Bifacial World 2016

Summary and Status

Radovan Kopecek et al.

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

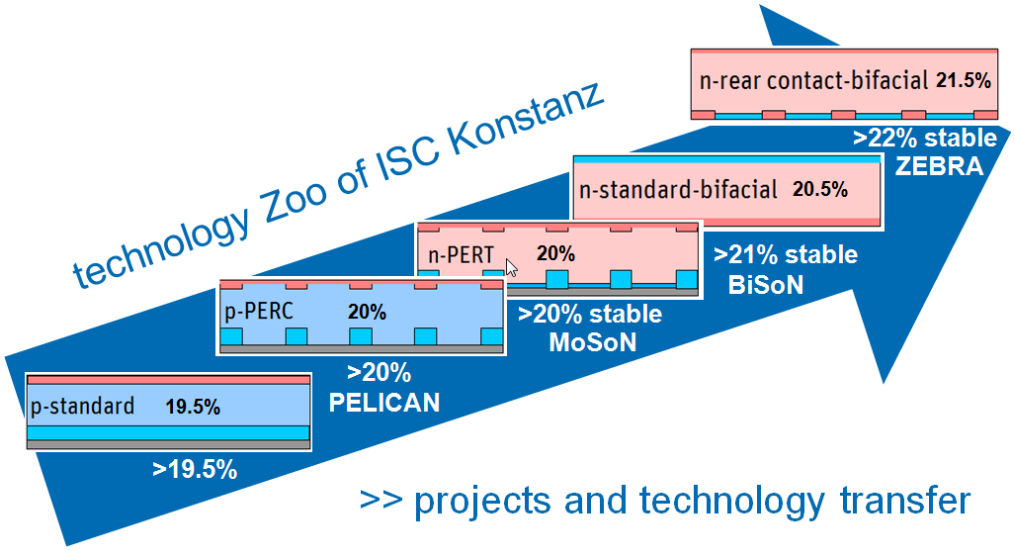
ISC Konstanz: who we are

International Solar Energy Research Center Konstanz

International Solar Energy Research Center e.V.

– a nonprofit organization
– Founded in 2005
– R&D on c-Si solar cells, modules and systems
– Technology transfer

– About 50 employees
– Turnover about 4 Mio€/a



cells

modules

systems

ISC Konstanz: workshop organisation

International Solar Energy Research Center Konstanz

1) Metallisation workshop started in 2008

2) nPV workshop started in 2011

3) bifiPV started in 2012

Goals of such focused workshops

International Solar Energy Research Center Konstanz

1) Industry and institutes present new results and findings

2) Platform for discussions and business

nPV WS: April 5/6, 2017 in Freiburg

International Solar Energy Research Center Konstanz

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

linked to: SiliconPV 2017

bifiPV workshops

International Solar Energy Research Center Konstanz

1) bifiPV 2012 in Konstanz (120 people)

2) bifiPV 2014 in Chambery (80 people)

3) “bifiPV 2015” in Antofagasta (40 people)

4) bifiPV 2016 in Miyazaki (ca. 80 people?)

all presentations at

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

bifiPV 2014 in Chambery

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2016
bifi PV
workshop
Miyazaki

bifiPV 2016: sponsors

International Solar Energy Research Center Konstanz

media partners:

bifiPV 2016: facts

International Solar Energy Research Center Konstanz

1) Visitors: ca. 80 from ?? countries

2) Sessions: 7

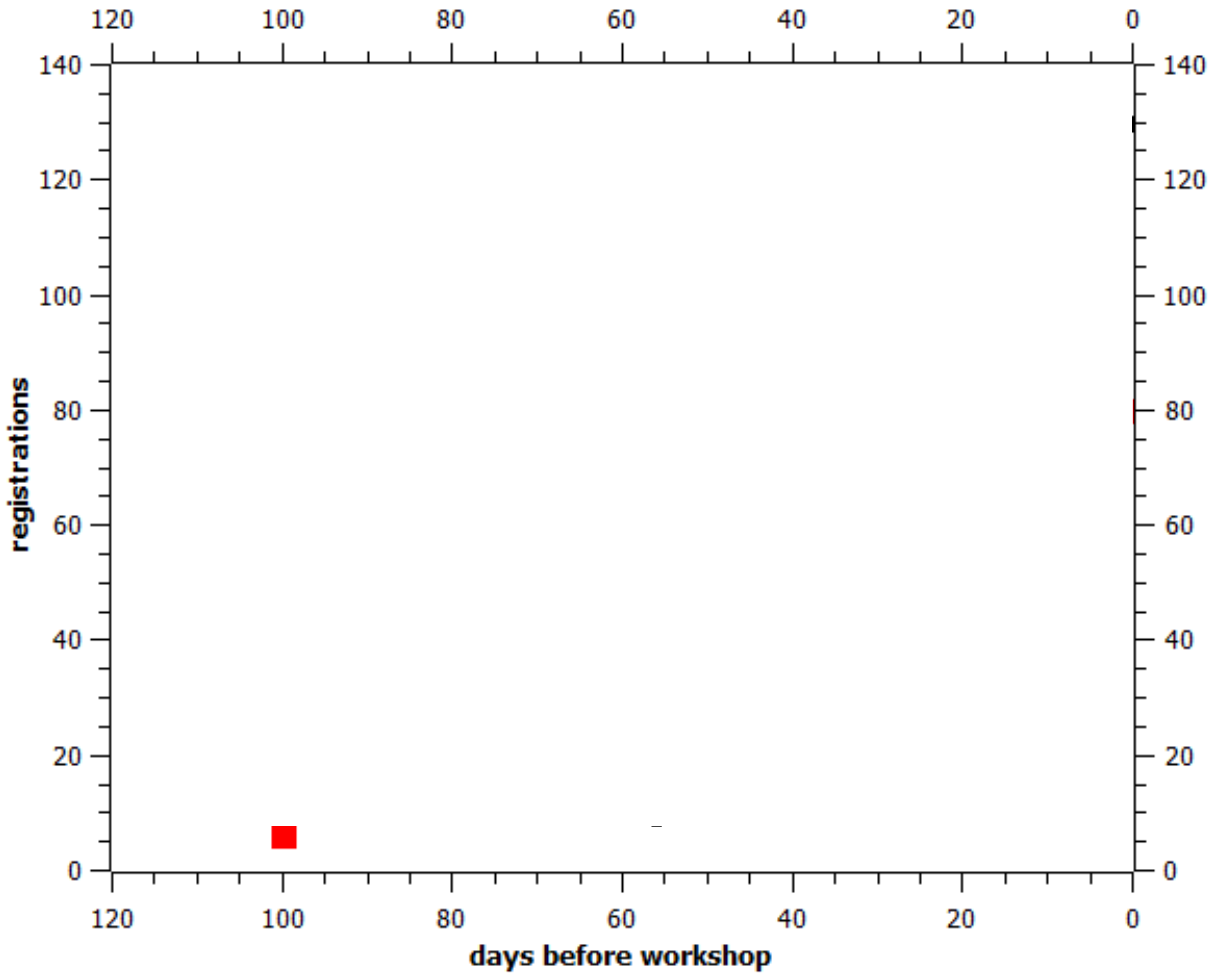
- Motivation
- **Systems and Bankability**
- **Cells and Modules**
- Group discussion
- **Simulations**
- **Standards**
- Round table standards

3) Presentations: 32

4) Lots of DISCUSSION

bifiPV 2016: registrations in time

International Solar Energy Research Center Konstanz



bifiPV 2016: registrations in time

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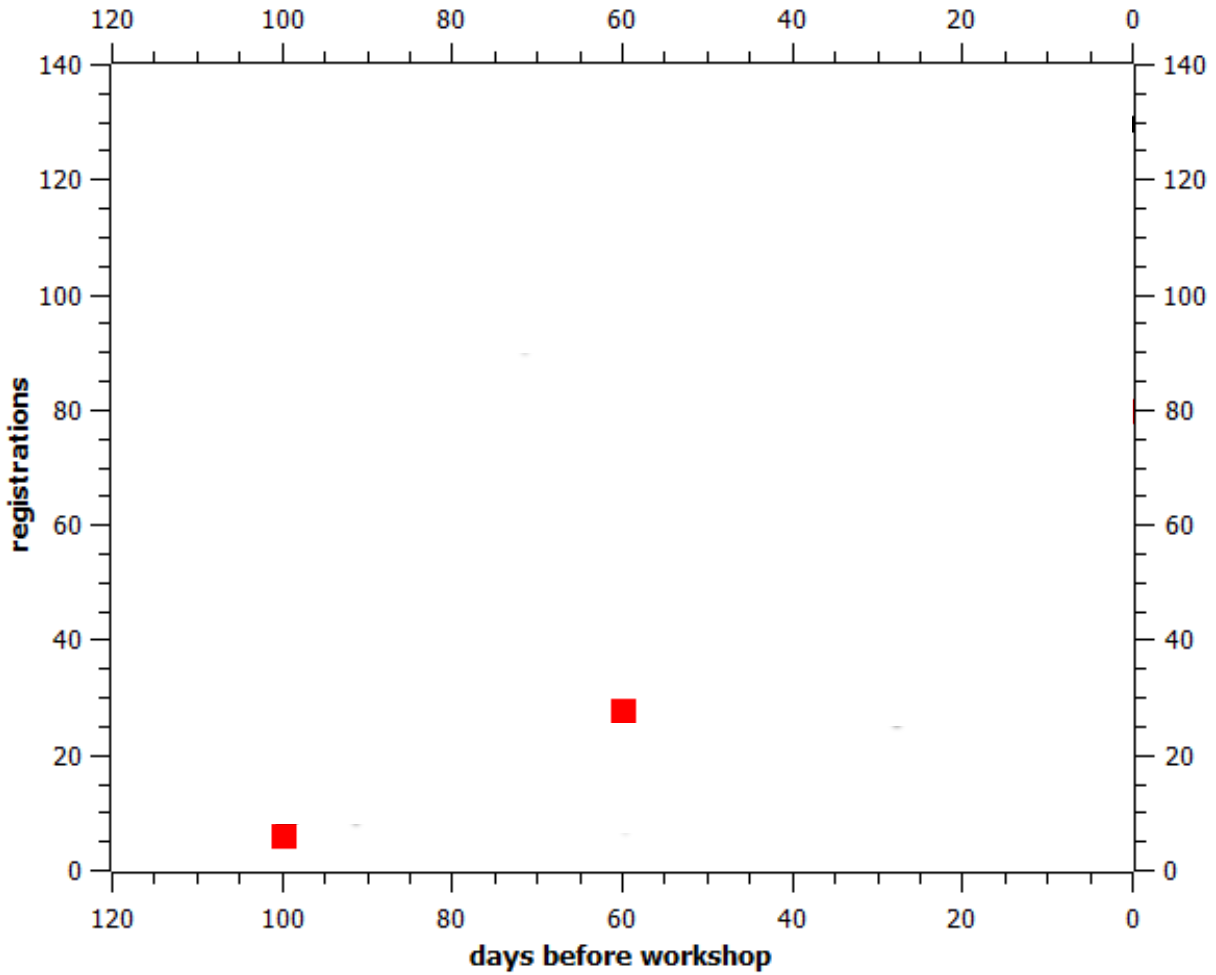

