

Need for development of a bifacial glass-glass c-Si module for Atacama Desert

high power AtaMo with Chile's local content

, Dr. Enrique Cabrera

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

GOOD NEWS FOR PV MANUFACTURERS FROM EUROPE



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Research Center Konstanz

French President calls for 'Airbus' style Euro solar manufacturer



President Hollande said France and Germany could form a "beautiful alliance" in the energy sector. Source: Flickr/jmayrault.

France's President Francois Hollande has called for an 'Airbus' style model of collaboration for the European solar industry.

On Tuesday, Hollande said collaboration with Germany in the energy sector would be a "beautiful alliance".

"Germany has a head-start in renewables, but we have our vanguard in energy storage and power grids," he said.

"We have to work together to expand new industrial branches. We are very proud of Airbus, now we want joint action for the energy transition."

17. 01.2014

The announcement received a cool reception in Europe.

The German Economy and Energy Ministry told broadcaster Deutsche Welle it welcomed the plans and was open to discuss them.

It was unclear specifically what form of collaboration the president was referring to, however his overtures are in line with the goals of the ambitious HERCULES research project.

The project's name is derived from High Efficiency Rear Contact solar cells and Ultra powerful moduLES.

The research collaboration between universities, research bodies and private sector firms including EDF and Meyer Burger, aims to drive cell efficiencies to 25% and module power conversion over the 21% mark while keeping the cost at around €0.7 per Watt.

The stated goal of HERCULES, which received a €7 million grant from the European Commission,



GOOD NEWS FOR PV MANUFACTURERS FROM EUROPE



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Does solar cell or module production
outside of Asia make sense??

YES: if

- large scale is foreseen or/and
- innovations implemented or/and
- local market addressed

ISC Konstanz in 5 min

PV past and future

why new developments are important now?

PV in desert areas

which module technology is most suited?

Bifacialty

why will it become important for future systems?

AtaMo (Atacama Module)

what will such a module look like?





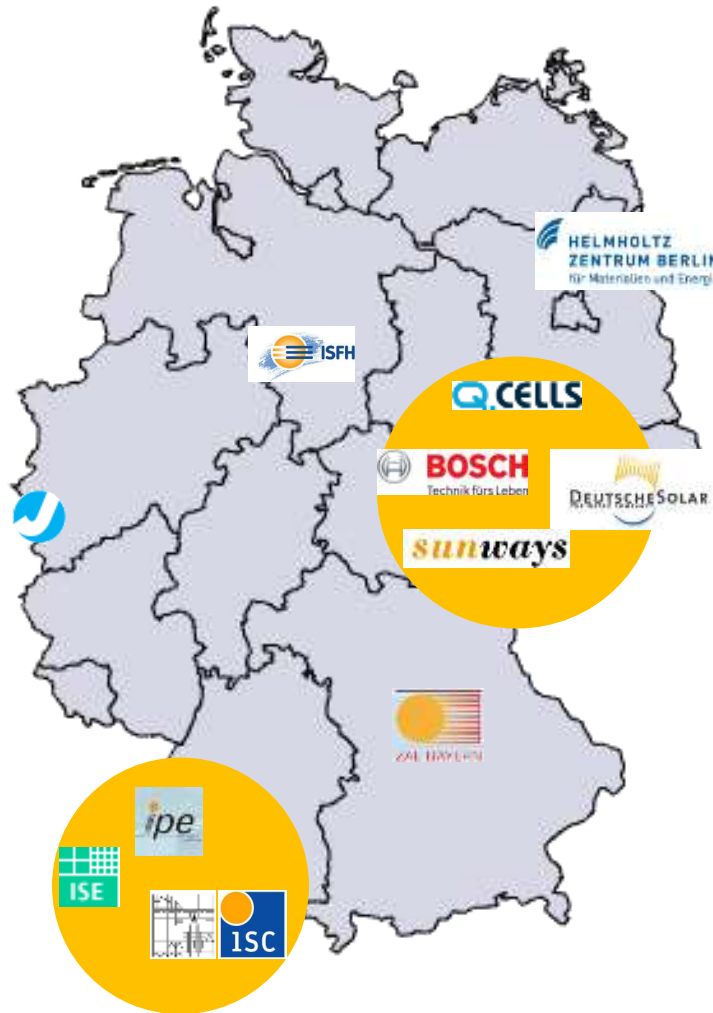
ISC Konstanz

- International Solar Energy Research Center e.V.
- Non profit organisation
- Founded in December 2005
- R&D in the area of c-Si solar cells and modules
- About 50 employees
- Turnover in 2013: 4.5 Mio€



location within Germany

universities,
institutes



solar cell
manufacturers

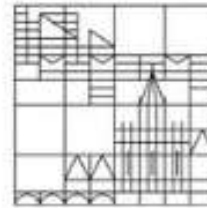
top PV research institutes world wide



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Universität
Konstanz



THE UNIVERSITY OF
NEW SOUTH WALES



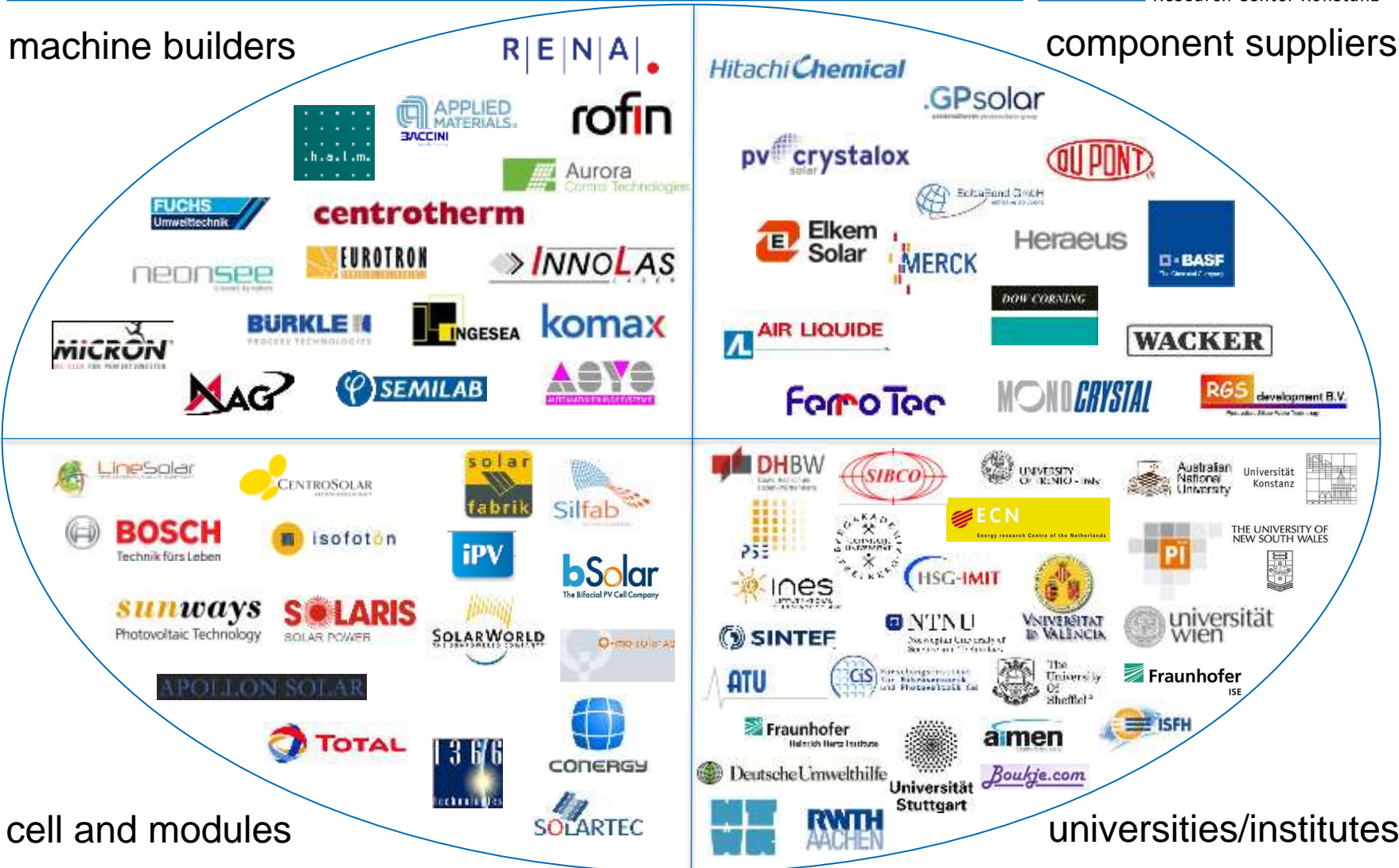
ISC partners/customers



International Solar Energy
Research Center Konstanz

machine builders

component suppliers



cell and modules

universities/institutes



financed by Federal German Ministries

PVscan (BMU) studies of module degradation in the field

MetalTopp (BMU) development of p+-contacting pastes for n-type solar cells

B-PV (ZIM) development of building integrated PV devices

10ct development of diffused ZEBRA technology with FHG ISE and RENA

SolarChild development of Atacama module (AtaMo) with SERC Chile



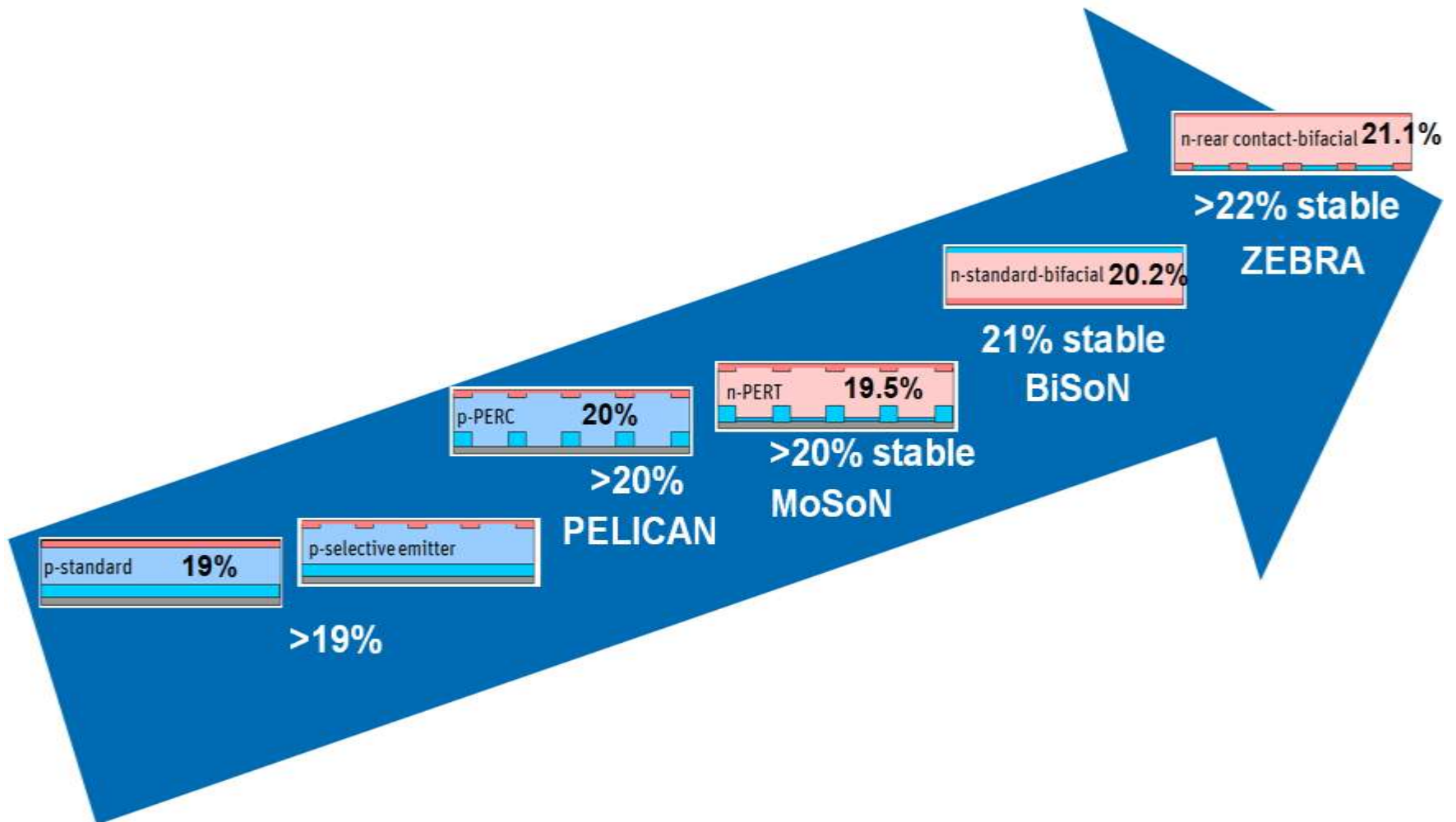
financed by European Union within FP7

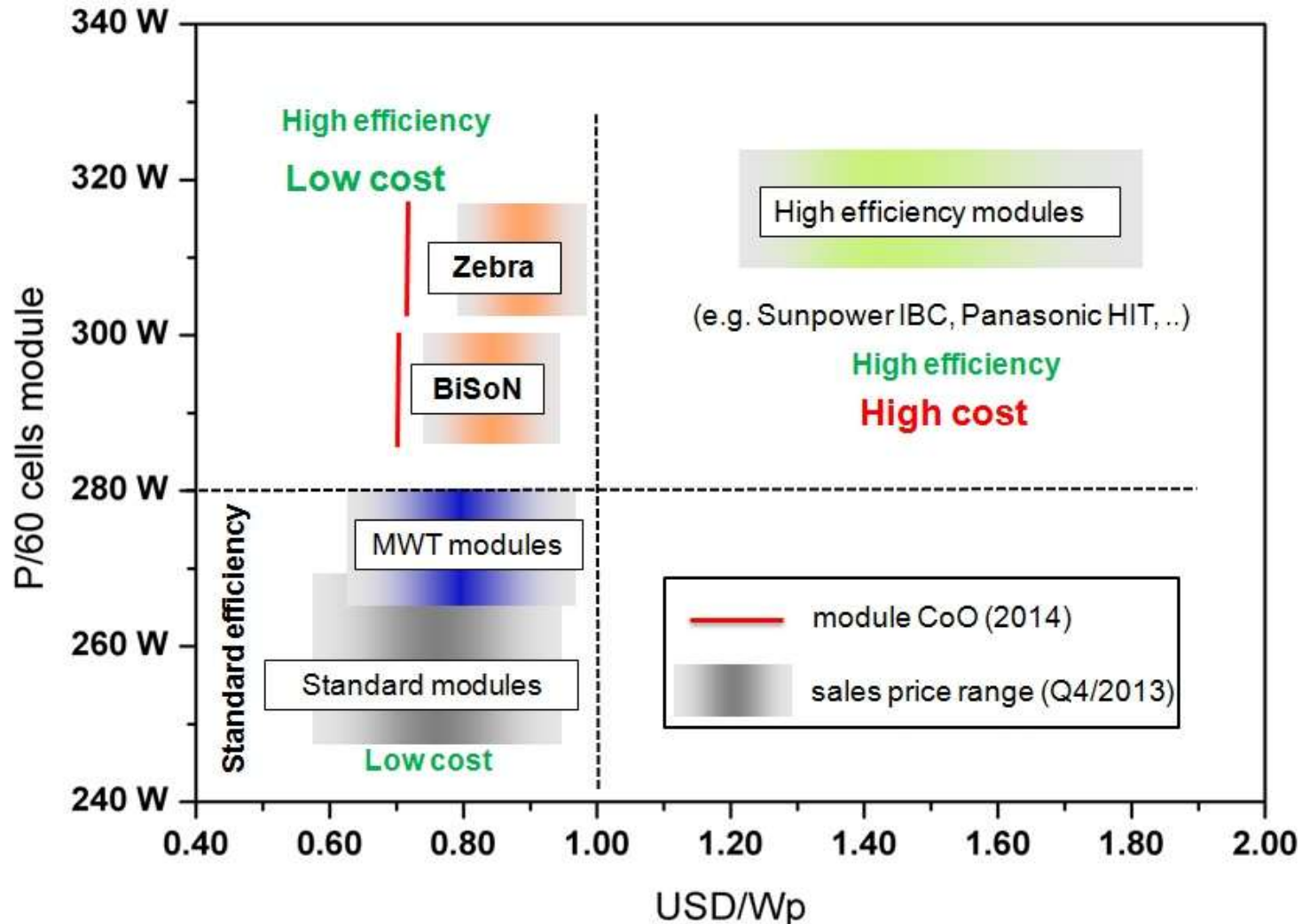
HERCULES development of IBC solar cells and modules

