

Entering the bifacial n-type TW era technology and production landscape



research
for a sunny future

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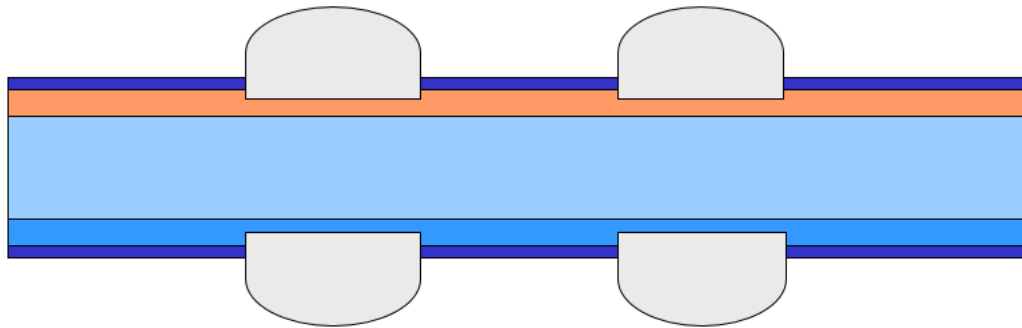
ISC Konstanz: bifacial nPV institute



sub¹⁰⁰



Front junction bifacial device with BSF



Main advantages

- elimination of bow
- improved rear side passivation
- less paste used
- increased power output
- applicable for p and n-type Si
- simplified module interconnection

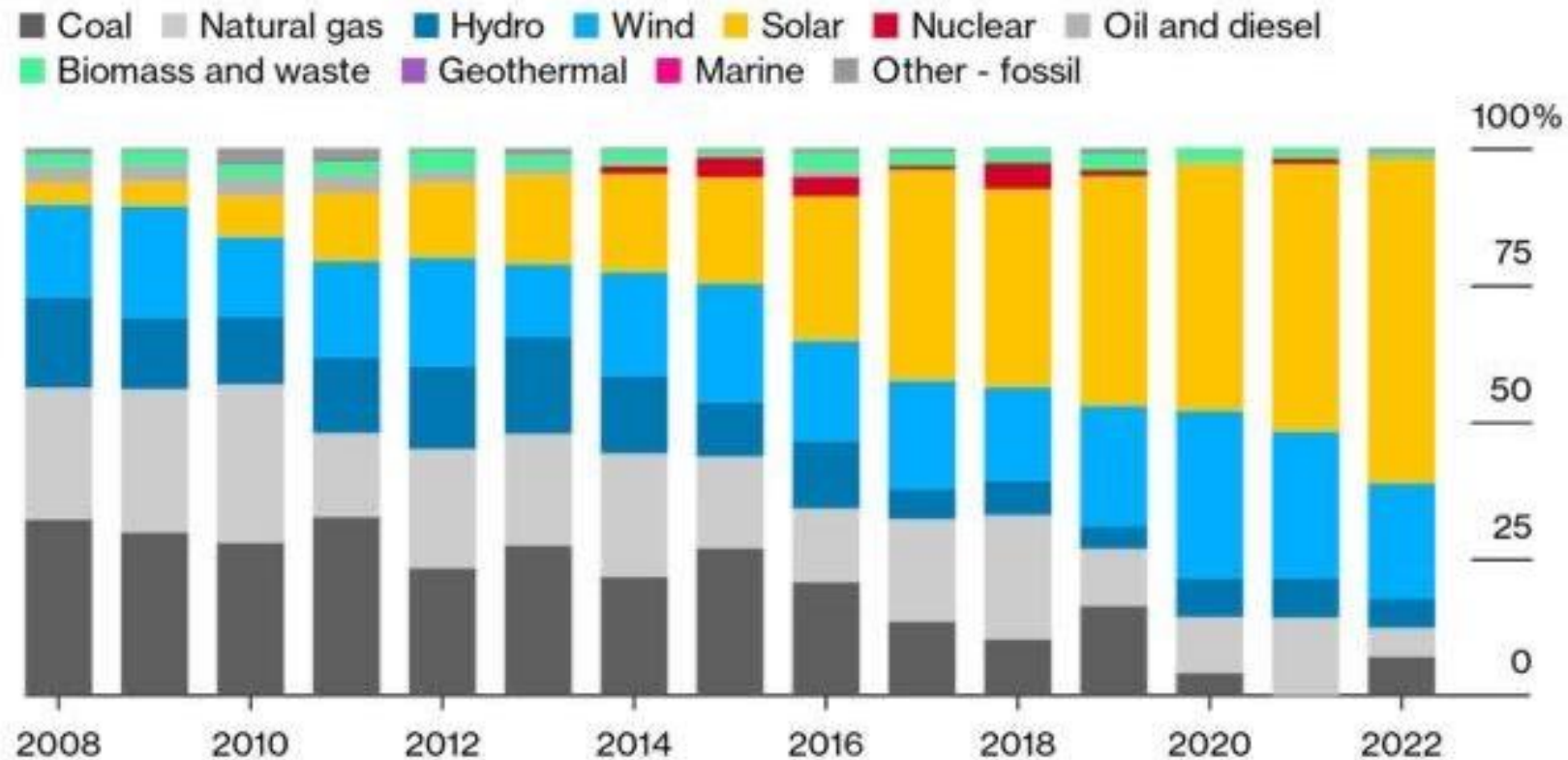
- 2000+: EU projects NESSI and FOXY on low cost nPV
- 2005+: Cooperation with Ersol later BOSCH
- 2010+: Development of industrial nPERT and IBC
- 2015+: Transfer of BiSoN and ZEBRA
- 2018+: Development of TOPCon and TBC
- 2023+: Transfer of TOUCAN and polyZEBRA

Agenda

1. PV market 2024-2050
2. ISC Konstanz: worldwide technol. trans.
3. Status of PV tech
4. Bifacial n-type tech
5. Summary



Share of global electricity capacity additions by technology by **Bloomberg**



Source: BloombergNEF

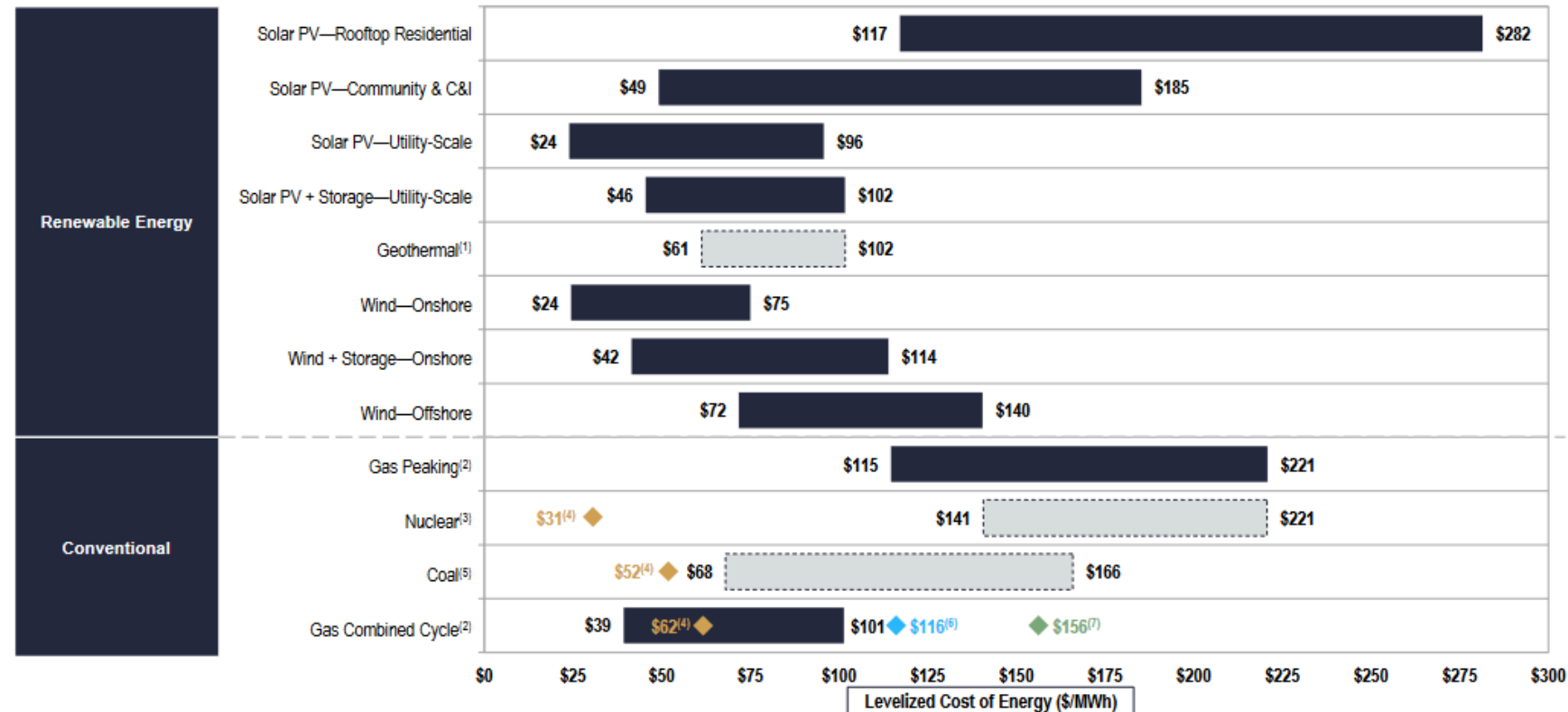
Note: Excludes retirements. "Other - fossil" accounts for plants that use more than one fuel or fuels other than coal, oil, gas, hydro and nuclear.

BloombergNEF

New LCOE calculations by Lazard

Levelized Cost of Energy Comparison—Unsubsidized Analysis

Selected renewable energy generation technologies are cost-competitive with conventional generation technologies under certain circumstances



<https://www.lazard.com/research-insights/2023-levelized-cost-of-energyplus/>

Year 2024 – an extremely DYNAMIC year for PV

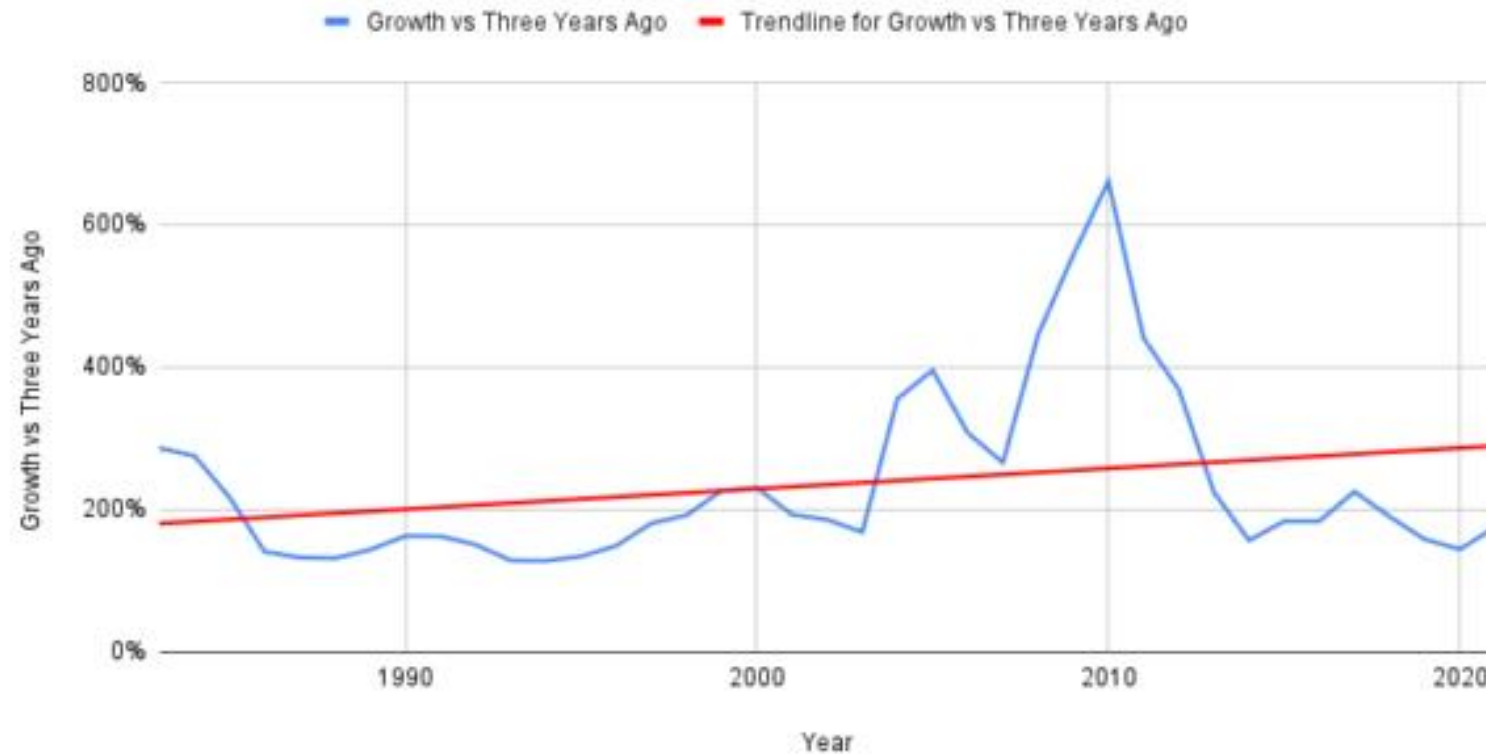
- in 2023 >1GW PV per day is installed >> 400 GW (in 2015 1GW per week)
- we will reach PV installations of 1TW yearly from 2027
- we have PV overcapacity at the moment (e.g. 50GW modules on stock in EU)
- modules for below 10ct/Wp are offered (TOPCon at 10ct/Wp)
- TOPCon will become mainstream from 2024 on (60% market share)
- PLI: **India** sets up 50GW production until 2027
- IRA: Conditions in **US** are good. Silicon-rush exists. 30GW until 2027 expected
- Green Deal: Political will is there. **EU**'s market is not ready.