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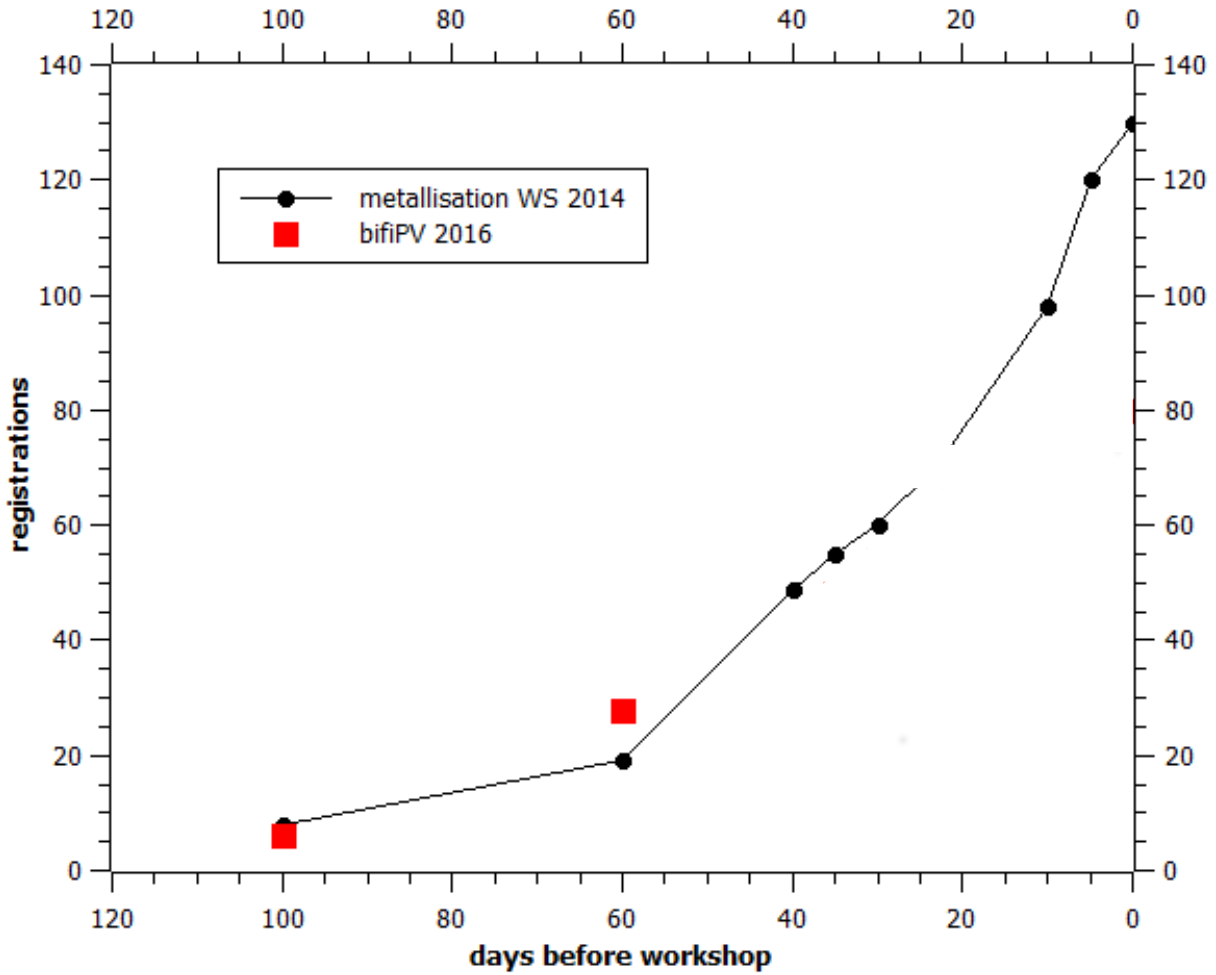

bifiPV 2016: registrations in time

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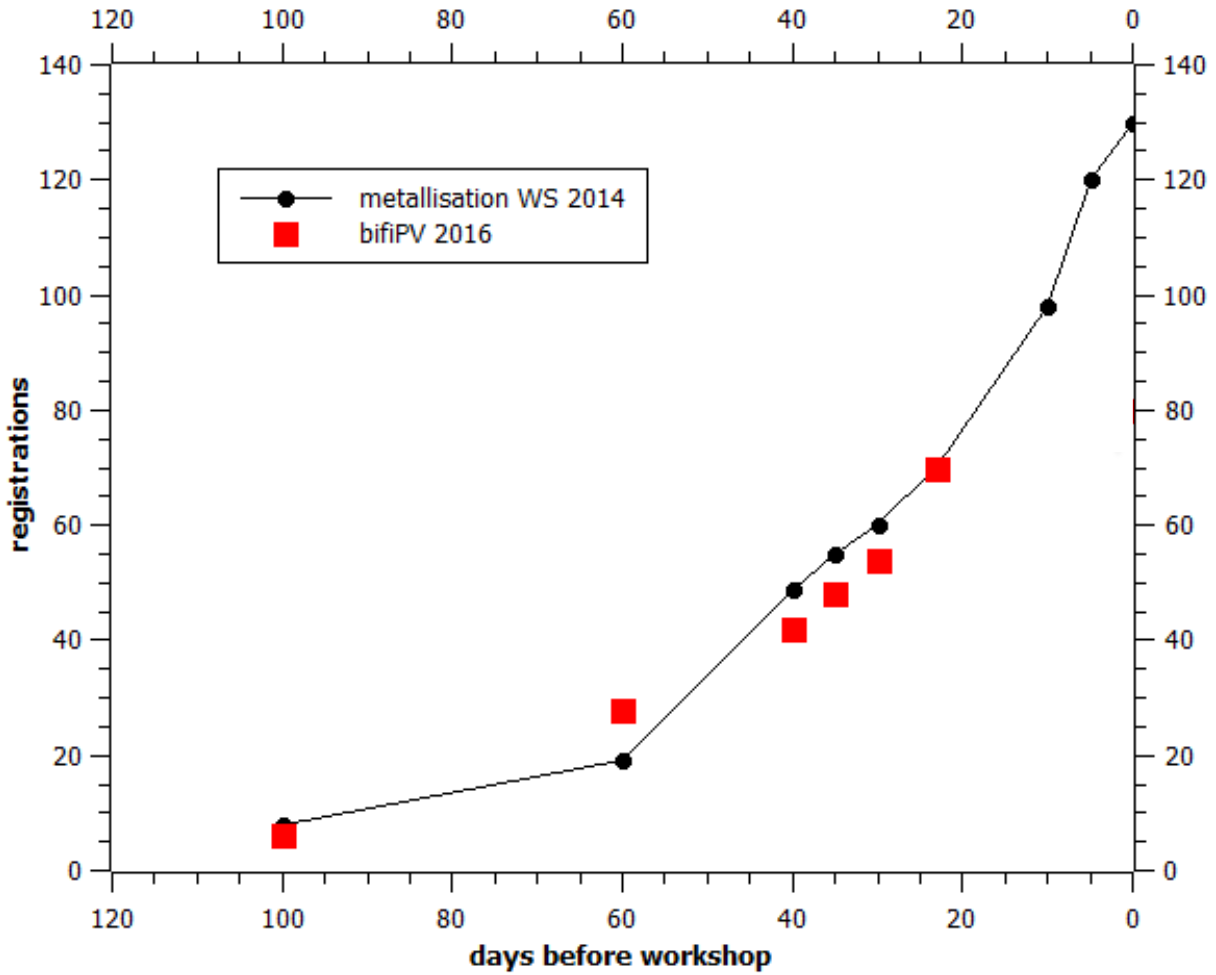

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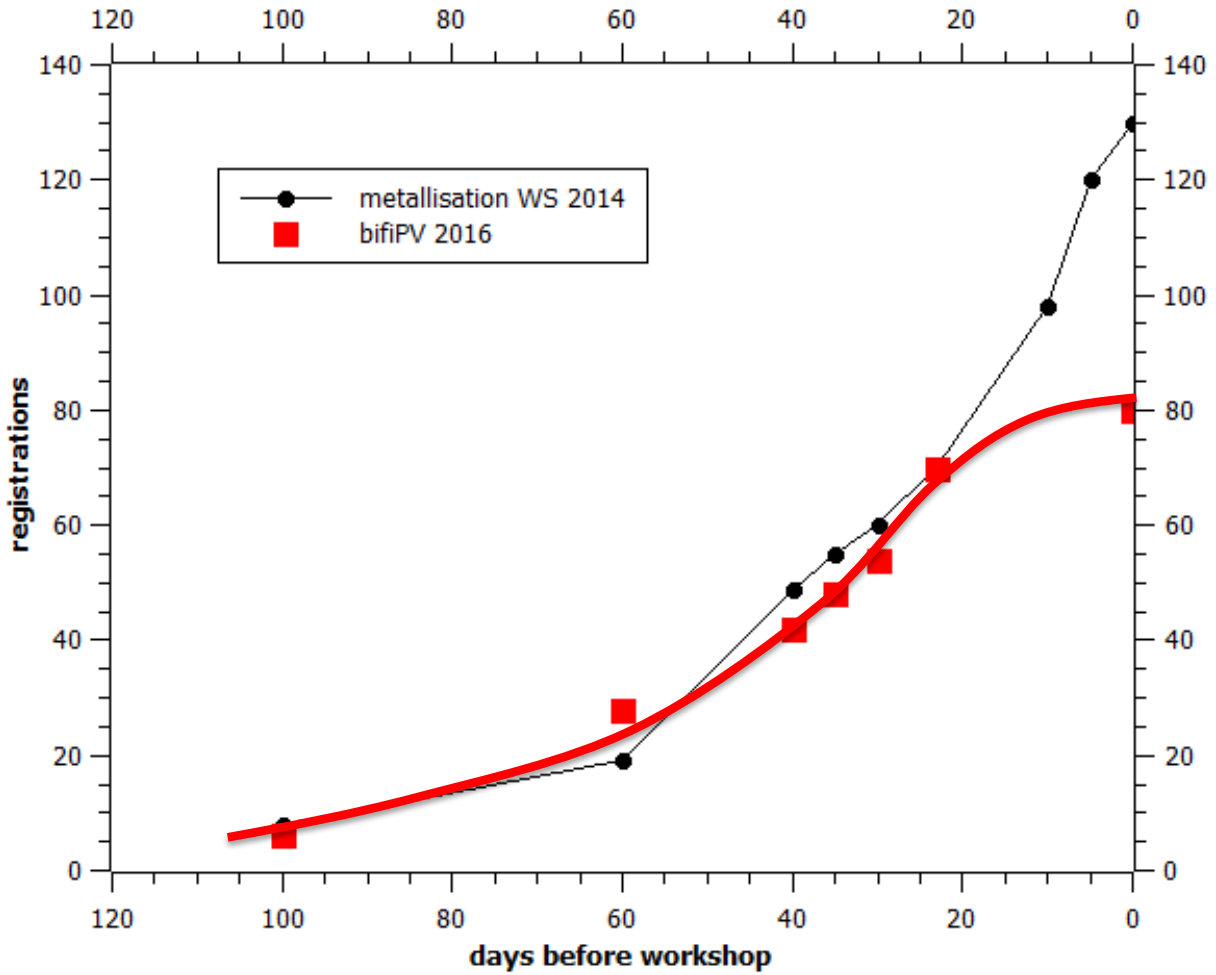
International Solar Energy Research Center Konstanz



