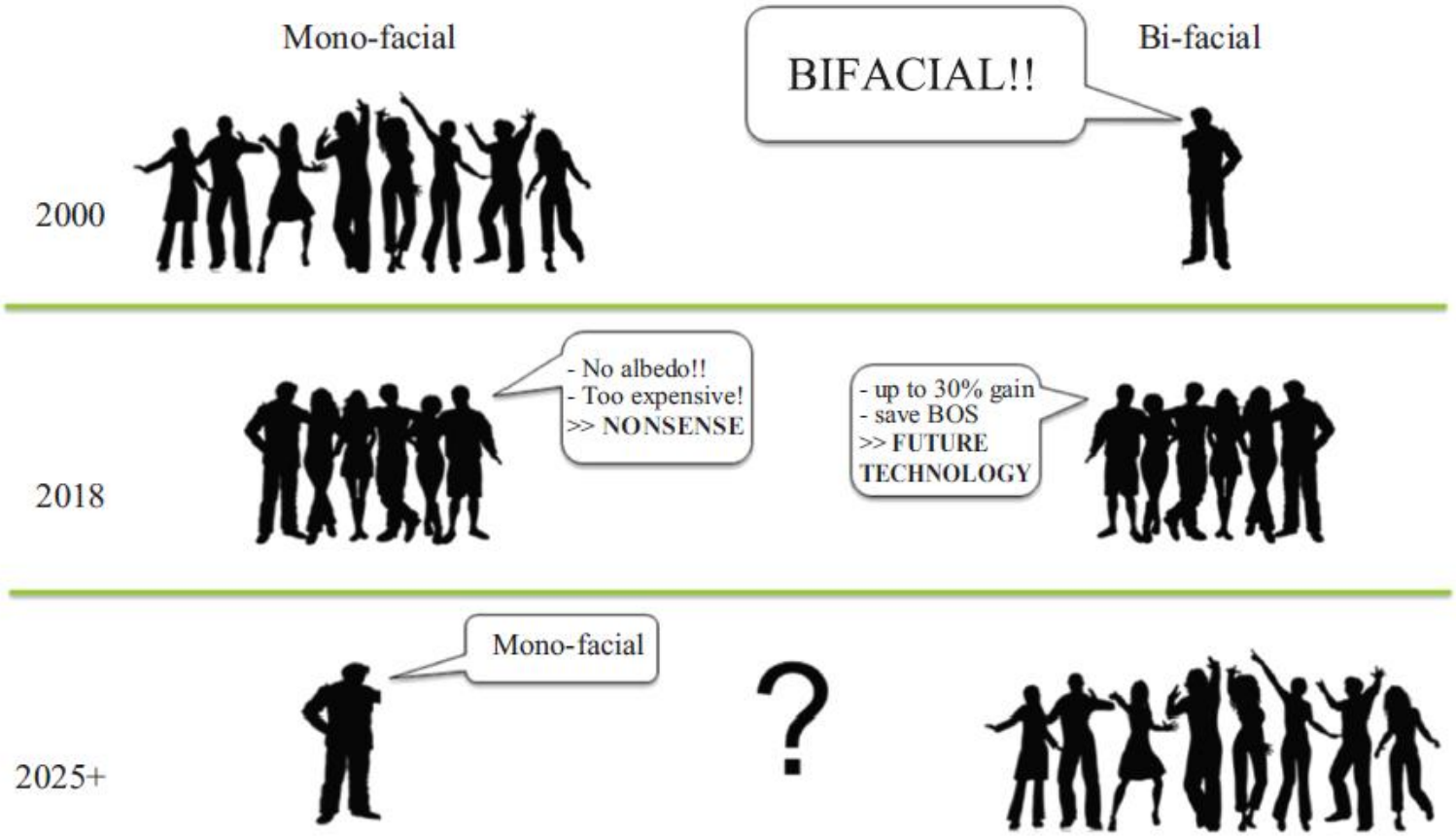
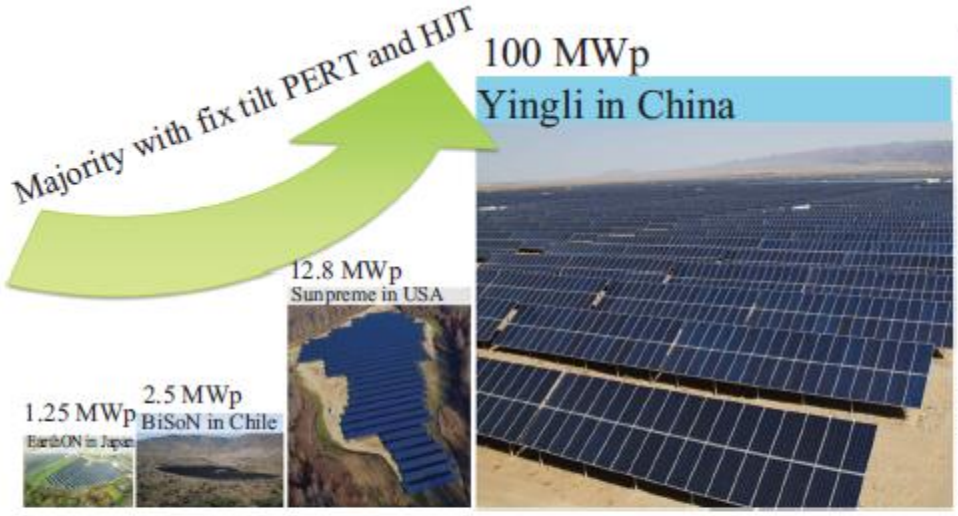


Figure 1.5 Bifacial comic explaining the change of mind of the PV industry [13]

Bifacial book 2018

Bifacial history



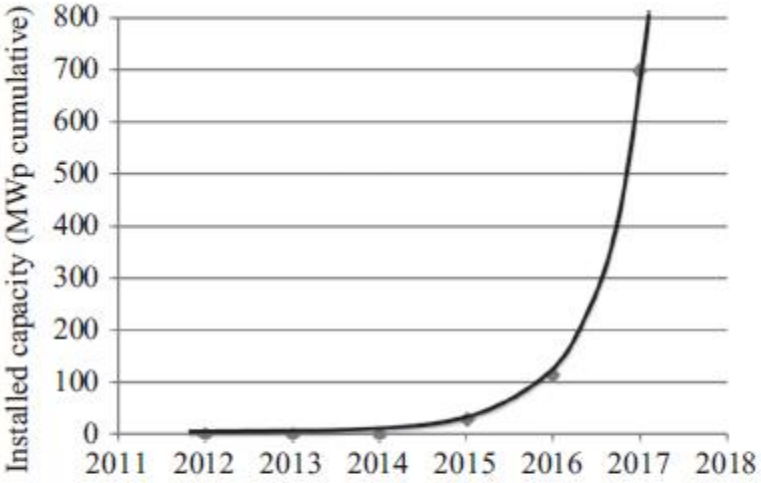


Figure 1.7 Largest bifacial PV systems (left) and cumulated bifacial power (right) [13]

Bifacial book 2018

Figure 1.11 4th bifiPV workshop 25/26 October 2017 in Konstanz

Why will bifacial win?

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- Modules become cost effective
- To save BOS powerful modules are needed

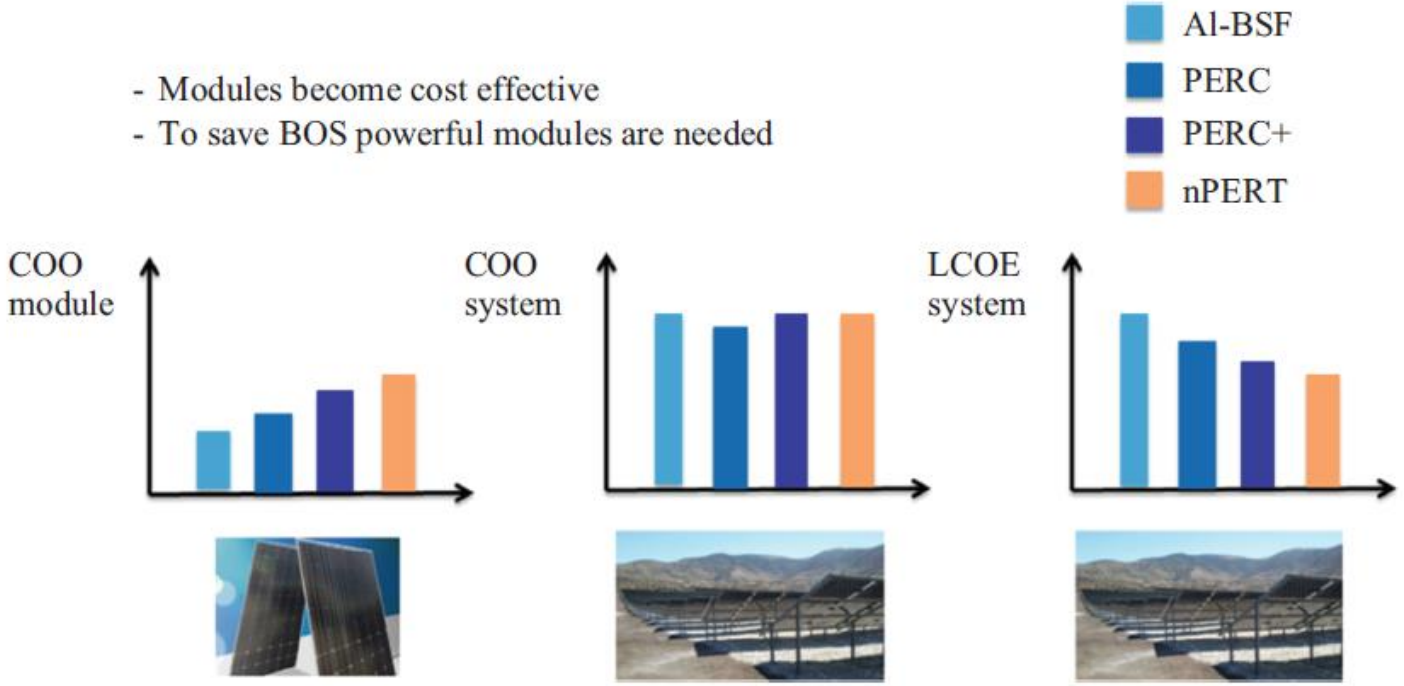

Figure 1.9 Schematic graphs for COO calculations for the most prominent c-Si technologies on module and system level and respective LCOE calculations. The trend in module COO and LCOE of a system is reversed due to savings of BOS and longer lifetime of double-glass modules

Bifacial book 2018

Possible cell technologies

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Table 2.1 Bifacial solar cells and their main parameters

	Cell concept	Bifaciality factor (on cell level)	Si base material	Junction and BSF doping method	Contacts	(Front) Efficiency potential
2.5.1	Heterojunction	>92%	n mono	a-Si:H p- and n-type doped	TCO/Ag printed TCO/Cu plated	22%–25%
2.5.2	n-PERT	>90%	n mono	Boron and Phosphorous diffusion	Ag and Ag/Al printed	21%–22%
2.5.3	p-PERT	>90%	p mono	Phosphorous and Boron diffusion	Ag and Ag/Al printed	21%–22%
2.5.4	PERC+	>80%	p-mono	Phosphorous diffusion and local Al BSF	Ag and Al printed	21%–22%
2.5.5	IBC	>70%	n-mono	Boron and Phosphorous diffusion	Ag and Ag/Al printed	22%–23%