PV market outlook: learning from the past

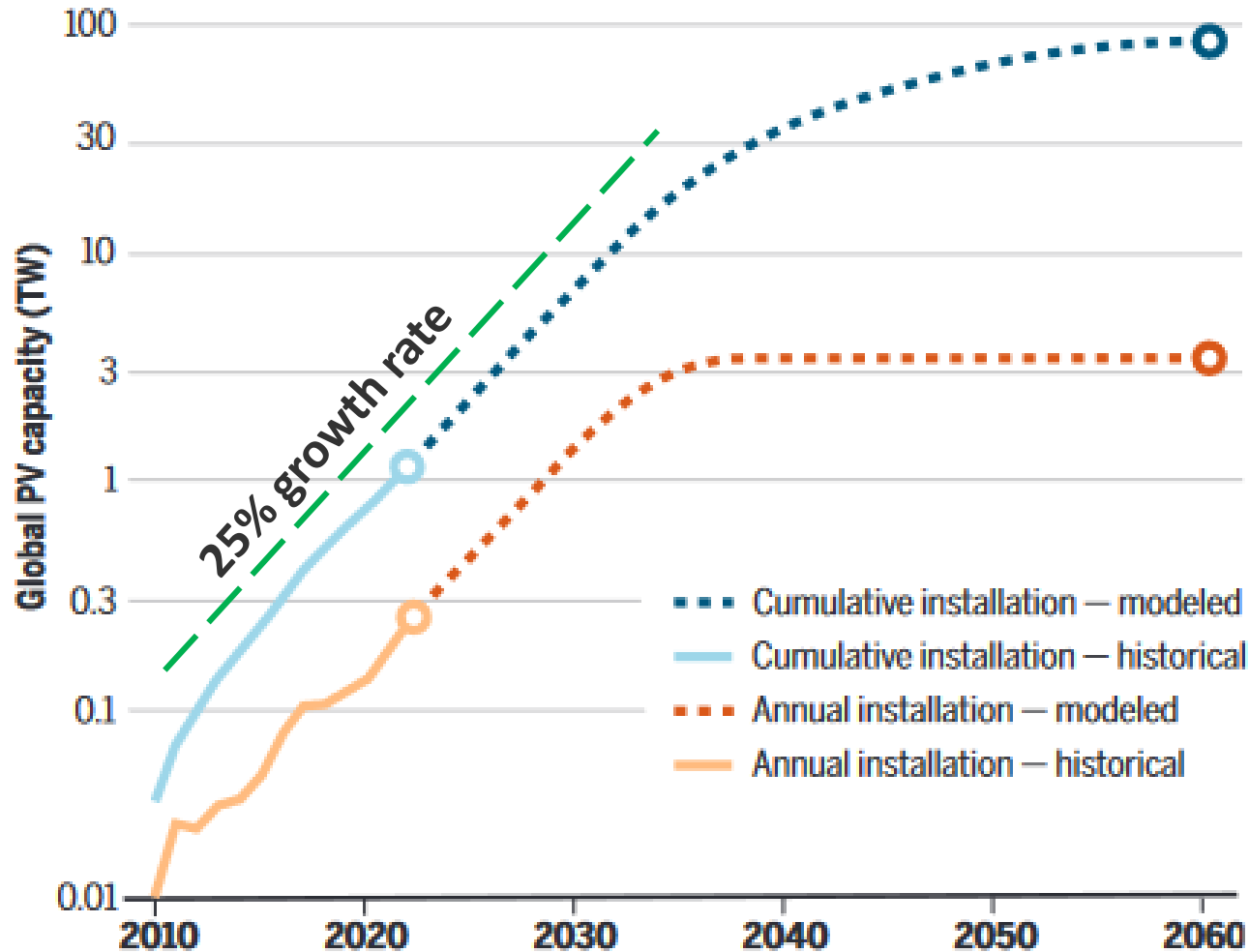
Growth vs Three Years Ago

Source: BloombergNEF Solar PV Deployment Data 1980-Present



Source: BloombergNEF in <https://pv-magazine-usa.com/2022/05/16/a-fate-realized-1-tw-of-solar-to-be-deployed-annually-by-2030/>

PV market outlook: towards terawatt PV-era



- Innovation driven with rapid technology transitions into market
- Sustainable TW-deployment with policies addressing PV supply chain constraints
- A technology mix era ahead

Haegel, Nancy M., et al. "Photovoltaics at multi-terawatt scale: waiting is not an option." Science 380.6640 (2023): 39-42



2. ISC Konstanz



Employees at
ISC Konstanz

65 ↗

Turnover
2022

5 Mio € ↗

Educated
scientists

100 ↗

Achieved solar
cell efficiency*

24.6% ↗

Transferred
technology

3.5GW ↗

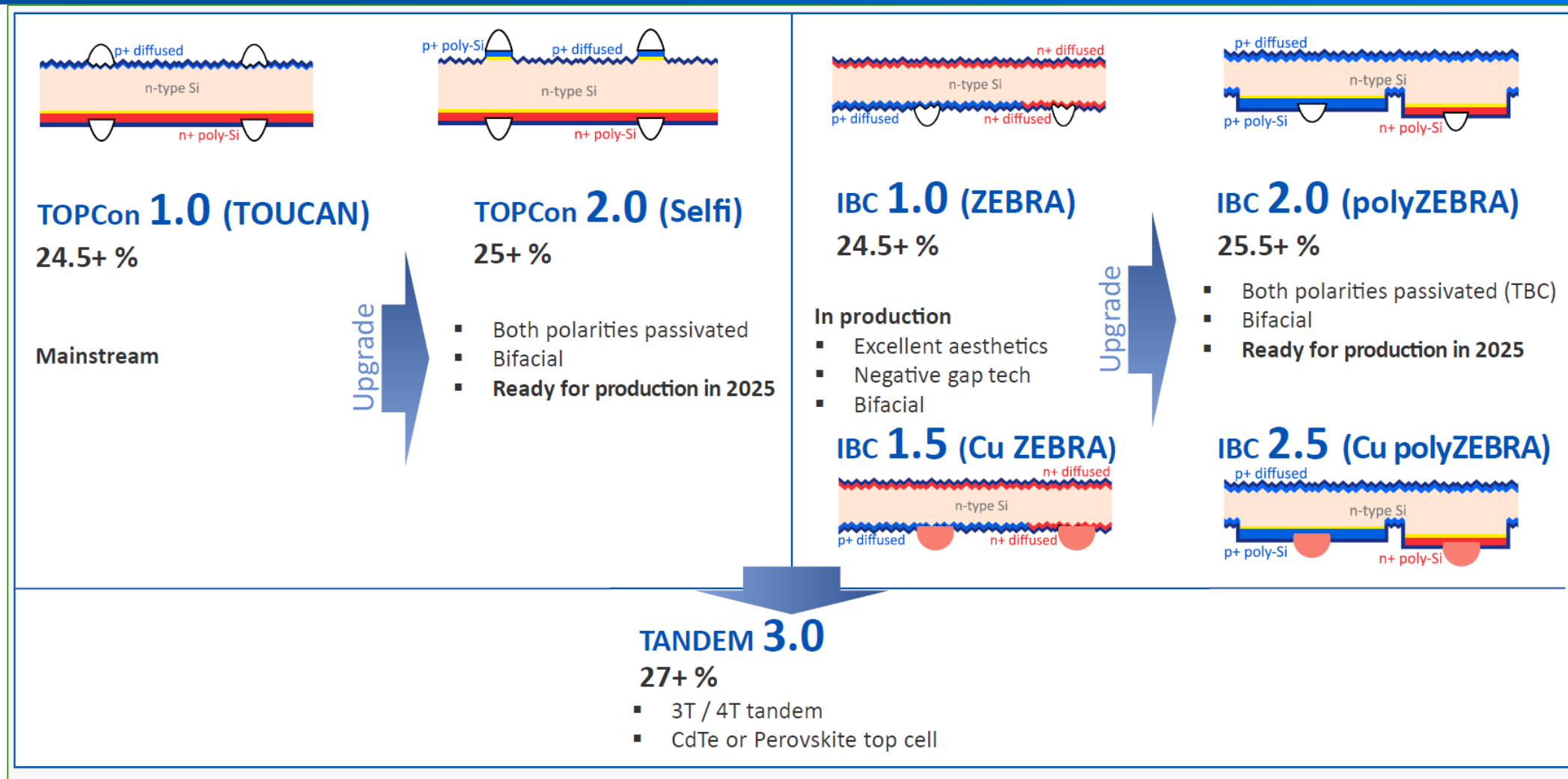
*in industrial manufacturing

ISC Konstanz: who we are

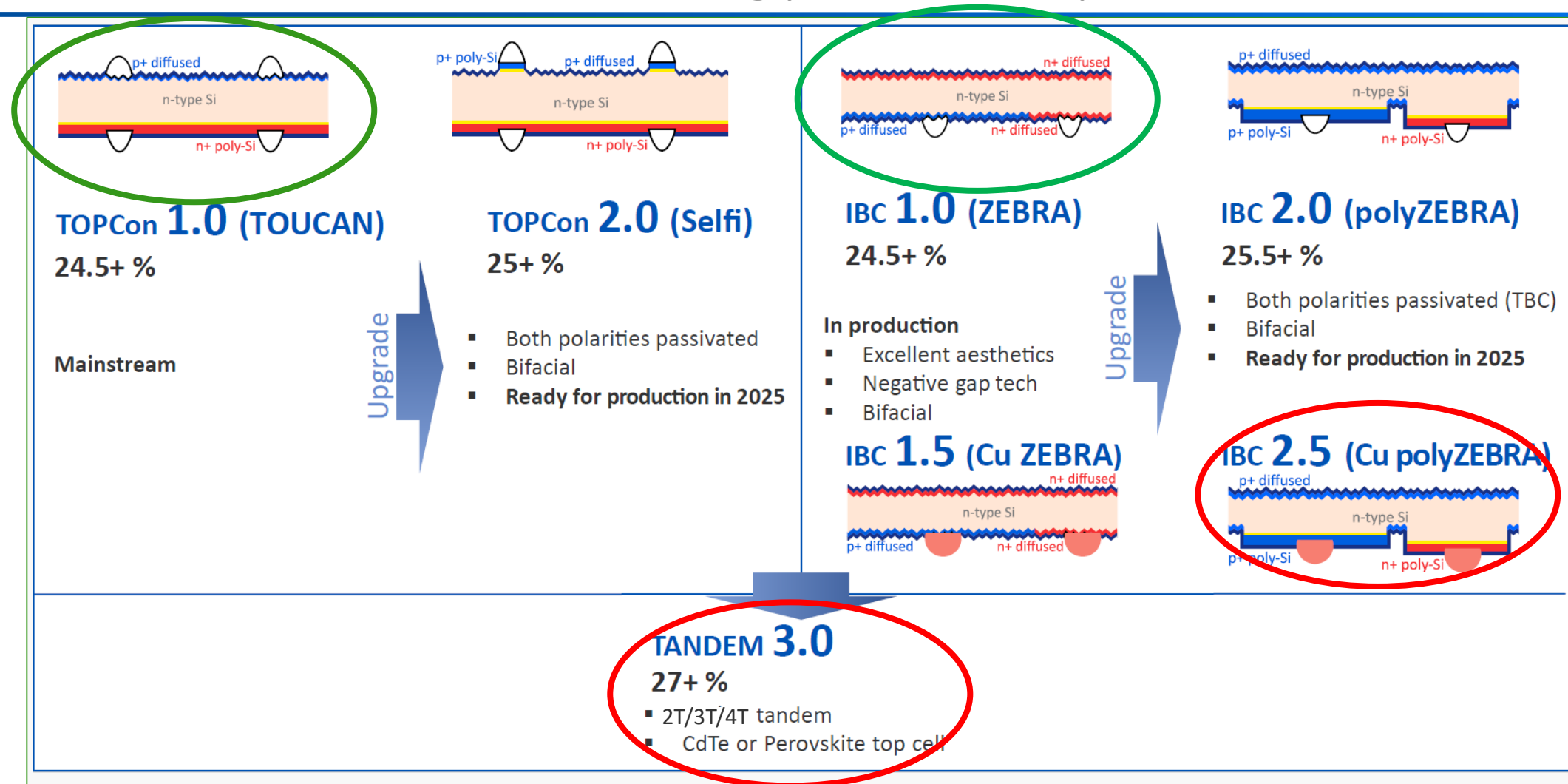
- **International Solar Energy Research Center e.V.**
 - a nonprofit organization
 - Founded in 2005
 - R&D on c-Si solar cells, modules and systems
- **Technology transfer: PERC/TOPCon (TOUCAN)/TBC (ZEBRA)**
- Track record: 8 transfers from 2015
- 10 transfers planned for 2024-2027
- Asia, Africa, US now- EU from 2025