bifiPV 2016: Thursday program

International Solar Energy Research Center Konstanz

DAY 1: 29.09.2016

		Session/Title	Speaker	Company
		1: Opening		
08:30	08:40	Welcome to Miyazaki and opening of 3rd bifiPV 2016	K Nishioka	Uni Miyazaki
		2: Motivation N Ishikawa		
08:40	09:00	PV market 2016: room for innovations?	A Teppe	RCT
09:00	09:20	bifacial PV world 2016: summary of status	R Kopecek	ISC Konstanz
		3: Systems and bankability -1 R Kopecek / A Teppe		
09:20	09:40	Review of bifacial systems	J Libal	ISC Konstanz
09:40	09:55	Largest bifacial PV System and its technology	A Sinha	Sunpreme
09:55	10:10	1.25 MWp bifacial PV system in Japan	N Ishikawa	PVGS
10:10	10:25	Bifacial tracking system in snowy region	N Ishikawa	PVGS
20 min coffee break				
		3: Systems and bankalility -2 R Kopecek / A Teppe		
10:45	11:00	Monitoring of bifacial systems in different configurations	Y Veschetti	CEA-INES
11:00	11:15	Bankability evaluation on Japanese PV system including bifacial application	T Ohigashi	RTS
11:15	11:30	Reduction of risk by choosing the right technical components	A Richer	Meyer Burger
11:30	11:50	Discussion of Session 3		
70 min LUNCH				
		4: Solar cells and modules -1 N Ishikawa / I Romijn		
13:00	13:20	Review on bifacial cells	Y Veschetti	CEA-INES
13:20	13:35	Industrial high efficiency N-type bifacial solar cell with selective back surface field (SBSF)	D Liu	Yingli
13:35	13:50	High efficient bifacial multicrystalline p-type cells in industrial pilot production	A Teppe	RCT
13:50	14:05	Opportunity and Challenge: >21% large-area n-type PERT bifacial solar cells in research and production	Y Chen	TRINA
14:05	14:20	SERIS bifacial photovoltaic module: advanced light management for superior front and rear side performance	K Y Sheng	SERIS
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		4: Solar cells and modules -2 N Ishikawa / I Romijn		
14:40	15:00	Review on bifacial modules	I Romijn	ECN
15:00	15:15	PERC Bifacial PV: BiFi Cell, module, and system	A Hsu	NSP
15:15	15:30	Bifacial High-efficiency Panels based on First Solar´s "Tetrasun" Technology	L Podlowski	First Solar
15:30	15:45	Heterojunction cells combined with smart wire bifacial modules	A Waltinger	Meyer Burger
15:45	16:00	315W 60-cell bifacial module using N-type mono cells with 21.5% efficiency manufactured on production scale equipment	A Hsu	REC
16:00	16:15	DSM materials application in Bifacial modules light management	M Mrcarica	DSM
16:15	16:35	Discussion of Session 4		

20 min coffee break

16:55	17:30	**5: GROUP discussion about bifacial future** Y Veschetti 4 group brain storming led by the organizers: N Ishikawa, I Romijn, R Kopecek, Y Veschetti	
17:30		closing of first day / info about dinner etc.	K Nishioka

19:00 DINNER

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Outline

International Solar Energy Research Center Konstanz

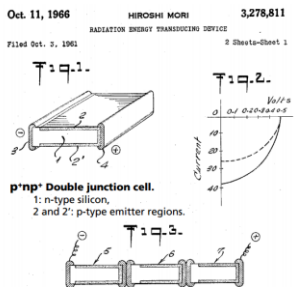
1) **Bifaciality- why not more wide spread?**
2) **Companies involved in bifaciality**
3) Chile - a bifacial country?
4) Bifacial book
5) **How to bring bifaciality more into the market?**

BIFACIALITY

bifacial history

International Solar Energy Research Center Konstanz

1974-2000 russian space applications



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1966 bifacial cell proposals

1954 bifacial n-type IBC

Gerald Pearson, Darryl Chapin, and Calvin Fuller testing their silicon solar cell.

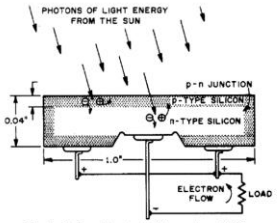
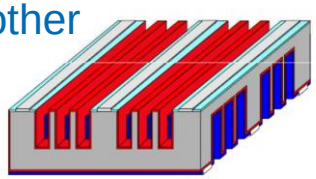


Fig. 2. Schematic of early silicon solar cell [8].

Cross section of the first cell:
- Arsenic-doped n-type base
- Boron-doped emitter

1998 bifacial installations Nordmann in Switzerland

2000+ bifacial concepts
UKN- POWER 2001
ISFH- OEKO 2003
ANU- SLIVER 2003
ISC/ECN- FOXY2007
and other



2010+ first bifacial cell production

2012
first bifiPV

2013 large bifacial installations in Japan

2014 2nd bifiPV

2015 bifacial cell productions

Radovan Kopecek, bifiPV2016, Miyazaki, September 29, 2016

Kopecek at al., PV international from December 2014

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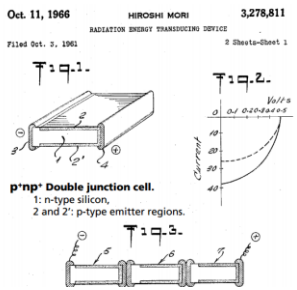

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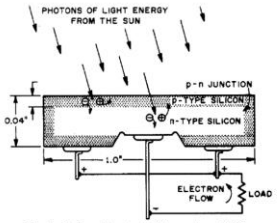

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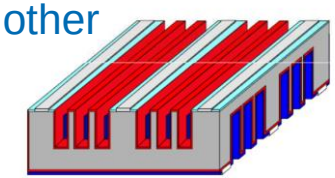

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Radovan Kopecek, bifiPV2016, Miyazaki, September 29, 2016

Kopecek at al., PV international from December 2014

“new bifacial history” and future

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monofacial

bifacial

BIFACIAL!!

2000

2015

- No albedo!!
- Too expensive!
>> NONSENSE

- up to 30% gain
- save BOS
>> **FUTURE TECHNOLOGY**

2030+

monofacial

?

Bifaciality: a natural evolution

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1) Glass-Glass modules are coming anyhow
2) Solar cells are becoming bifacial anyhow

>> Bifaciality will come in the next 15 years

Bifaciality: a natural evolution

International Solar Energy Research Center Konstanz

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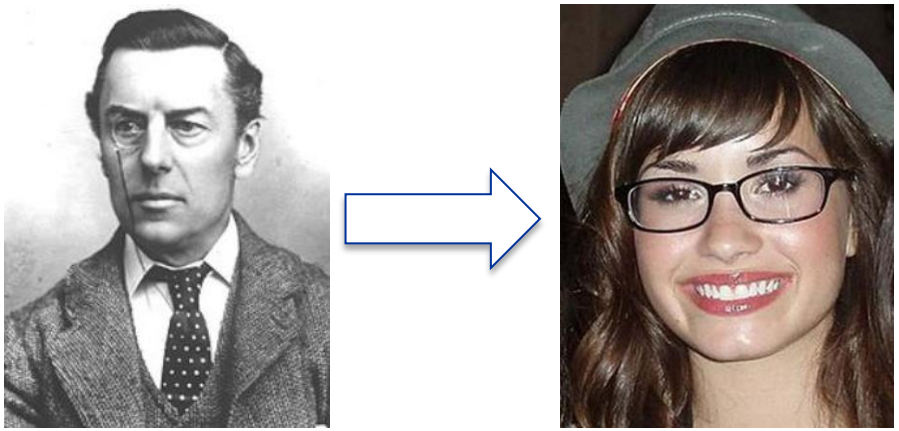

Bifaciality: a natural evolution

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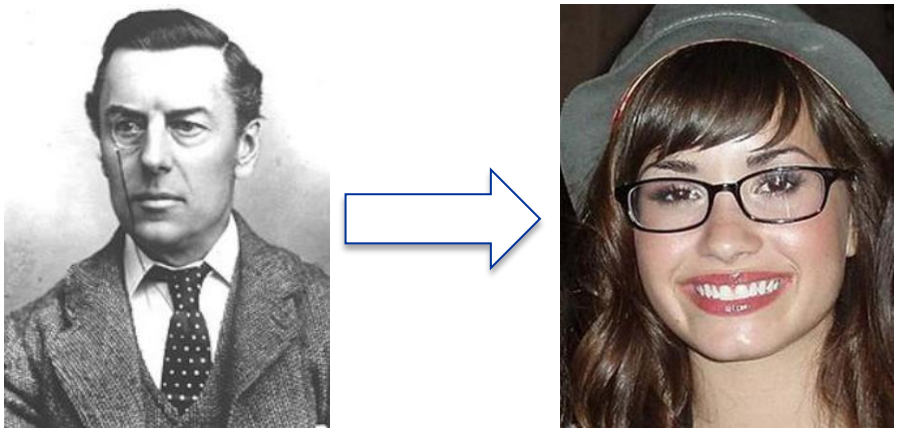

BUT: lack of standards, bankability and simulations and confusion information (5%-50% bifacial gain)