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Bifacial gain for fixed tilt

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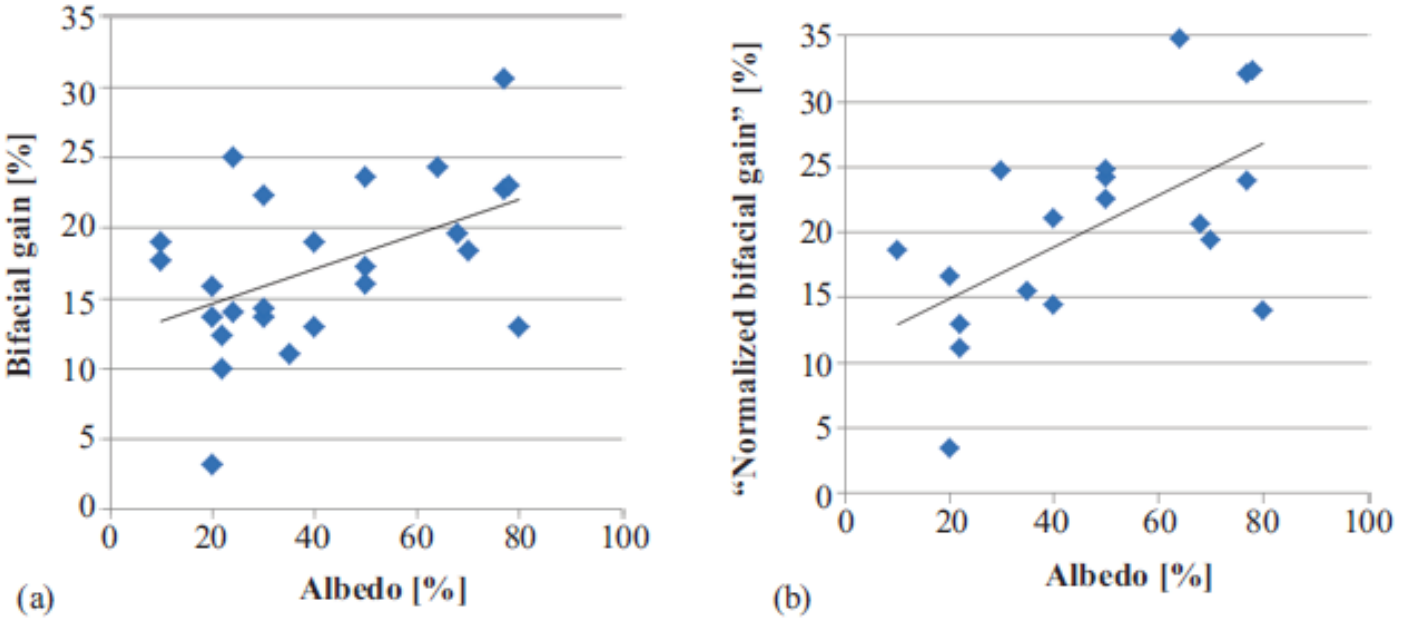

Figure 5.19 *(a) Bifacial gain plotted versus the albedo for "typical" south-oriented arrays. The trend is visible, but the fluctuation range is significant. The smallest observed bifacial gain is above of 10%, except of one outliner. (b) "Normalized bifacial gain" as an attempt to take the different bifaciality factors into account. No obvious improvement and reduced amount of data, but the concept may be useful when comparing more similar PV installations*

Bifacial book 2018

Bifacial gain

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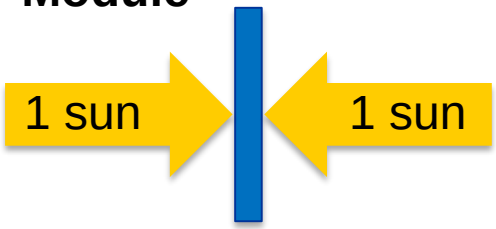
Module



HJT:	b>92
PERT:	b>90
PERC:	b>80
IBC:	b>70

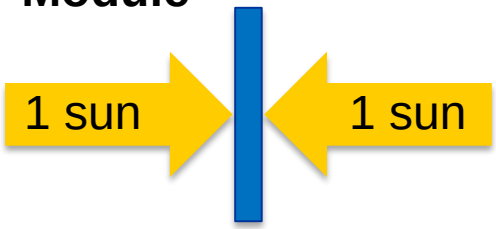
Ground

Dark soil:	a>10%
Grass:	a>15%
Sand:	a>30%
White roof:	a>70%

Bifacial gain

International Solar Energy Research Center Konstanz

Module



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Ground

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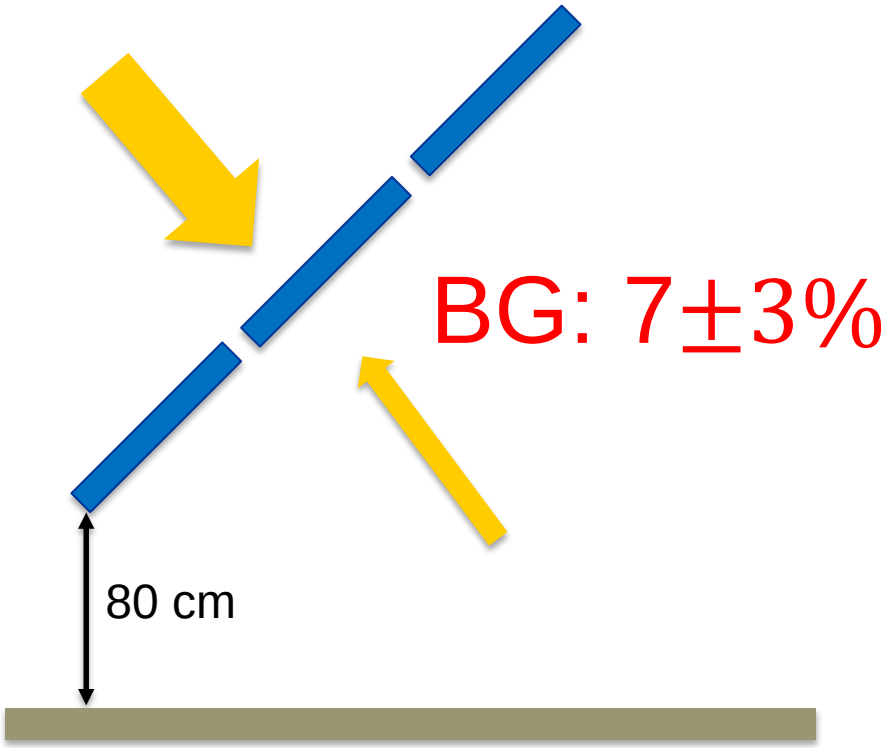
Sand:	a>30%
White roof:	a>70%

Construction: fixed tilt



Bifacial gain

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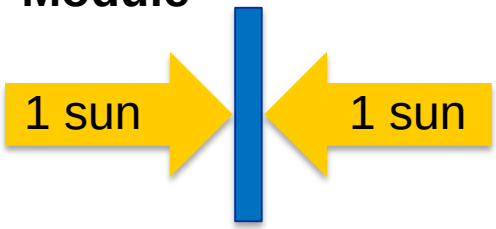
Module



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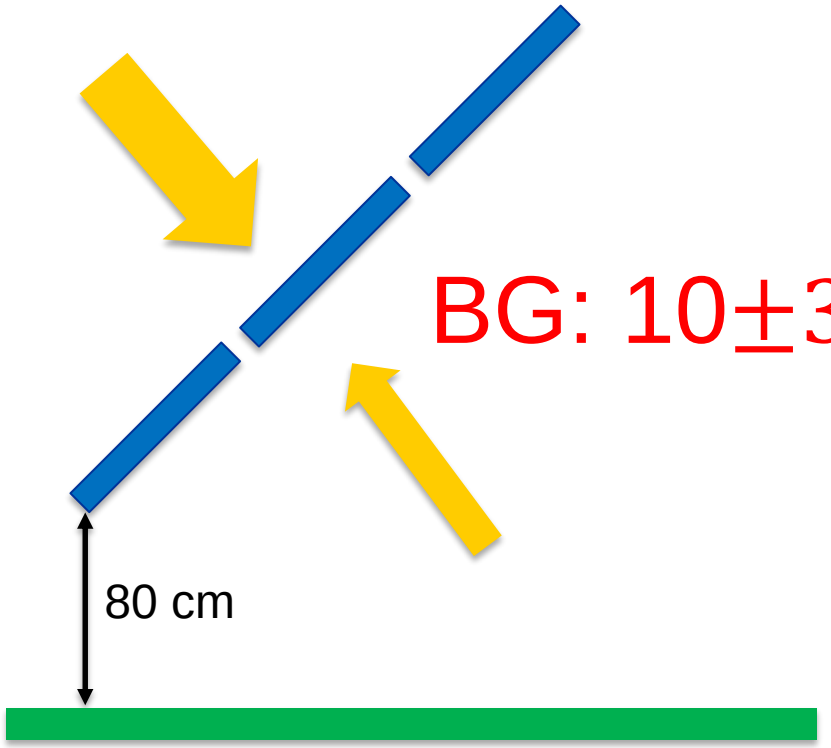

BG: 10±3%

Bifacial gain

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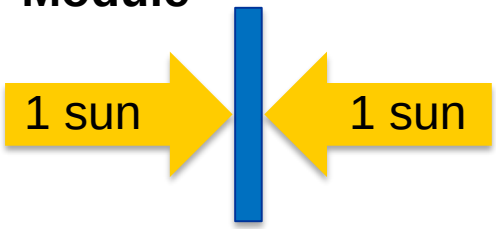
Module



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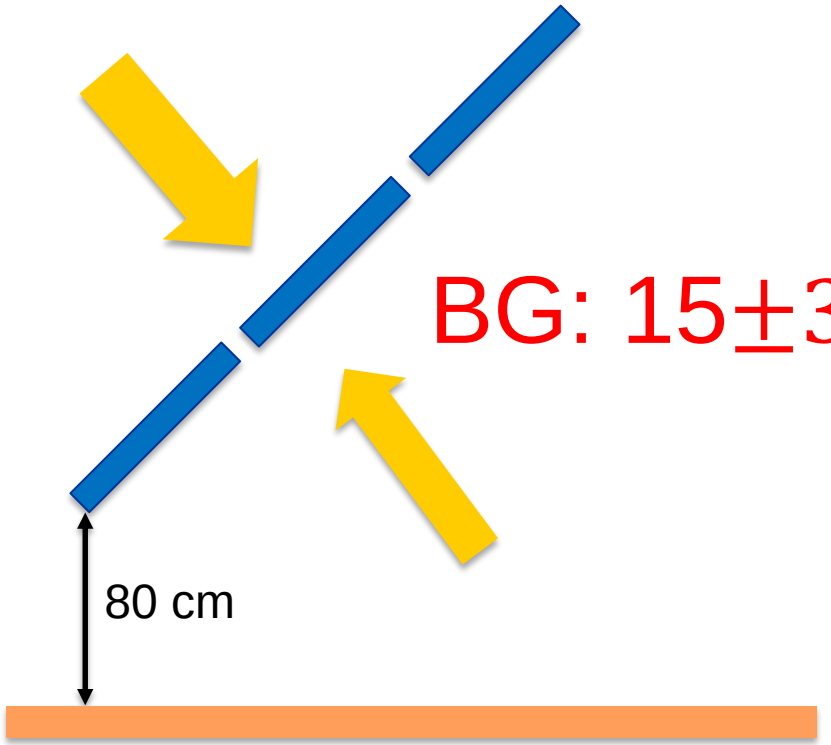
White roof:	a>70%