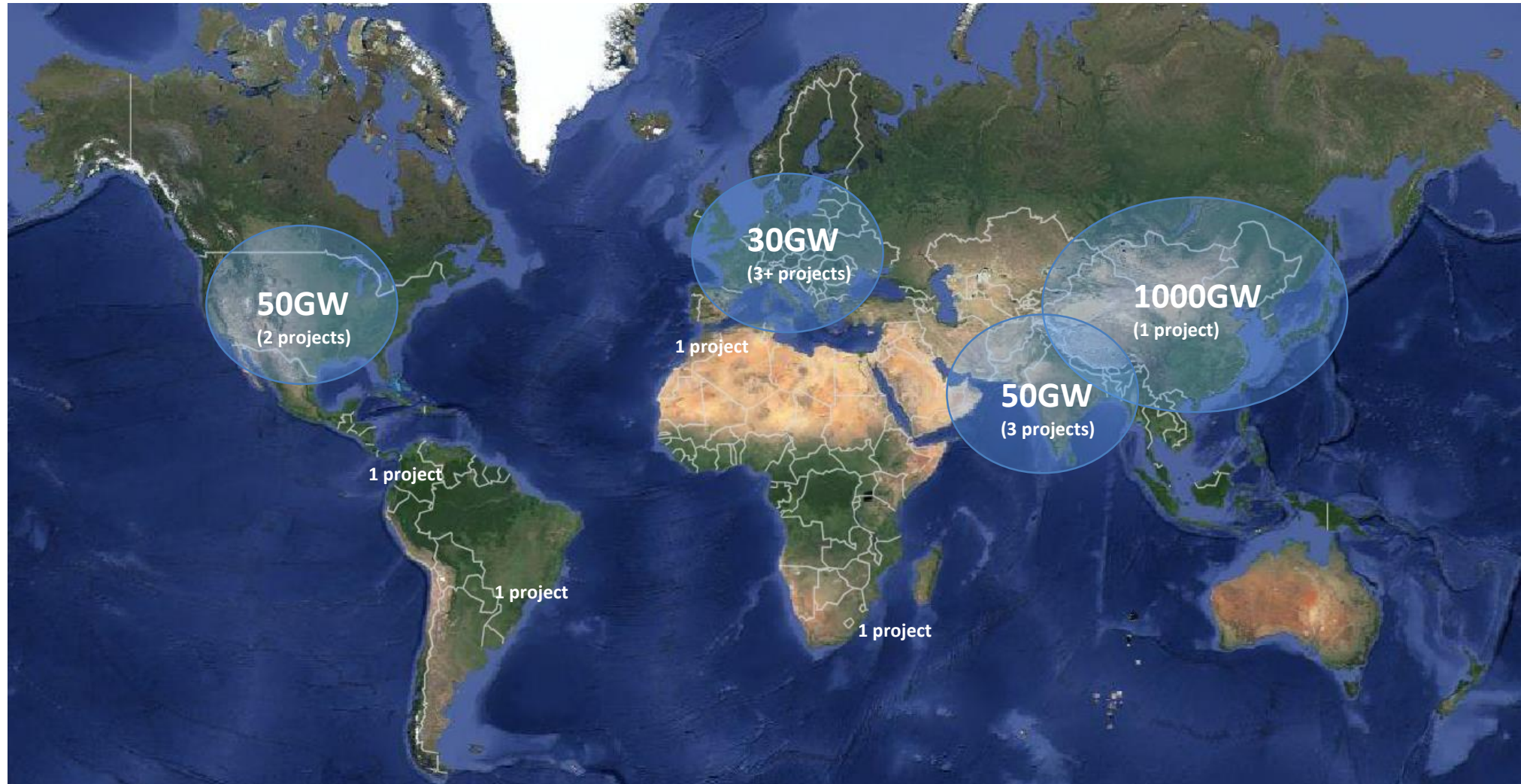
ISC Konstanz's technology for GW production



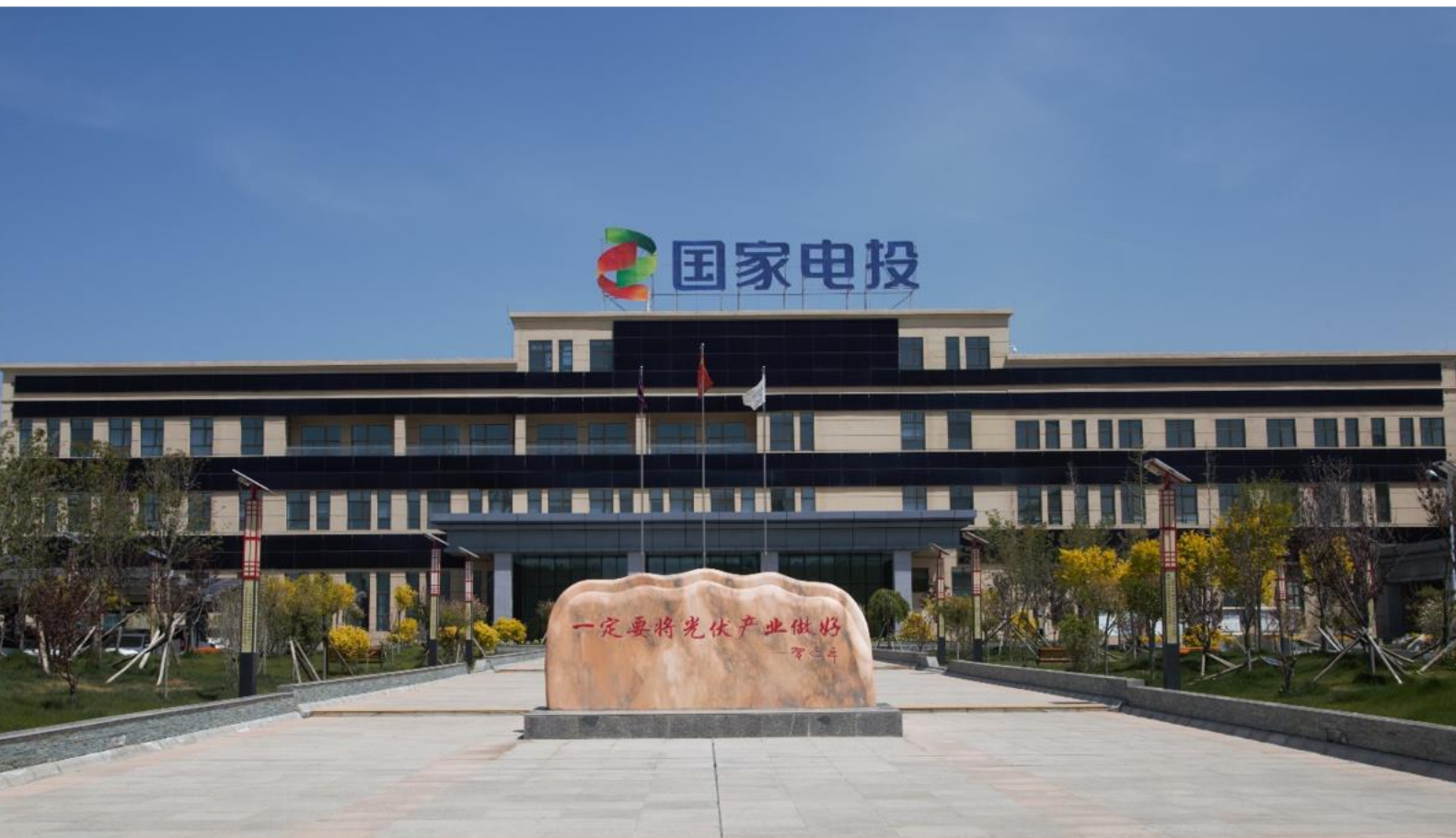
ISC Konstanz's technology for GW production



ISC K upcoming projects and total capacity until 2027



Introduction of SPIC Solar: IBC production



Commissioned at the end of 2019

The first mass production of IBC cells and modules in China

ZEBRA IBC at SPIC: 2019



2019: 200 MW IBC cell & module line



24+% ZEBRA IBC

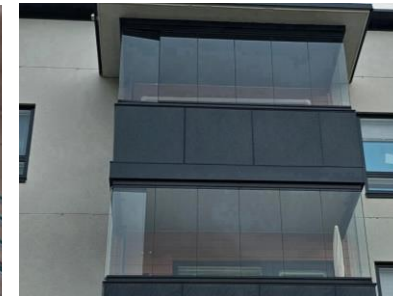
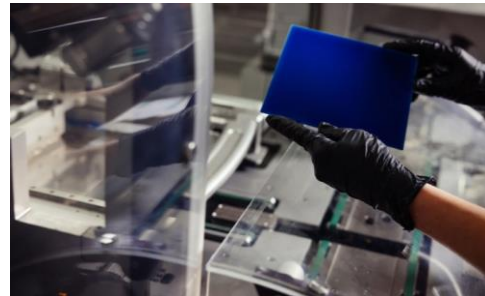
PERC mainstream 2020: 22.8%



Only IBC production in EU at ValoeCell in Vilnius



VALOe



Next ISC's TBC at Futura Sun: modules in Italy with cells from China

FuturaSun to build 2GW PV module capacity in Italy

By Simon Yuen

March 9, 2023

Manufacturing, Companies, Fab & Facilities, Markets & Finance, Modules

Europe



LATEST

Sol Systems bags US\$250 million for 189MW Illinois PV project
NEWS

Unpredictable environmental changes mean solar irradiance fluctuations, study finds
NEWS

UL Solutions awards carbon footprint certification to Trina Solar's Vertex modules
NEWS

Adani commissions 1GW at Khavda PV park, world's 'largest'



The new factory will also include an R&D centre and a test field for product control and improvement. Image: FuturaSun



Das Internetportal

STROM WÄRME MOBILITÄT THEMEN

Termine Branchenverzeichnis

Solarinstitut ISC Konstanz unterzeichnet Lizenzvertrag mit Futurasun

06.10.2023 / Solarserver / Forschung / International / Photovoltaik / Solarzelle / Wirtschaft



Foto: ISC Konstanz e.V.

Dr. Radovan Kopecek (Vorstand ISC Konstanz), Alessandro Barin (CEO FuturaSun) und Dr. Florian Buchholz (Vorstand ISC Konstanz) unterzeichnen den Lizenzvertrag auf der Solarkonferenz EU PVSEC in Lissabon (vlnr).

Next EU's TBC cell production at CARBON: 5GW factory in Marseille

CARBON, ISC Konstanz, and CEA-INES join forces to advance next-gen PV technologies

By Vera Wang 10/18/2023 0



French manufacturer Carbon has unveiled a strategic partnership with two European counterparts, the [International Solar Center \(ISC\)](#) Konstanz in Germany and CEA-INES in France.



Image: Carbon

This collaborative effort is aimed at propelling the advancement of cutting-edge PV technologies, specifically focusing on [TOPCon](#), TBC (TOPCon back-contact), and [tandem](#) cell technologies.



Last transfer at Adani in India



Last transfer at Adani in India



Workshops (re-)initiated by ISC Konstanz

Following our specific research and development interests, we (co-) organize international workshops on the following topics:

Metallization and interconnection, n-type solar cells, bifacial solar cells & modules, tandem solar cells and back contact technology. In Future: cSiMATPV and c-SiSPACEPV.

	metallisation	nPV	bifiPV	tandemPV	BCworkshop
Websites	https://miworkshop.info/	http://npv-workshop.com	https://www.bifipv-workshop.com/	http://tandempv-workshop.com	https://www.backcontact-workshop.com/
Start	Since 2008	Since 2011	Since 2012	Since 2020	Since 2022
Next events	11 th edition October 2024, Chambéry	13 th edition April 17-18 2024, Chambéry nPV book in 2023	11 th and 12 th edition April 18-19 2024, Chambéry November 2024, AIKO bifiPV book in 2018 bifiPV book in 2024	4 rd edition June 2024, Amsterdam tandemPV book in 2030	4 nd edition December 2024 in Delft BCPV book in 2026

cSiMATPV workshops will start from May 16-17 2024 in Konstanz

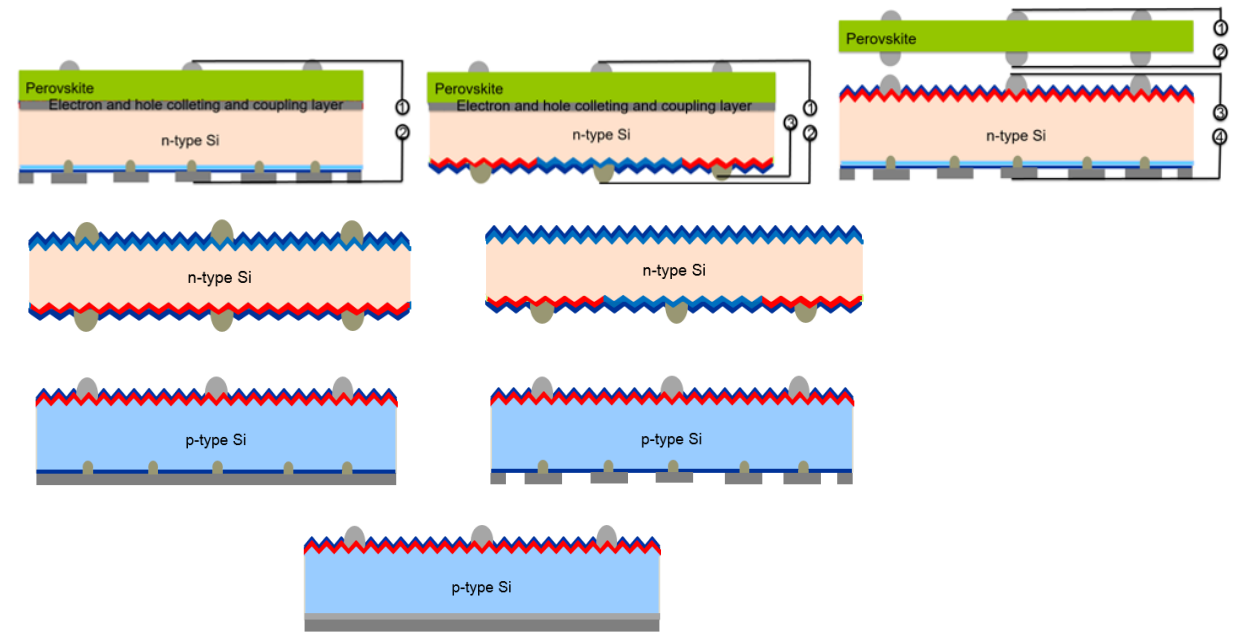
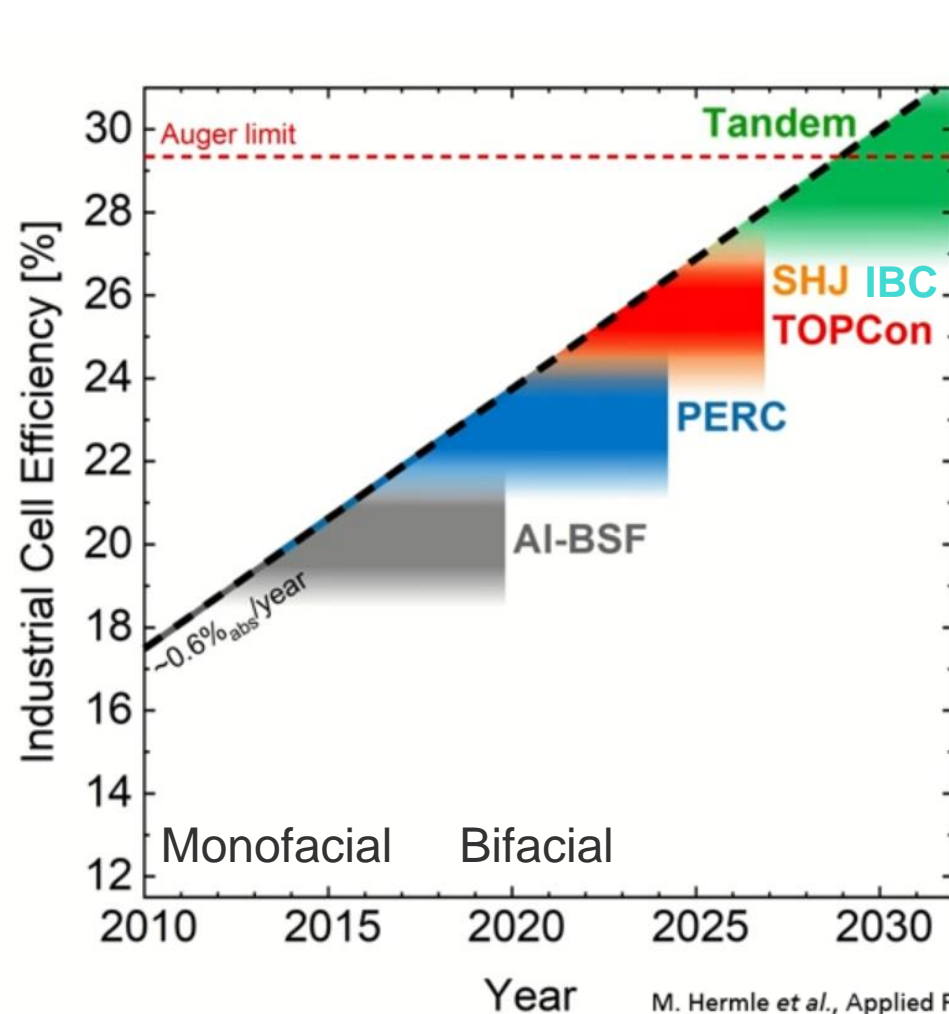
cSiSPACEPV workshops will start from 2025 in Konstanz