SolarTeam SoG-Si for mass production

CoSSmic smart micro grids in city of Konstanz

moderN-Type (Eurostar) development of new powerful IBC module

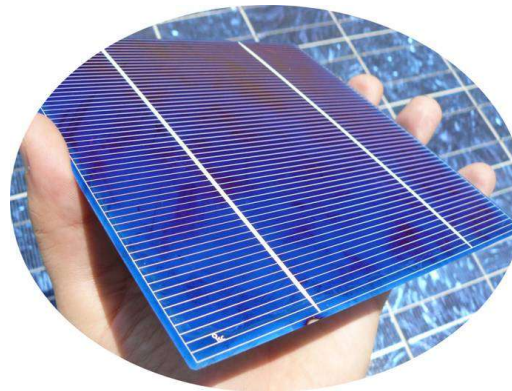




research and development



mc-Si: 16-17% > 17%
Cz-Si: 18-19.5% > 21%



training and education



7 PhD
2 Master / 3 DHBW
5 practice



Claudia Duran



Enrique Cabrera



Pablo Ferrada



Elias Urrejola

4 PhD students from Chile

development cooperation

Cameroon: 5 projects
India: 4 project
Tanzania: 2 projects
Kenya: 3 projects
Ghana: 1 project
Mexico: 1 project



spreading of PV

development cooperation



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international solar
development cooperation
an initiative of ISC Konstanz

development cooperation



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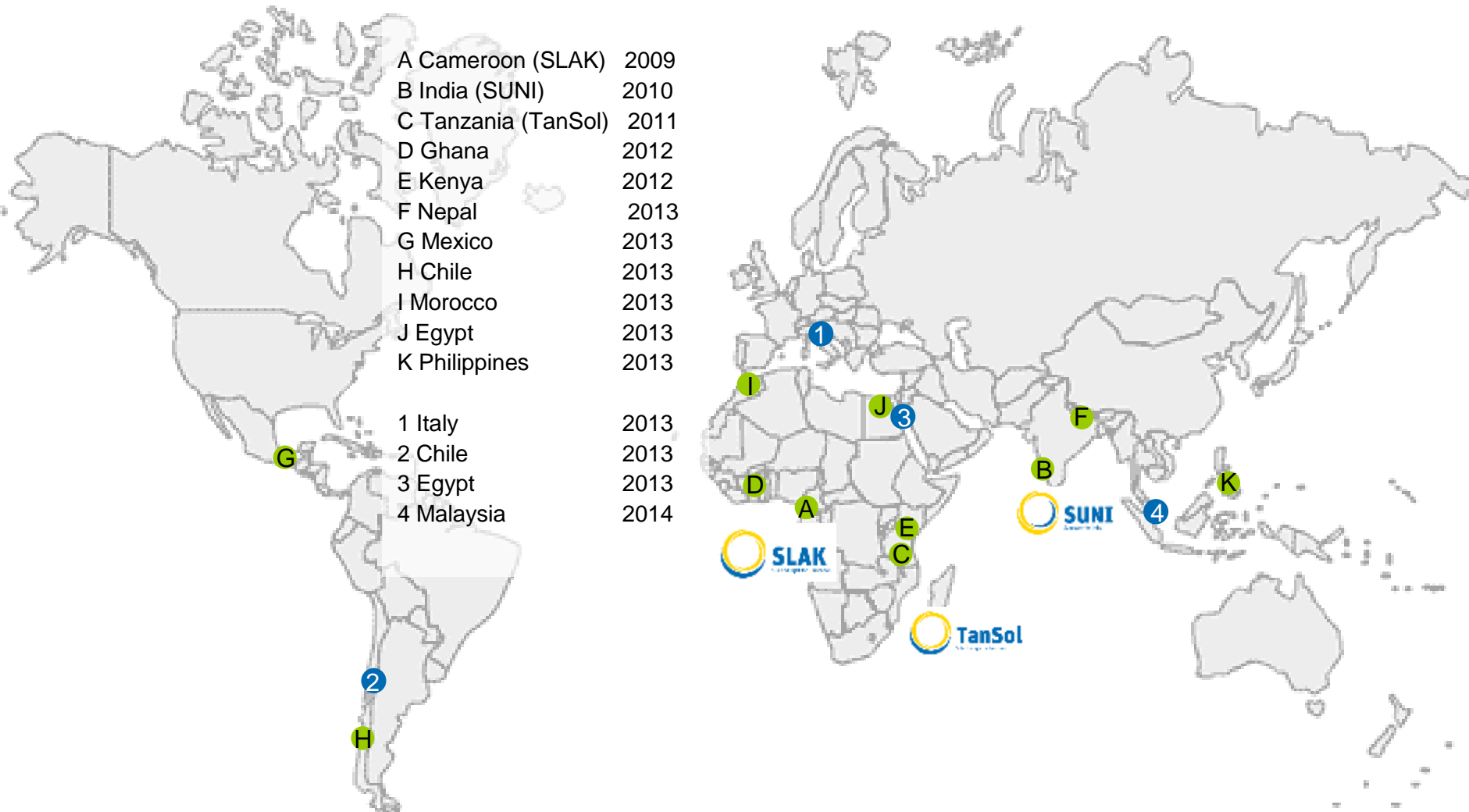
Year	Solar power for	Number of beneficiaries	Total power in kWp	Training to / construction with
India				
2011	Light and water purification for school in Kalappetty	600	1.0	Students, teachers
2012	Light and water purification for primary school in Kalappetty	300	1.0	Students, teachers
2013	Light and electricity for medical equipment for tribal hospital	75,000 in the vicinity	5.0	Hospital staff
Cameroon				
2009	All houses in the village Bôtbadjang	150	5.4	Local community, local technicians
2010	Technical High School in Douala	350	1.5	Local community, local technicians
2011	Health station Bôtbadjang	500	1.5	Local community, local technicians
2012	Homes and hospital in Ndambog	260	5.5	Local community, local technician, students of high school
Tanzania				
2012	Girls' Secondary School in Kashozi	600	12.0	Girls (age: 13 – 17 years), local technicians
2013	Massai Naserian Primary School in Malambo	300	1.2	Students (age: 8 – 13 years)
Ghana				
2012	Technical High School in Nyakrom	1,200	9.0	Student project: training for German and Ghanaian students (age: 13 - 18 years), common installation



development cooperation and R&D



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A photograph of three men standing on a rooftop covered with solar panels. The man on the left is holding a long, thin object, possibly a tool or a piece of equipment. The man in the middle is also holding a similar object. The man on the right is wearing sunglasses and holding a long, thin object. In the background, there are some buildings and a clear sky. The text "status of PV 2014" is overlaid on the image in a blue font.

status of PV 2014

energy turn around



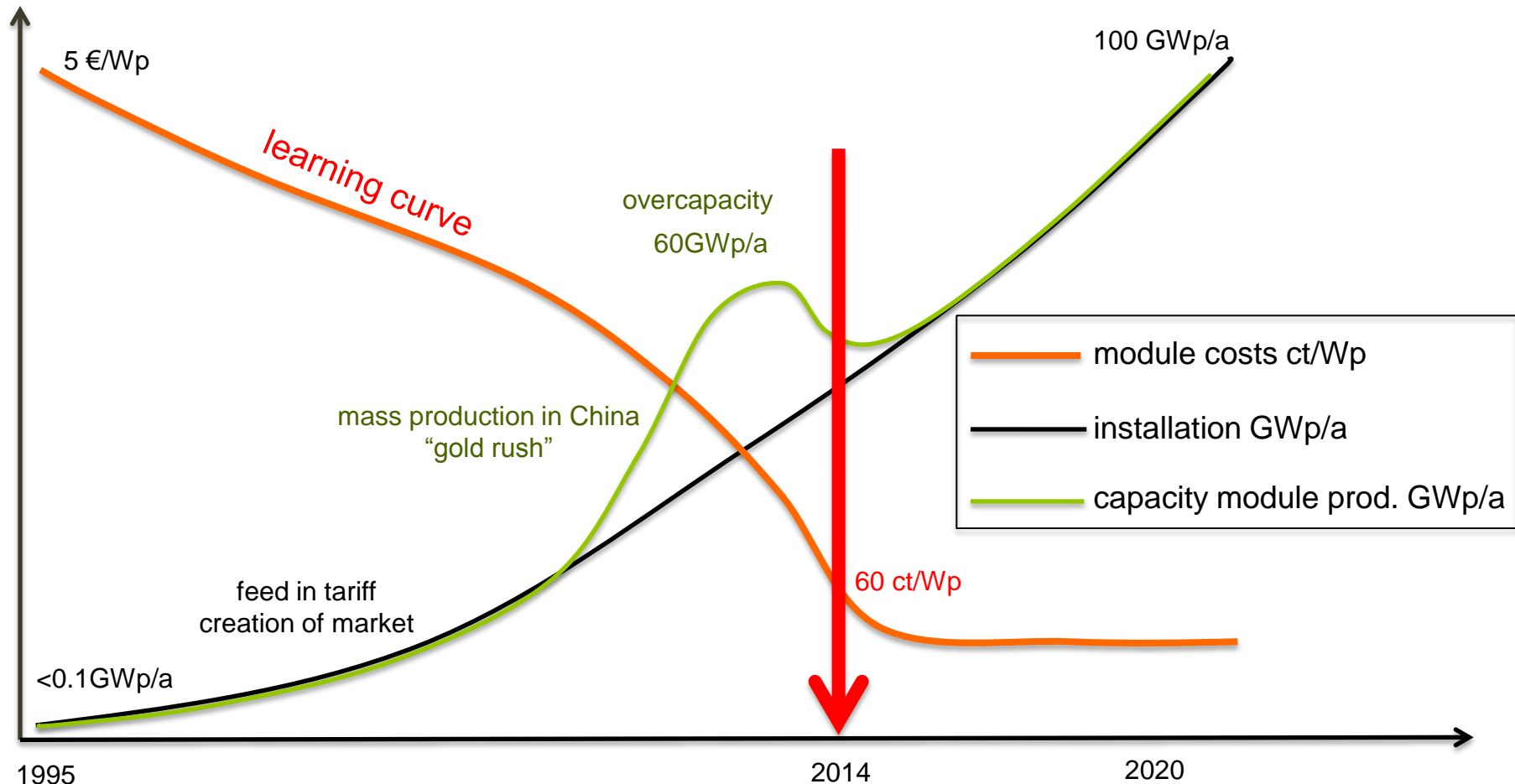
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status of PV 2014: history, present and future



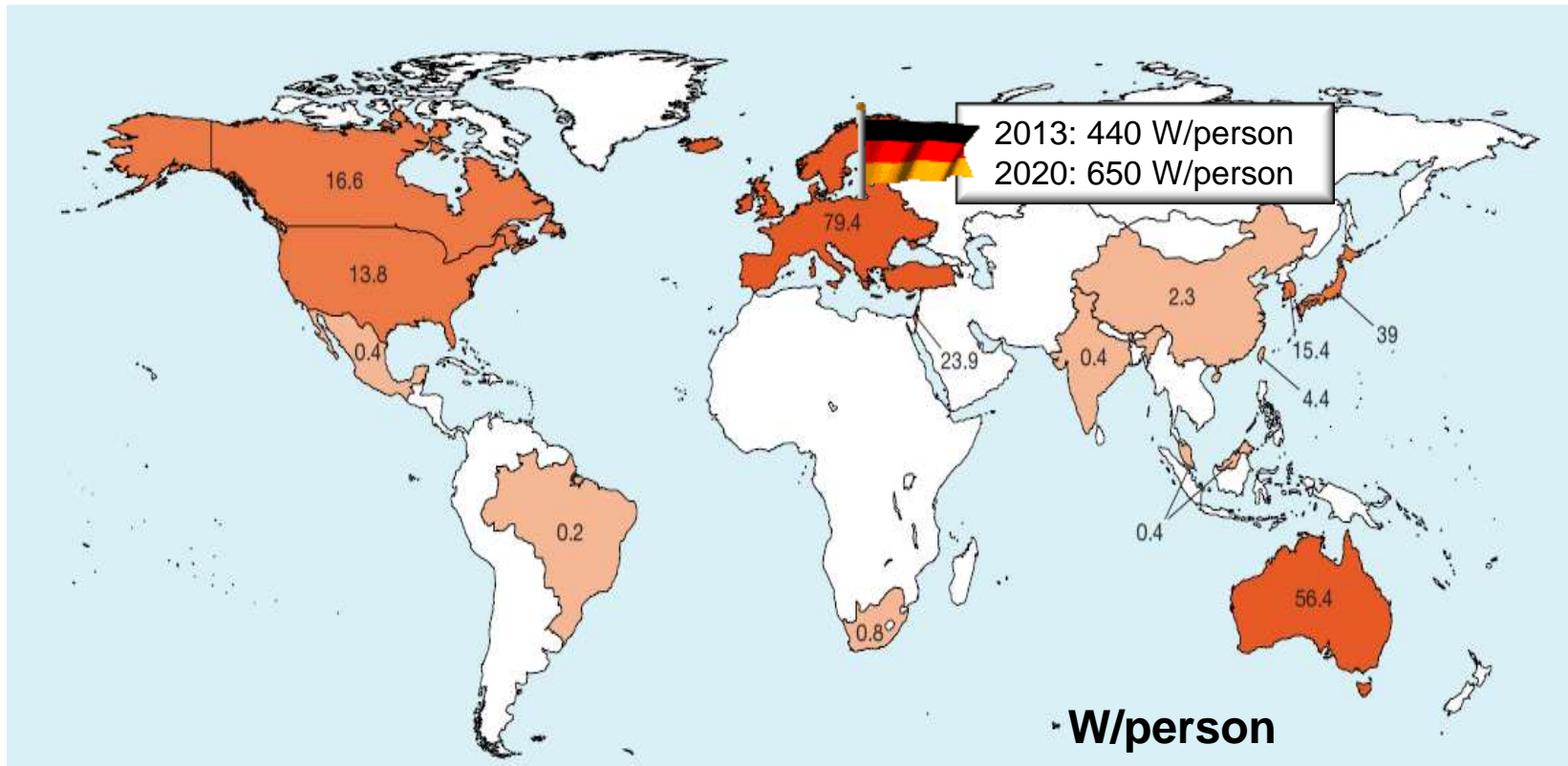
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“First they ignore you, then they laugh at you, then they fight you, then you win.”

status of PV 2014: market

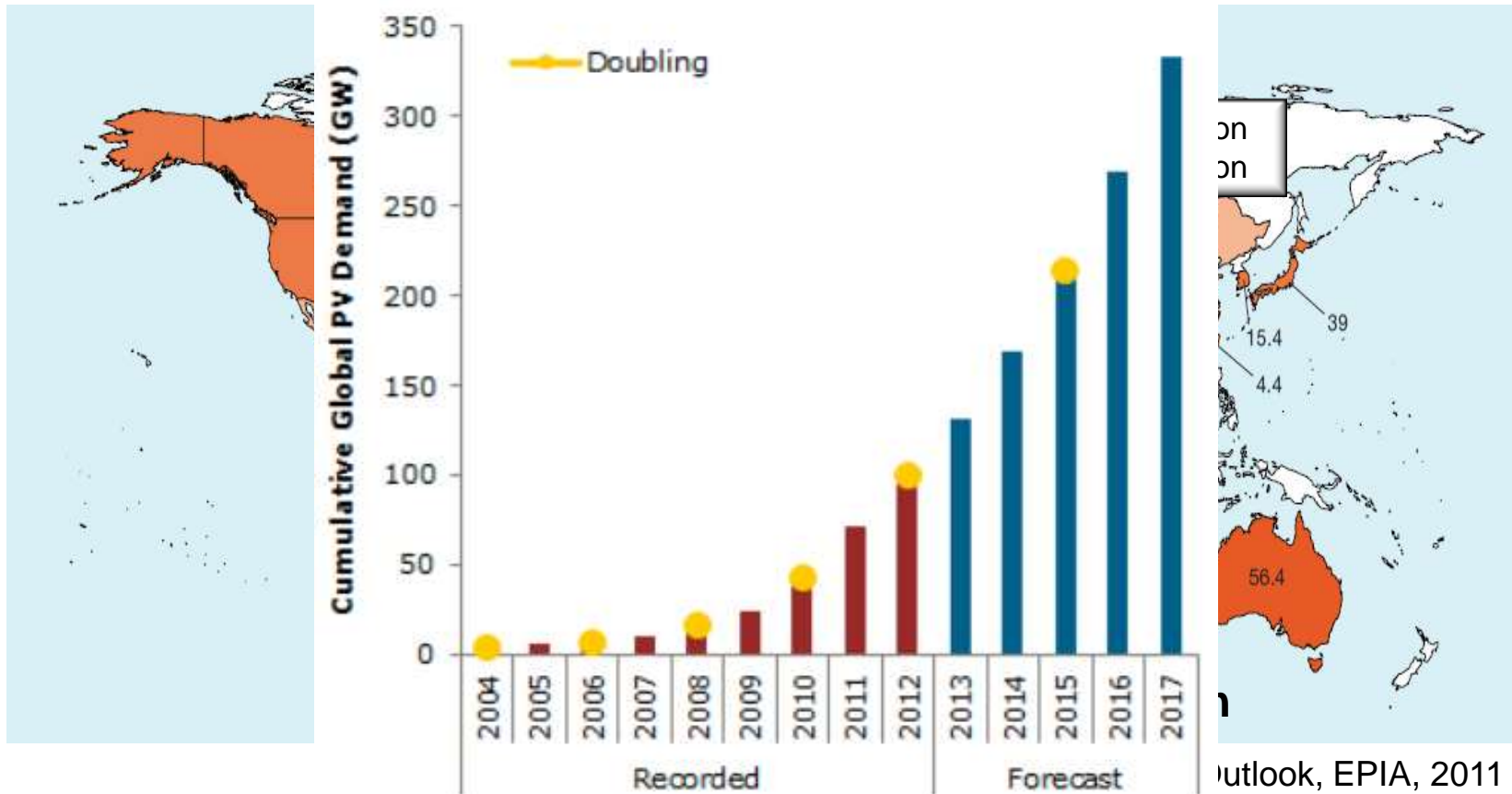
total installed capacity of ca. **130GWp**