Construction: fixed tilt



BG: 15±3%

Bifacial gain

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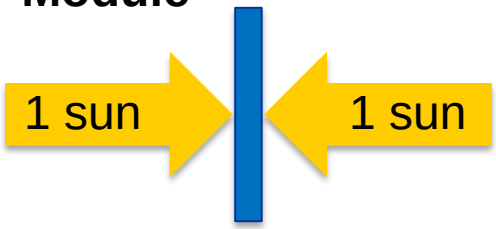
Module



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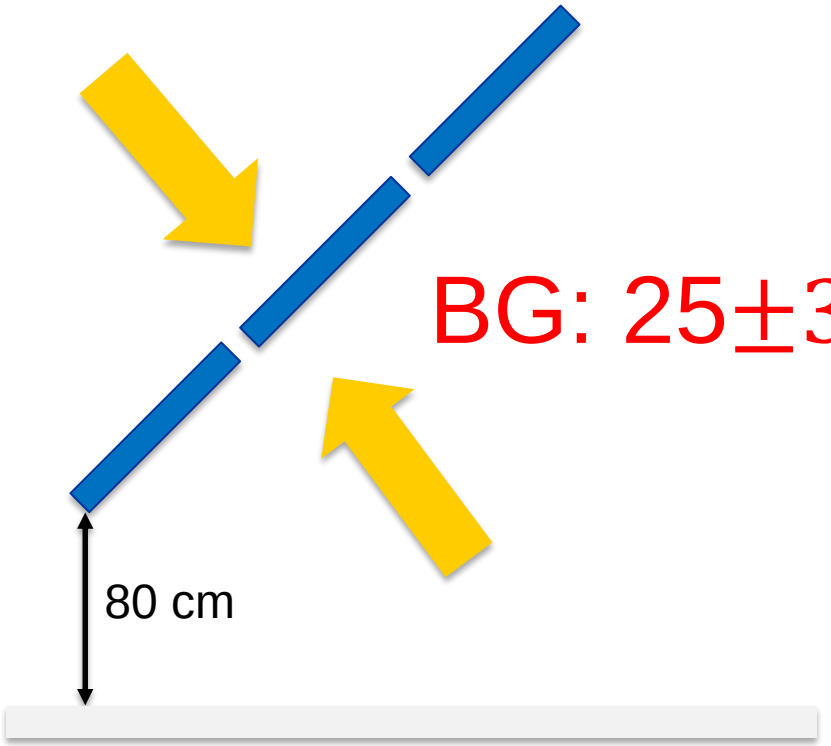
Construction: fixed tilt



BG: 25±3%

Bifacial gain

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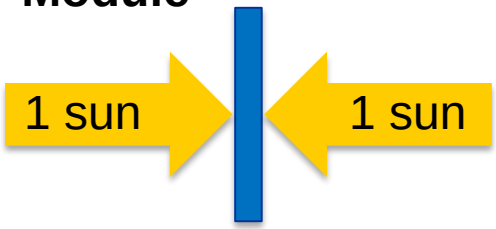
Module



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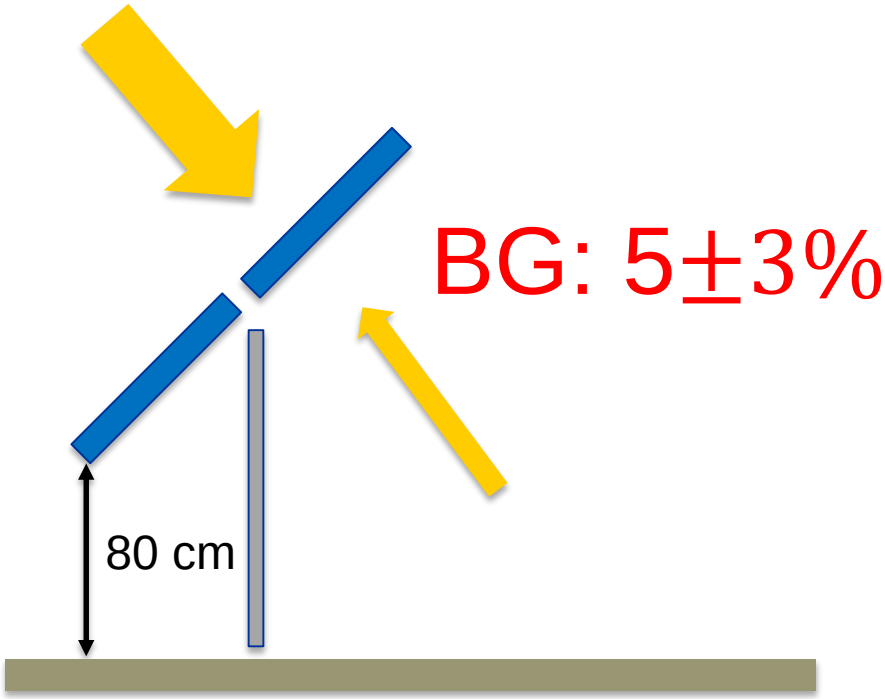
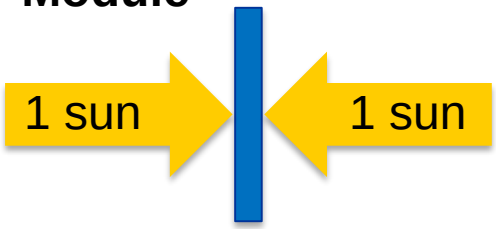
Construction: HSAT



Bifacial gain

International Solar Energy Research Center Konstanz

Module



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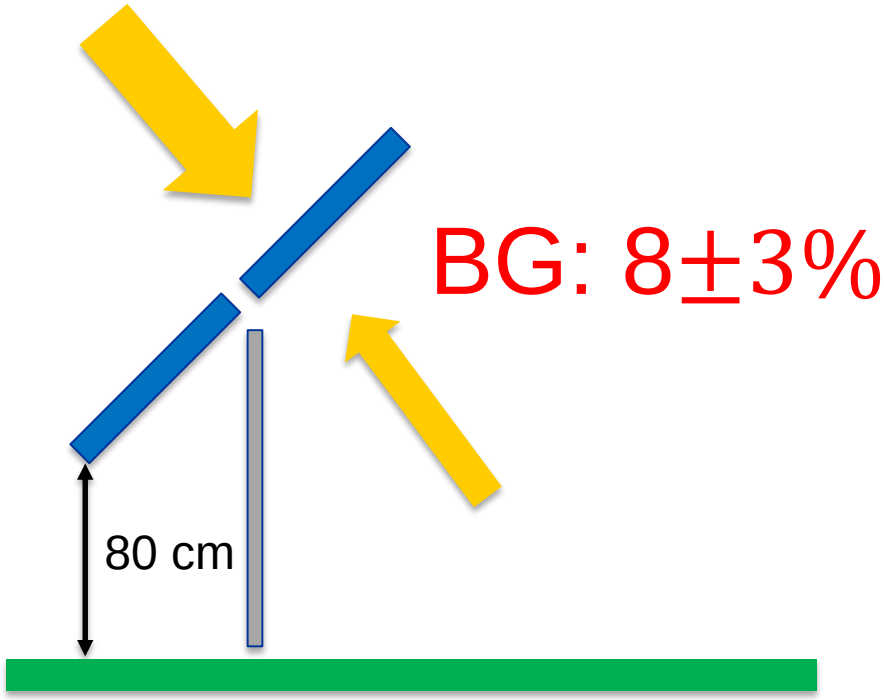

BG: 8±3%

Bifacial gain

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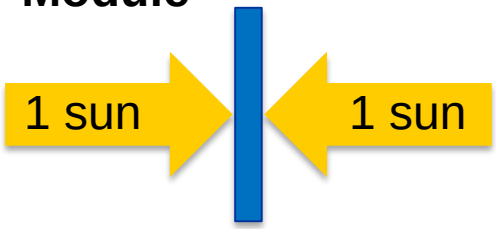
Module



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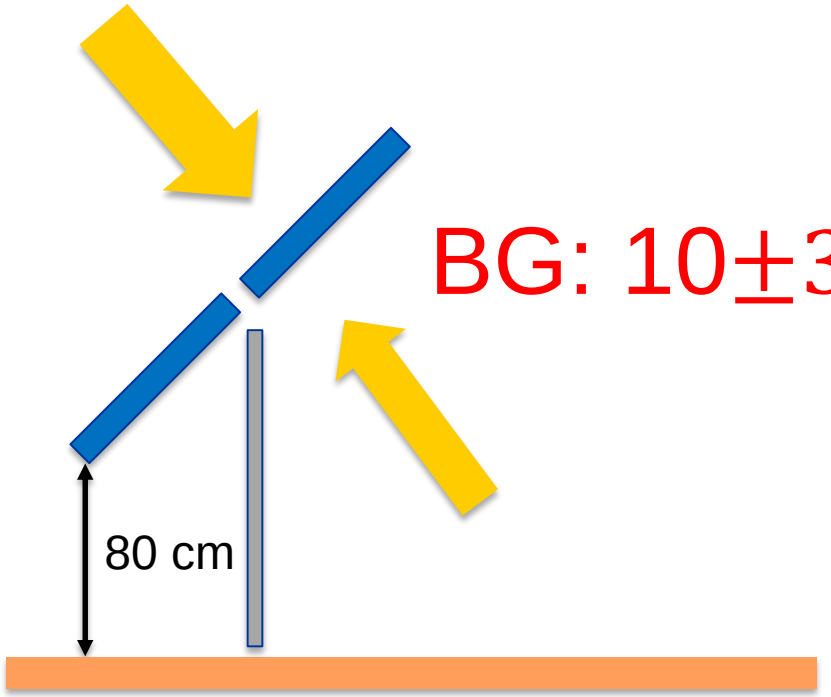
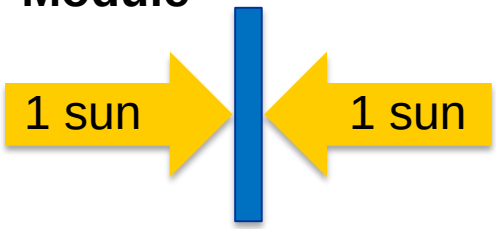