Companies: cell and module

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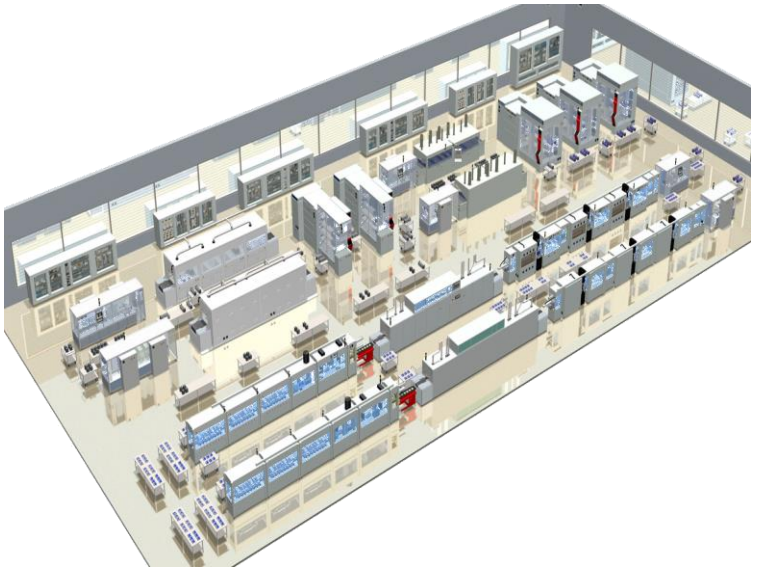
In production

1) **PVGS: PERT** (EarthON)
2) **Panasonic: HJ**
3) **NSP: PERT** and now **PERC+**
4) **Yingli: PERT** (Panda)
5) **Mission Solar: PERT**
6) MegaCell: PERT (BiSoN)
7) **Solarworld: PERC+** (Bisun)
8) **LG: PERT** (Neon)
9) **Sunpreme: HJ**
10) **HT-SAAE: PERT**
11) First Solar/Tetra Sun: HJ
12) **QXPV: PERT**
13) **Shanxi Lu´an: mcPERCT**
14) and others



In pilot

a) **Motech: PERT**
b) **TRINA: PERT**
c) **Tesla/Solar City?: HJ**
d) **REC: PERT**
e) and others

Cell concept with bifacial potential

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ITRPV

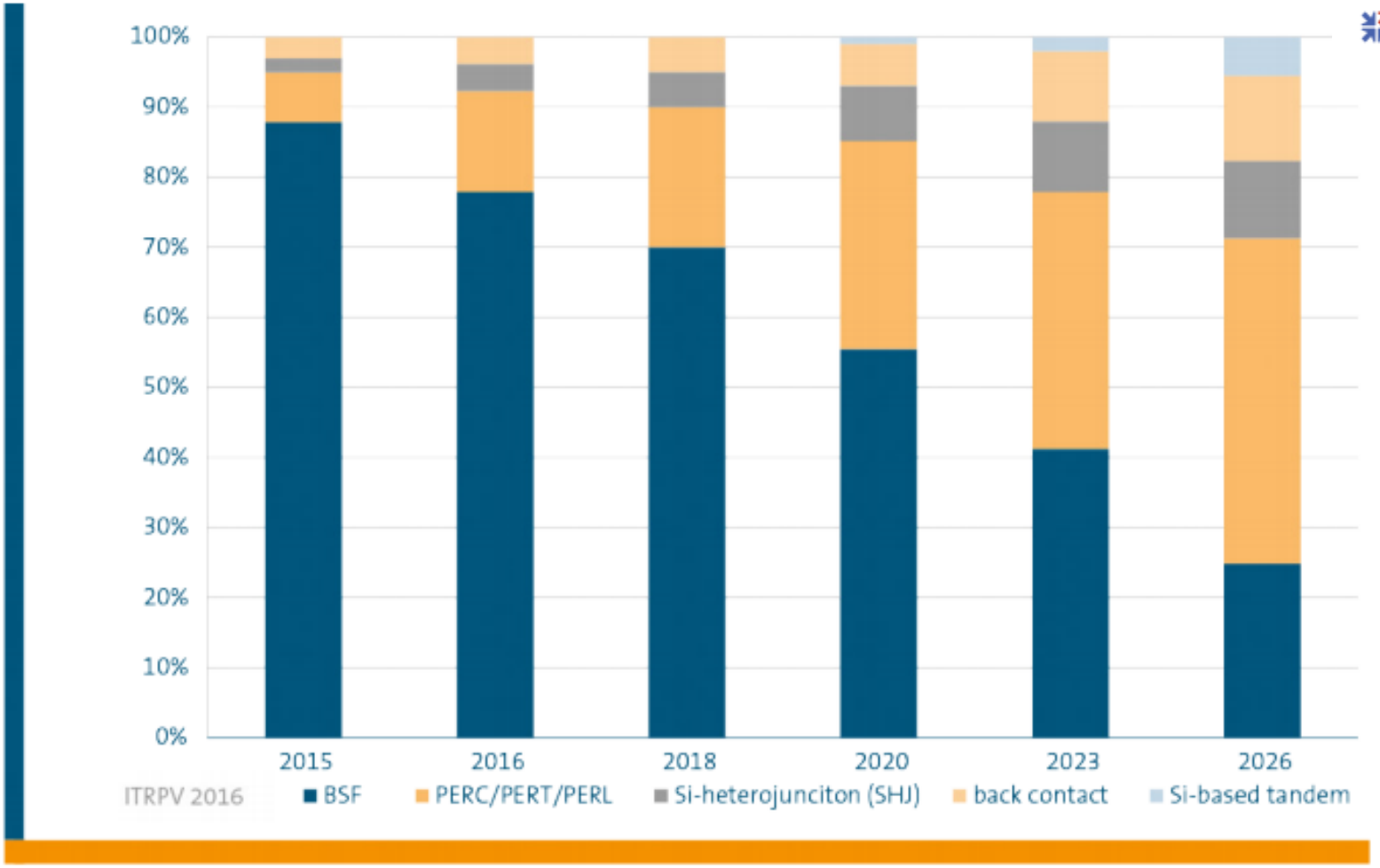

Fig. 33: Worldwide market shares for different cell technologies.

Cell concept with bifacial potential

International Solar Energy Research Center Konstanz

ITRPV

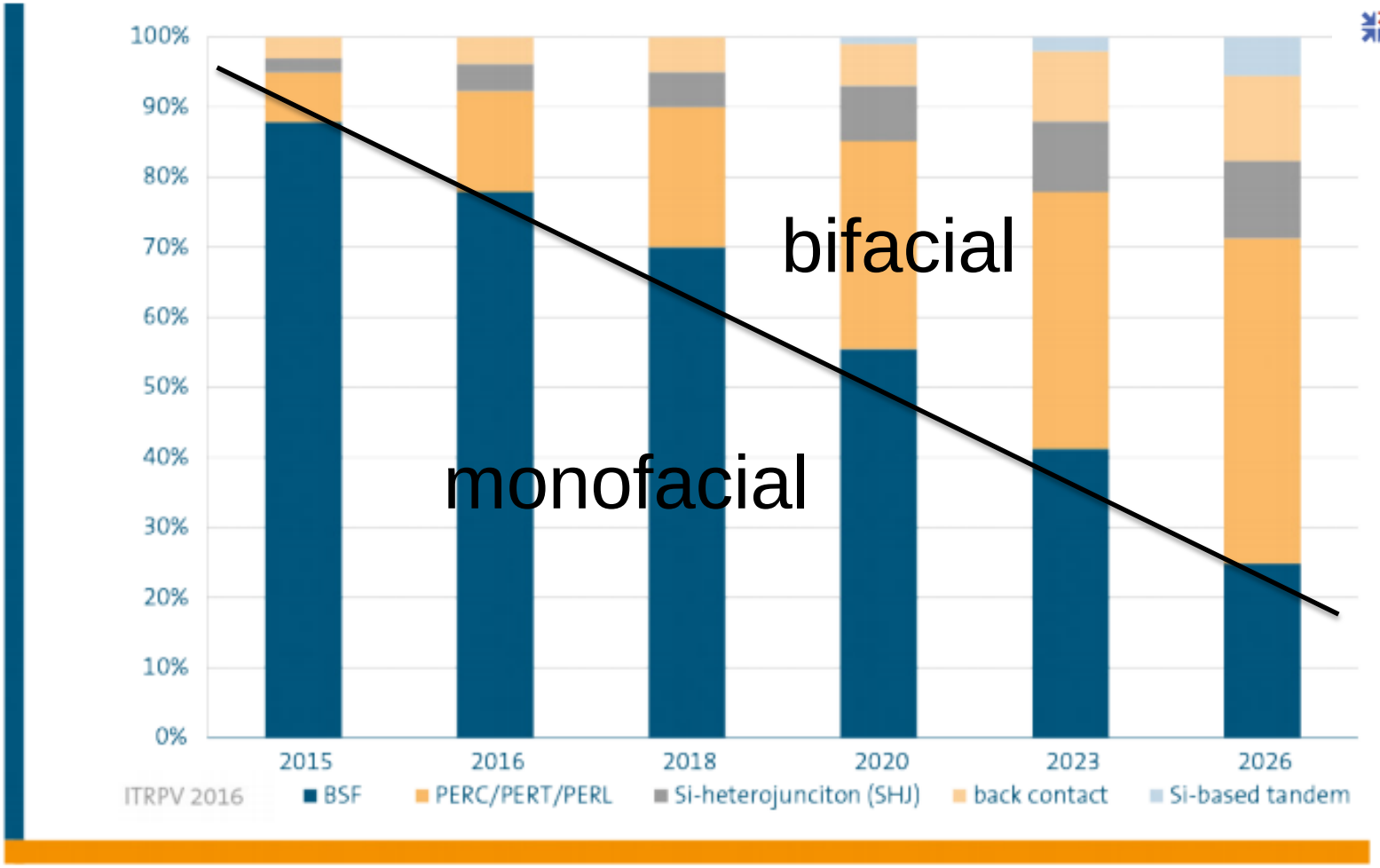

Fig. 33: Worldwide market shares for different cell technologies.