Source: Market Outlook, EPIA, 2011

status of PV 2014: market

total installed capacity of ca. **130GWp**



status of PV 2013: costs for system

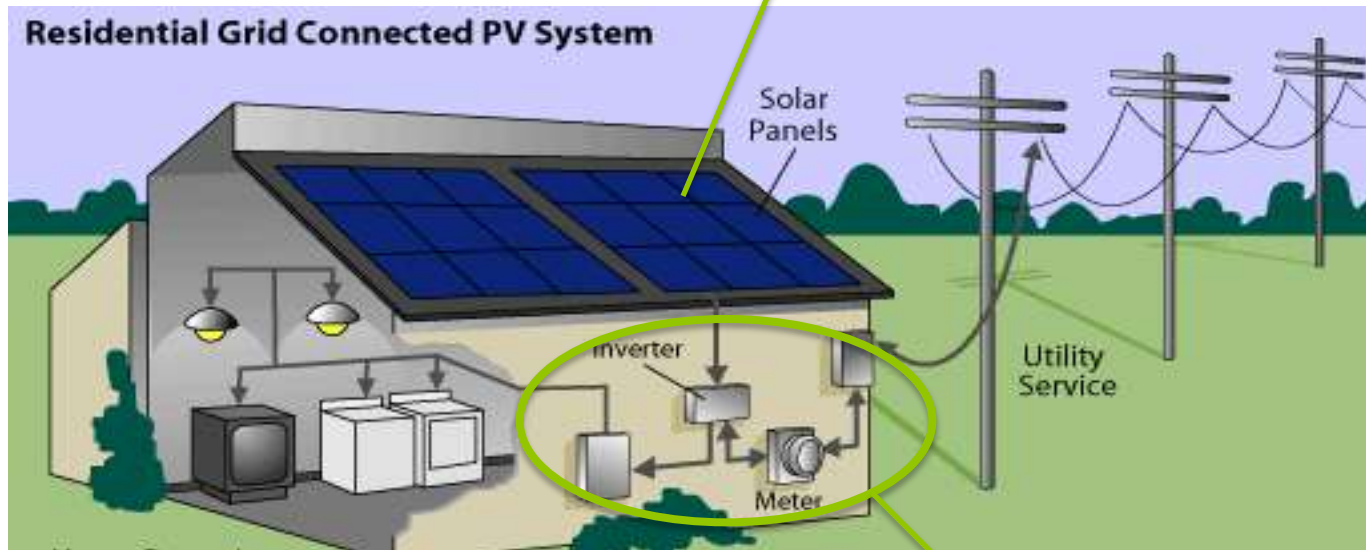


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modules



0.6€/Wp



1€/Wp

BOS (balance of system)

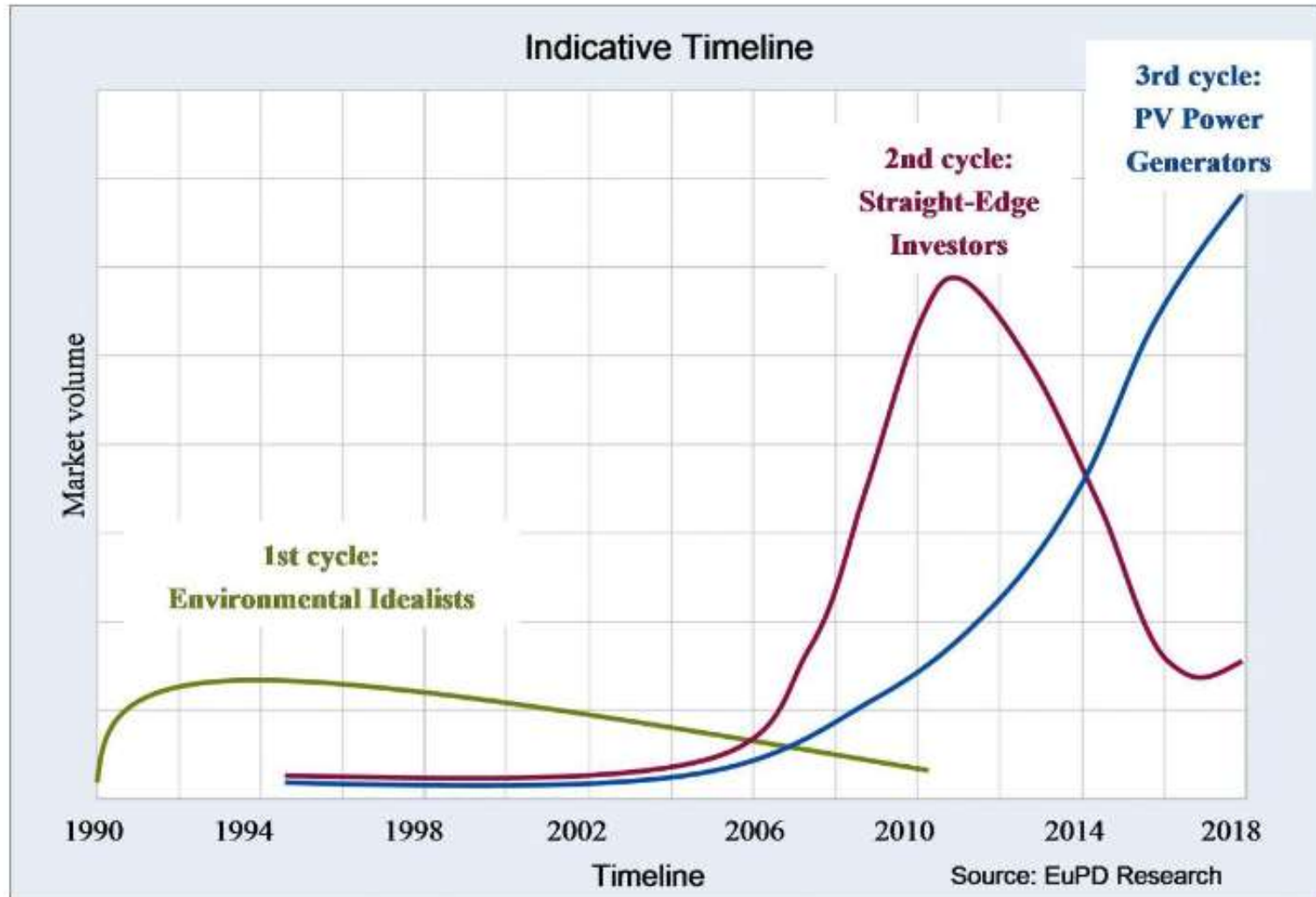
- inverter, meter
- cables, mounting system
- mounting

source of picture: *internet*

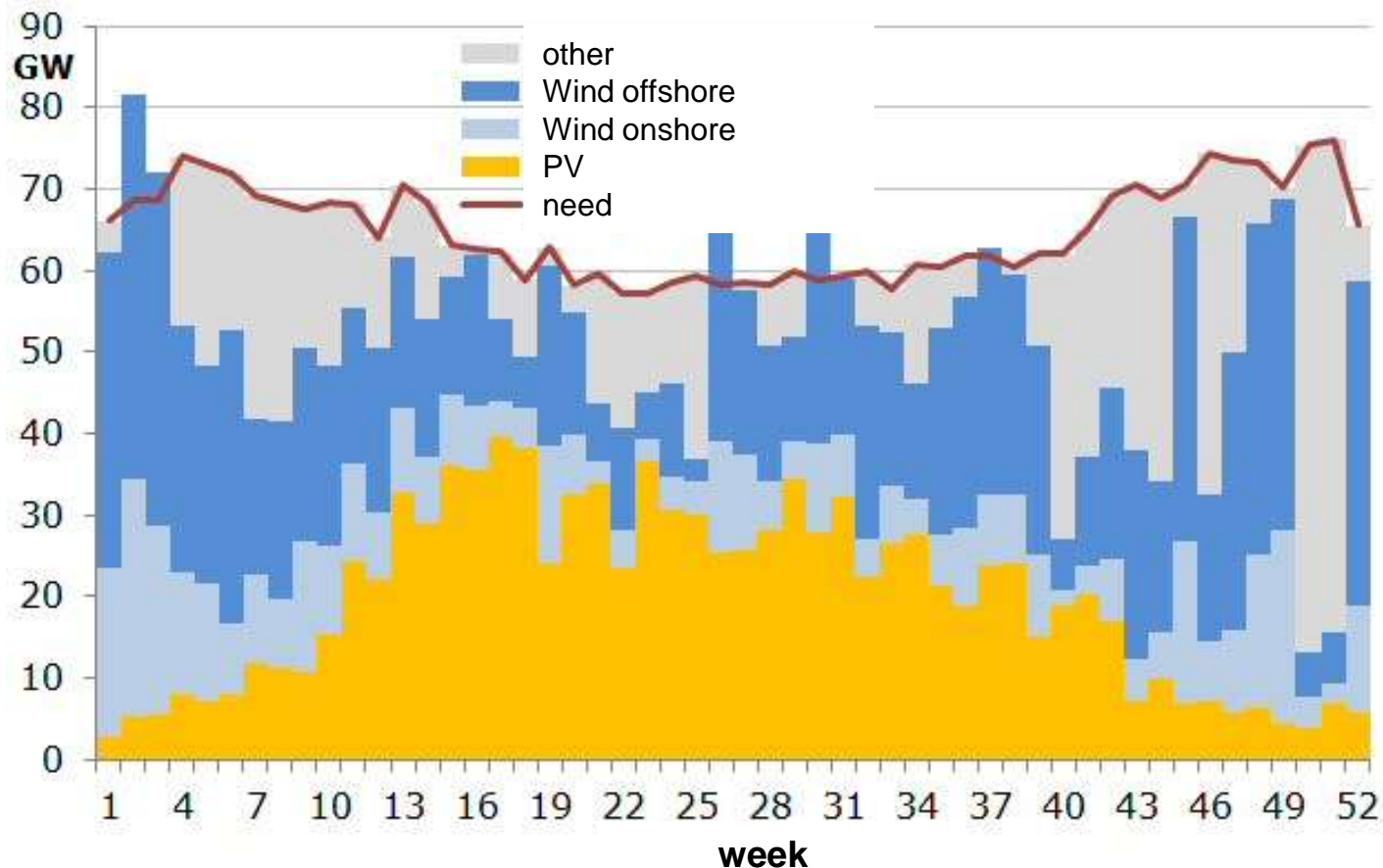
status of PV 2013: history, present and future



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fact: 100% renewable in Germany



weekly electricity power need and production in Germany

200 GW PV, 100 GW wind power

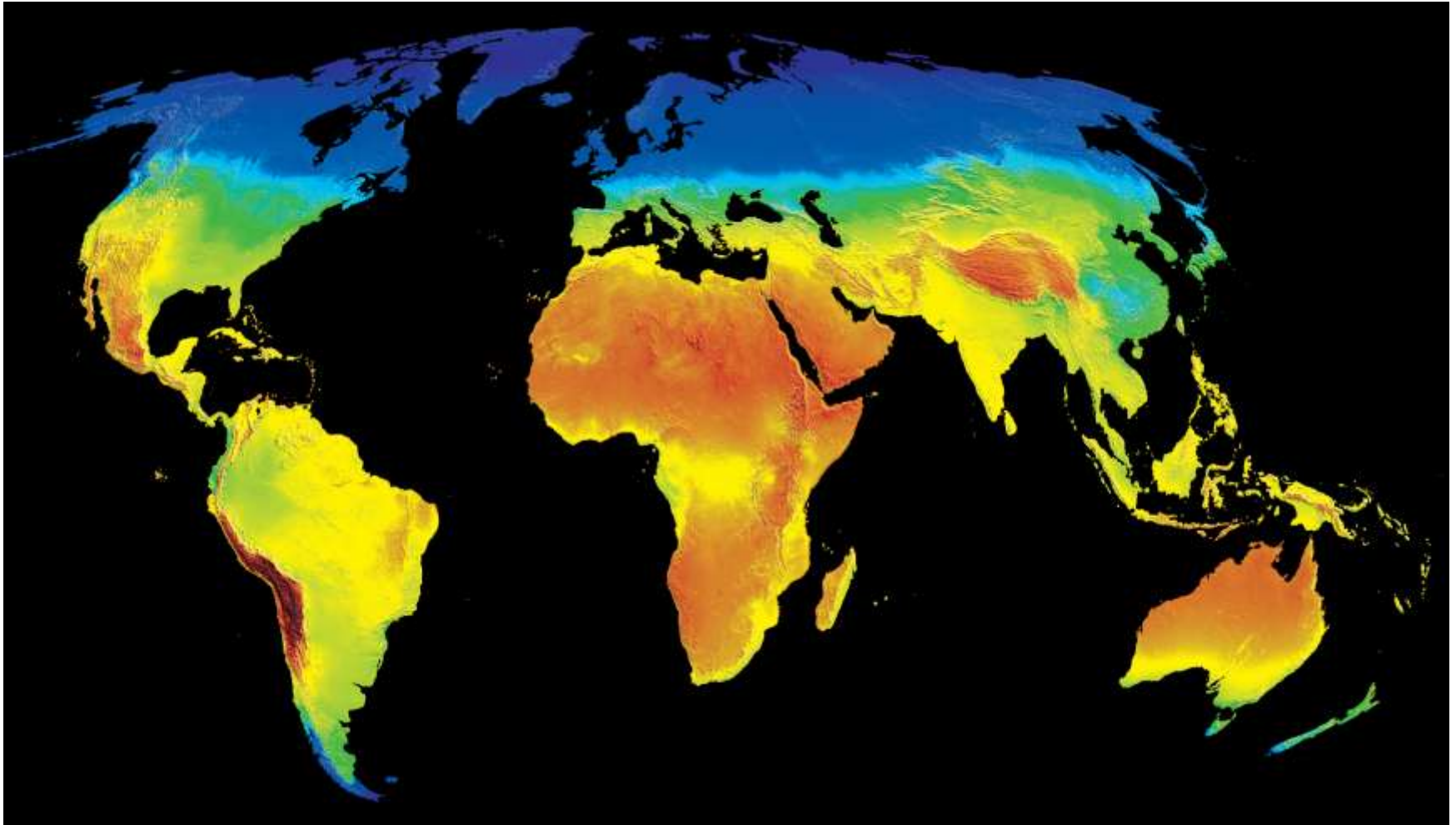
A person wearing blue gloves is holding a large, rectangular, blue solar panel. The panel has a grid of white lines. The background is slightly blurred, showing some greenery and a white object.

PV technologies on the market
which concepts are suitable for
Latin America?

irradiation map



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interesting technologies for Chile

c-Si



thin film



C-PV



interesting technologies for Chile

c-Si



thin film



C-PV



interesting technologies for Chile

c-Si



mc / Cz –Si

- high efficiencies
- high temperature coefficient
- low costs and high reduction potential
- excellent future
- innovations expected in production

thin film



CdTe / CIGS

- low efficiencies
- low temperature coefficient
- low costs and high reduction potential
- unsure future
- innovations need time
- environmental aspect

C-PV



low / high conc.

- highest efficiencies
- no temperature coefficient
- rather high costs (low volume)?
- very unsure future
- innovations need time

interesting technologies for Chile

c-Si



mc / Cz –Si

- high efficiencies
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thin film



CdTe / CIGS

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C-PV



low / high conc.