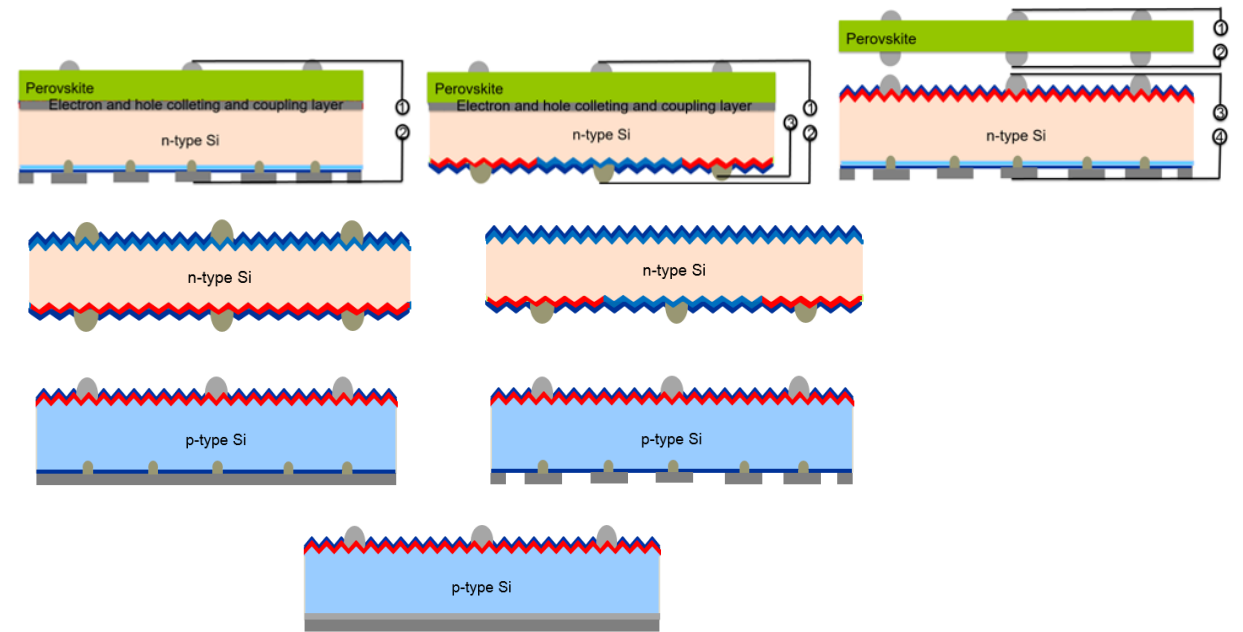
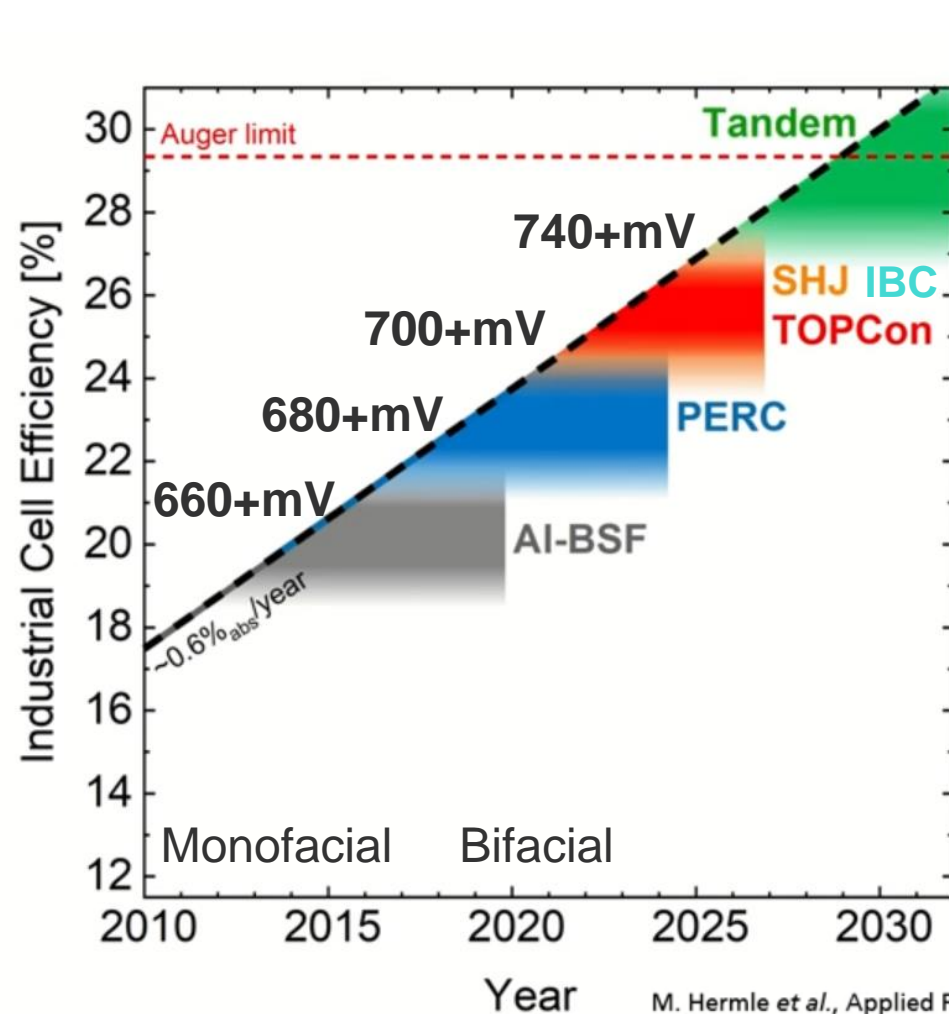
3. Status of n-type tech

Evolution of (bifacial) PV technologies: from 3G to 6G



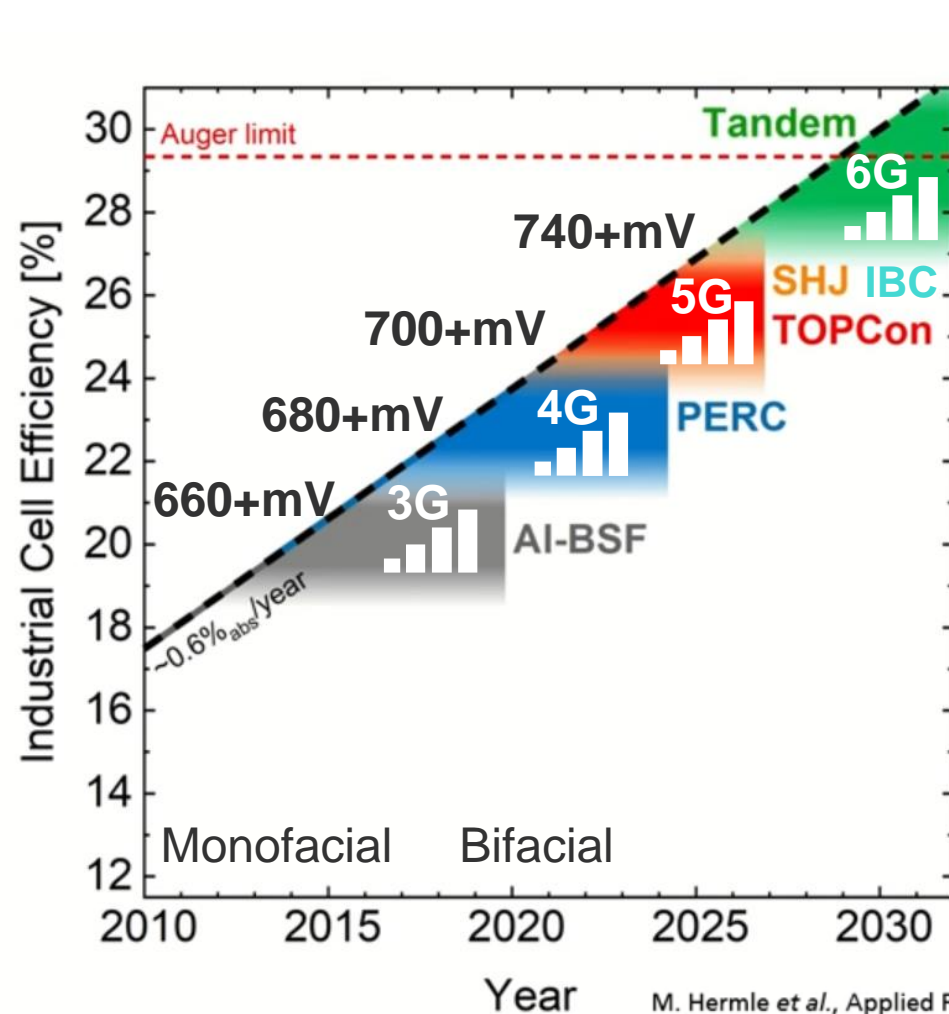
All advanced cell concepts are **bifacial** and based on a better surface passivation.

Evolution of (bifacial) PV technologies: from 3G to 6G

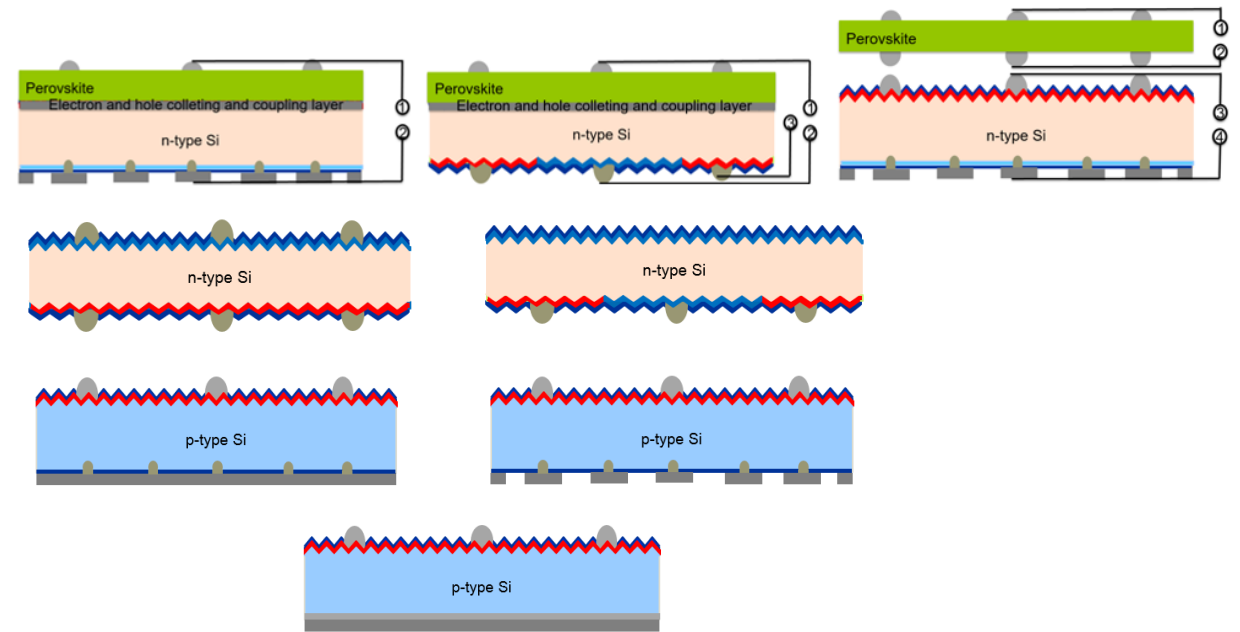


All advanced cell concepts are **bifacial** and based on a better surface passivation.

Evolution of (bifacial) PV technologies: from 3G to 6G



M. Hermle et al., Applied Physics Reviews 7 (2), 2020



All advanced cell concepts are **bifacial** and based on a better surface passivation.