BIFACIAL GAIN

PV system close to equator

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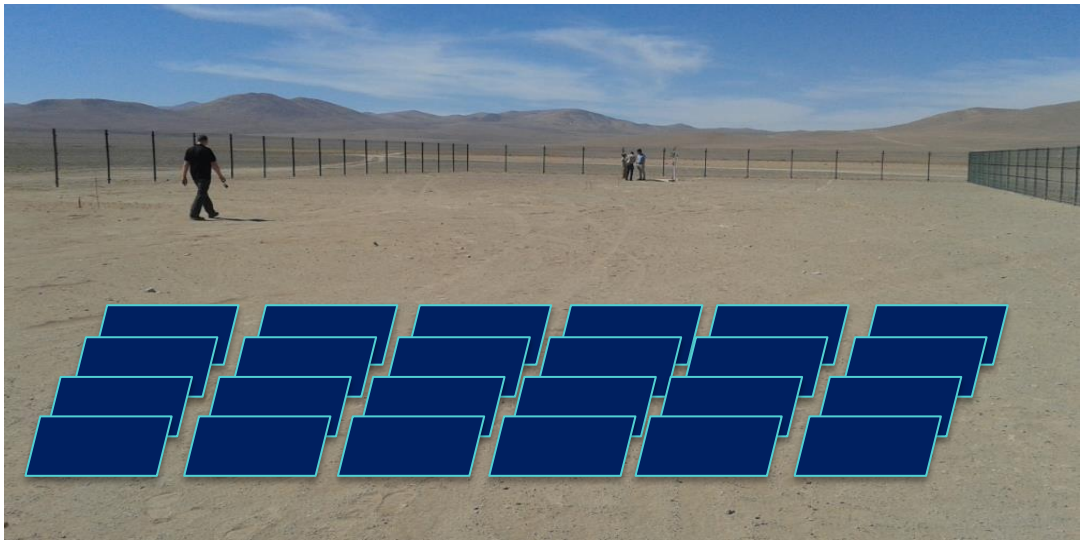
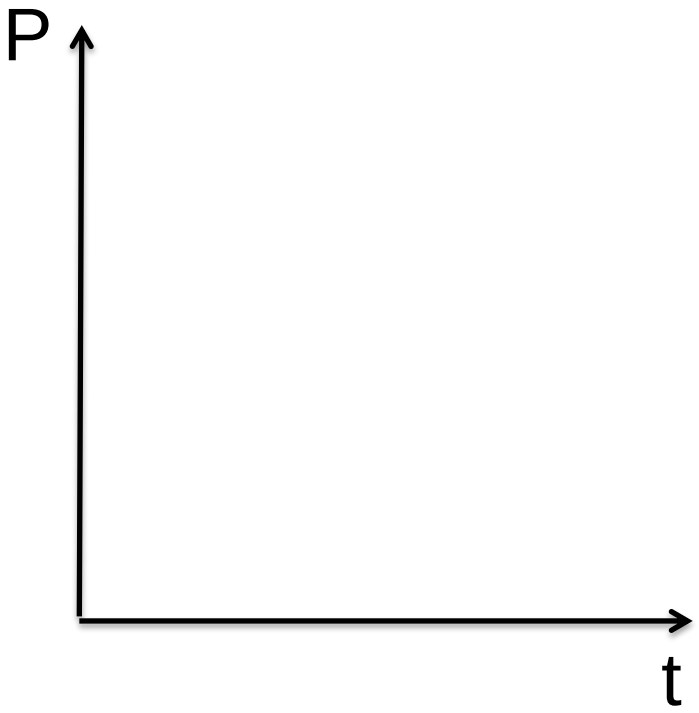
PV system close to equator
daily energy production: N oriented

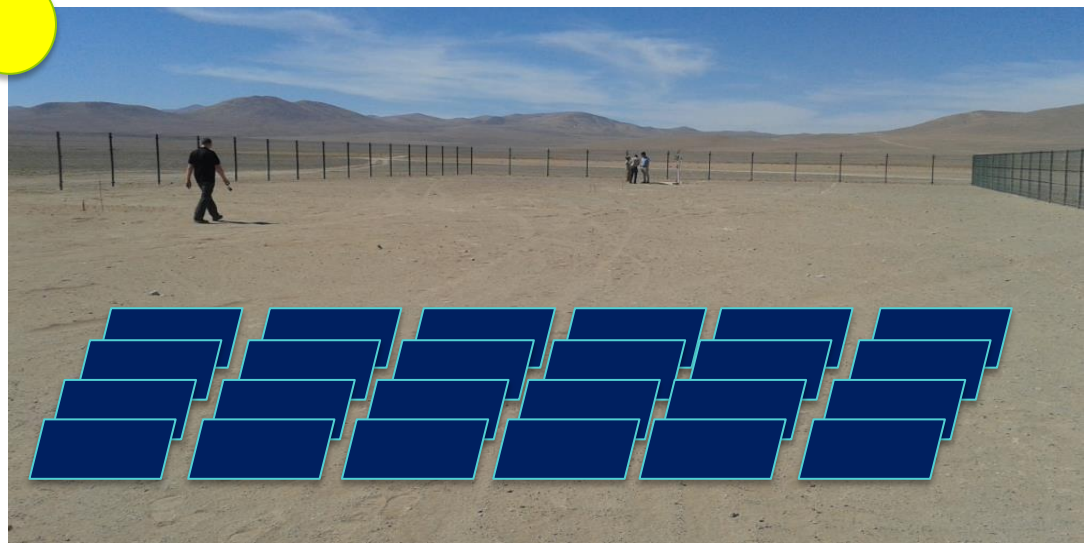
International Solar Energy
Research Center Konstanz



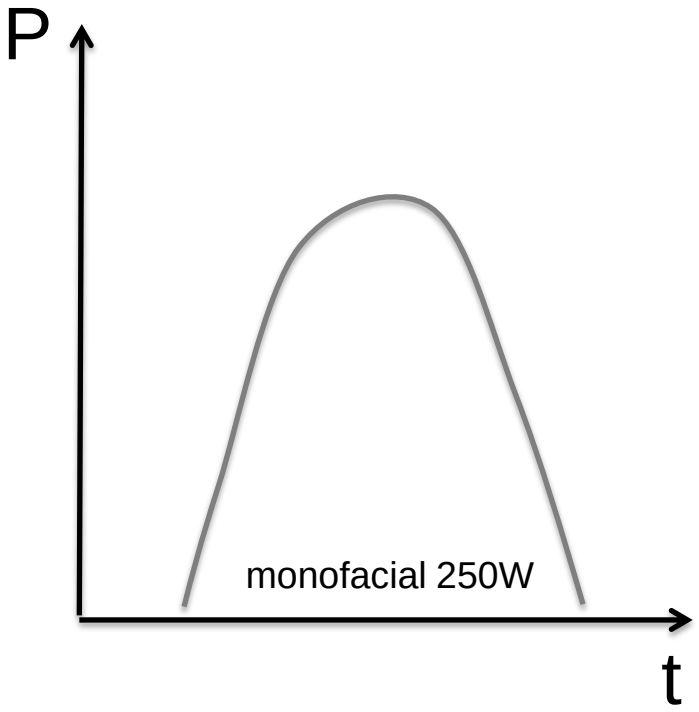
monofacial 250W



PV system close to equator
daily energy production: N oriented



monofacial 250W



PV system close to equator
daily energy production: N oriented

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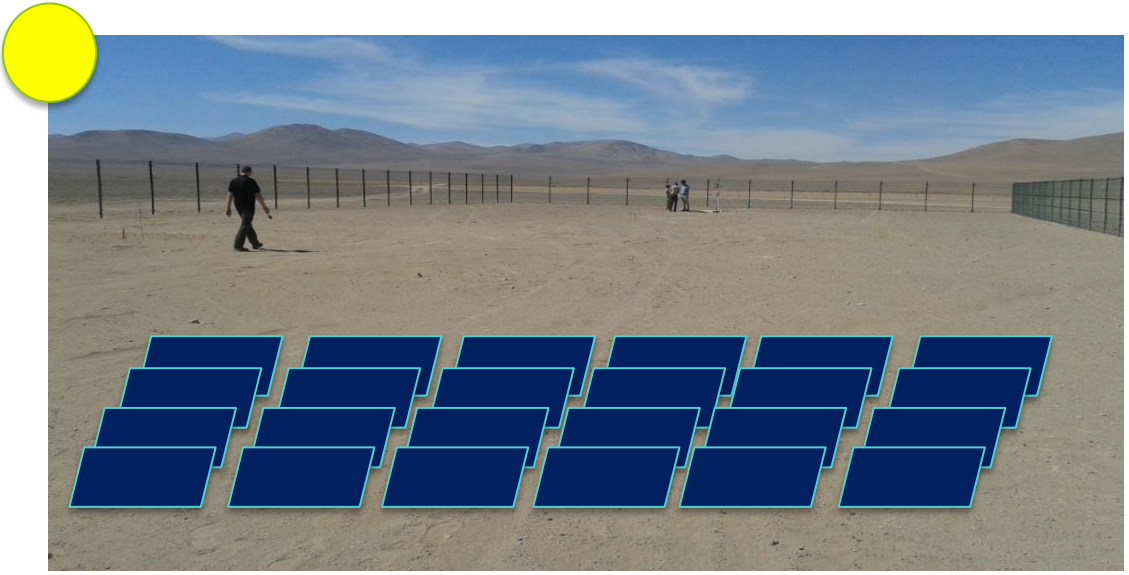
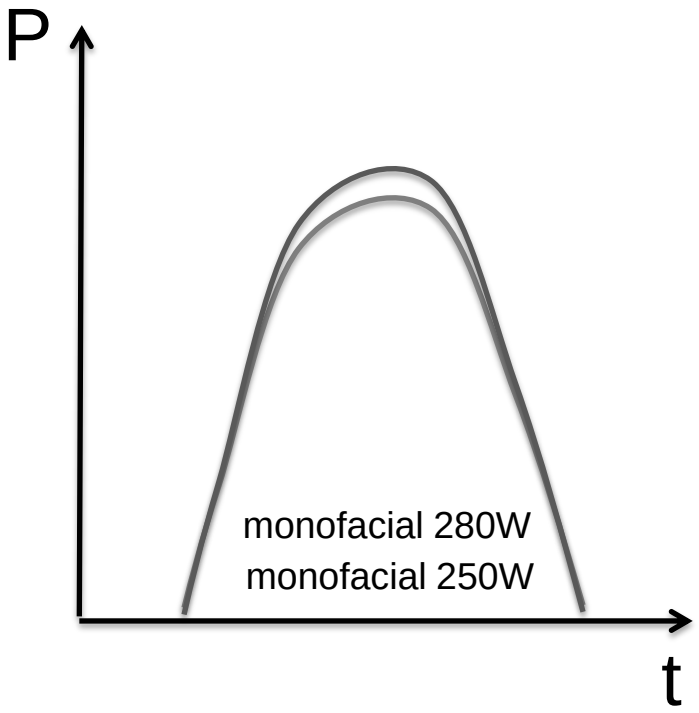