BG: 10±3%

Bifacial gain

International Solar Energy Research Center Konstanz

Module



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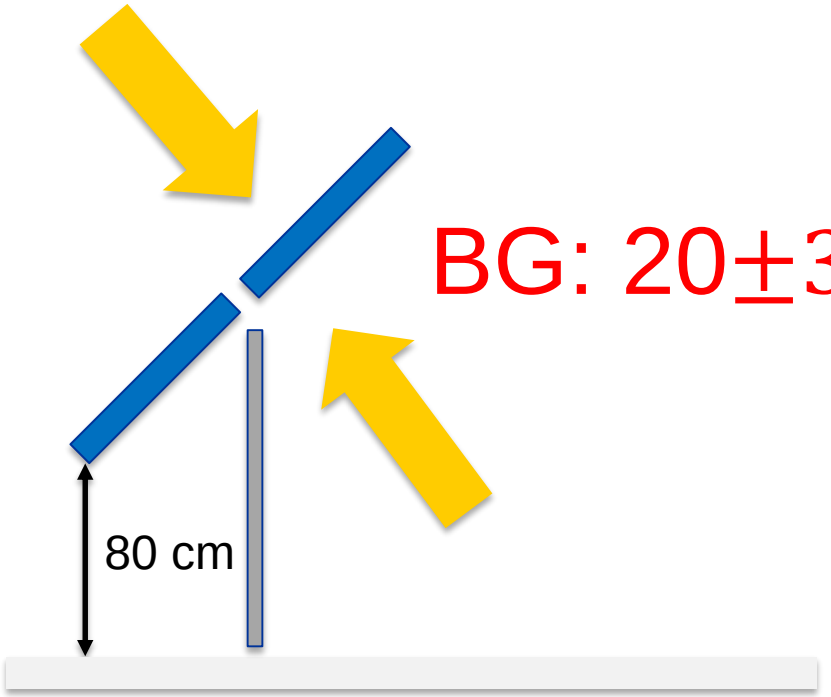
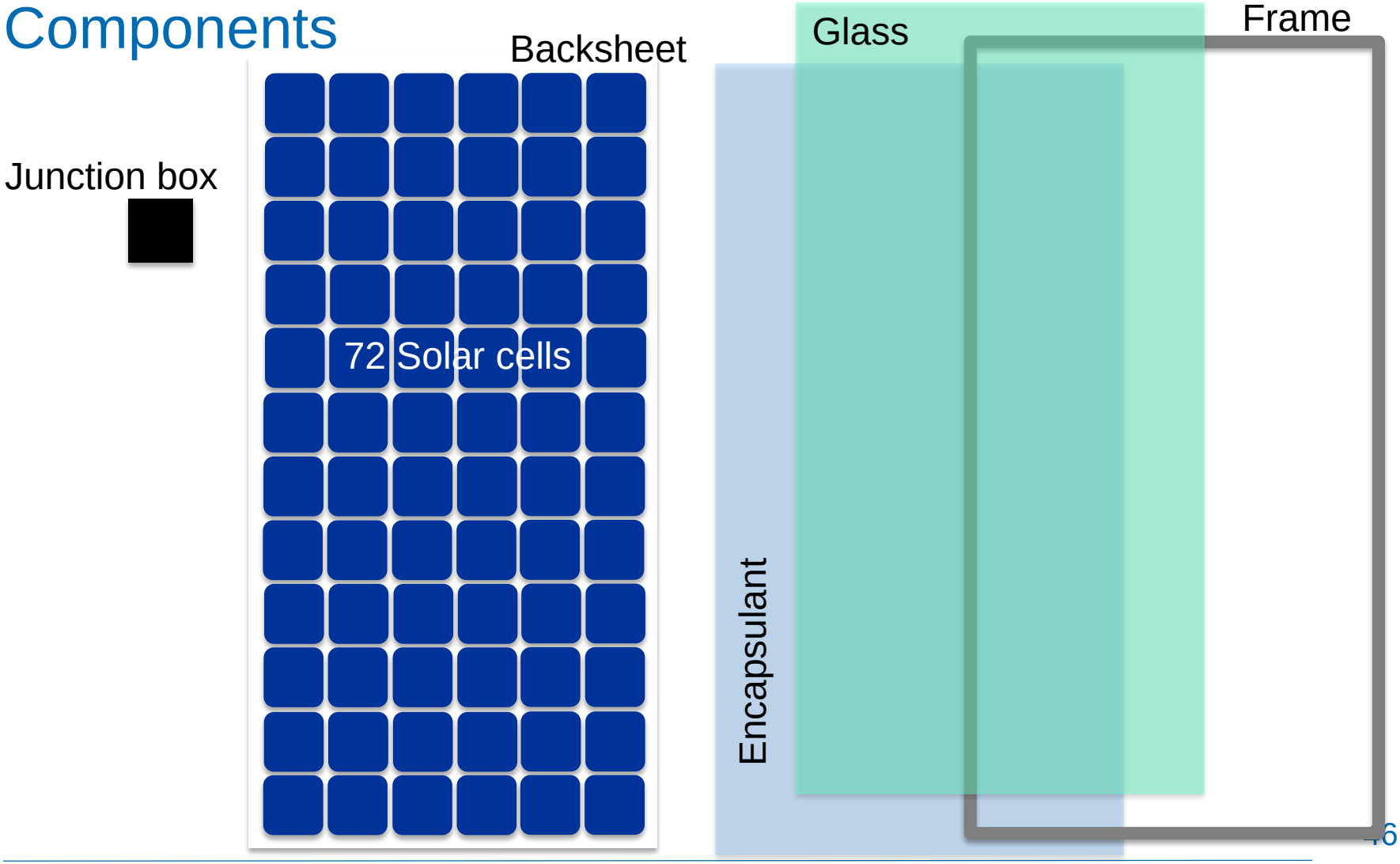