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interesting technologies for Chile



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c-Si



thin film



C-PV



- high efficiencies

- **low efficiencies**

- highest efficiencies

cheap robust
technology
with future
reduction

- low temperature
coefficient

- low temperature
coefficient

- low costs and high
reduction potential

useful for
countries in
sunbelt

- excellent future

- **unsure future**

- **very unsure future**

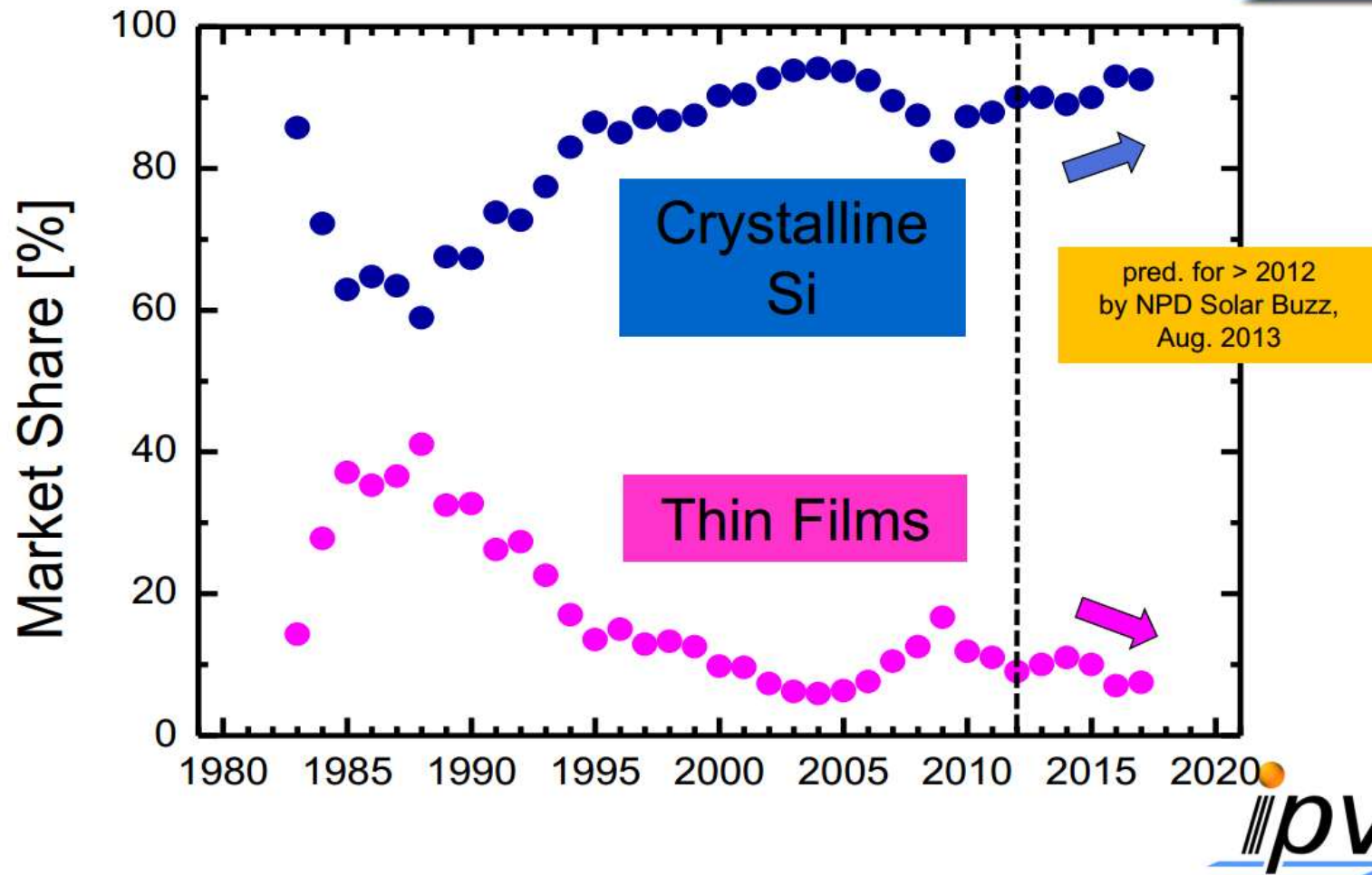
- innovations expected
in production

- innovations need time

- innovations need time

- **environmental aspect**

c-Si vs. thin film



interesting technologies for Chile



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residential



c-Si: mc- or Cz-Modules

- research is ongoing to reduce the temperature coefficient
- module properties have to be adapted to climatic properties
- module efficiency is fast improving

large power plants



c-Si (or C-PV)

- bifacial modules are extremely interesting
- large C-PV producer has to go in real mass production

interesting technologies for Chile



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residential



c-Si: mc- or Cz-Modules

- research is ongoing, especially for the temperate climate
- module properties need to be adapted to climatic properties
- module efficiency is fast improving

large power plants



c-Si (or C-PV)

bifacial modules are interesting

has to
be
checked

*at the end count costs/kWh
<10ct/kWh in 2014*

Research topics



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GERMANY

- snow
- cold



CHILE

- sand
- hot

Research topics in c-Si PV



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CELL

- material saving
 - thinner wafer
 - Cu instead of Ag
- colorful cells
- bifacial cells
- rear contact cells
- concentrators
- tandem
- 3rd generation?



MODULE

- material saving
 - thinner glass
 - less encapsulant
 - no frames
- longer lifetime
 - glass/glass
 - silcones instead EVA
- bifacial modules
- desert modules
- hybrides (solar thermal)



SYSTEM

- material saving
 - less frames
- more stable holders
- stable cables
- stable convertors
- smart-grid
- storage!!! (also e.g. power to gas)

Research topics in c-Si PV



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CELL

- material saving
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MODULE

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SYSTEM

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bifacial c-Si solar cells and modules

- 1) Advanced solar cells becoming bifacial anyhow
- 2) Module producers move to glass/glass anyhow
- 3) In dessert regions high ground reflectivity is guaranteed

Why bifacial now?? NEWS 2013



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1.25MW Solar Plant Starts Operation With Bifacial Panels

Kenji Kaneko, Nikkei BP CleanTech Institute

2013/12/11 12:31

f Like 2 t Tweet 0

Print

Nishiyama Sakata Denki Co Ltd, a Japan-based firm specialized in electrical system design, started operation of a 1.25MW mega-solar (large-scale solar) power plant using double-sided (bifacial) solar panels Nov 29, 2013.



"Asahikawa Hokuto Solar Power Plant," a 1.25MW solar plant using bifacial solar panels (source: Nishiyama Sakata Denki)

The plant is named "Asahikawa Hokuto Solar Power Plant." One side of the panel uses sunlight to generate electricity while the other side uses light reflected from snow. As a result, the total amount of electricity generated can be increased. Also, the company will perform field tests of a "stand-alone snow melting system" using the bifacial solar panels.

In December 2012, the government of Asahikawa City selected Nishiyama Sakata Denki (Asahikawa City), which proposed the construction of the mega-solar plant, as a developer for the site of the former ground of Hokkaido Asahikawa Hokuto Commercial High School. The company started the construction in May 2013.

REC desert panels at Intersolar Europe

20. JUNE 2013 | [GLOBAL PV MARKETS, INDUSTRY & SUPPLIERS](#), [INTERSOLAR EUROPE](#), [INVESTOR NEWS, MARKETS & TRENDS](#) | BY: MAX HALL

Norwegian manufacturer showcases its bifacial, desert-proof Peak Energy panels at Munich trade show. REC, which produces its panels in Singapore, has opened a Dubai office to target the MENA market.



REC, which manufactures panels in Singapore, is targeting the MENA region.
REC

Norwegian panel maker [Renewable Energy Corporation](#) (REC) is using this week's [Intersolar Europe](#) to showcase its desert-friendly technology as it makes a push for the Middle East and North Africa (MENA) region.

REC, which claims to be Europe's biggest solar panel manufacturer, is using its stand in Munich to demonstrate its bifacial REC Peak Energy Series panel, which has secured desert proof accreditation under the IEC 60068 sand blowing protocol of certification company SGS.

The Peak Energy panel has been tested in the field at the Desert Knowledge Australia Solar Center in Alice Springs and the manufacturer says the Australian center has stated the panel 'performs better than most of the monocrystalline competitors (c-Si) and achieved higher yields than panels produced by REC's industry peers.'

Why bifacial now?? NEWS 2013



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Meyer-Burger: <http://www.solarinternationalawards.net/shortlist/2013>

Meyer Burger Atacama Slate

The innovative concept presented by Meyer Burger, the solar module "Atacama Slate", meets the need of cost-effective solutions for producing electricity in regions with high solar irradiance, sand storms and high temperatures (i.e. deserts). The Atacama Slate is based on a combination of high efficiency technologies and innovative module design adapted to the specific requirements of desert regions. The Atacama Slate consists of a bi-facial, frameless, glass/glass module design combining the high efficiency heterojunction and SmartWire connection technology. The combination of all factors leads to an optimum energy yield while lowering the total cost of ownership.

The challenge in desert regions is to achieve an optimal energy yield given the delicate climatic conditions. High solar irradiance, high environmental temperatures, sand storms as well as a different light spectrum need to be considered in the design and technology of solar modules.

The Atacama Slate module is the solution for reaching maximum energy yield by combining high efficiency technologies with a dedicated module design adapted to desert regions.

Heterojunction cells have a low temperature coefficient of approx. 0.20% and are designed for high irradiance conditions. The SmartWire Connection Technology is a cost efficient method based on cell connection by wires instead of bus bars which are capable of reaching up to 5% higher power output compared to best-in-class bus bar technology. In addition, the Atacama Slate offers the possibility of bifacial use thanks to its vertical installation. Sand and dust retention is countered by a frameless design, while the glass/glass construction enables the long module endurance.

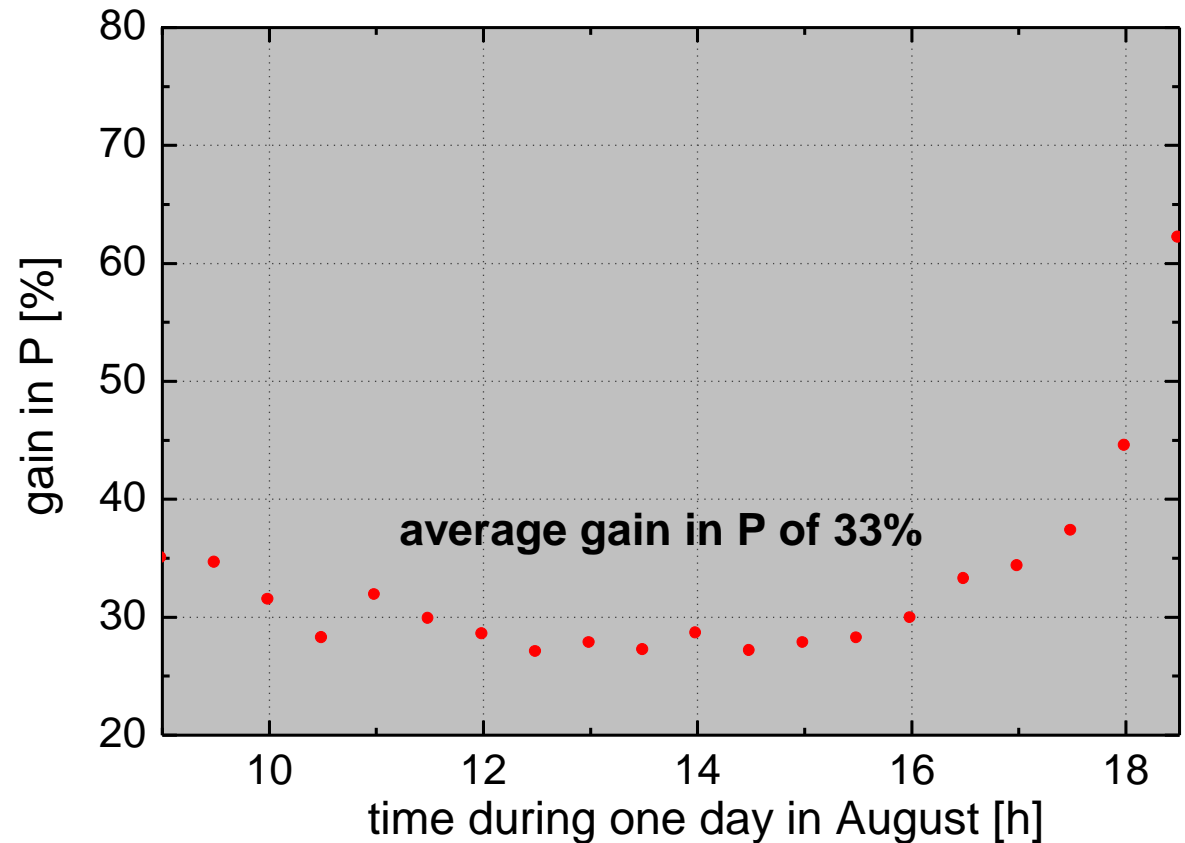
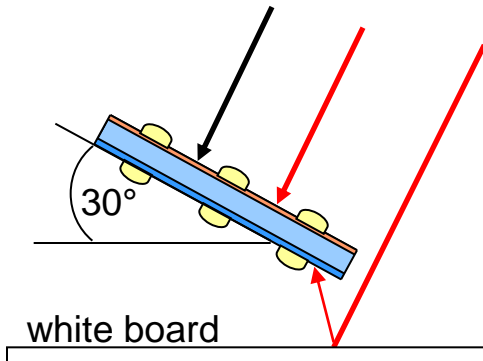
The Atacama Slate combines existing high efficiency technologies with a dedicated module design which takes the climatic conditions into consideration and thus delivers a product specifically adapted to these regions but also a cost-effective solution for producing electricity.

bifacial modules: standard orientation



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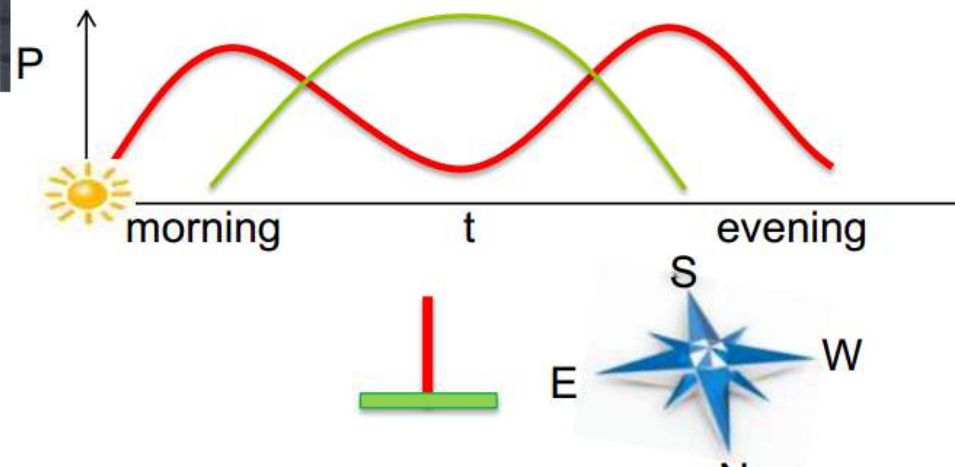
outdoors measurement on roof of PV lab at UKON
(southern Germany)



bifacial modules: east west orientation



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bifacial modules: system measurements



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APPLICATION:
Flat rooftop
installations,
white-coated



bSolar
The Bifacial PV Cell Company

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%**

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%**

measurements in desert conditions



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2 modules developed at ISC Konstanz



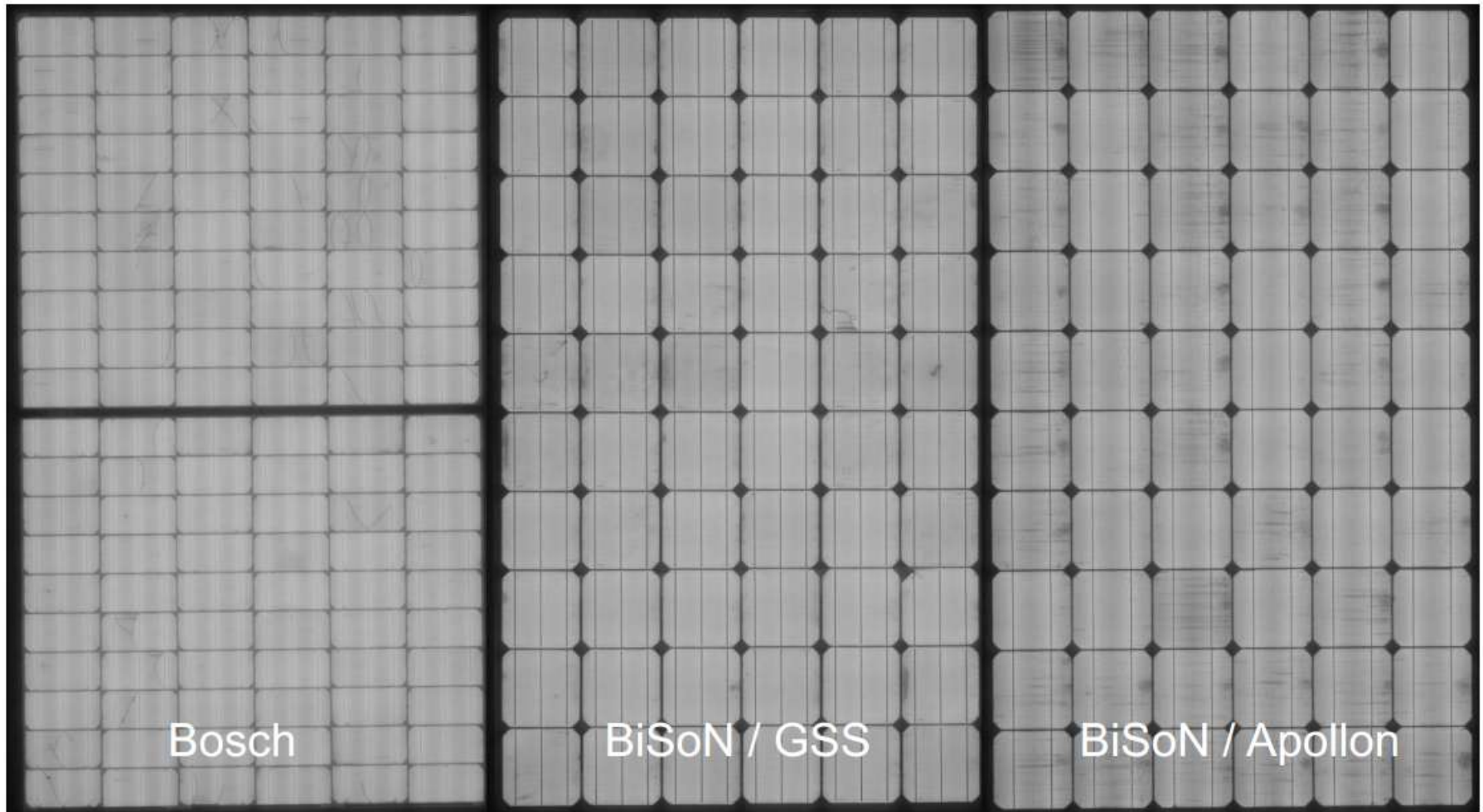
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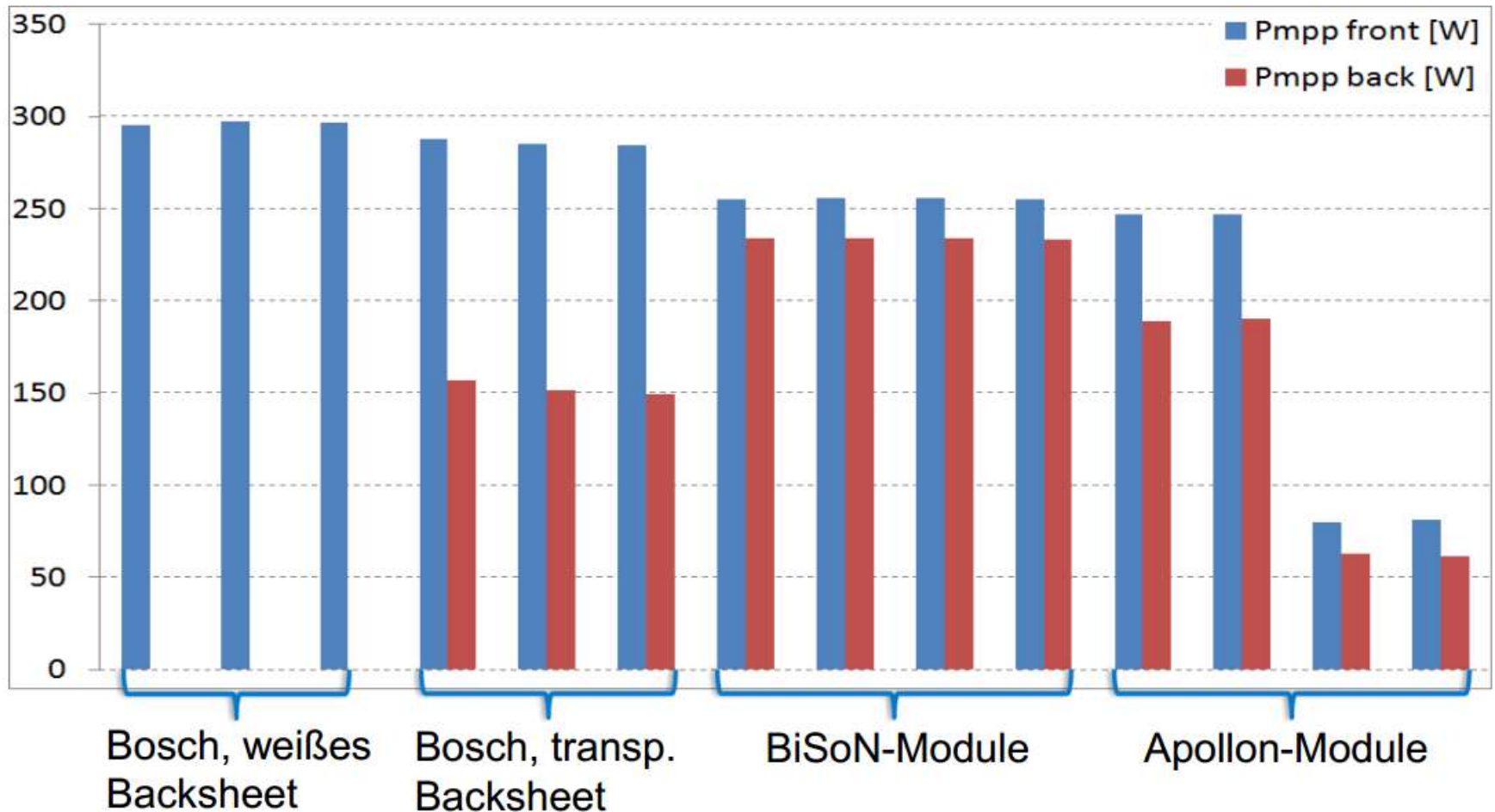
EL of three different bifacial modules