monofacial 280W



PV system close to equator
daily energy production: N oriented

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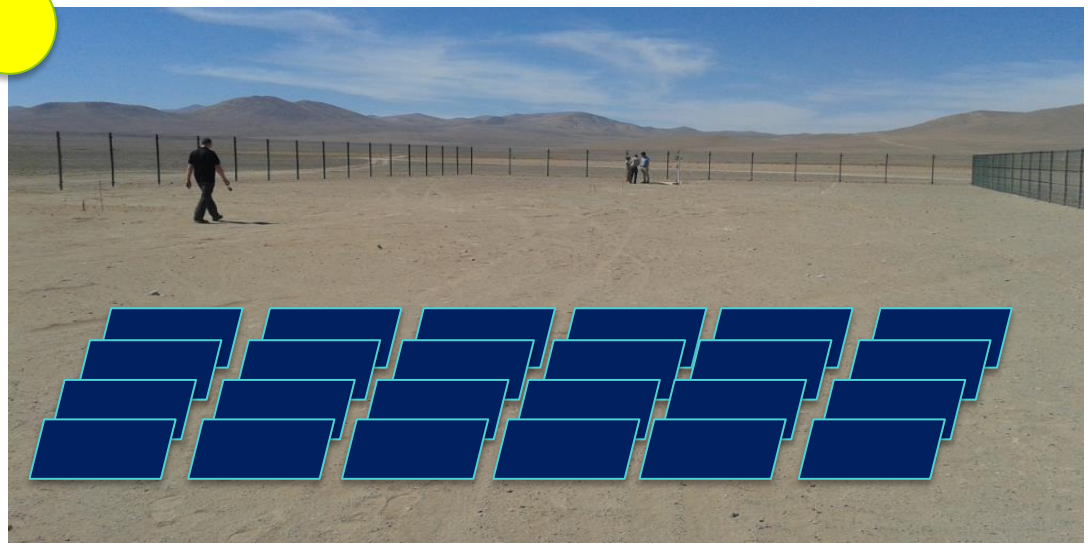
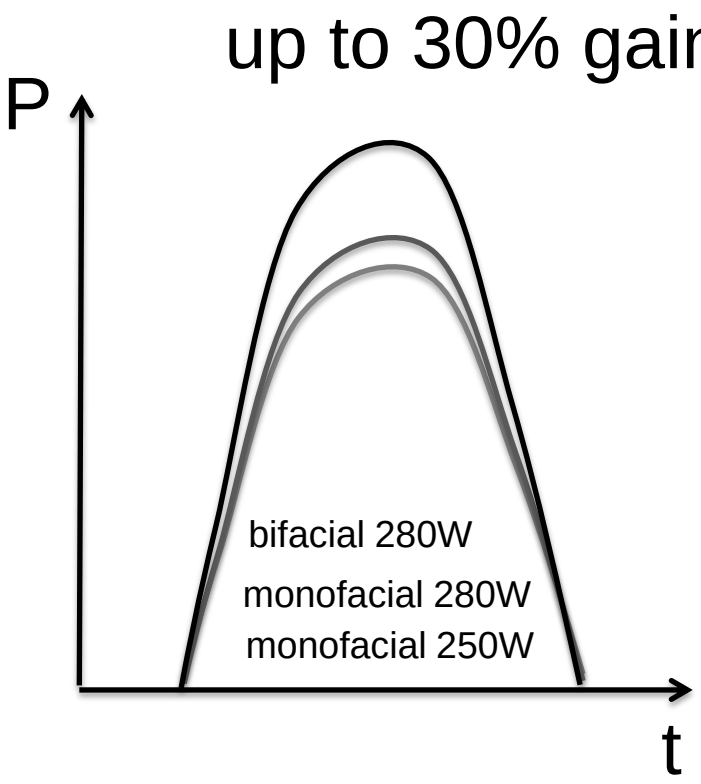


bifacial 280W (e.g. BiSoN)



PV systems world wide
bifacial gain in dependence of albedo

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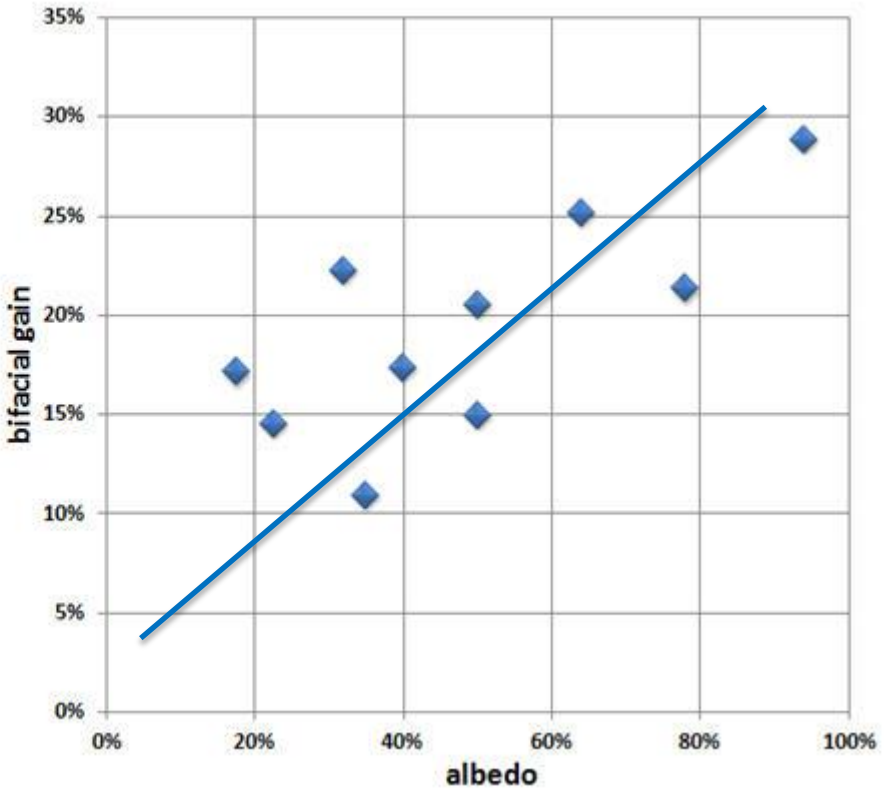
surface	albedo [%]
water	8
dry dark soil	13
grass	17-28
dry sand	35
dune sand	37
old snow	40-70
reflective roof coatings	80-90
fresh snow	75-95



PV system close to equator
daily energy production: E-W

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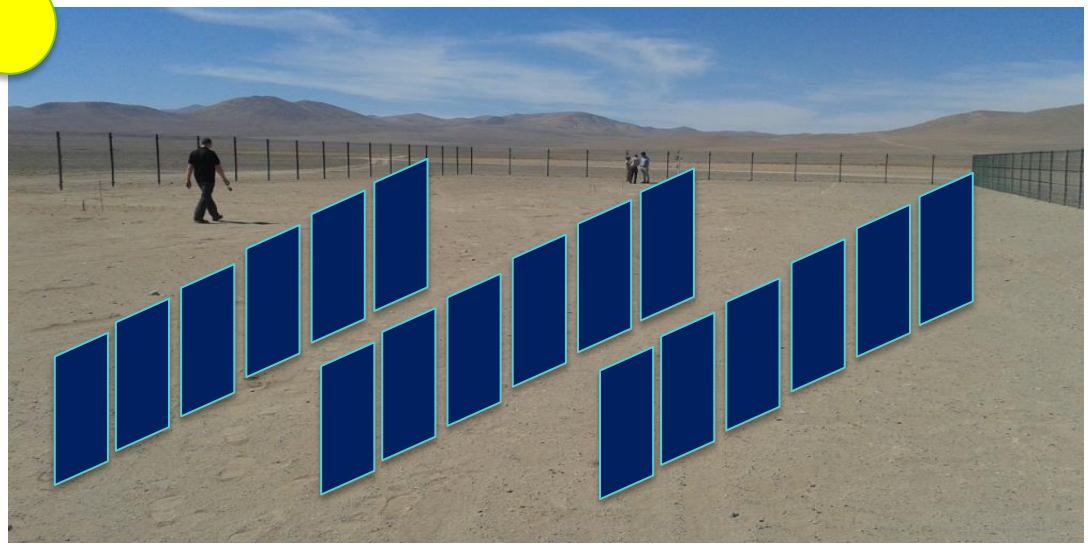
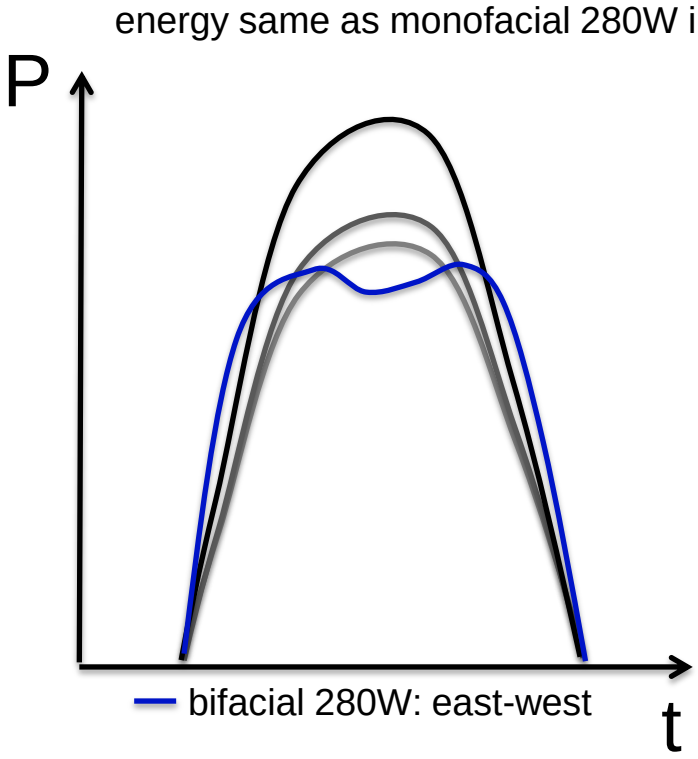