Highest efficiency versus industrial reality

TRL 4

Chinese reference

- wrong FF measurement
- other reference (not FhG ISE)
- premium material
- long gettering
- double poly
- zero BB
- other tricks
- tandem technology
- low stability
- other challenges
-

Industrial TOPCon efficiency vs.
high efficiency “muscle showing”

TRL 6

Chinese reference

- wrong FF measurement
- other reference (not FhG ISE)
- premium material
- long gettering
- double poly
- zero BB
- other tricks

Module efficiency of ave. 22.5%

TRL 9

Chinese reference

- wrong FF measurement
- other reference (not FhG ISE)

TRL 9

FhG ISE reference

24.5%

25.5%

26+%

33+%

Highest efficiency modules in February 2024

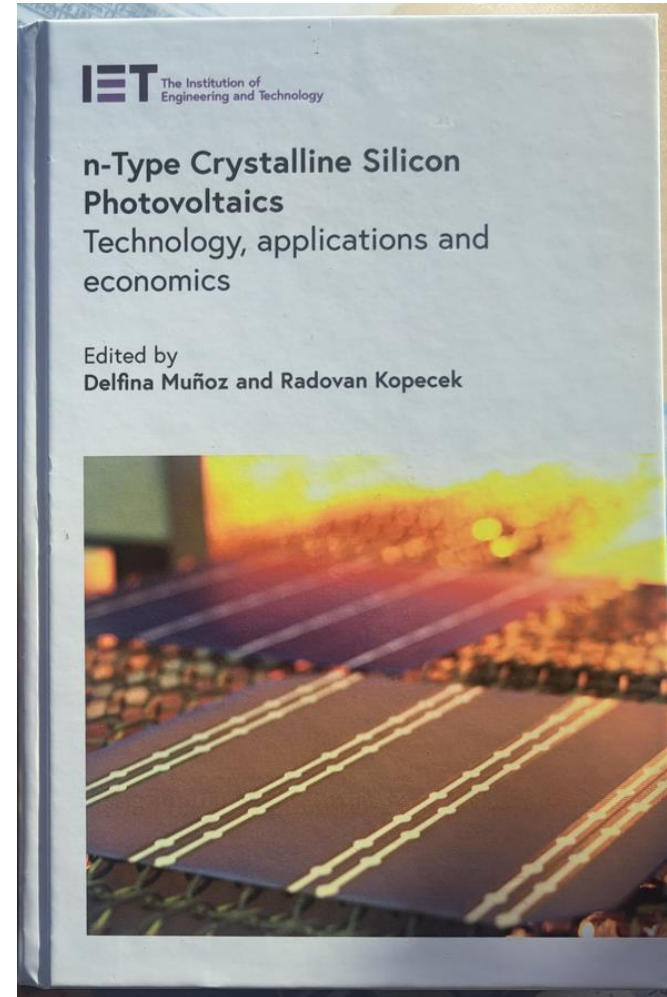
Manufacturer	Model	Power Rating	Cell Technology	Efficiency
SUNPOWER	Maxeon 7	445W	N-Type IBC	24.1 %
AIKO	Neostar 2N	470W	N-Type ABC Back Contact	23.6 %
RECOM	Black Tiger Series	460W	N-Type TOPcon Back Contact	23.6 %
AEG	BC Premium	460W	N-Type ABC Back Contact	23.6 %
LONGi Solar	Hi-MO 6 Scientist	455W	N-Type HPBC Hybrid Back Contact	23.3 %
HUASUN	Himalaya G12R	450W	N-Type HJT	23.0 %
CanadianSolar	TOPHiKu6	470W	N-Type TOPcon	23.0 %
TW SOLAR	Repower N G12R-48	455W	N-Type TOPcon	22.8 %
Philadelphia Solar	Nexus Series	455W	N-Type TOPcon	22.8 %
ASTROENERGY	Astro N5s	445W	N-Type TOPcon	22.8 %
TrinaSolar	Vertex N +	505W	N-Type TOPcon	22.7 %
REC Solar	Alpha Pure RX	470W	N-Type HJT	22.6 %
Jinko Solar	Tiger NEO N-Type	440W	N-Type TOPcon	22.5 %
PHONO	Helios	440W	N-Type HJT	22.5 %
JA SOLAR	Deep Blue 4.0	450W	N-Type TOPcon	22.5 %
Q CELLS	Q.TRON M-G2+	440W	N-Type TOPcon	22.5 %
risen	n-Type Topcon	440W	N-Type TOPcon	22.5 %
DASOLAR	Black Series	440W	N-Type TOPcon	22.5 %
AKCOME	Kookaburra Series	440W	N-Type TOPcon	22.5 %

5 x TBC

3 x HJT

11 x TOPCon

n-type PV book (2023) from nPV workshops

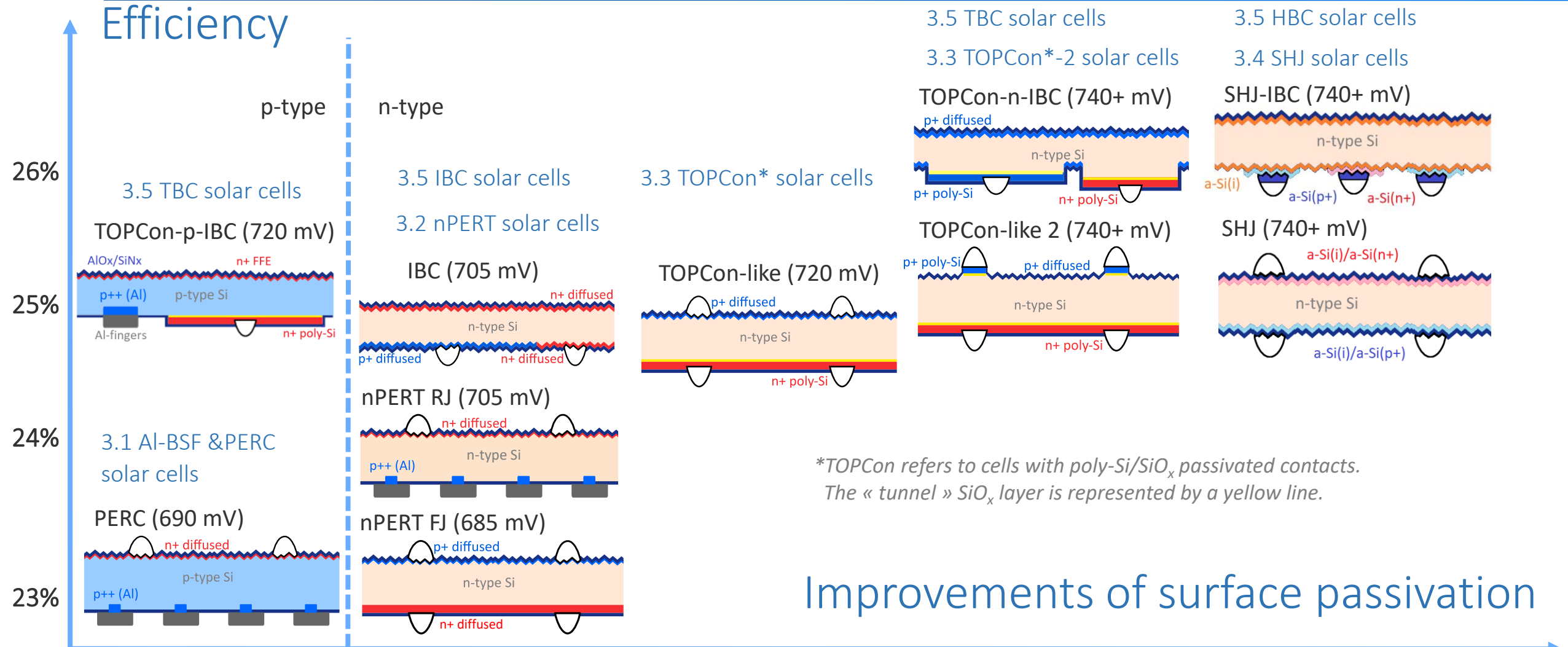


n-type PV book (2023) from nPV workshops



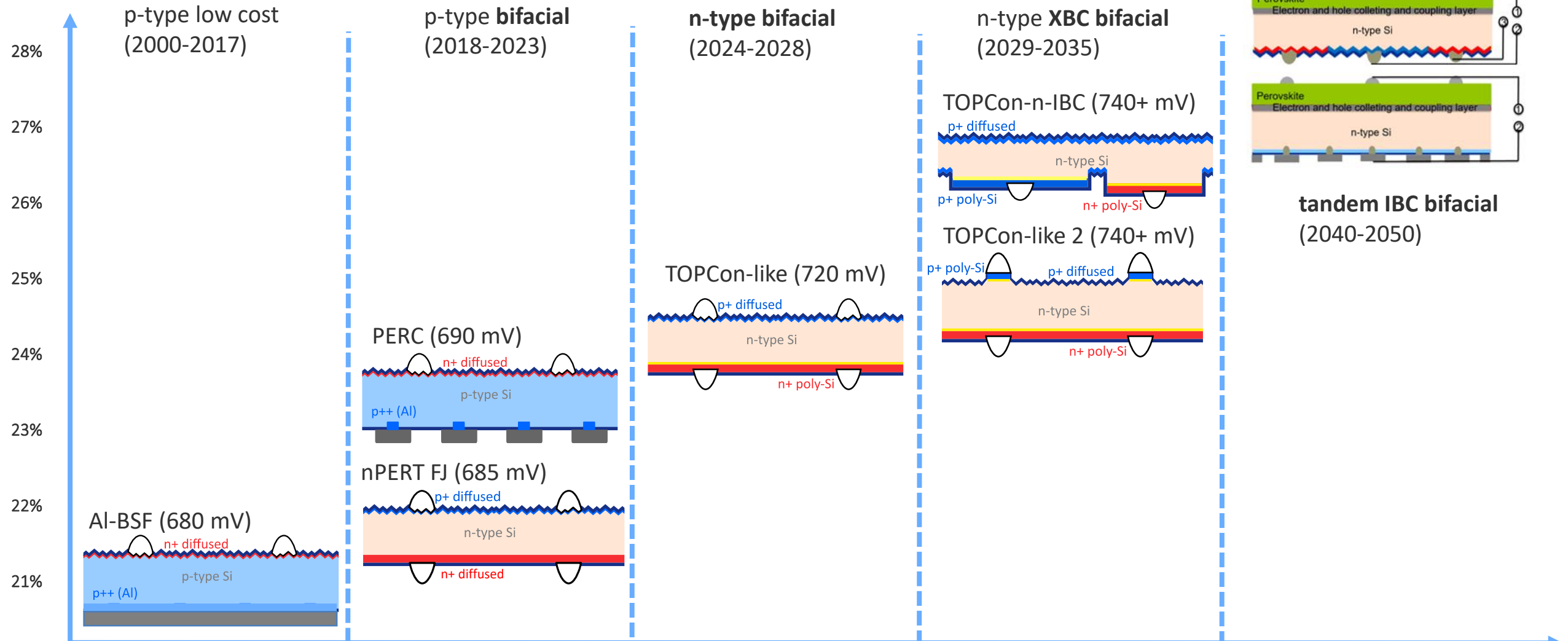
Crystalline silicon solar cell technology