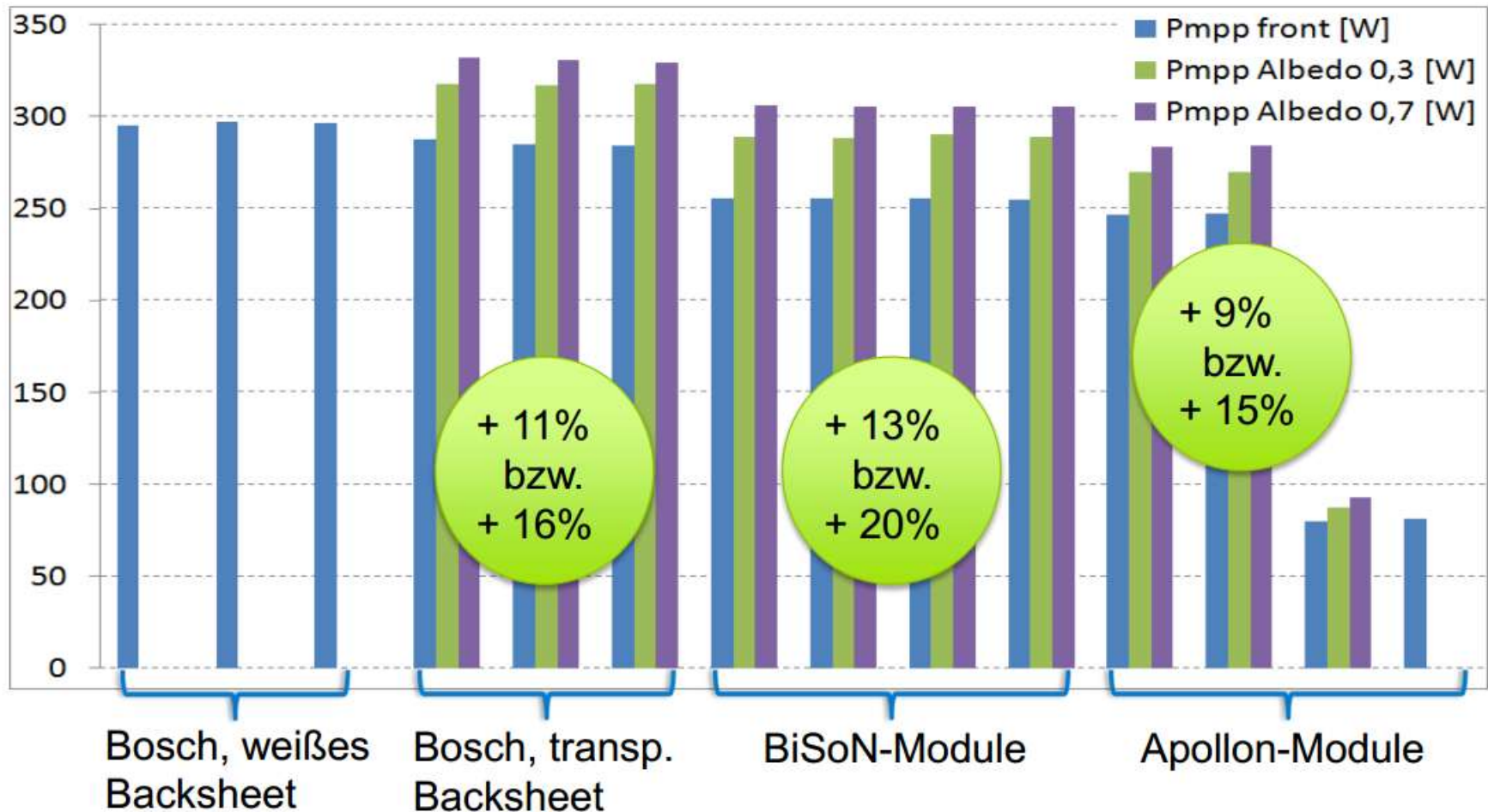
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indoor separate measurements



indoor bifacial measurements



outdoor measurements



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El Gouna, Egypt

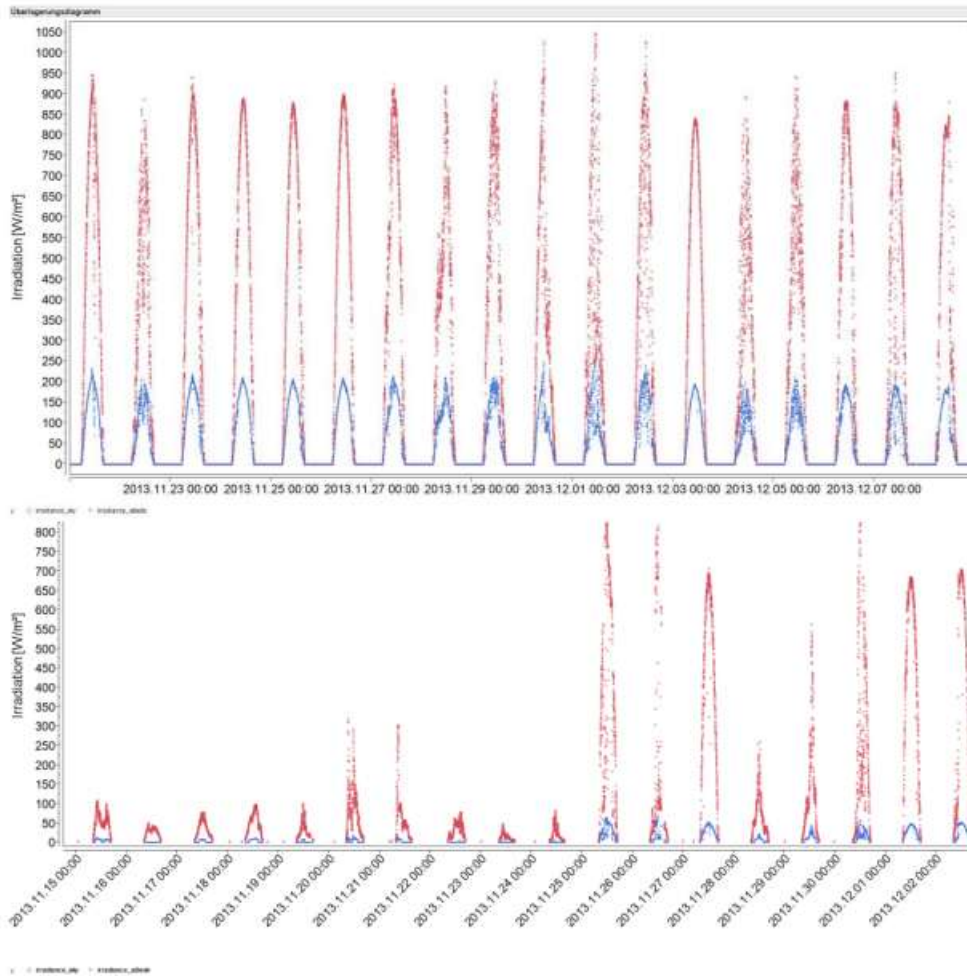


Konstanz, Germany

outdoor measurements: comparison



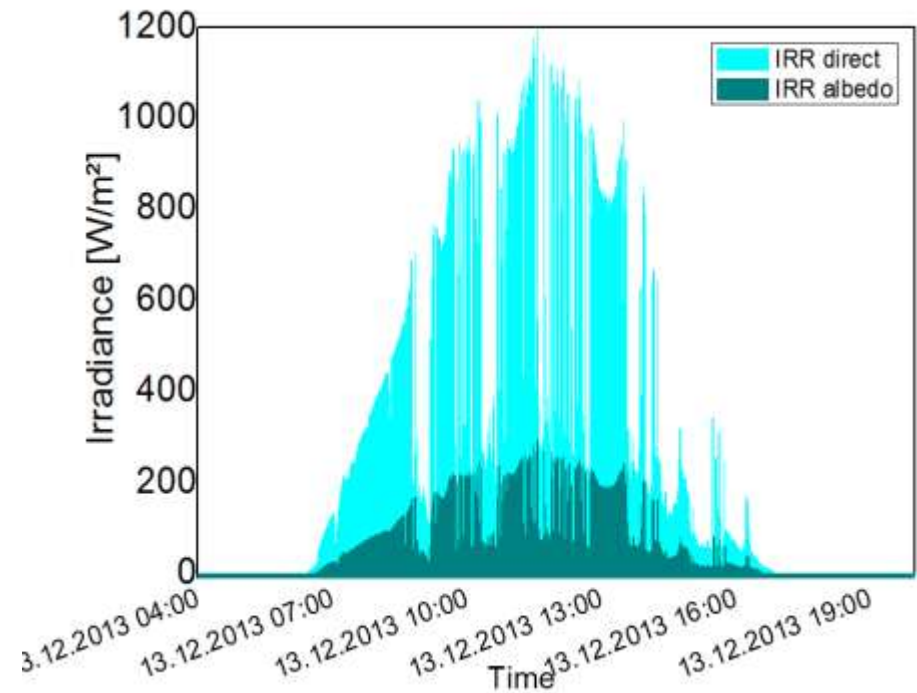
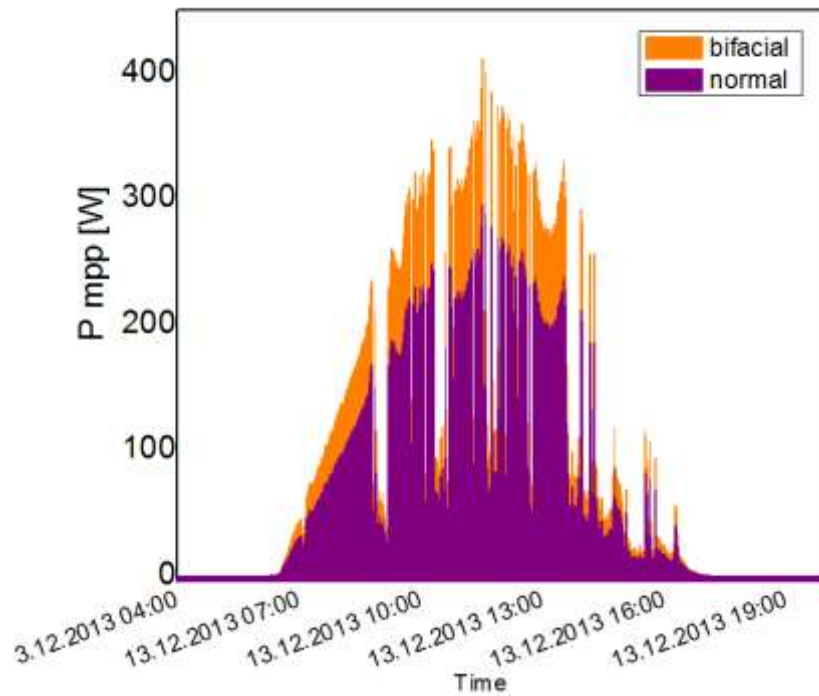
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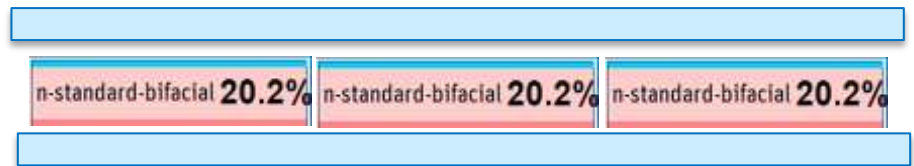
outdoor measurements: “400Wp”



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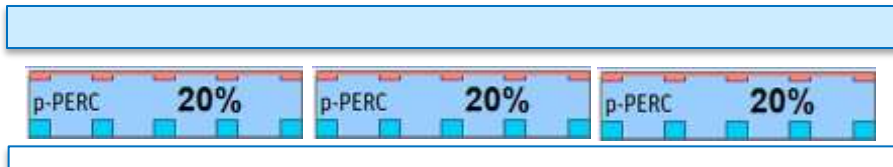


“400W”: 45ct/Wp



AtaMo

260W: 50ct/Wp



standard

Bifacial Cell >>> 20% efficiency

- high bifaciality coefficient >0.9
- high efficiency (high voltage) $>>$ low T-coefficient
- low costs (Cu-Metallisation)

Glass/glass Module >>> “400Wp”

- thin glasses
- frameless modules
- gluing or pressing instead of solder (no Pb and low micro cracks)
- silicones instead of EVA (better UV response, long stability)
- bypass diodes for 20 A (or half cells)
- junction boxes at sides

System design

- minimizing BOS (minimising installation material)
- novel reflective systems

2nd bifiPV workshop 2014



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Organizers:



International Solar Energy
Research Center Konstanz



Imprint

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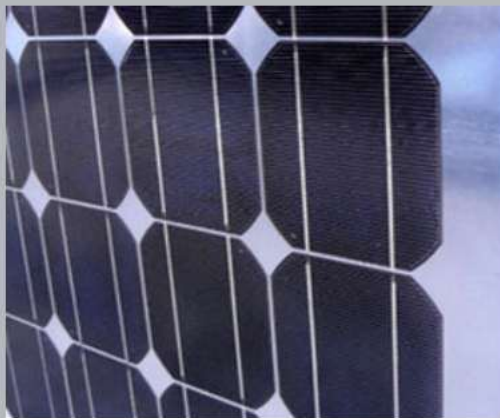
[Info about Chambéry](#)

[Registration](#)

[Accommodation](#)

[Contact](#)

[Previous Workshops](#)



Dear PV-scientists,

After having reached grid parity in many areas in Europe, the integration of photovoltaic into buildings and landscapes becomes an essential challenge to further increase the share of this renewable energy source. Bifacial modules have a great potential to increase the electricity yield of a system by up to 30%.

INES and ISC Konstanz organise the **second bifi PV workshop** which takes place in the **26th and 27th of May 2014 in Chambéry**. The goal of this workshop is not only to review all existing technologies on the market but also to start to set standards and to identify the market potential.

We hope to see you at the workshop.