bifacial 280W: east-west



PV system close to equator
daily energy production: E-W

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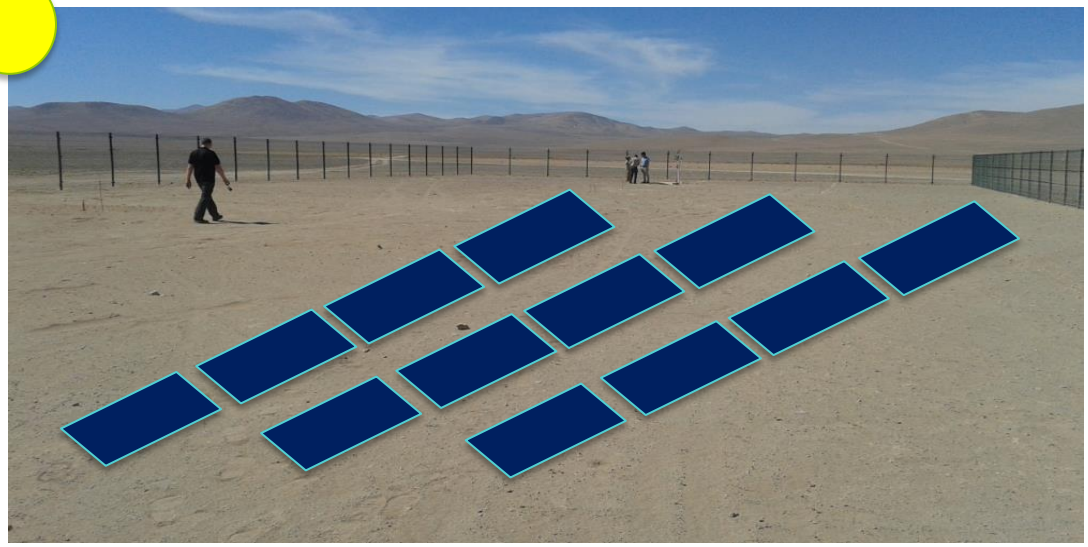
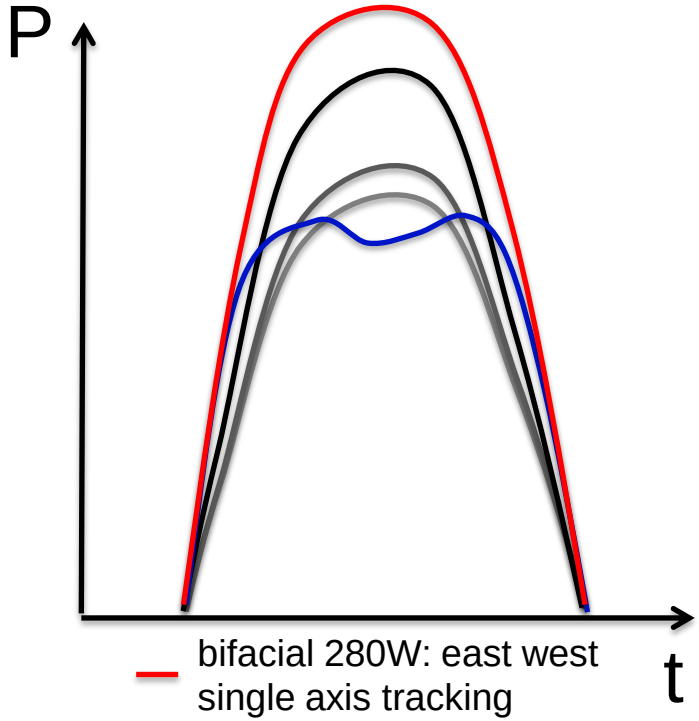


bifacial 280W: east west
single axis tracking

up to 50% gain



bifacial 280W: east west
single axis tracking

Words largest bifacial PV systems

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all with fix tilt: PERT and HJ

12,8 MWp
Sunpreme in USA

2,5 MWp
BiSoN in Chile

1,25 MWp
EarthON in Japan

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The largest enemy of bifaciality is the old-fashioned “Wp thinking” of customers instead of a modern “kWh mentality”.

CHILE- a bifacial country?

Sun Edison PV-Plant in Chile 2014: 100 MW

tracked 250W mc-Si module technology

Mega Group´s PV-plants in Chile 2016: 2.5MWp in Hormiga and 1.24MWp in Currica

standard
8 US$ct/kWh

1MWp
standard 250Wp mc-Si technology

advanced
6 US$ct/kWh

1MWp
SunEdison 250Wp tracked, Mega Group in Hormiga 270Wp BiSoN fixed

most advanced
4.5 US$ct/kWh

1MWp
Mega Group in Currica 270Wp BiSoN tracked

Chiles´s Solar Program

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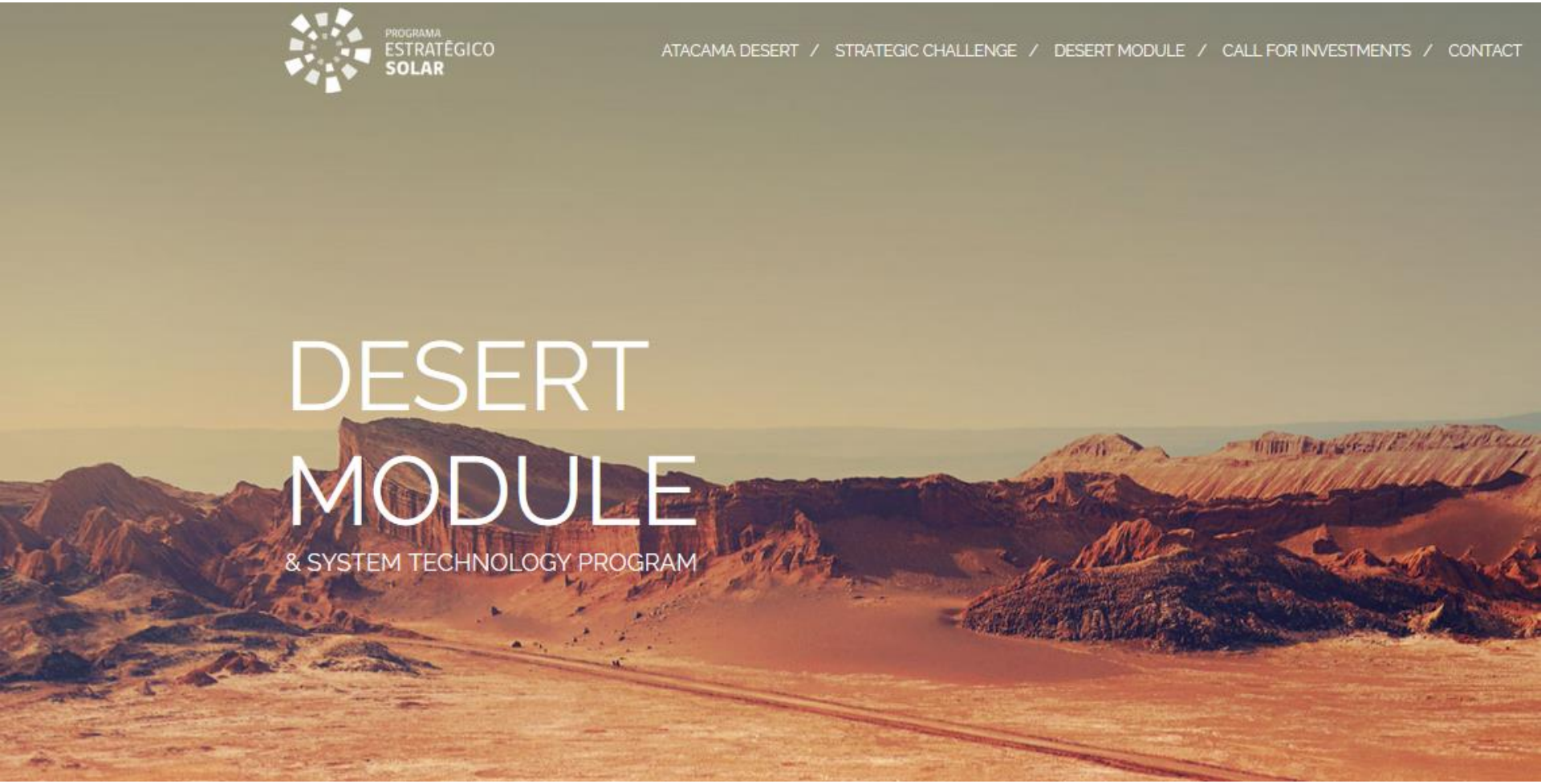