BG: 20±3%

Bifacial modules

Bifacial module technologies

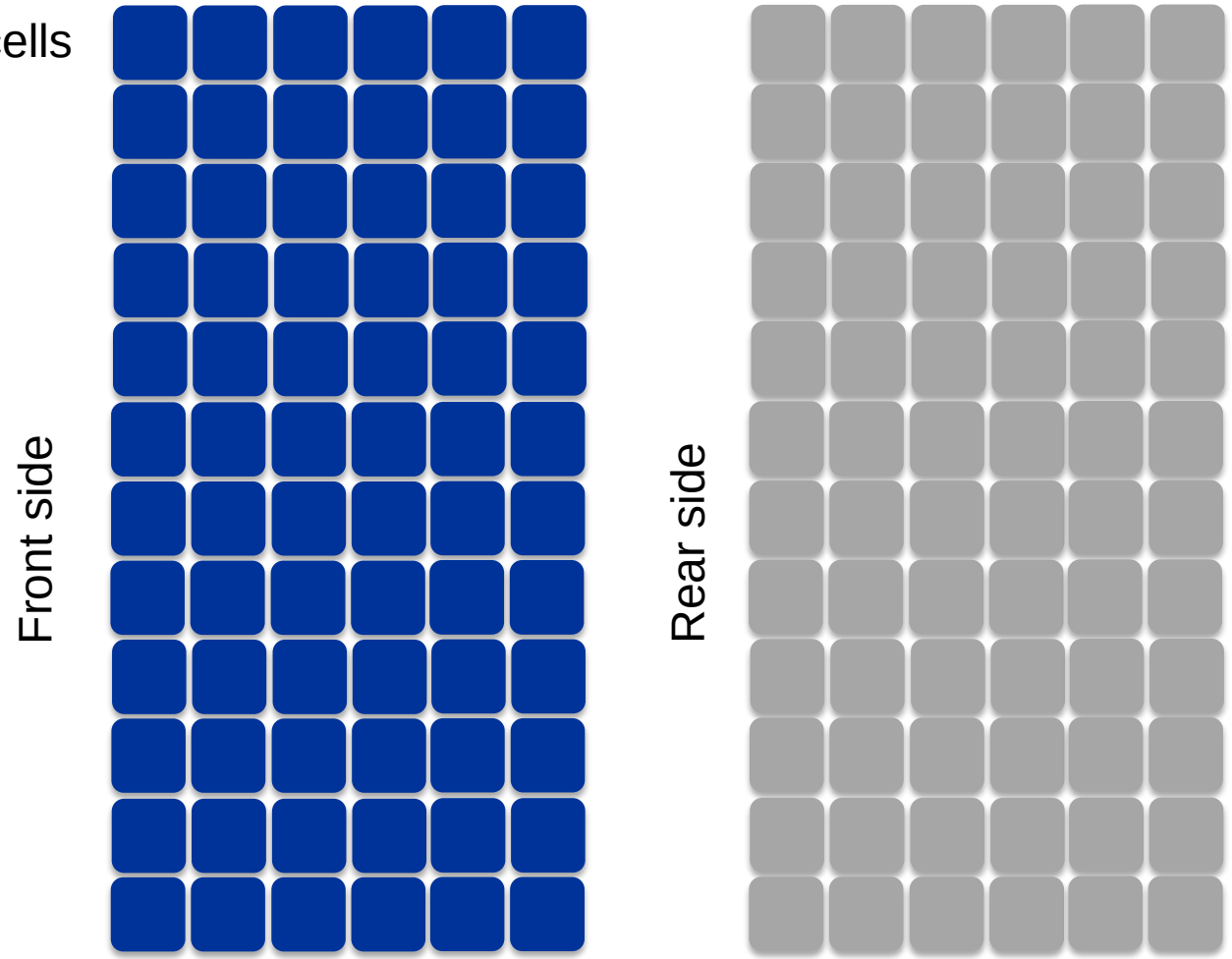
Components



Bifacial module technologies

Standard module

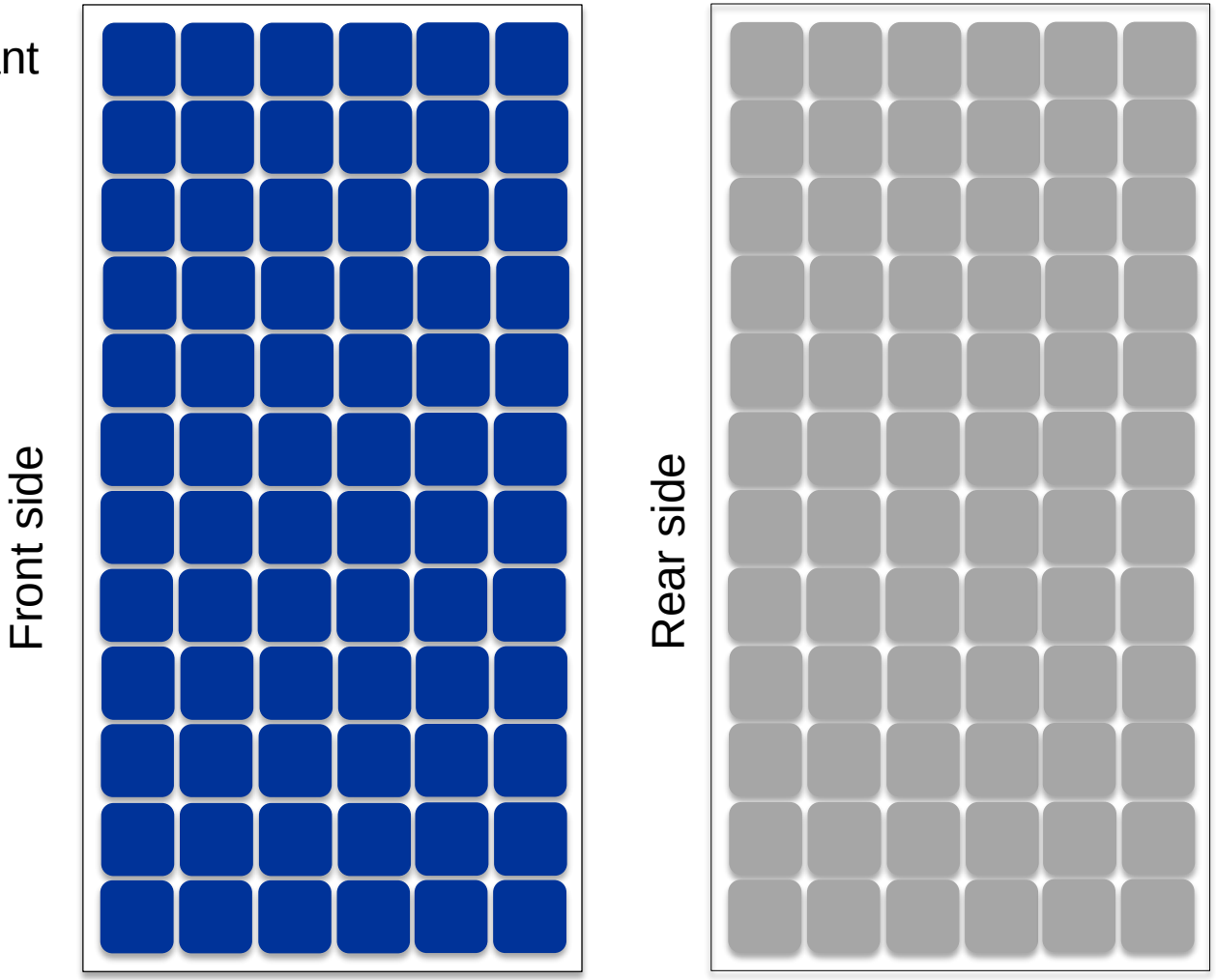
72 Solar cells



Bifacial module technologies

Standard module

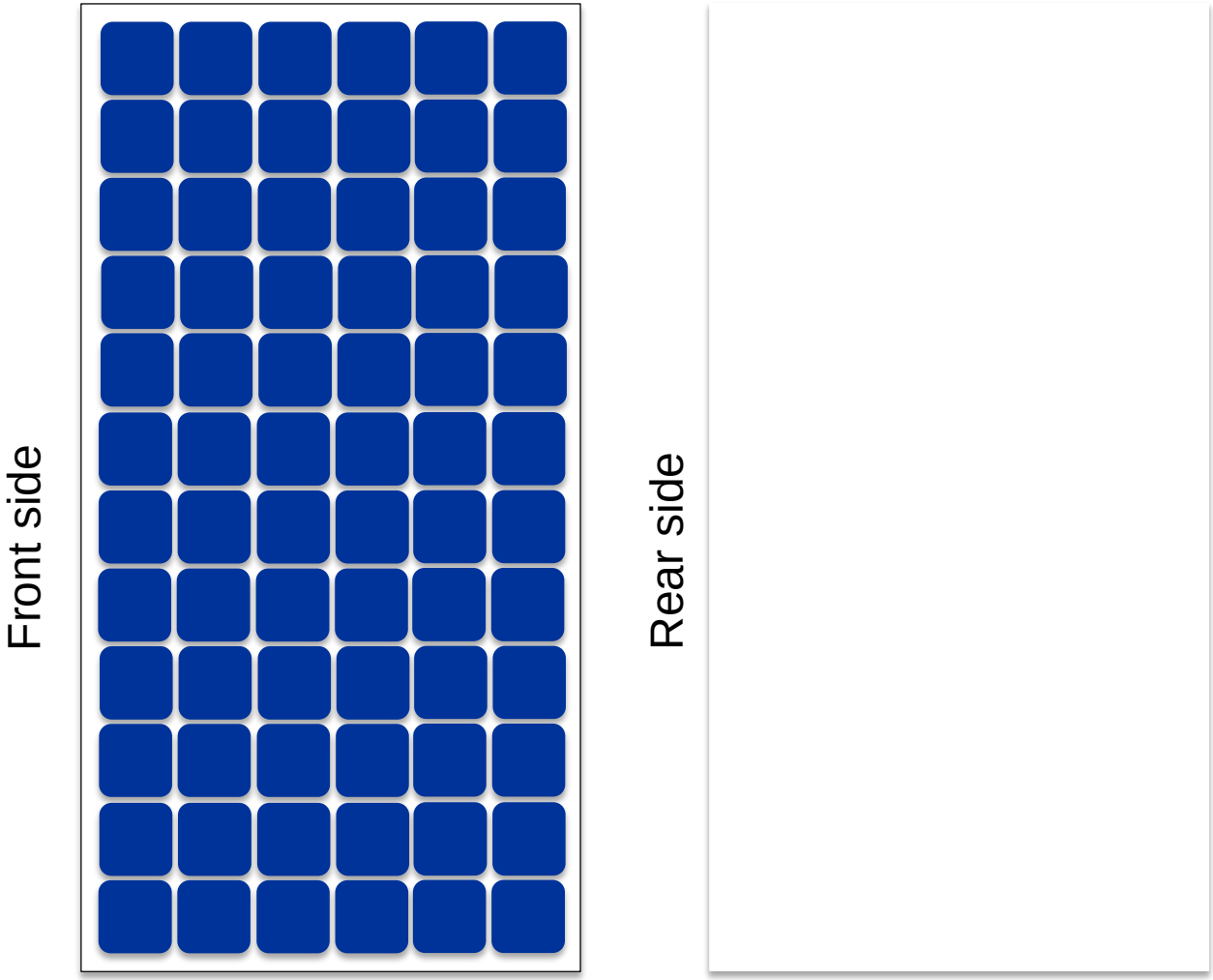
Encapsulant



Bifacial module technologies

Standard module

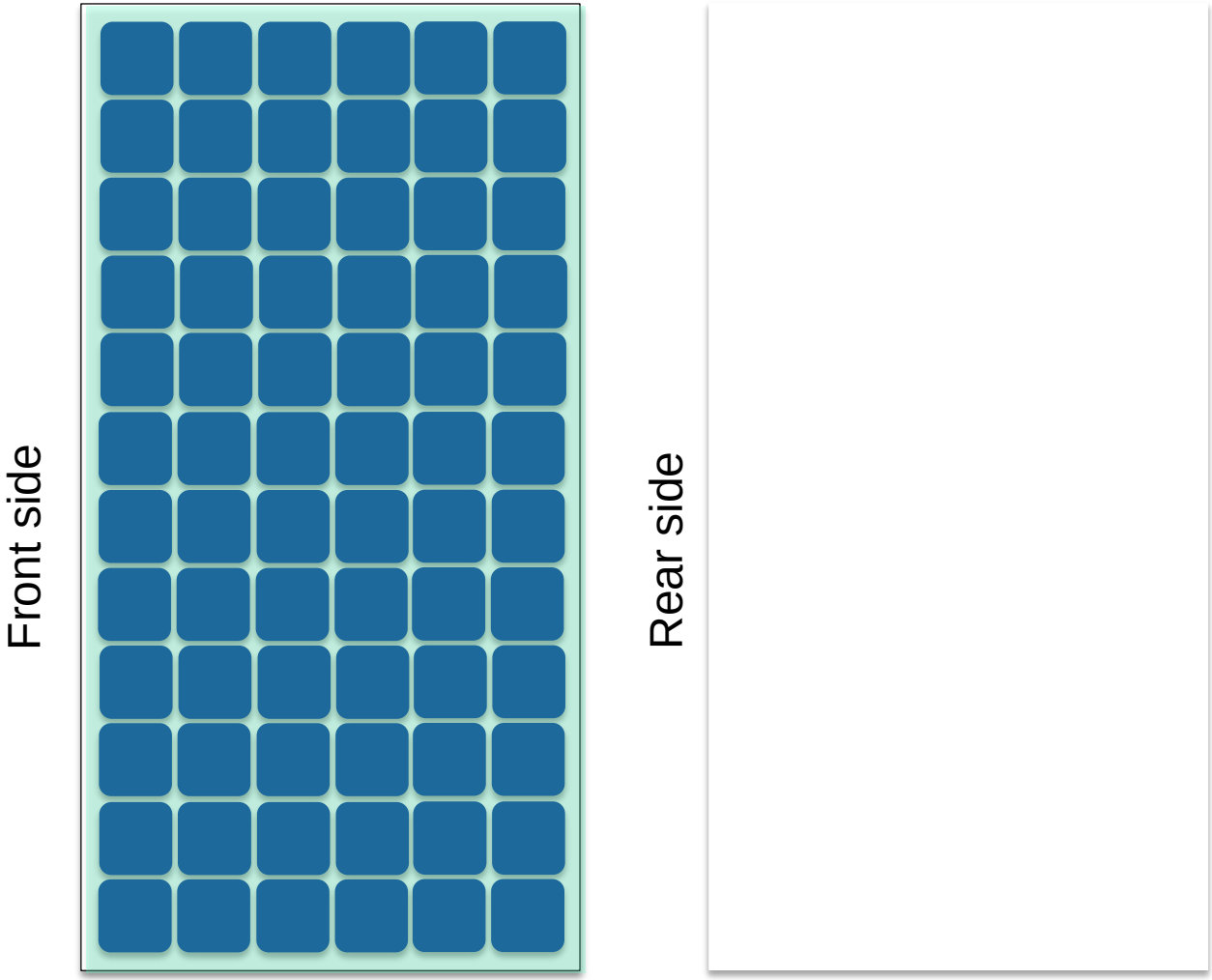
Backsheet



Bifacial module technologies

Standard module

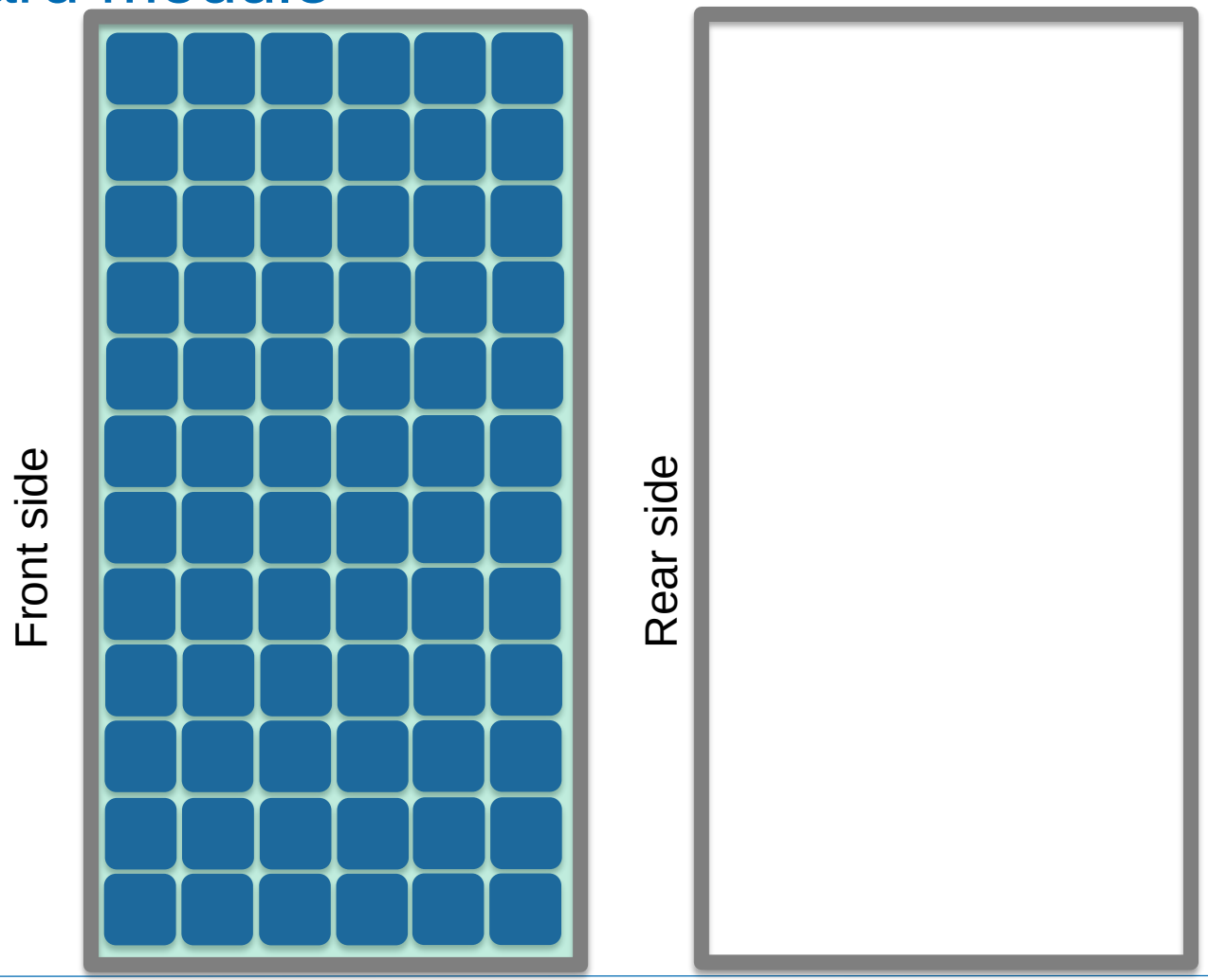
Glass



Bifacial module technologies

Standard module

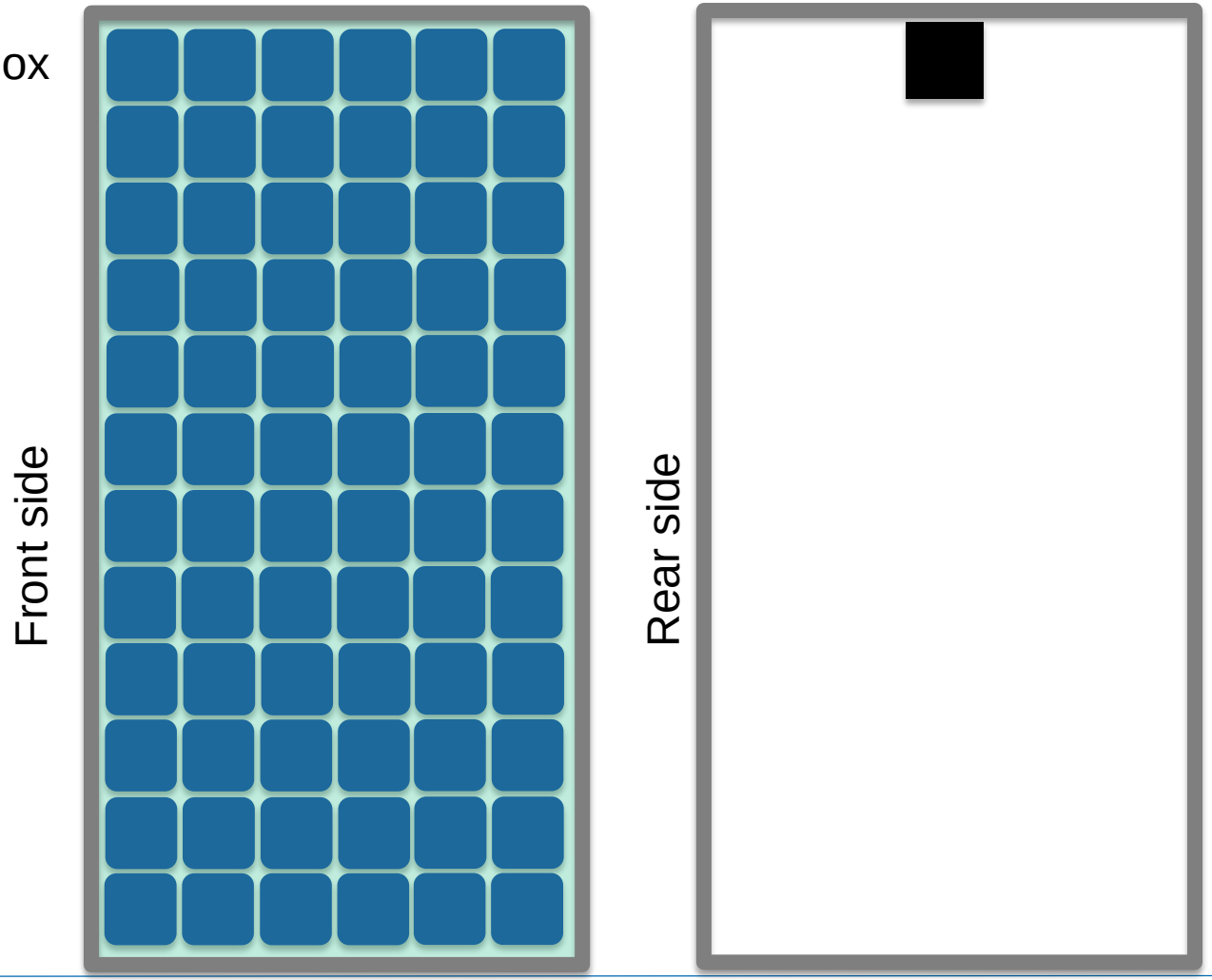
Frame



Bifacial module technologies

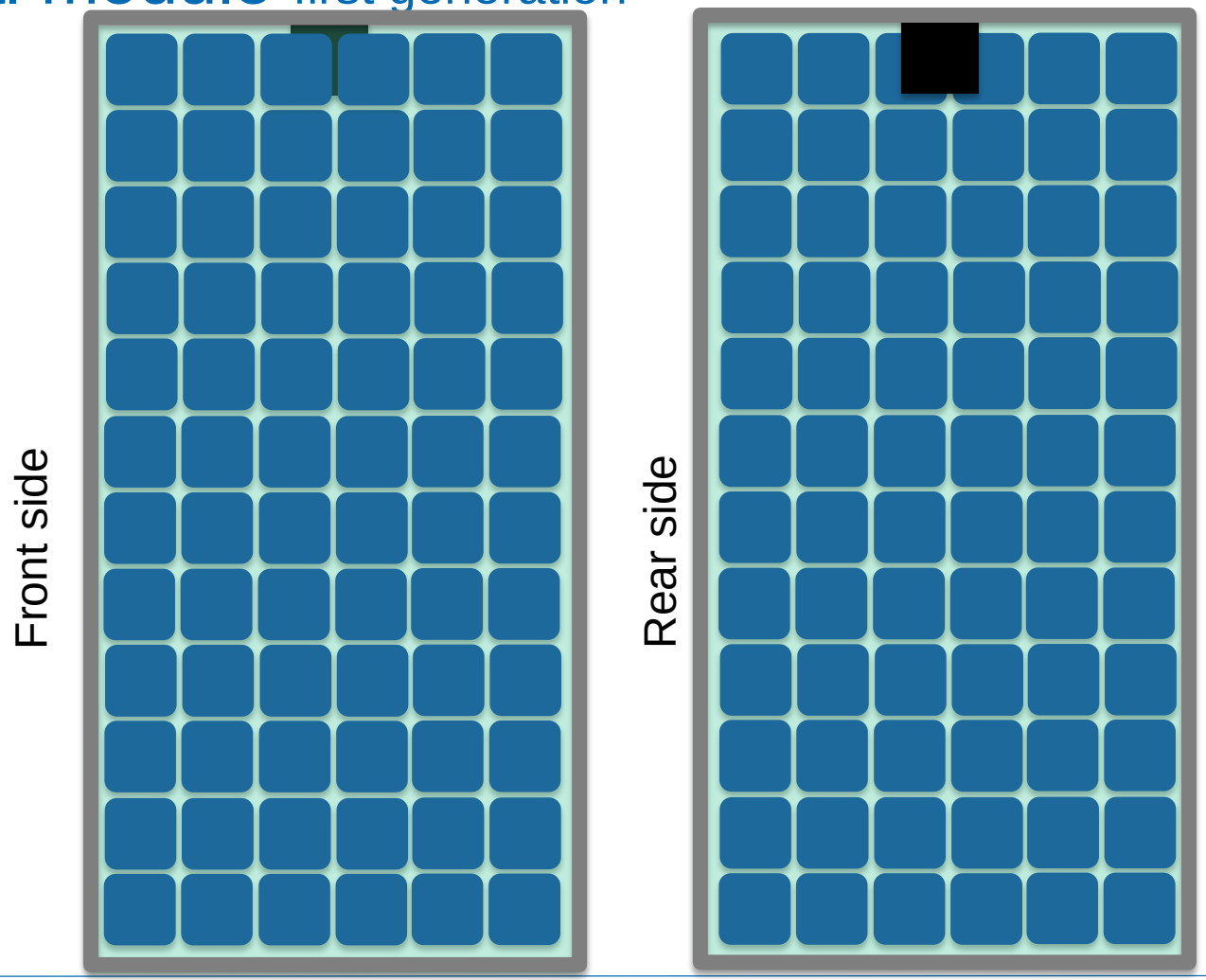
Standard module

Junction box



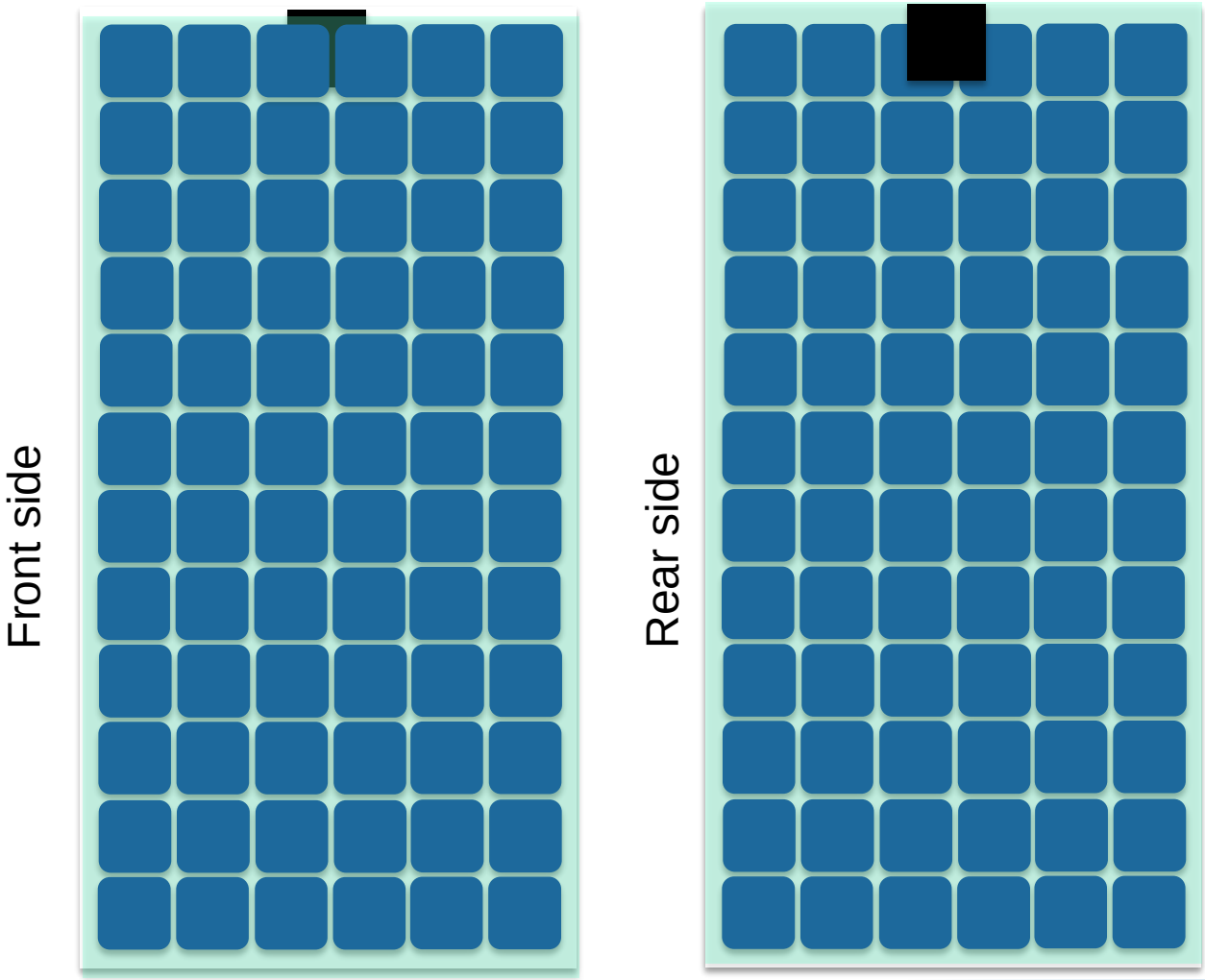