Your organisers,

Yannick Veschetti, Eric Gerritsen, Andreas Schneider and Radovan Kopecek

2nd bifiPV workshop 2014



International Solar Energy
Research Center Konstanz

TITLE	DURATION (min)	SPEAKER
WELCOMING	10	INES
GENERAL INTRODUCTION	30	R. Kopecek /ISC Konstanz
SESSION 1: Market Potential		
INTRODUCTION	20	INQUIRED
SPEAKER 1	15	Fatima Tur / LUX Research
SPEAKER 2	15	Felix Holz / Deutsche Bank
SPEAKER 3	15	INQUIRED
SPEAKER 4 (optional)	15	INQUIRED
SESSION 2: Cell		
INTRODUCTION	20	Y. Veschetti / INES
SPEAKER 1	15	MOTECH / Po-Tsung Hsieh
SPEAKER 2	15	sunpower
SPEAKER 3	15	INQUIRED
SPEAKER 4 (optional)	15	INQUIRED
SESSION 3: Module		
INTRODUCTION	20	pi Berlin / Paul Grunow
SPEAKER 1	15	Apollon Solar / Roland Einhaus
SPEAKER 2	15	IHT Aachen / Tobias Plezer
SPEAKER 3	15	INQUIRED
SPEAKER 4 (optional)	15	INQUIRED
SESSION 4: Systems		
INTRODUCTION	20	Silfab / Franco Traverso
SPEAKER 1	15	PVGS
SPEAKER 3	15	B-Solar / Naftali Eisenberg
SPEAKER 2	15	INQUIRED
SPEAKER 4 (optional)	15	INQUIRED
SESSION 5: Standardization		
INTRODUCTION	20	HALM / Axel Metz
SPEAKER 1	15	TÜV Rheinland
SPEAKER 2	15	INQUIRED
SPEAKER 3	15	INQUIRED

Large bifacial c-Si PV System



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1.25MW Solar Plant Starts Operation With Bifacial Panels



"Asahikawa Hokuto Solar Power Plant," a 1.25MW solar plant using bifacial solar panels (source: Nishiyama Sakata Denki)

Costs: large bifacial c-Si PV system



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10 ct/kWh: Germany, 250W c-Si module

PRESENT

Costs: large bifacial c-Si PV system



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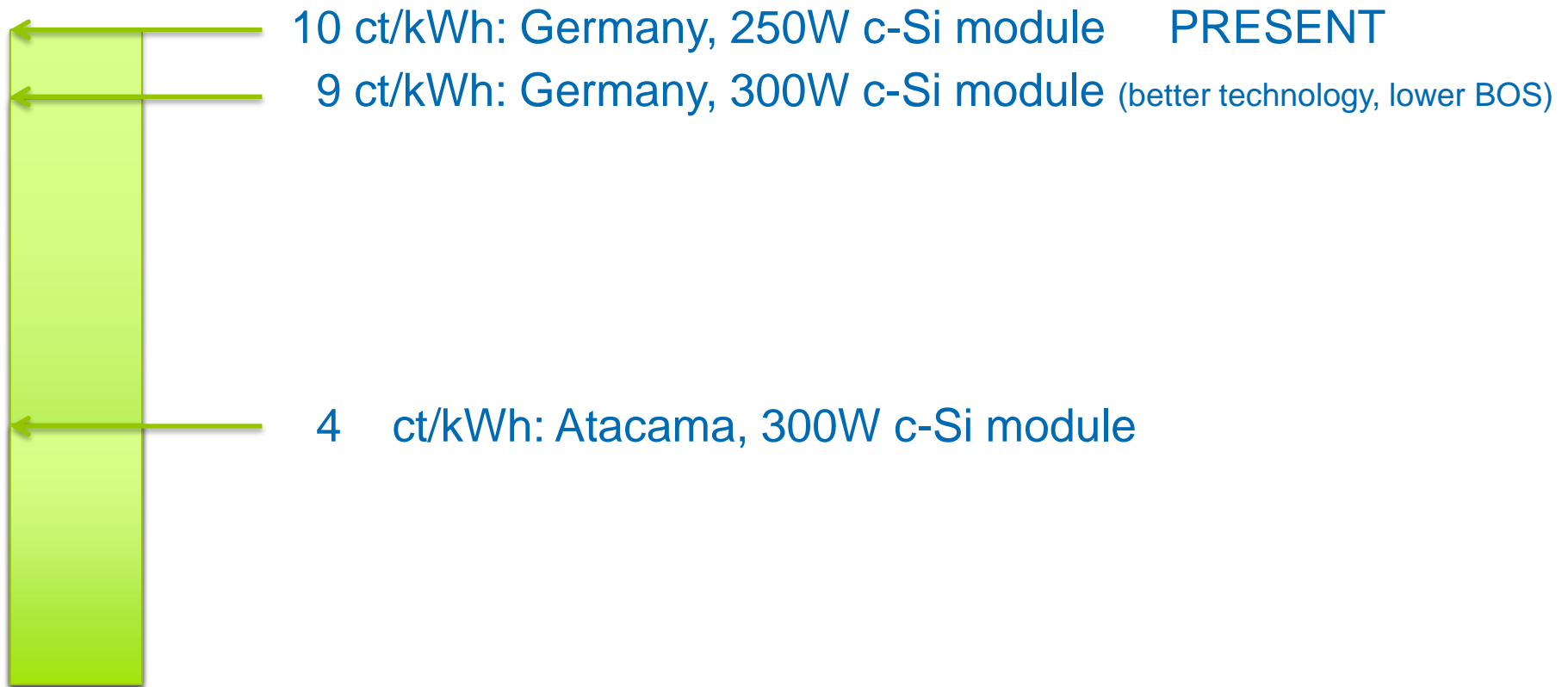
10 ct/kWh: Germany, 250W c-Si module **PRESENT**

9 ct/kWh: Germany, 300W c-Si module (better technology, lower BOS)

Costs: large bifacial c-Si PV system



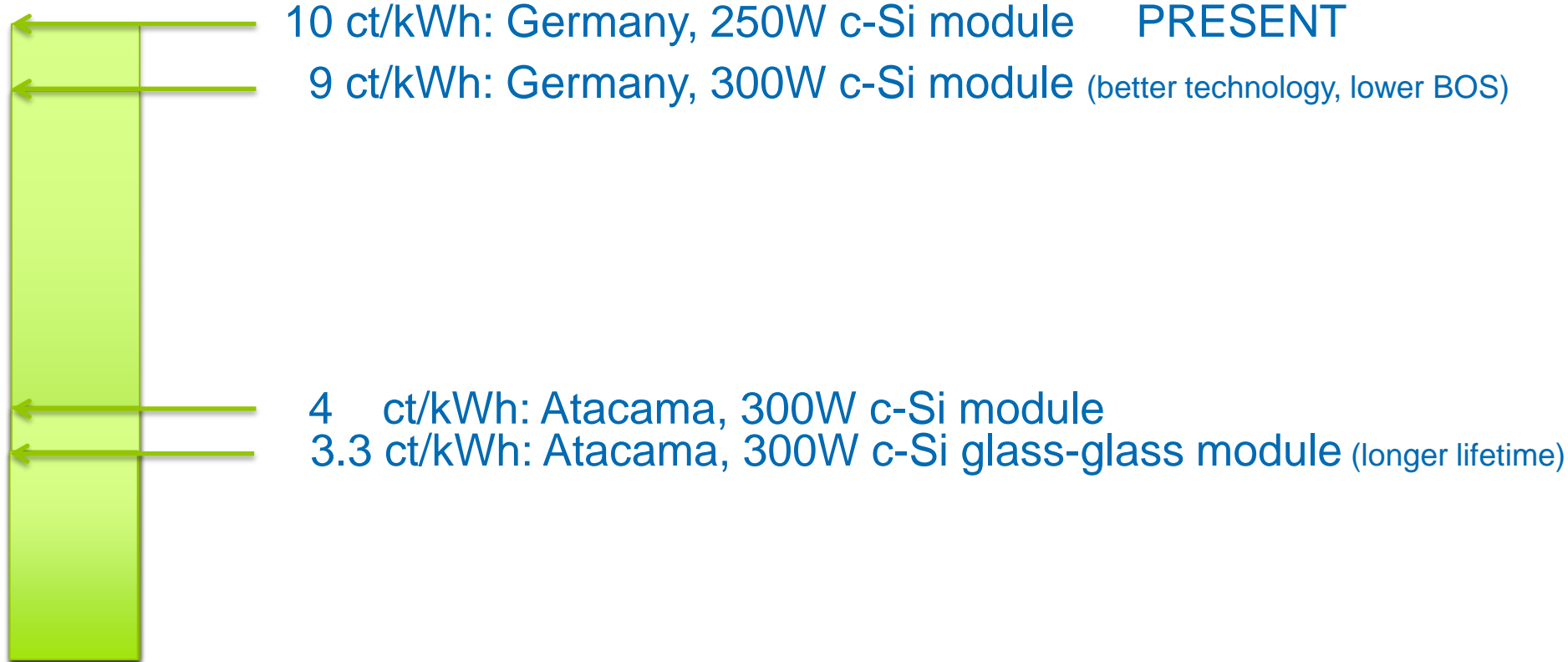
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Costs: large bifacial c-Si PV system



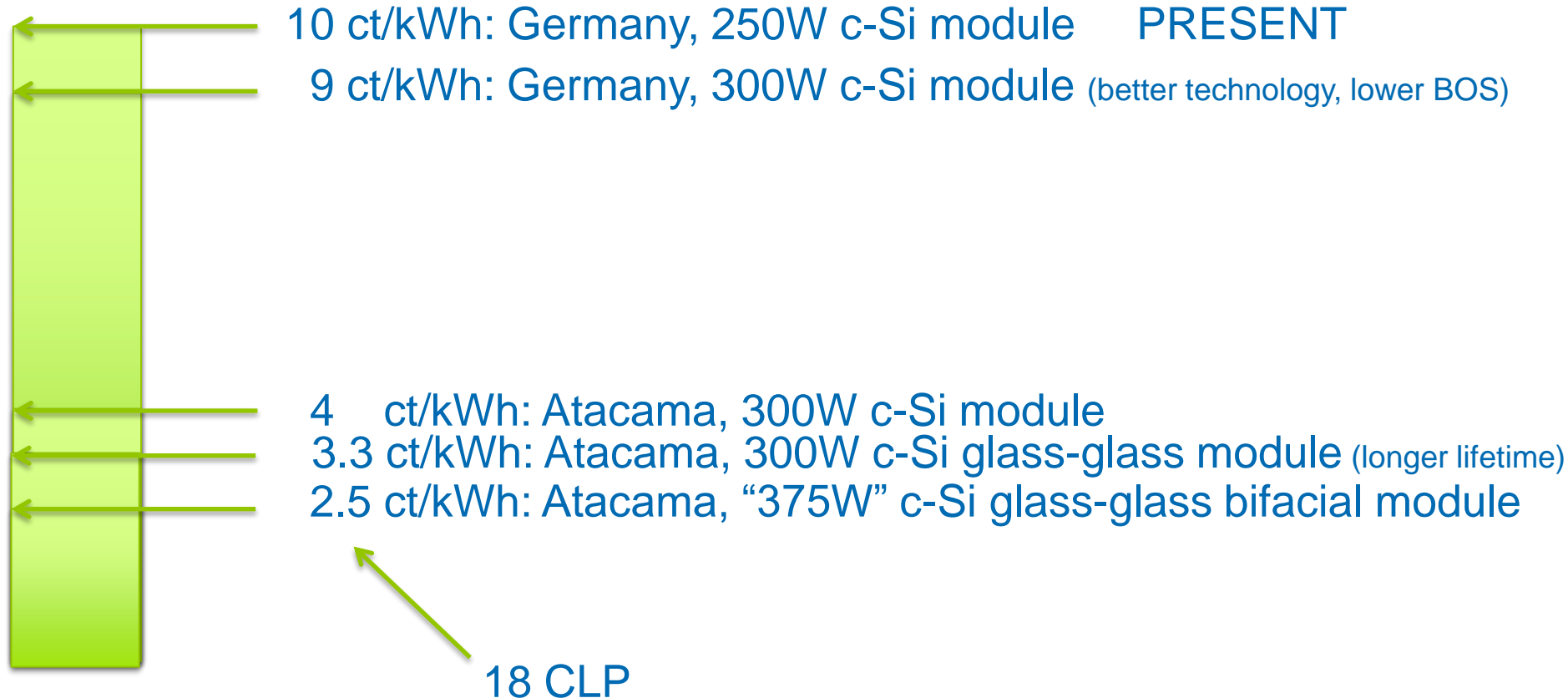
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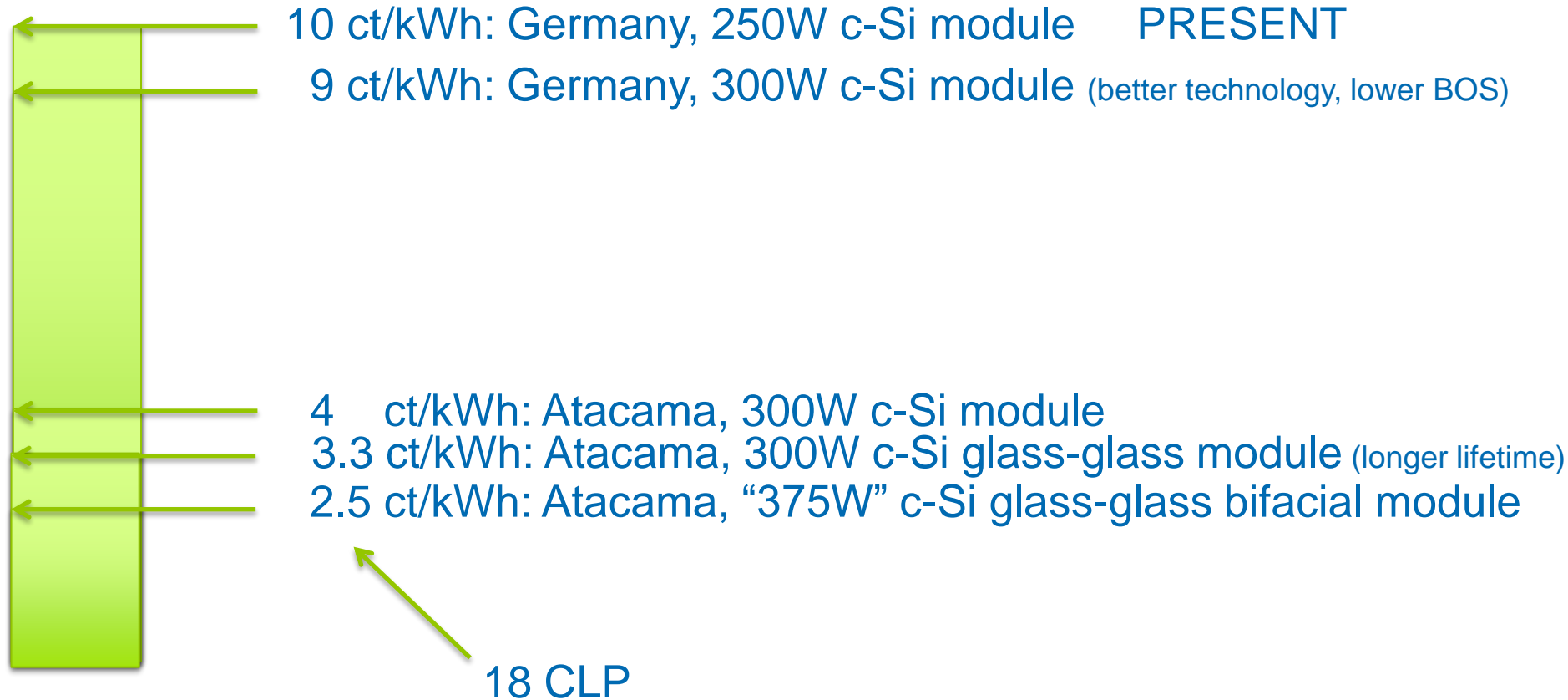
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Costs: large bifacial c-Si PV system



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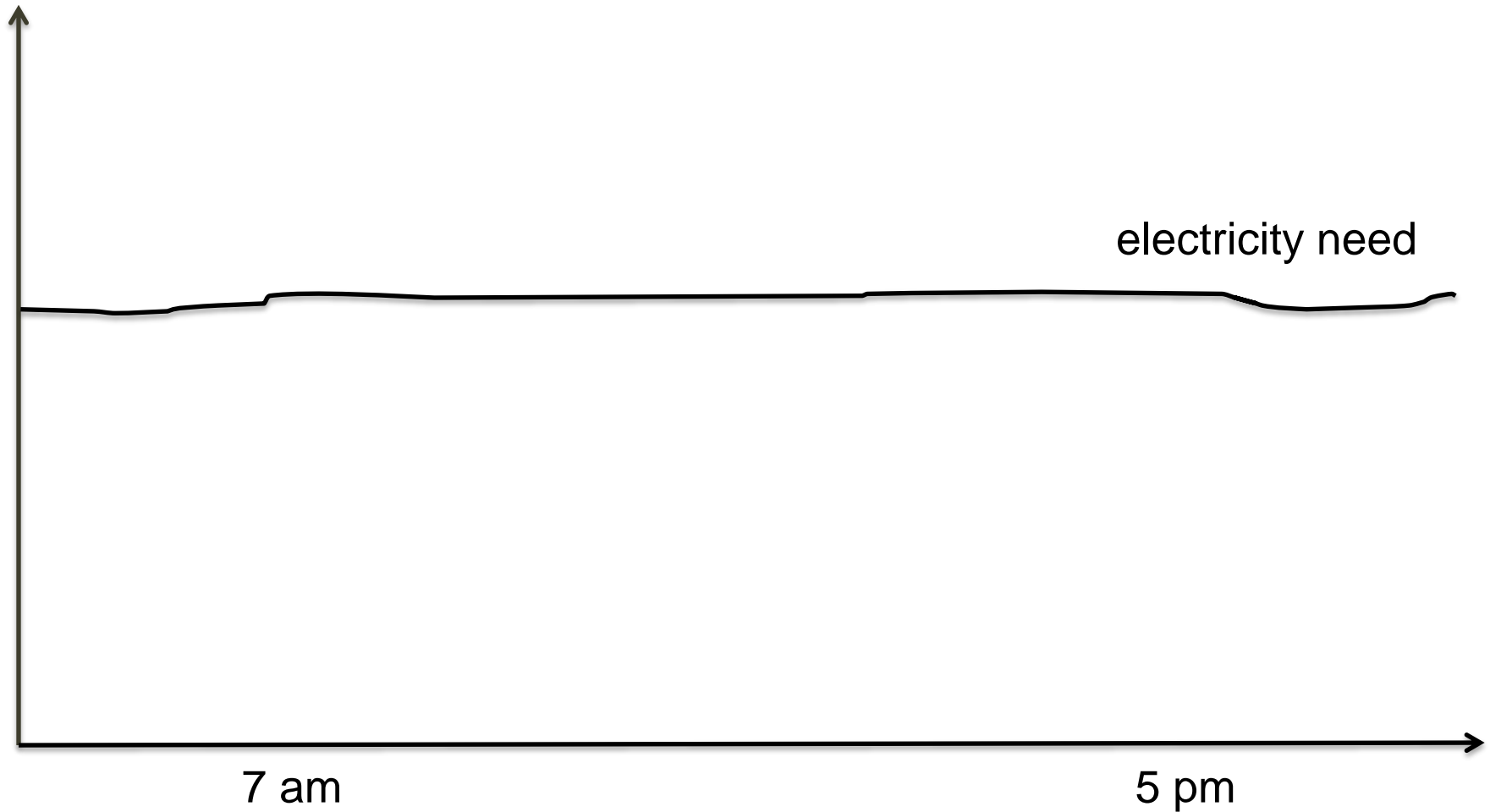


only evolution we can have tomorrow!!