Efficiency

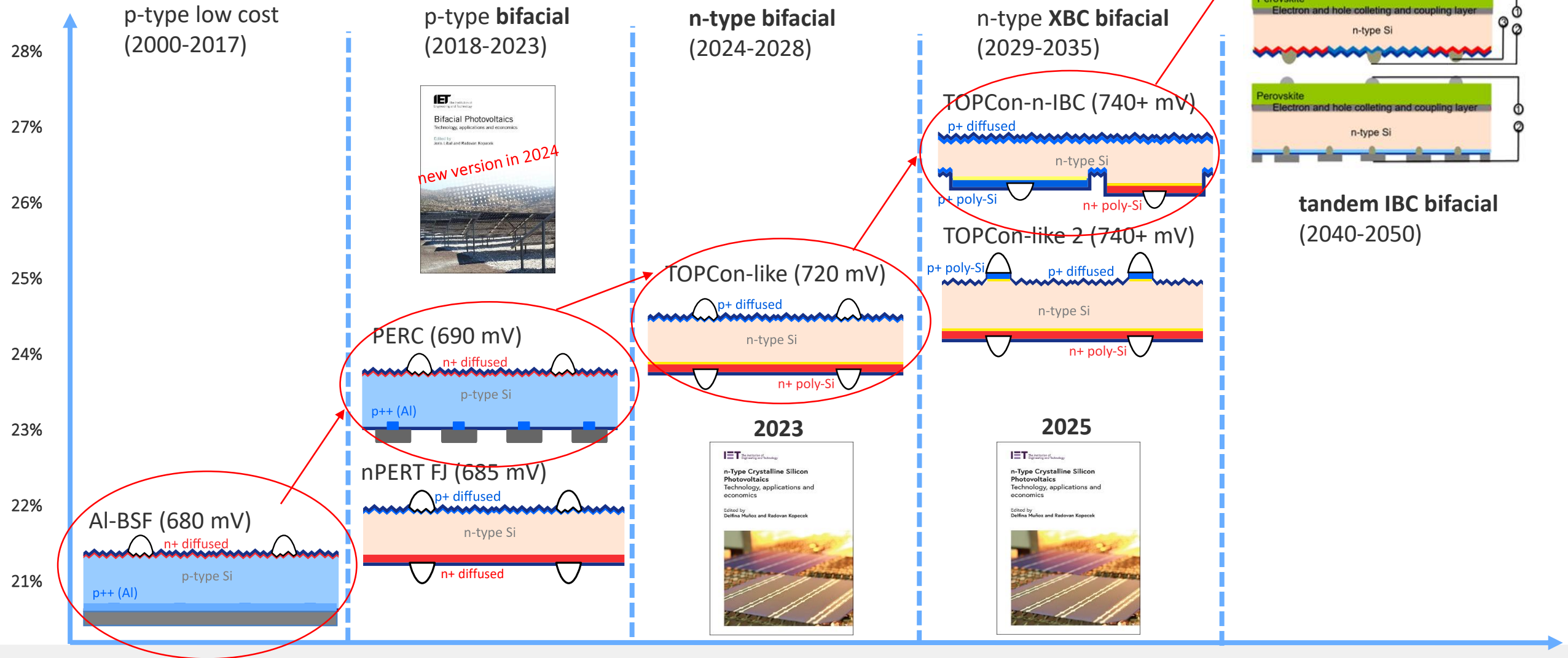


Improvements of surface passivation

Crystalline silicon solar cell technology



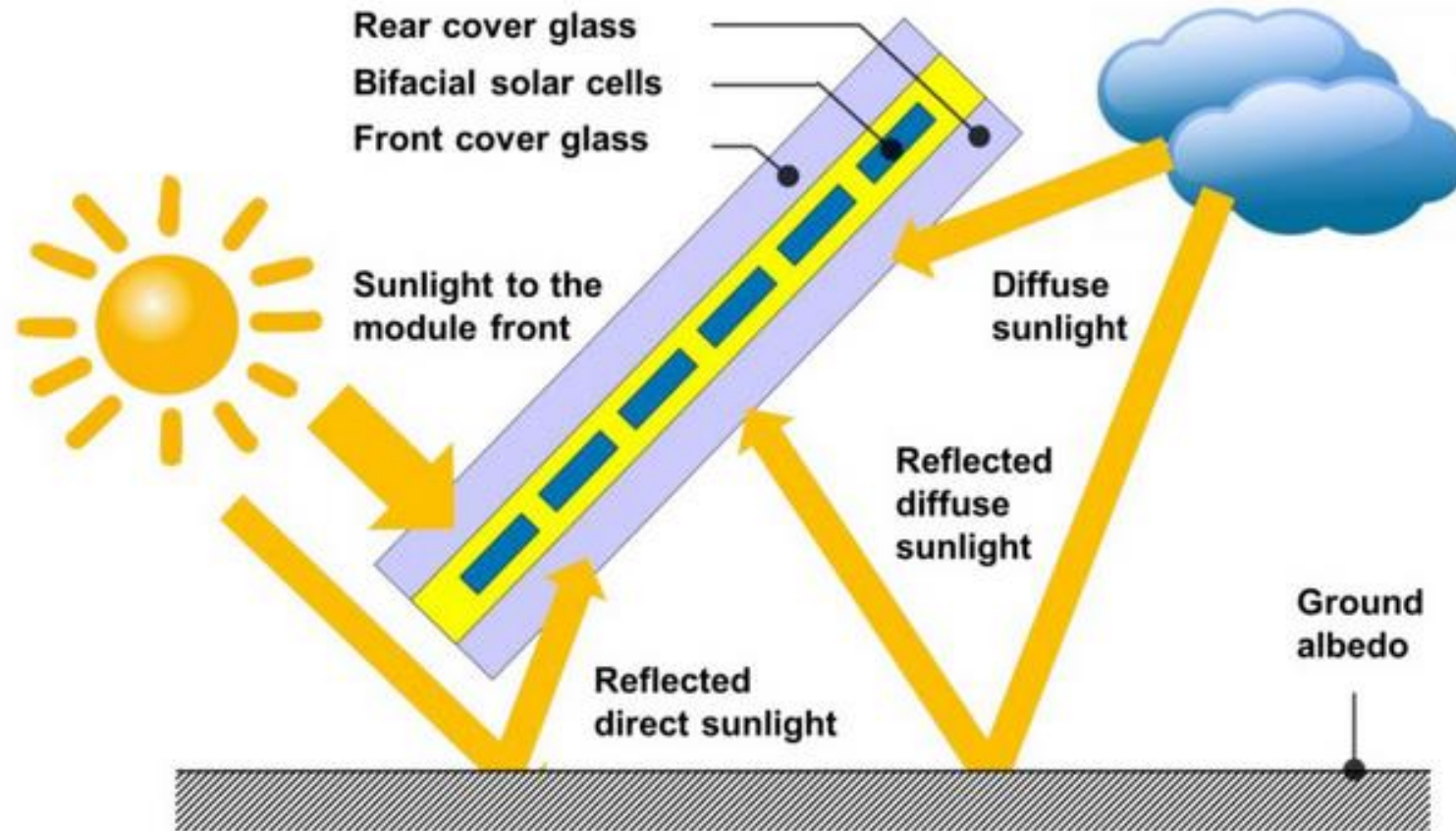
Crystalline silicon solar cell technology





4. Entering the bifacial nPV era

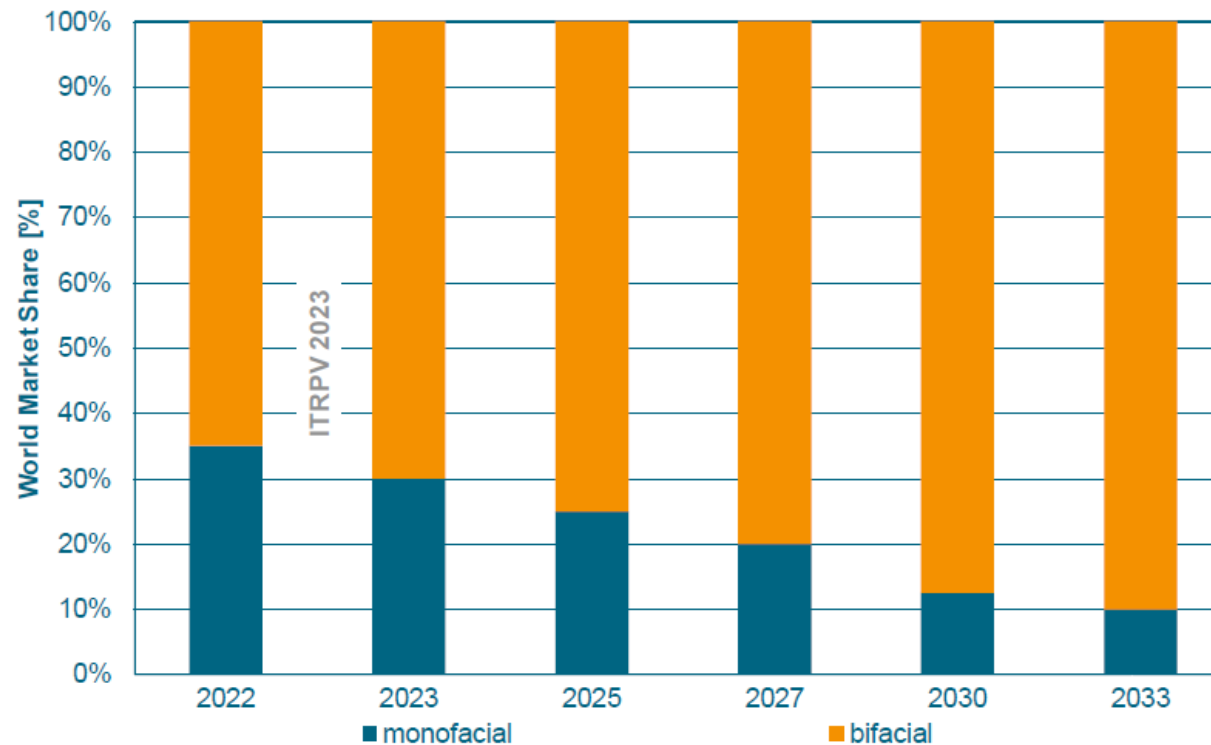
bifiPV: how it works



picture: TÜV Rheinland

bifiPV: market share

Bifacial cell in world market



bifiPV: bifacial applications and gains

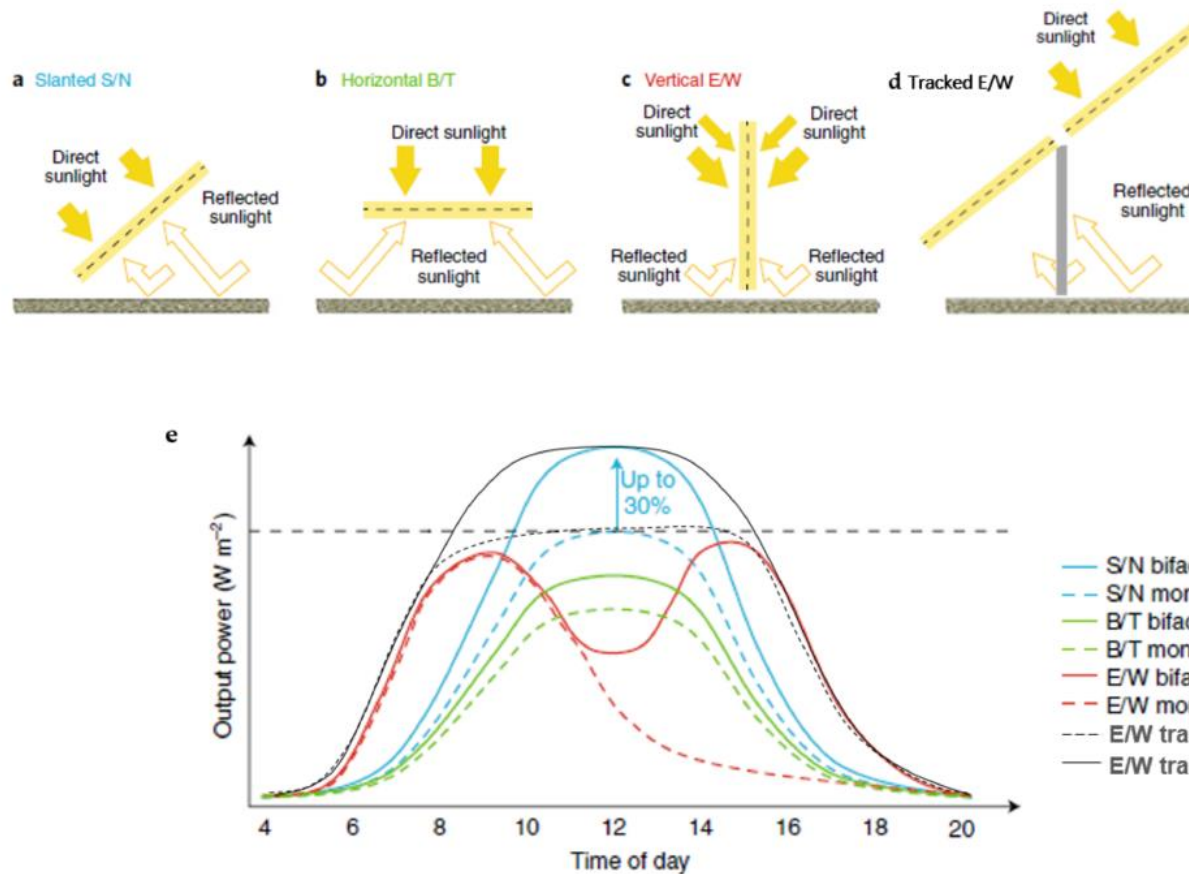


Table 2. Energy gains in systems using tracking and bifacial modules [20].

Installation Geometry	Monofacial [%]	Bifacial [%]
Fixed tilt (flat roof)	100	105–115
Fixed tilt (utility scale)	100	107–130
Vertical (utility scale)	40–50	95–140 *
HSAT	110–122	117–145

* comparison with monofacial fixed tilt.

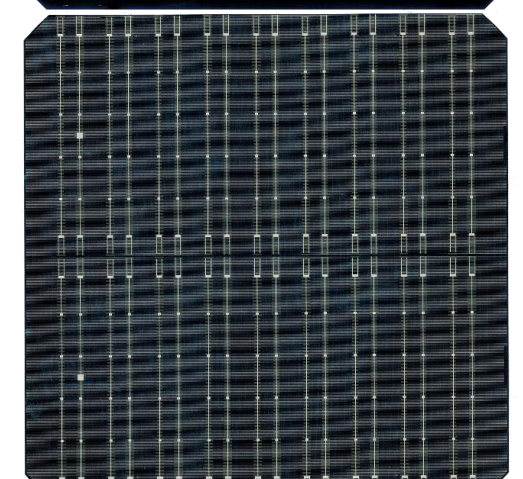
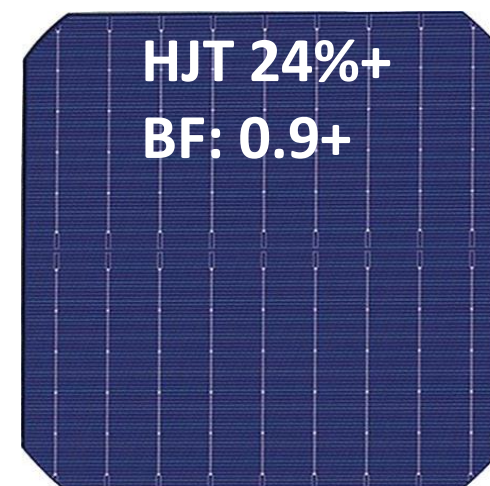
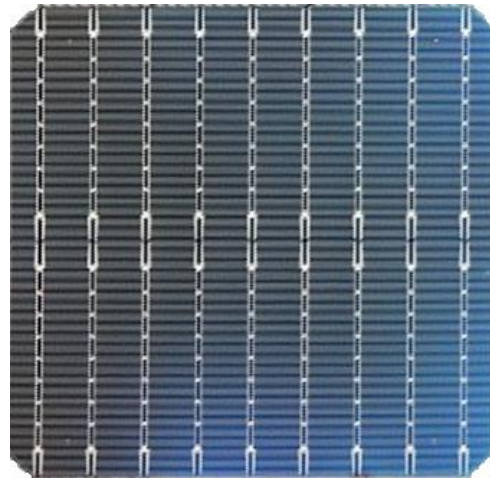
R Kopecek; J Libal, Bifacial Photovoltaics 2021: Status, Opportunities and Challenges, Energies 2021, 14, 2076.
<https://doi.org/10.3390/en14082076>

bifacial gains of 5-30%

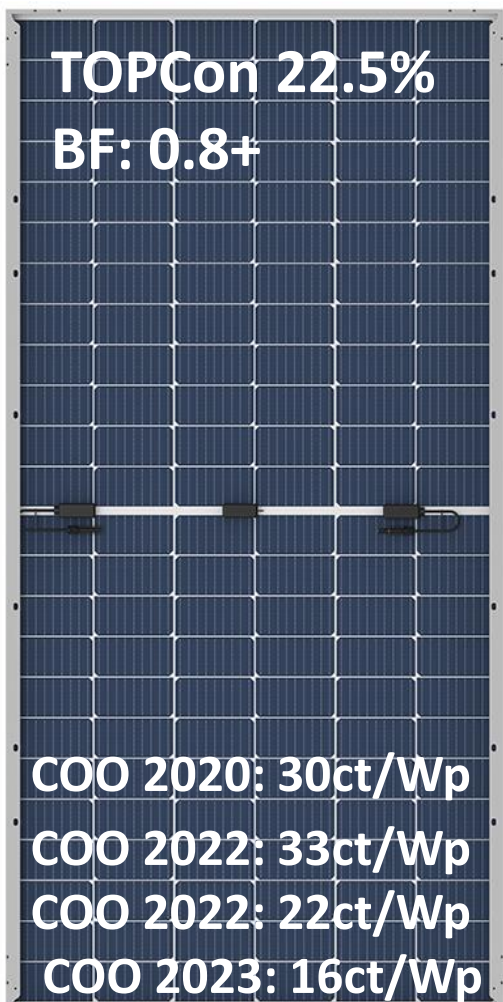
Figure 5. (a–d) possibilities for installations of bifacial modules and (e) comparison of power generation curves for monofacial and bifacial modules [16]. S/N means South/North, B/T is Bottom/Top and E/W is East/West.