Bifacial module technologies

Bifacial module first generation



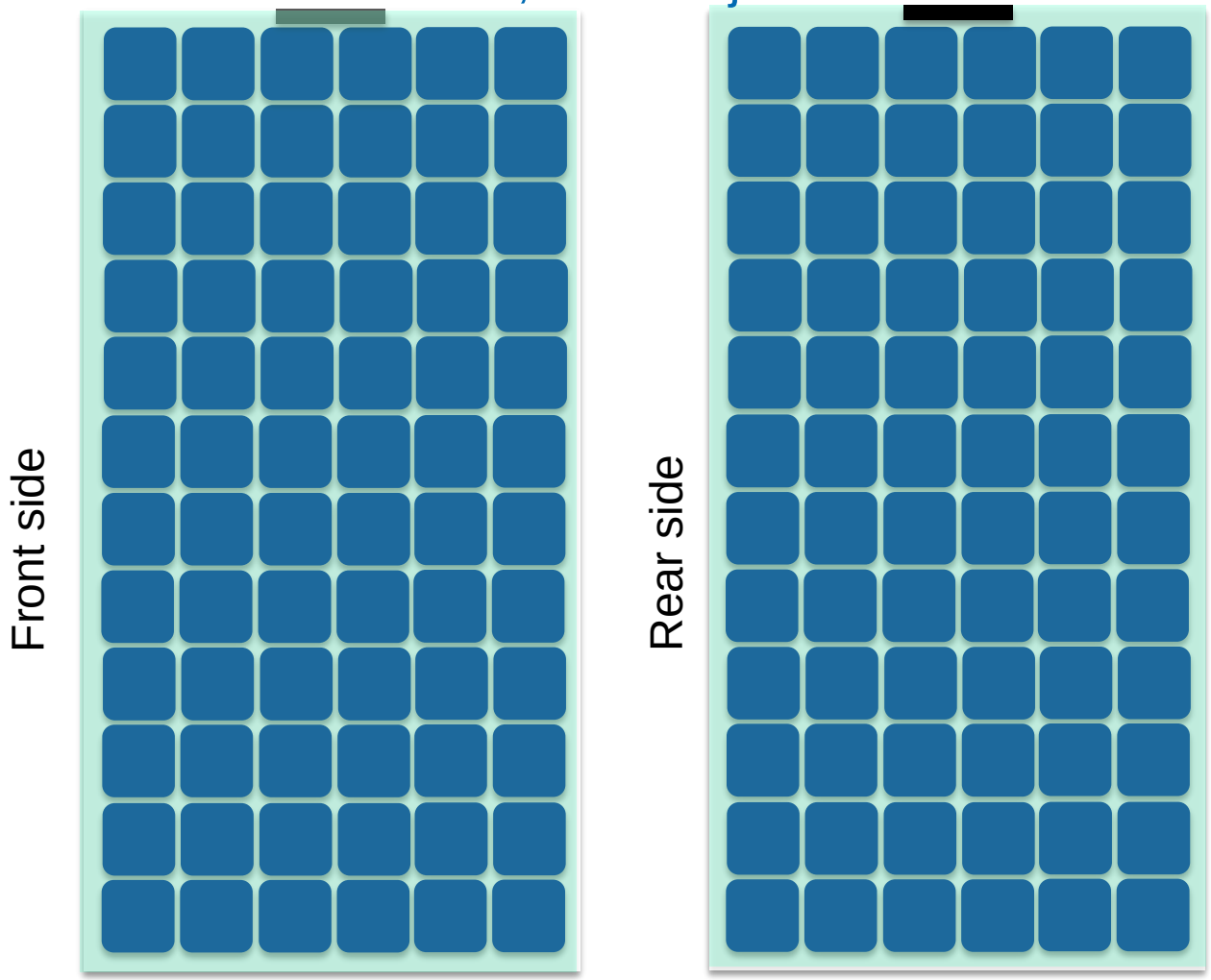
Bifacial module technologies

Bifacial module frameless



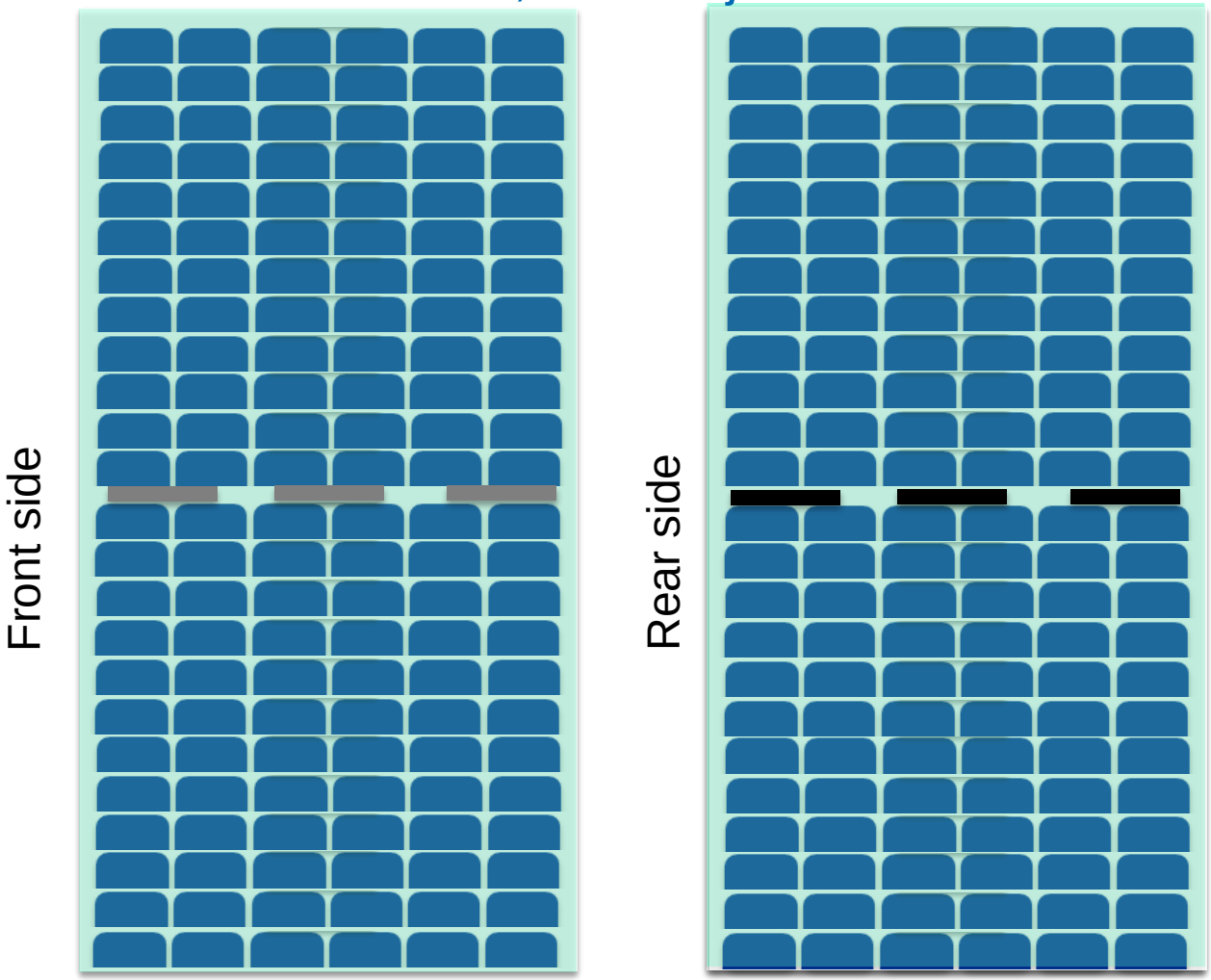
Bifacial module technologies

Bifacial module frameless, shallow junction box



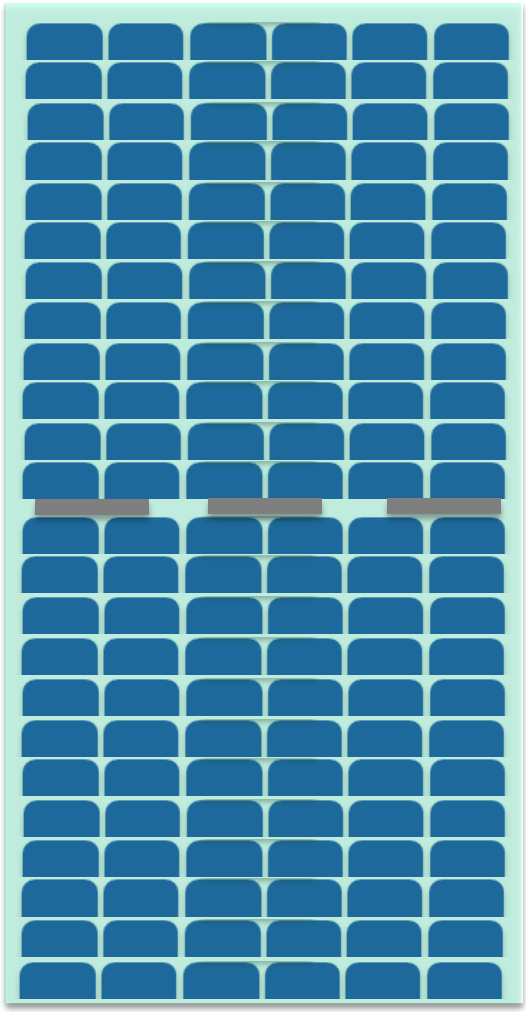
Bifacial module technologies

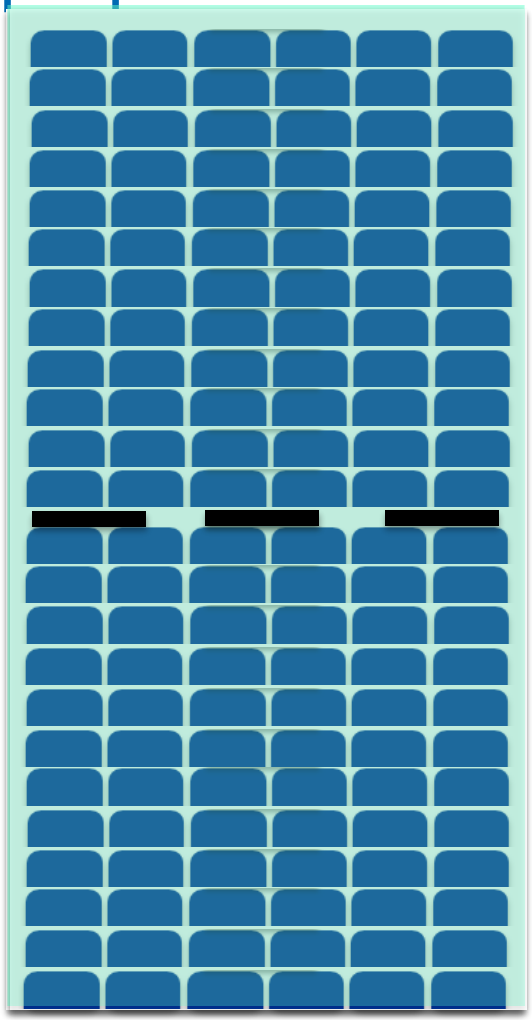
Bifacial module frameless, shallow junction box and half cells



Bifacial module technologies

Bifacial module: properties





- **frameless**
(or with frame)

- **double glass**
(or transparent backsheet)

- **shallow junction box**
(or more boxes)

- **Polyolefin**
(or EVA)

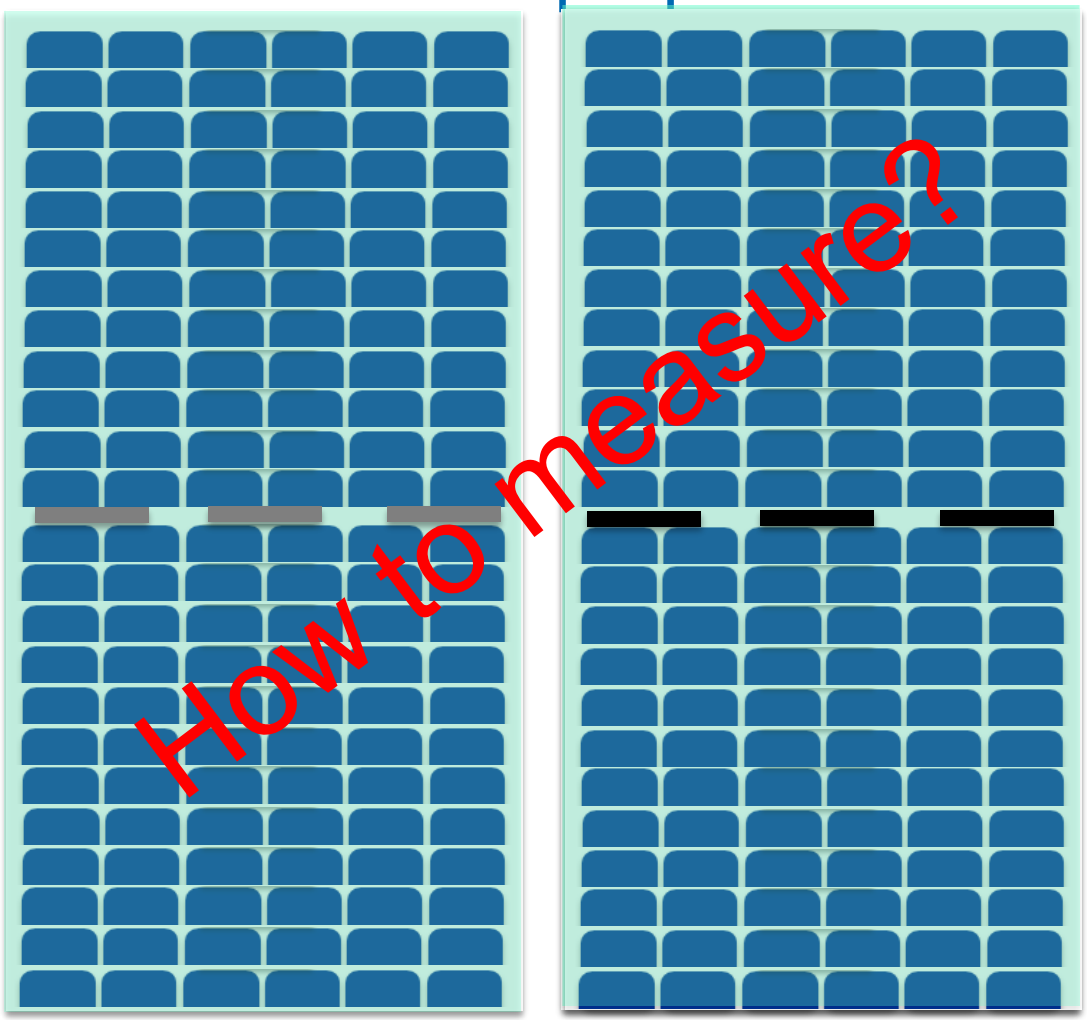
- **n-type solar cells**
(or p-type)

- **5 BB solar cells**