Electricity production and consumption



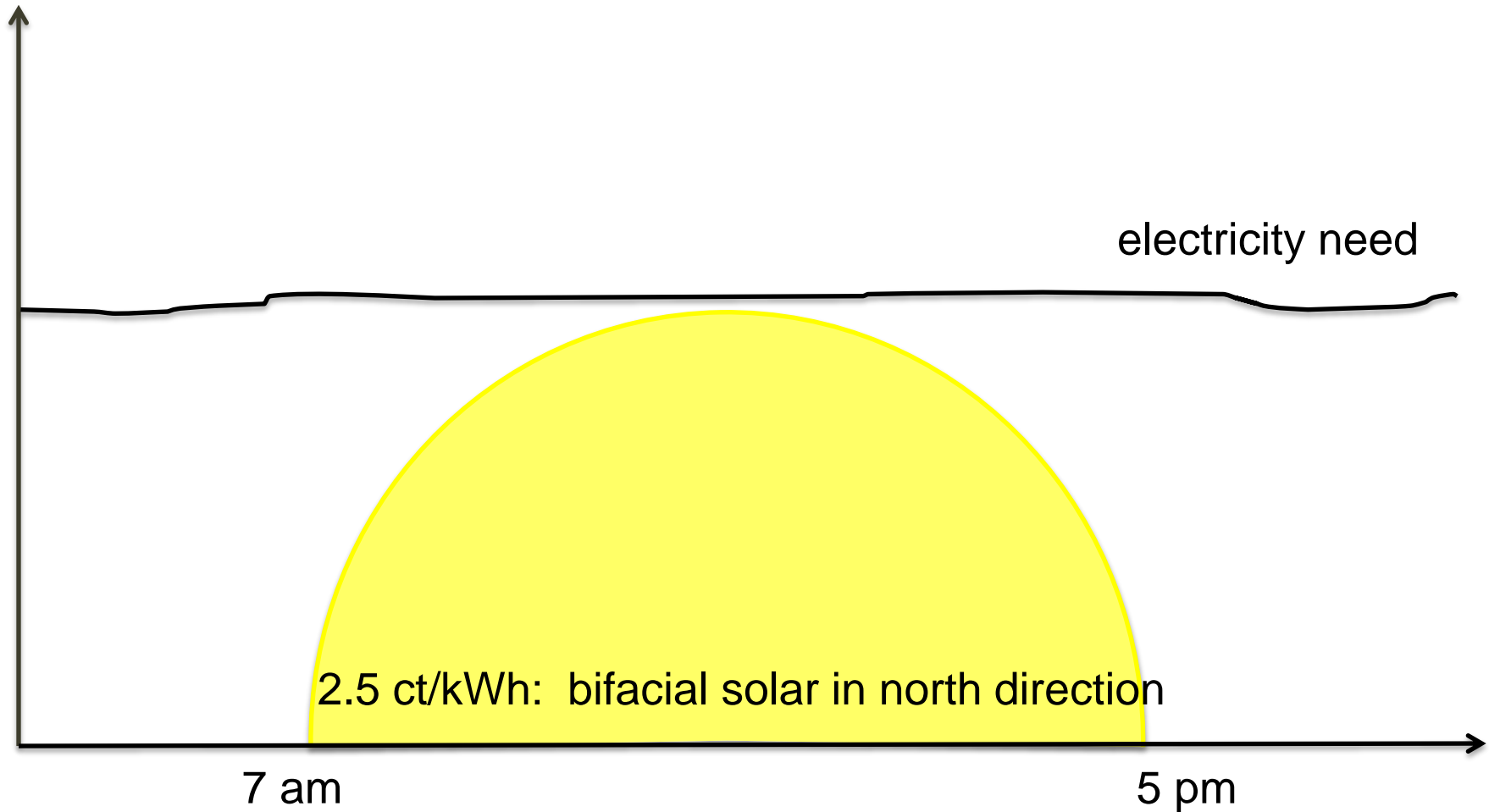
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Electricity production and consumption



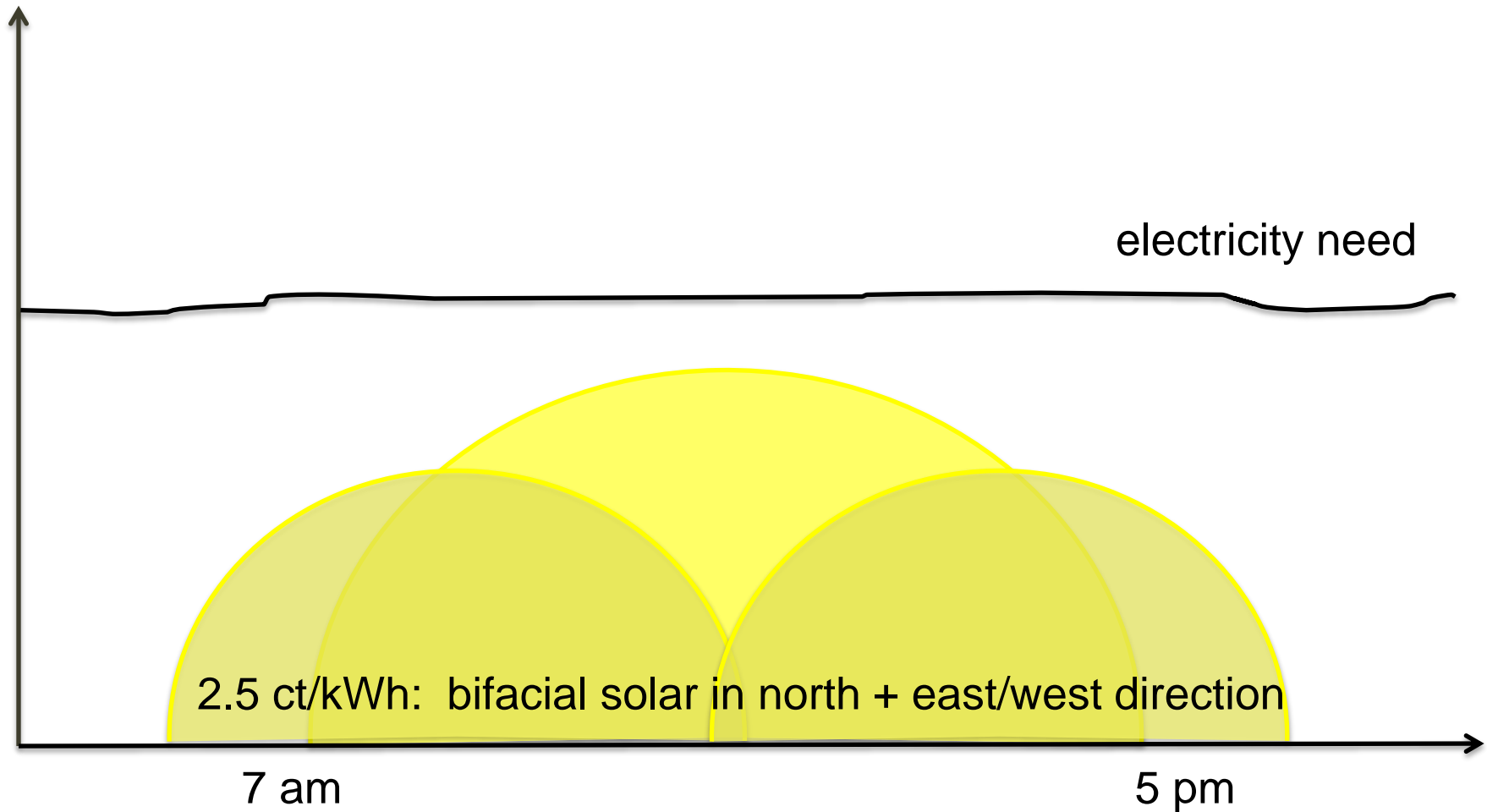
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Electricity production and consumption



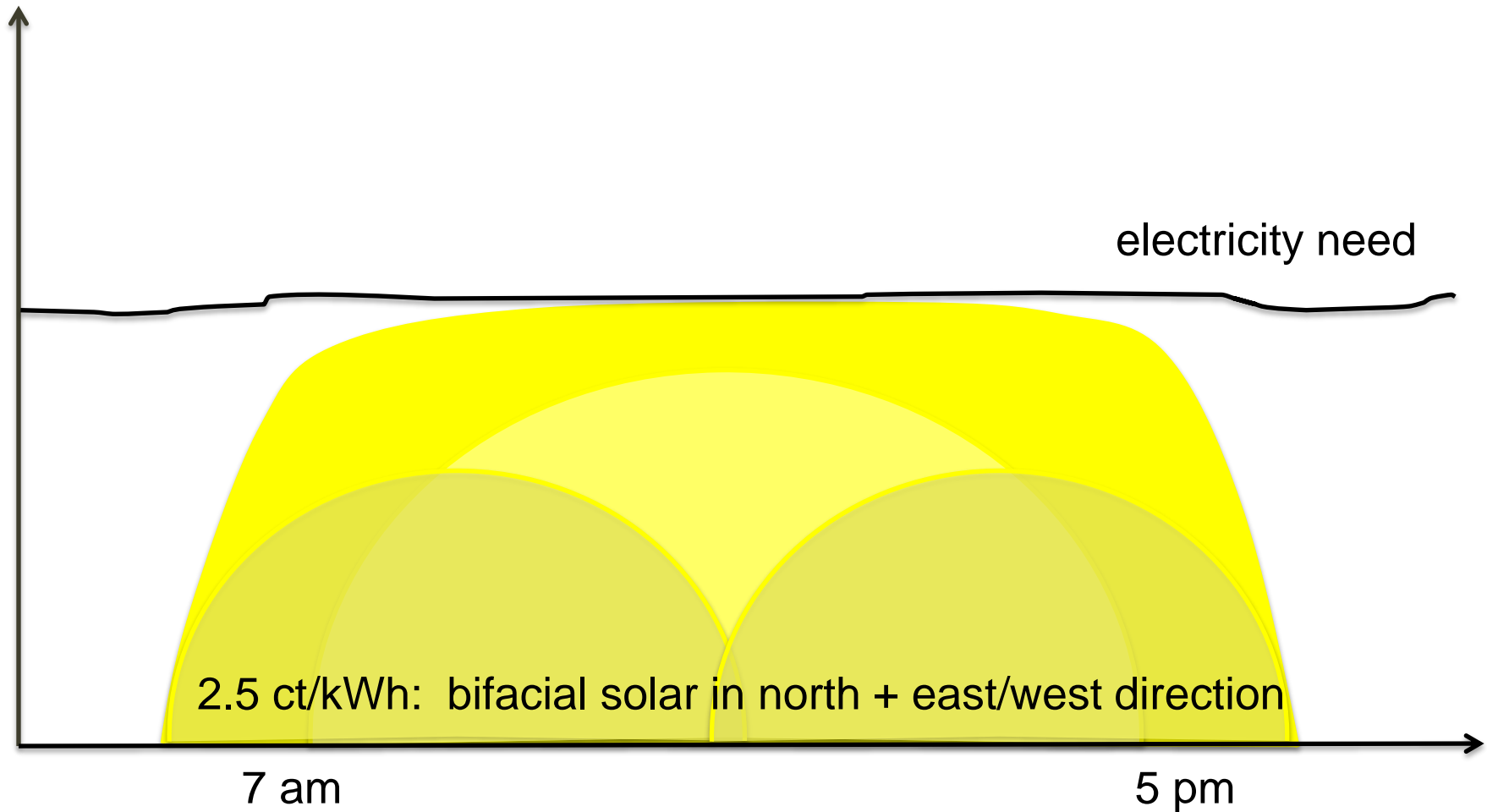
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Electricity production and consumption



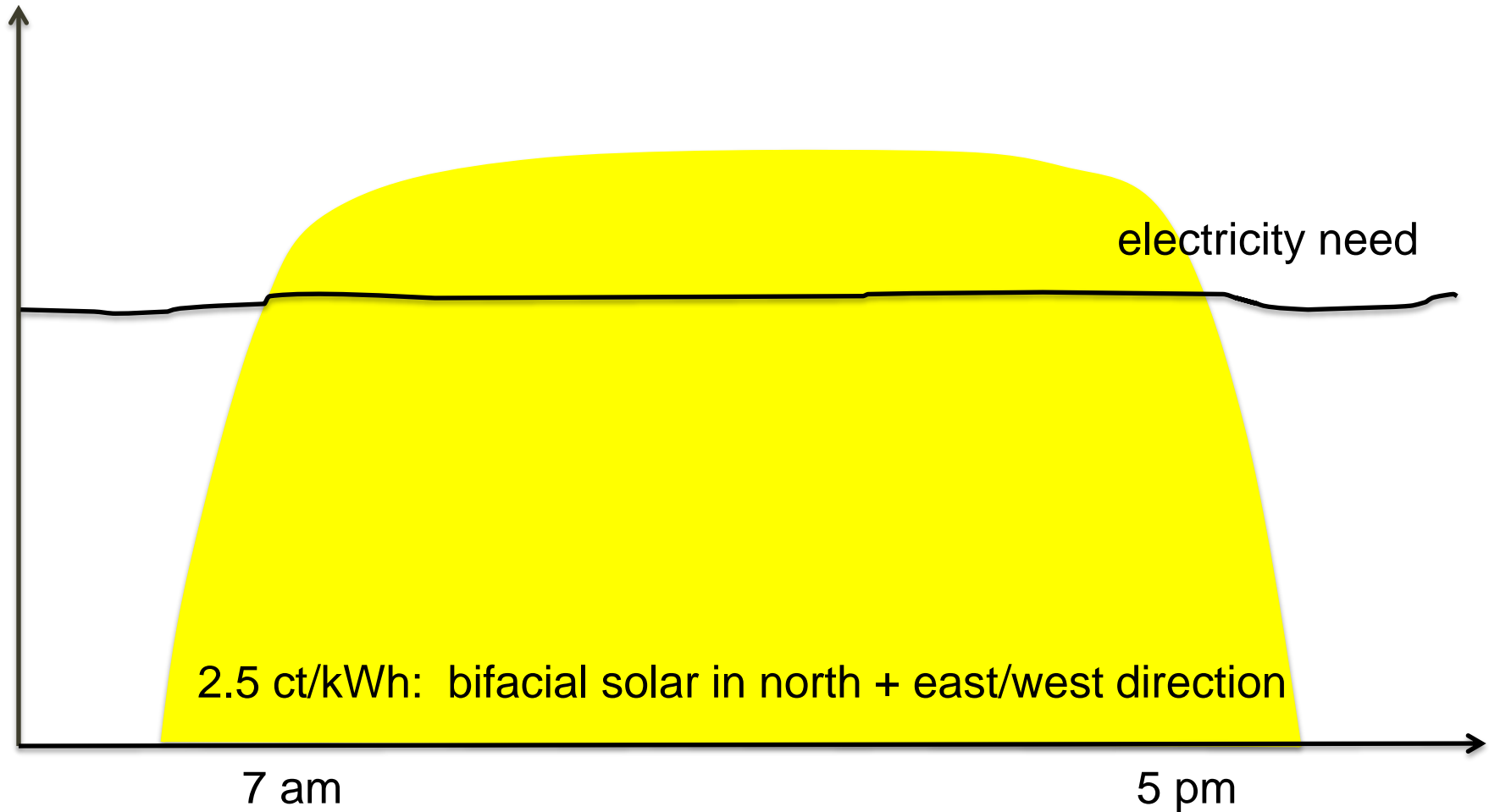
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Electricity production and consumption