R Kopecek, J Libal, Towards large-scale deployment of bifacial photovoltaics, Nature Energy 3 (6) 2018, 443-446

Solar cell pictures of PERC, TOPCon, HJT and IBC



Rear side module pictures of PERC, TOPCon, HJT and IBC



BifiPV applications: mobility



VIPV for cars: Sion/ Sonomotors



VIPV for boats: small ZEBRA modules

BifiPV applications: mobility



VIPV for cars: Sion/ Sonomotors



VIPV for boats: small ZEBRA modules

BifiPV applications: mobility



VIPV for eFerry: Artemis at Lake of Konstanz with bifacial ZEBRA modules

BifiPV applications: mobility



VIPV for eFerry: Artemis at Lake of Konstanz with bifacial ZEBRA modules

BifiPV applications: building



Roof applications

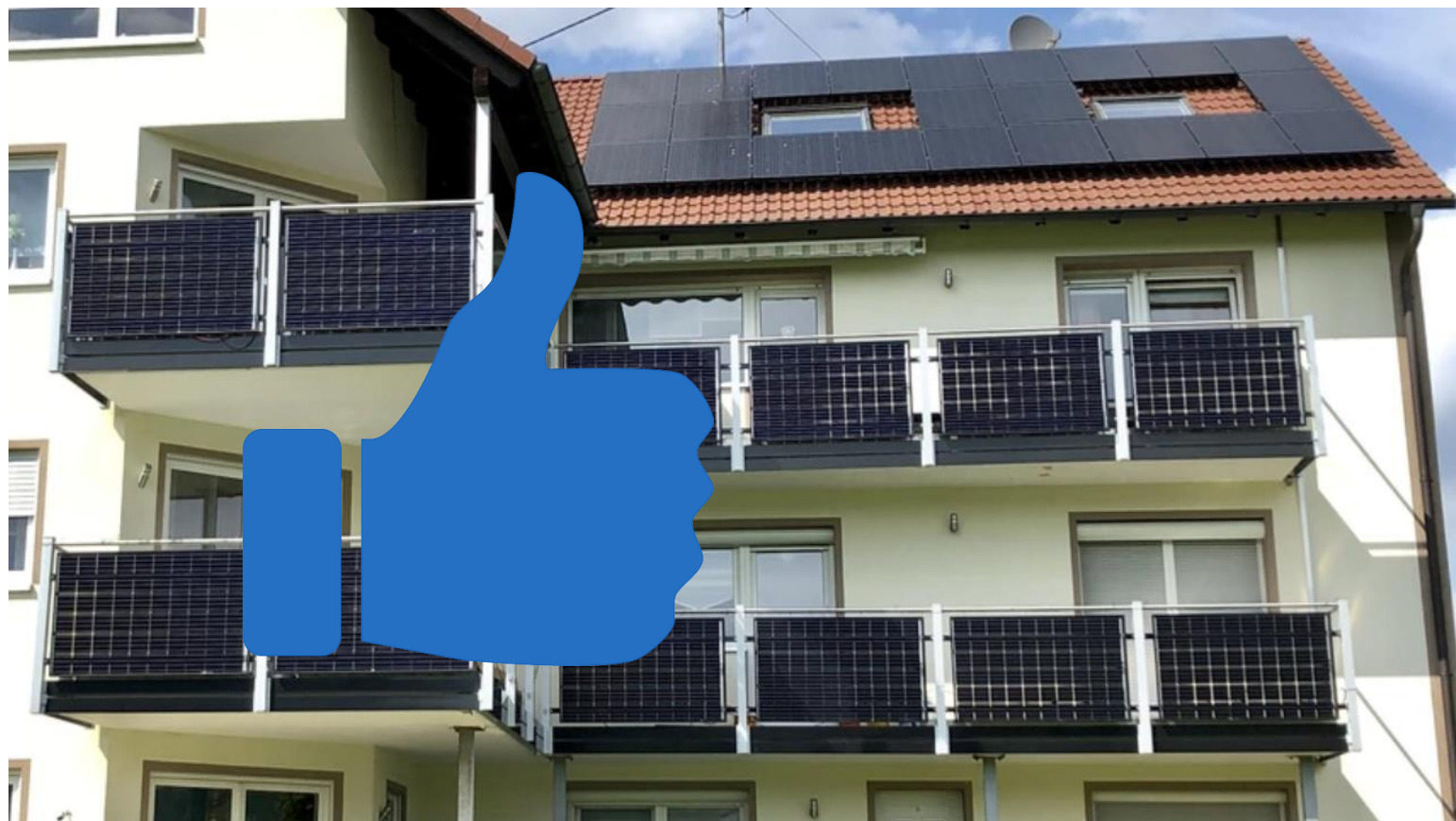


Balcony “power-station”

BifiPV applications: building



Roof applications



Balcony “power-station”

BifiPV applications: building



Flat roof applications: Hongkong/ bifacial IBC modules from SPIC

BifiPV applications: building



Flat roof applications: Hongkong/ bifacial IBC modules from SPIC

BifiPV applications: building



Flat roof applications: fixed tilt



Tracking (HSAT)

BifiPV applications: building

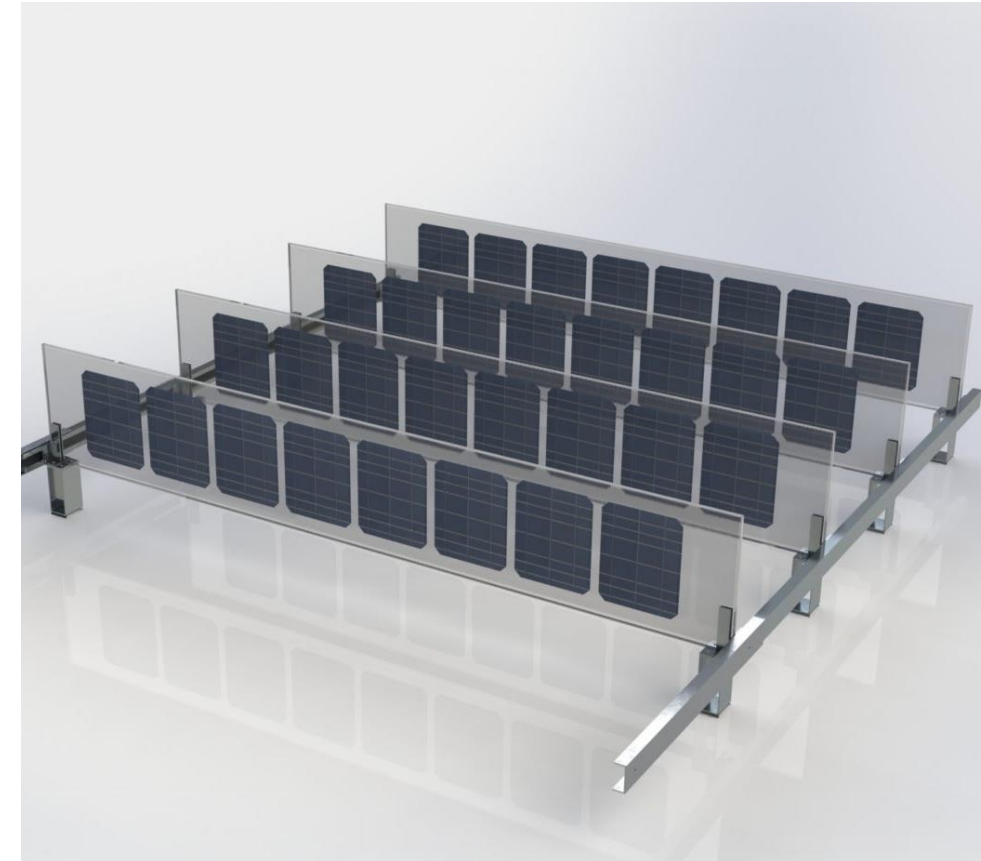


Flat roof applications: fixed tilt



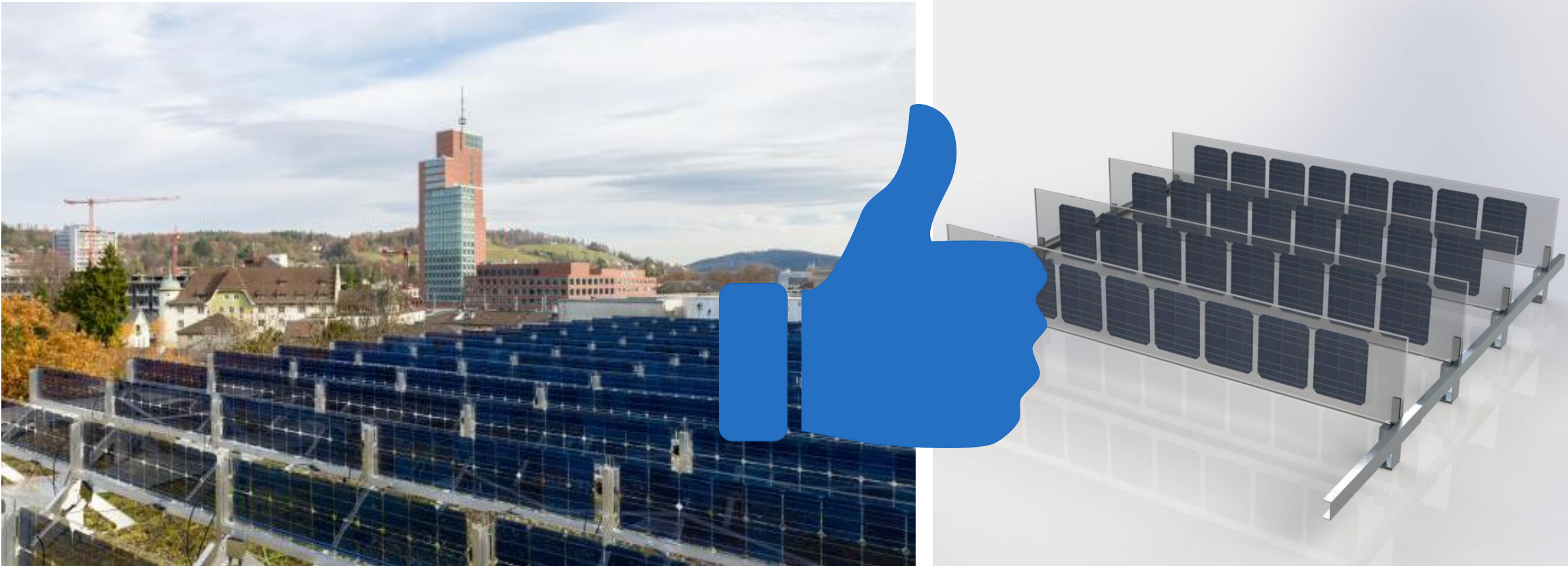
Tracking (HSAT)

BifiPV applications: building



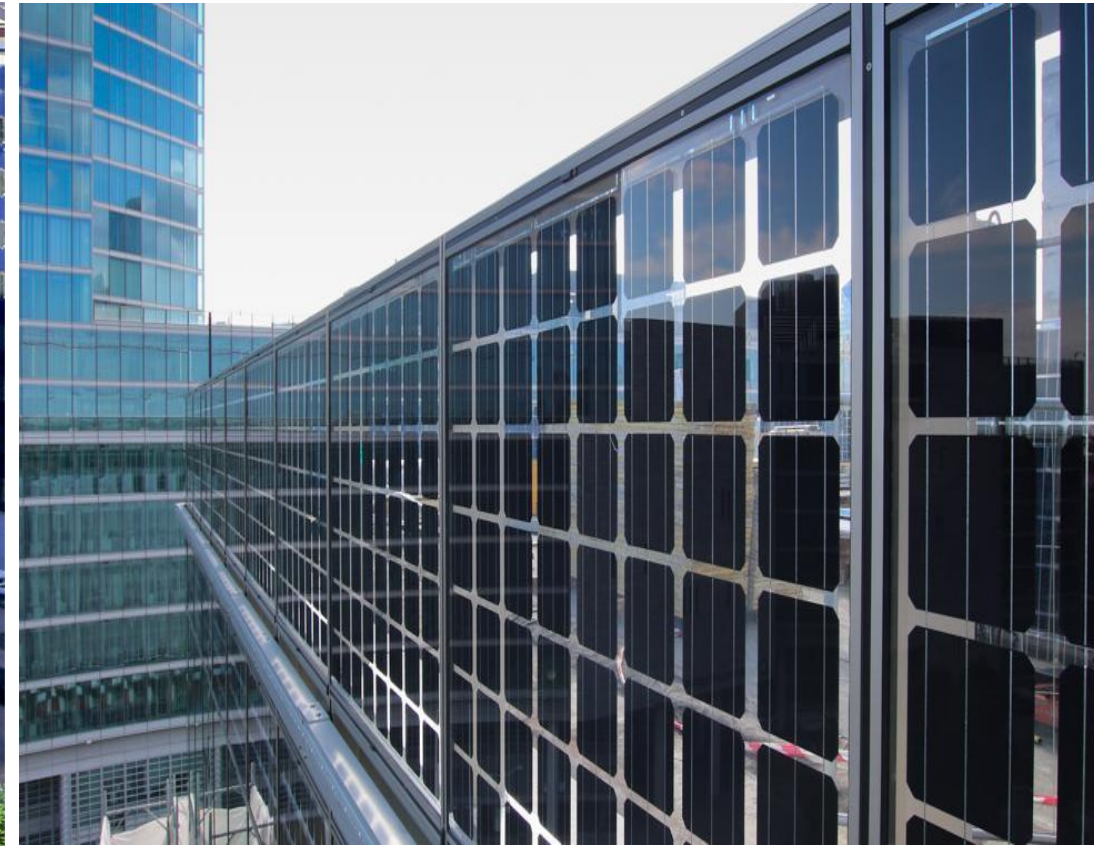
Flat roof applications: vertical systems (ZHAW and Solyco)