http://www.desertmodule.cl/

Chiles´s Solar Program

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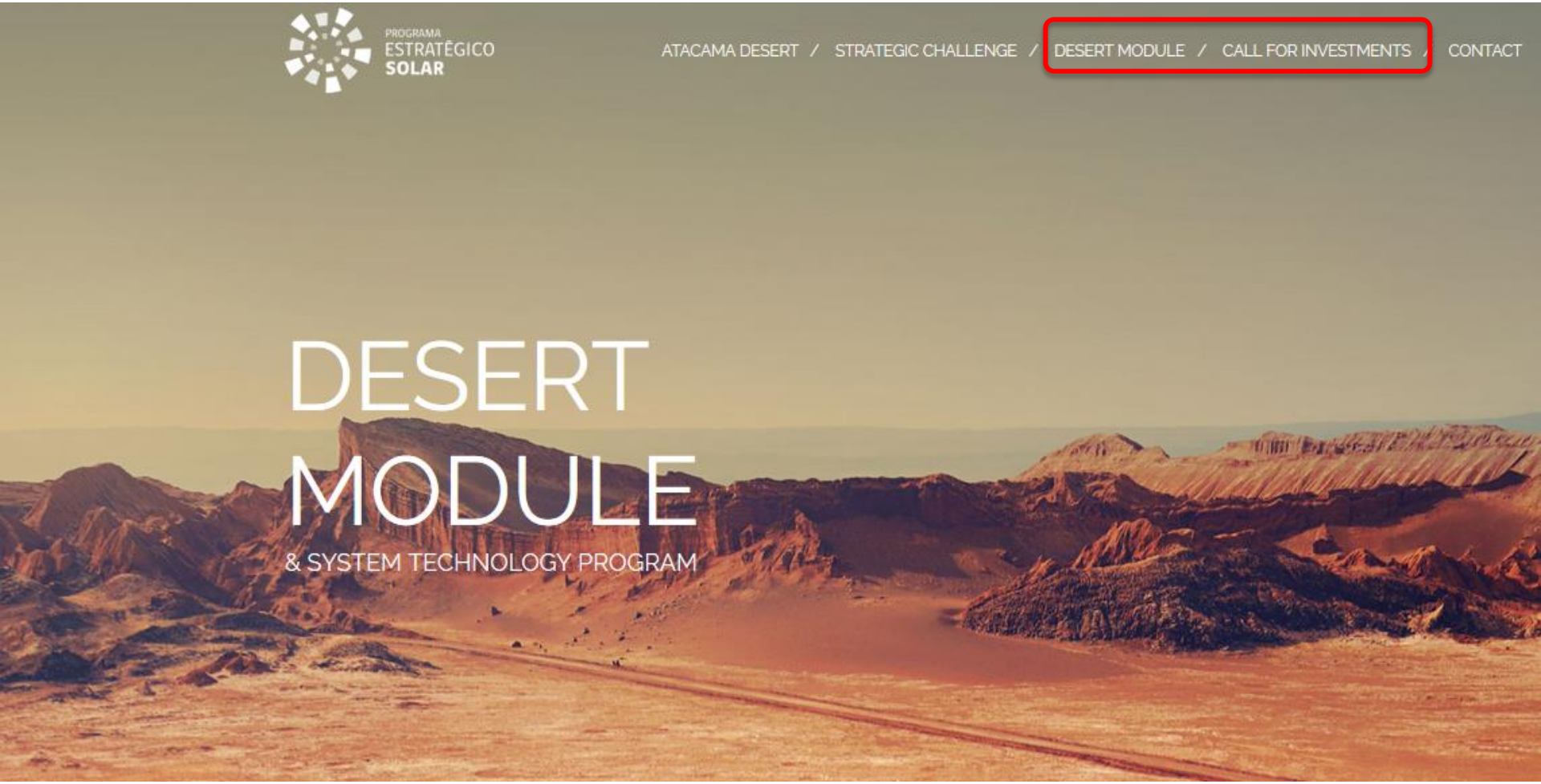
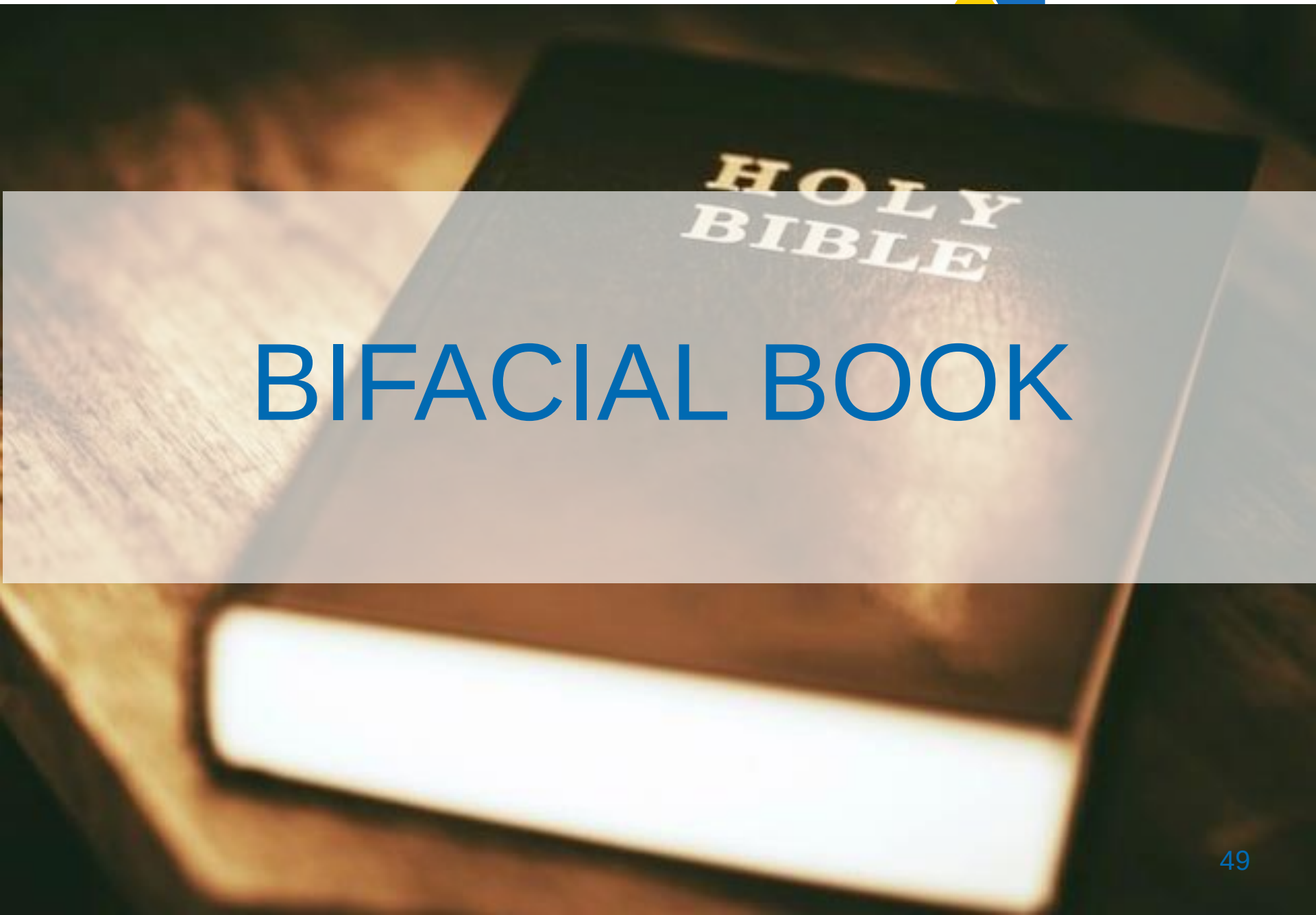


http://www.desertmodule.cl/



BIFACIAL BOOK

PV international from December 2014

ISC International Solar Energy Research Center Konstanz

Bifaciality: One small step for technology, one giant leap for kWh cost reduction

Radovan Kopecek[1], Yannick Veschetti[2], Eric Gerritsen[2], Andreas Schneider[1], Corrado Comparotto[1], Valentin D. Mihailetchi[1], Jan Lossen[1] & Joris Libal[1]

[1]ISC Konstanz, Konstanz, Germany; [2]CEA-INES, Le Bourget du Lac, France

ABSTRACT

The aim of this paper is to dispel the common belief that bifaciality is nonsense as it is not a mature technology, it is expensive and, because in large systems there is limited albedo from the rear side, it only serves the niche market. A complete picture of bifacial cell technologies and module concepts is presented, as well as levelized cost of electricity (LCOE) results for present and future bifacial systems.

Fab & Facilities
Materials
Cell Processing
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PV Modules
Power Generation
Market Watch

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By Dr Joris Libal,Dr Radovan Kopecek - 13 January 2015, 09:26 | In Guest Blog

Bifaciality: One small step for technology, one giant leap for kWh cost reduction

ISC Konstanz's BISoN cell, licensed to MegaCell. Image: MegaCell.

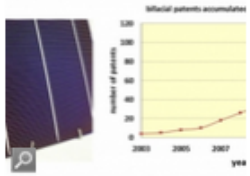
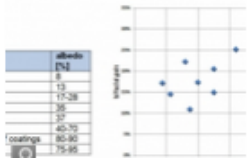


Figure 1: (left) BISoN (Bifacial Solar Cell on N-type); and (right) patent search by Eric Gerritsen from INES of the EPO database on bifacial PV.



Sometimes, if you deal with or work on a topic for a long time, things become so obvious that you cannot believe that others do not understand it as well. One such thing is that electricity production from PV in the last years has become so cost effective that it will be hard to beat by any other technology in future. This is not yet understood, particularly by many politicians – or it is but there is a strong lobby behind or other interests so they don't get this point. Another obvious fact is that in order to minimise a PV system's LCOE (levelised costs of electricity), low cost but powerful and long-lasting modules have to be used in order to minimise the costs for the balance of system (space, material, installation, maintenance). This is not yet understood, for example by many venture capital providers, who still invest in low cost but low-efficiency (and often nondurable) PV module technologies.

Finally, and the topic of this blog post: if you want to maximise the kilowatt-hour output of a ground-mounted PV system or of one on a flat roof, bifaciality offers a very easy possibility to achieve this. Many PV scientists are still

Blogger

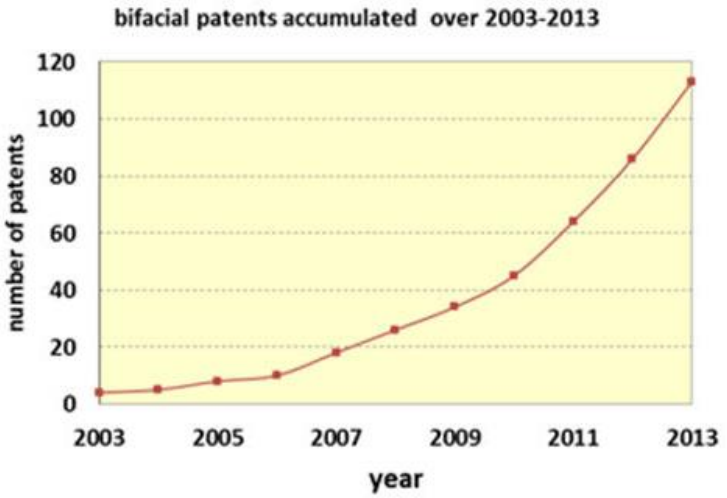
Dr Joris Libal

Dr Joris Libal works at ISC Konstanz as a research engineer, focusing on business development and technology transfer in the areas of high-efficiency n-type solar cells and innovative module technology.

Blogger

Dr Radovan Kopecek

Dr Radovan Kopecek is one of the founders of ISC Konstanz. He has been working at the



Book to be written until end 2016

International Solar Energy Research Center Konstanz

1. **Proposed Book Title**

"Bifacial Photovoltaics: Technology and Economy"

Chapter	Chapter Title	Full Author Name(s)
1	Introduction	R.Kopecek, J. Libal
2	Bifacial cell technologies	J. Lossen, V. Mihailetchi; I. Romijn
3	Bifacial module design and electrical characterization	A. Schneider, ISC Konstanz. Germany E. Gerritsen, B. van Aken
4	Energy Yield Simulations and design rules for bifacial PV systems	I. Shoukry; Y. Veschetti
5	Bifacial PV systems: yield data (bifacial gain) from literature	Radovan Kopecek, Y. Veschetti, B. van Aken; H. Nussbaumer, M. Klenk, F Baumgartner
6	Importance of bankability for market introduction of new PV technologies - bifaciality as example	N.N.
7	Impact of bifaciality on the levelized cost of PV generated electricity	J. Libal
8	Grid integration of bifacial PV	K. Peter, H. Nussbaumer, M. Klenk, F Baumgartner
9	Overview and status of bifacial PV in industrial production	J. Libal; R. Kopecek

summary

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

- some companies are already producing bifacial cells: mcPERCT, PERC+, PERT, HJ

- many modules in future will be glass-glass based

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

>> WE HAVE TO CHANGE TO COSTS/KWH THINKING, CREATE STANDARDS AND BRING BIFACIALITY INTO PV MARKET

Bifacial PV will not only reduce LCOE-
it will bring you to great places!!

ENJOY!!!