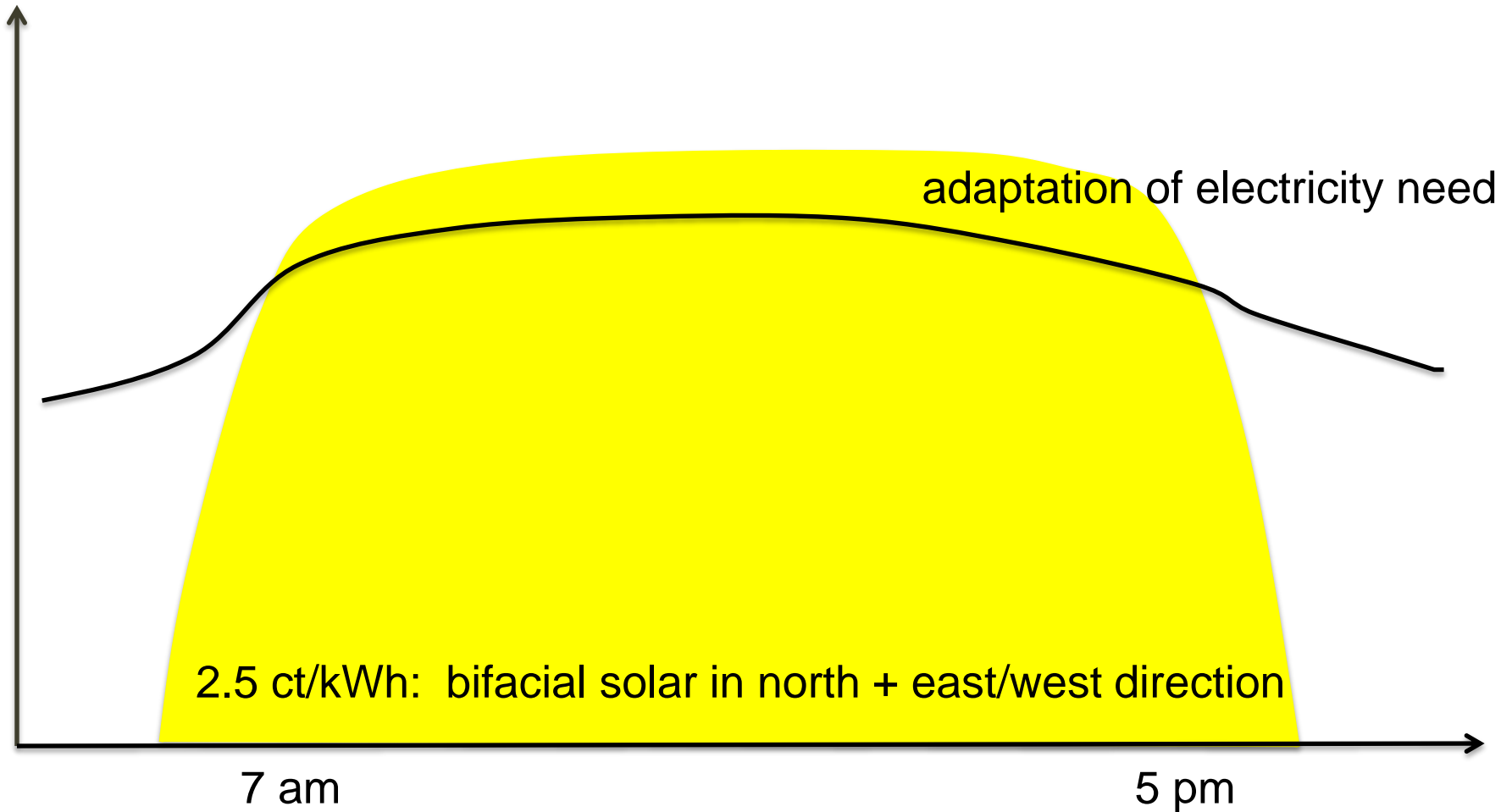
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Electricity production and consumption



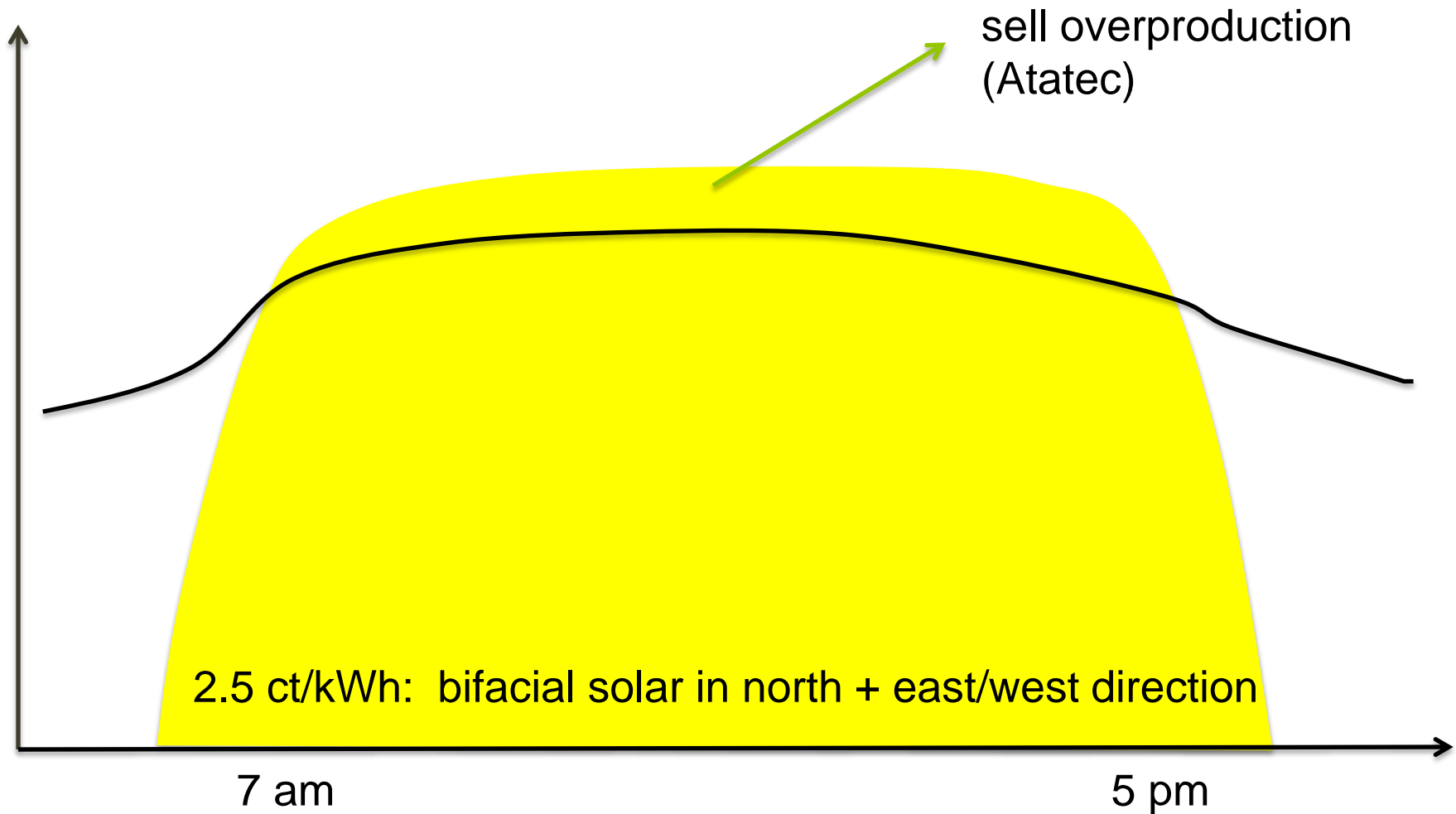
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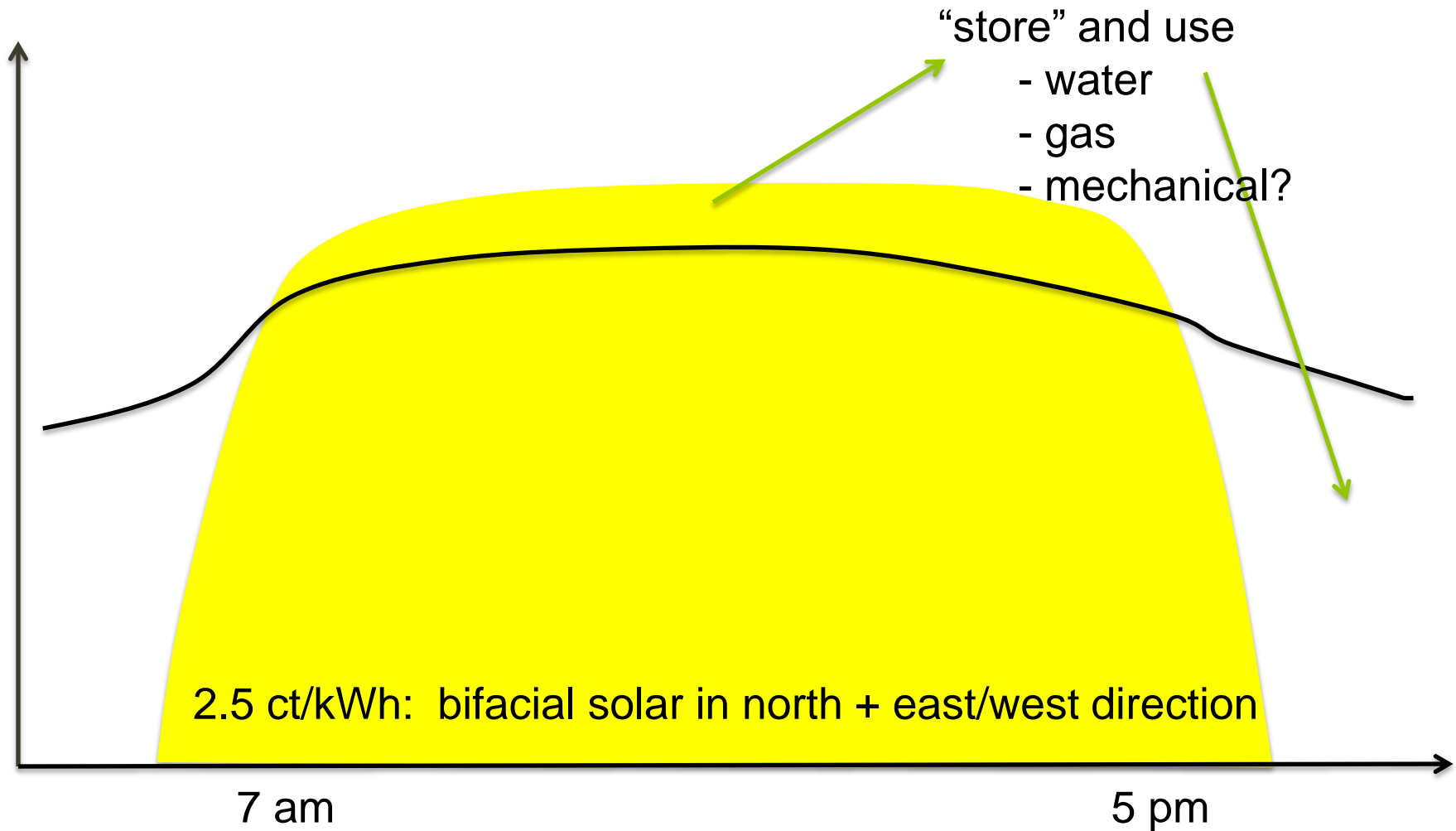
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Electricity production and consumption



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Förderung der Wissenschaftlich-Technologische Zusammenarbeit (WTZ) mit Chile, 2013



SolarChild: 2 years project



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III. Ausführliche Beschreibung der Methodologie und des Arbeitsplans

Es wird eine enge Kooperation zwischen SERC und dem ISC Konstanz geben mit Austausch von Studenten und Technologien.

Struktur des Gesamtprojekts

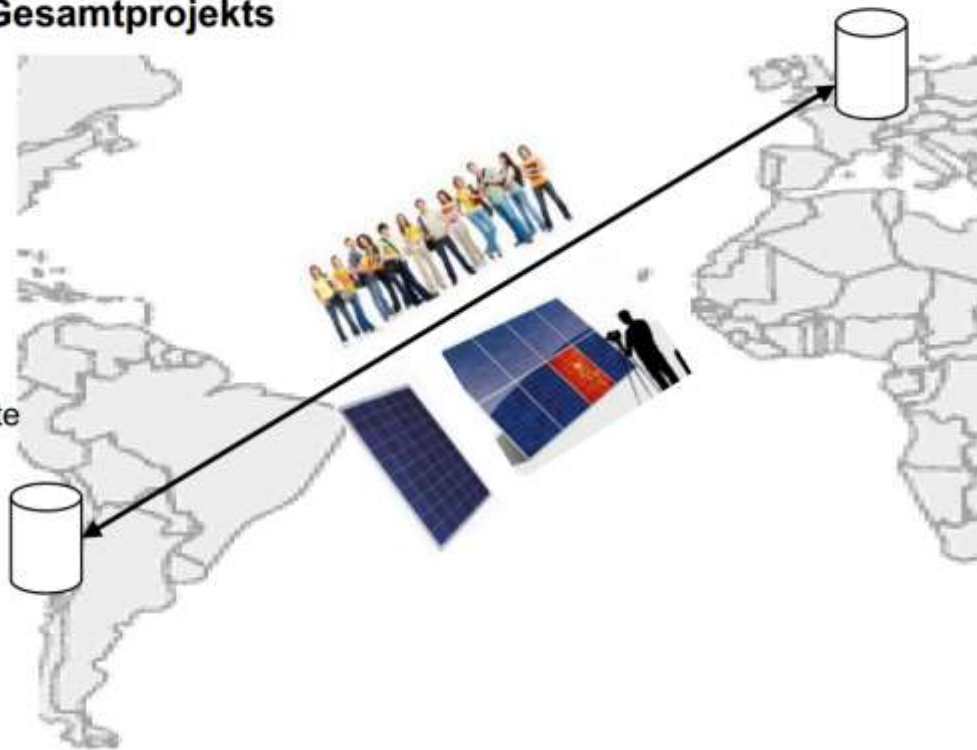
Uni de Chile

Expertise

- Leistungselektronik
- Systeme
- Netze

Ziele im Projekt

- Austausch
- gemeinsame Veranstaltungen
- gemeinsame Projekte



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ISC Konstanz

Expertise

- Material
- Solarzellen
- Module

Ziele im Projekt

- Austausch
- gemeinsame Veranstaltungen
- gemeinsame Projekte

SolarChild: 2 years project (1.6.2014)



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testing



Pablo Ferrada

AtaMo
← module development →

- demonstrators
- exchange of students
- workshops
- publications
- new project proposals



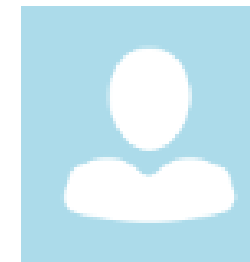
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cell development



Enrique Cabrera



PhD student from Chile
paid by ISC Konstanz

SolarChilD: 2 years project (1.6.2014)



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Research Center Konstanz

testing



International Solar Energy
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cell development



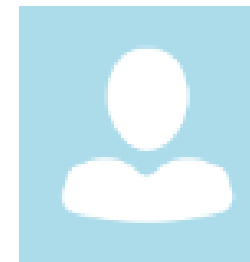
Pablo Ferrada

AtaMo
module development

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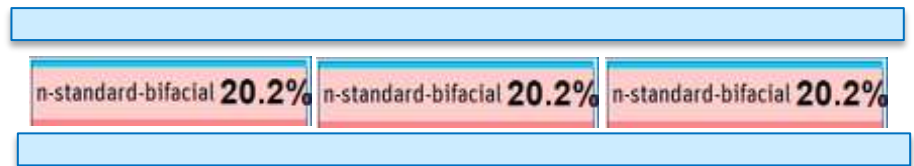
Enrique Cabrera



PhD student
Jorge Rabanal

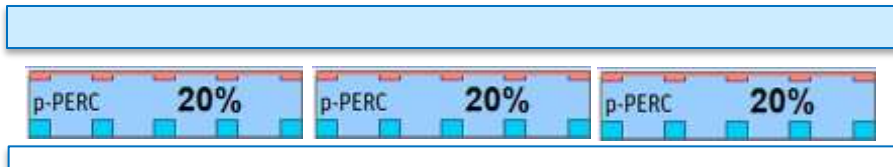


“400W”: 45ct/Wp



AtaMo

260W: 50ct/Wp



standard

Bifacial Cell >>> 20% efficiency

- high bifaciality coefficient >0.9
- high efficiency (high voltage) $>>$ low T-coefficient
- low costs (Cu-Metallisation)

Glass/glass Module >>> “400Wp”

- thin glasses
- frameless modules
- gluing or pressing instead of solder (no Pb and low micro cracks)
- silicones instead of EVA (better UV response, long stability)
- bypass diodes for 20 A (or half cells)
- junction boxes at sides

System

- minimizing BOS (minimising installation material)
- novel reflective systems
- 1 axis trackers
- recycling
- storage

AtaMo: first idea of cell and module



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AtaMo: ISC Konstanz: BiSoN >>> AtaMo

- >> low T coefficient
- >> more sensitive to UV
- >> Cu metallisation

AtaMo: Apollon Solar



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NICE
New Industrial Cells Encapsulation
TECHNOLOGY





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research for a sunny future

THANK YOU!
LET'S GO FOR AtaMo

Following presentations



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Enrique Cabrera

Metallisation for low cost and high efficient devices



Axel Metz

Characterisation of high efficiency cells, modules and systems