(or multi BB, or shingling)

- **half cells**
(or full cells)

Bifacial module technologies

Bifacial module: properties



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(or full cells)

Bifacial module technologies: standard

International Solar Energy Research Center Konstanz

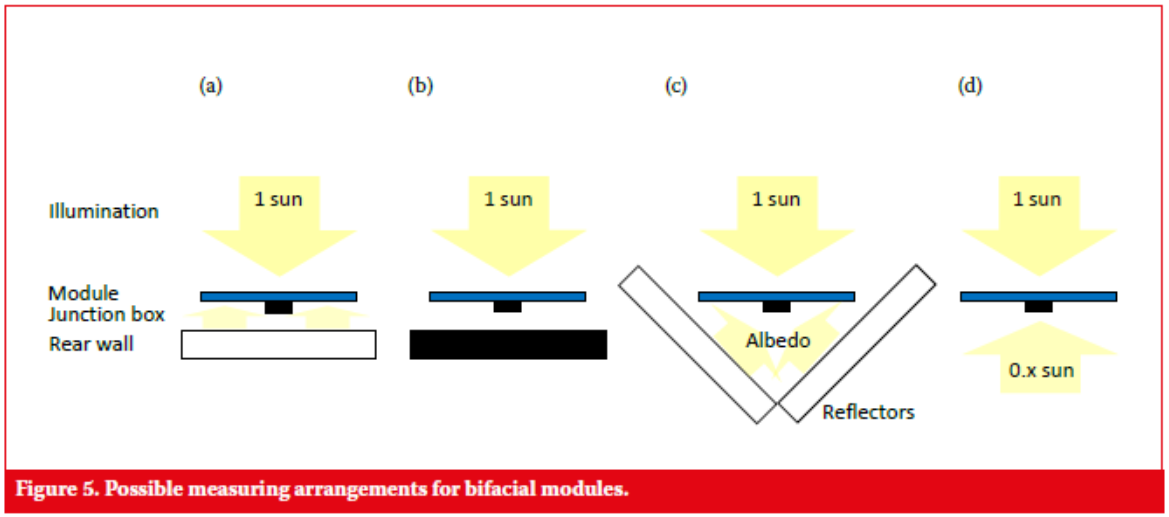

Figure 5. Possible measuring arrangements for bifacial modules.

R. Kopecek et al., PVI37, September 2017

Possible measurements

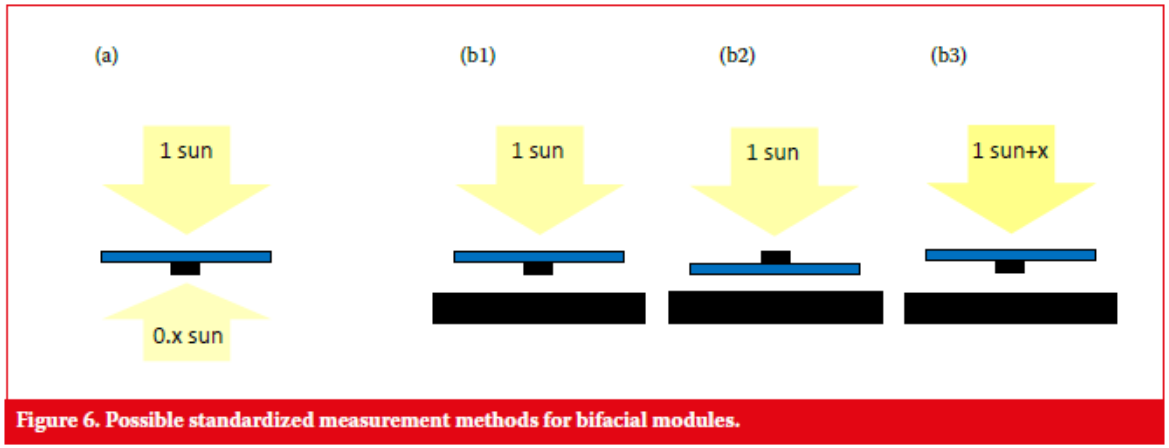

Figure 6. Possible standardized measurement methods for bifacial modules.

Standards: Vahid and now Pasan in lead

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electricity costs from PV (utility scale)

International Solar Energy Research Center Konstanz

for 1500-2000 kWh/kWp

electricity costs from PV (utility scale)

International Solar Energy Research Center Konstanz

for 1500-2000 kWh/kWp

summary

International Solar Energy Research Center Konstanz

- c-Si solar cells in future will be bifacial anyhow

- many companies are already producing bifacial cells: PERC+, nPERT, HJT and soon IBC

- PERC will become Nr.1 technology in 2018/2019

- many modules in future will be double glass based anyhow

- the system kWh can be extremely increased by using bifacial modules and/or simple tracking in addition

- in total >1GWp large bifacial systems are already installed

>> EVAUATION OF EXISTINING SIMULATION PROGRAMS ARE NEEDED TO MAKE BIFACIALITY MORE BANKABLE


Bifacial HSAT is the way to go for LCOEs below 1ct/kWh