BifiPV applications: building



Flat roof applications: vertical systems (ZHAW and Solyco)

BifiPV applications: building



BIPV: 2 degree building in Milano (bifacial BiSoN modules)

BifiPV applications: building



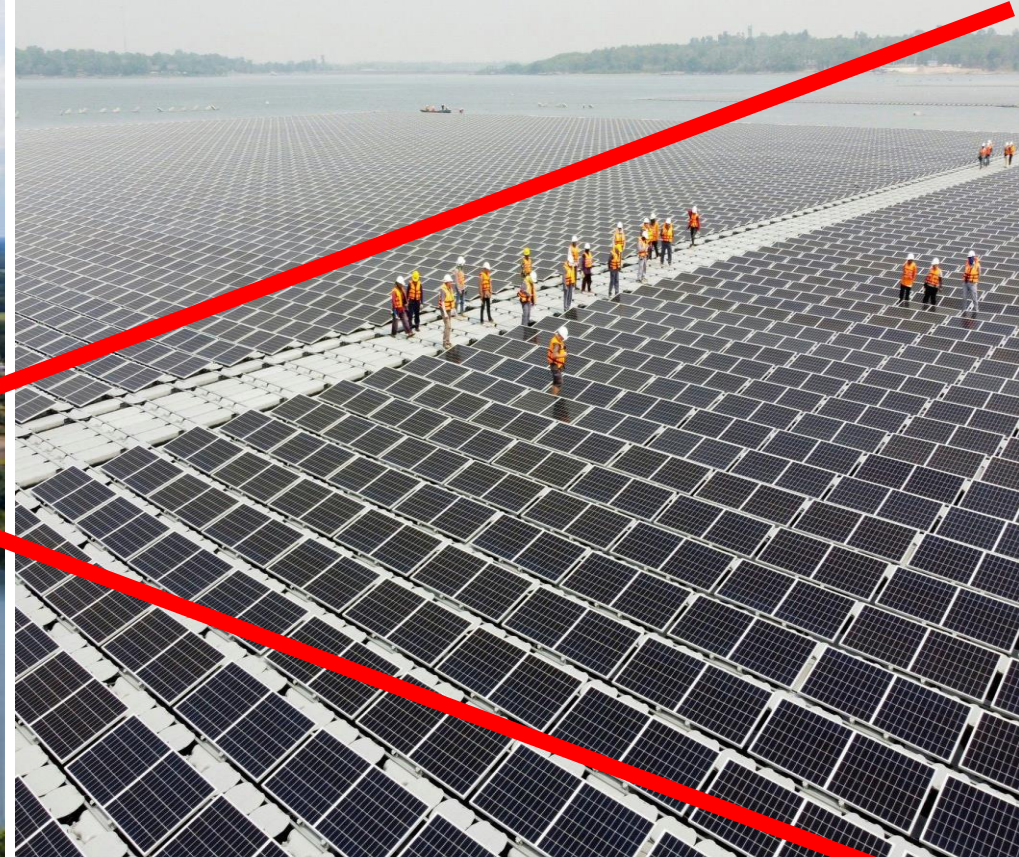
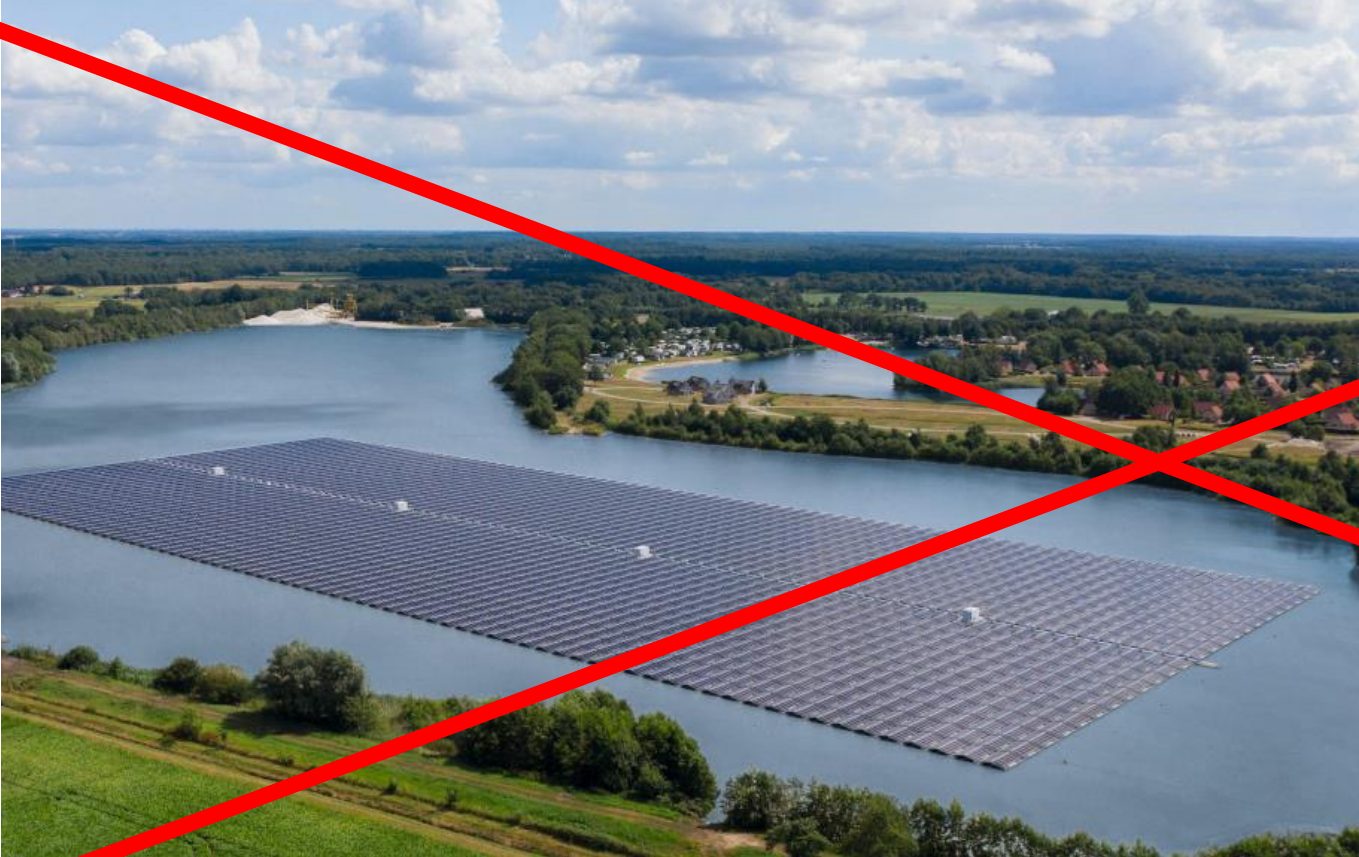
BIPV: 2 degree building in Milano (bifacial BiSoN modules)

BifiPV applications: water



Floating PV applications

BifiPV applications: water



Floating PV applications

BifiPV applications: AgriPV



Vertical applications: next2sun

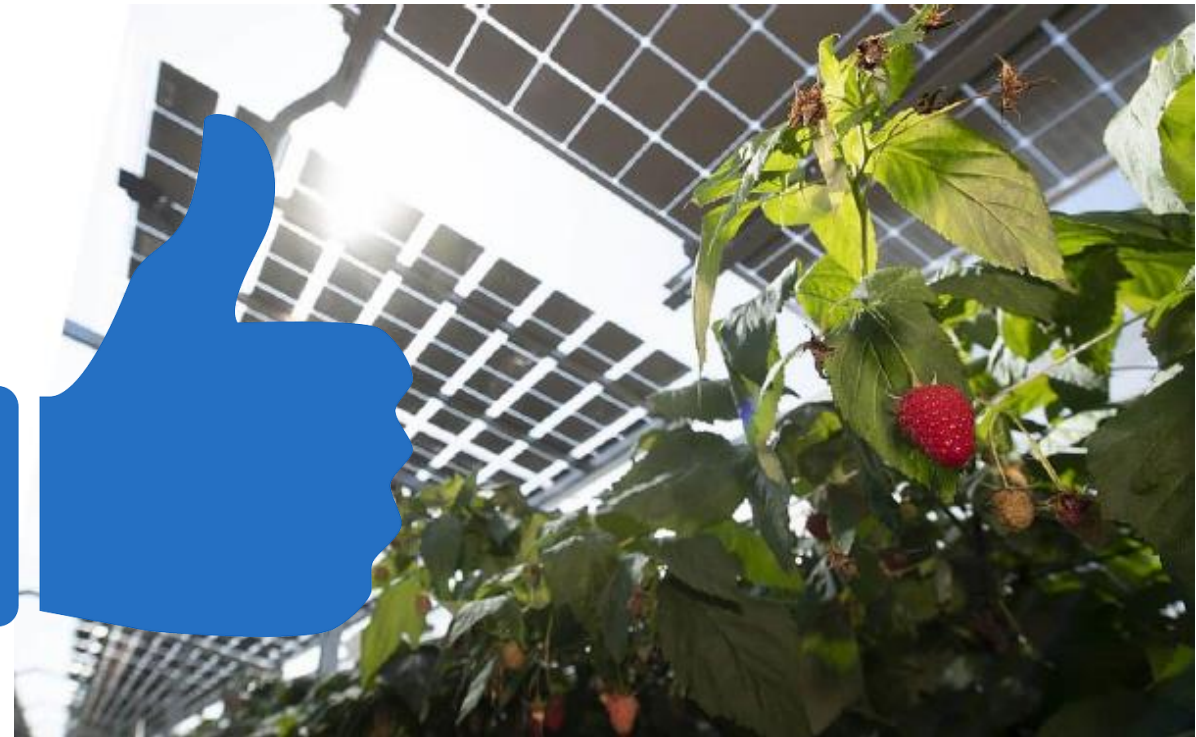


Overhead applications: Baywa Re

BifiPV applications: AgriPV



Vertical applications: next2sun



Overhead applications: Baywa Re

BifiPV applications: large utility scale



Desert HSAT systems: Ibri II / Jolywood's TOPCon modules



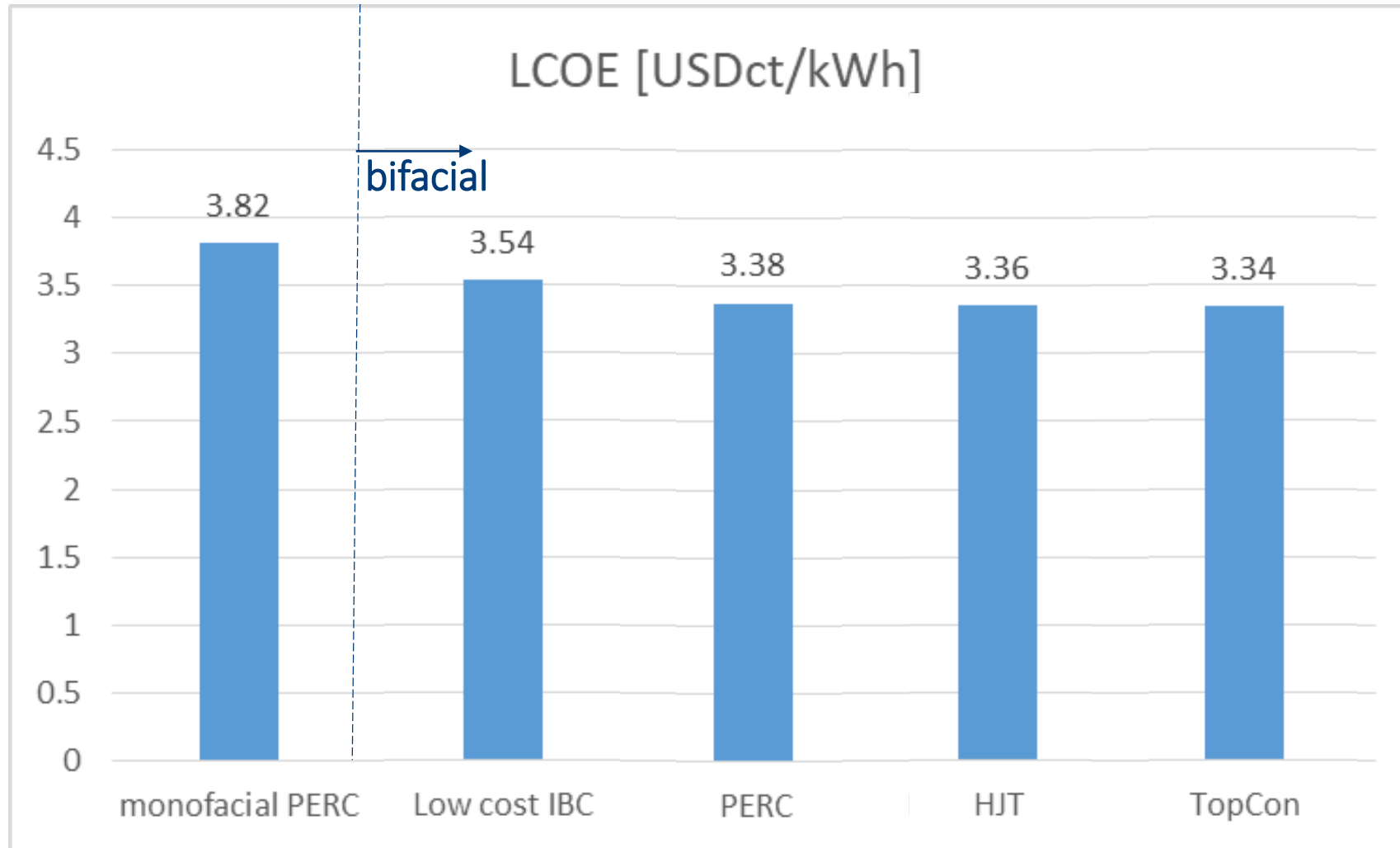
BifiPV applications: large utility scale



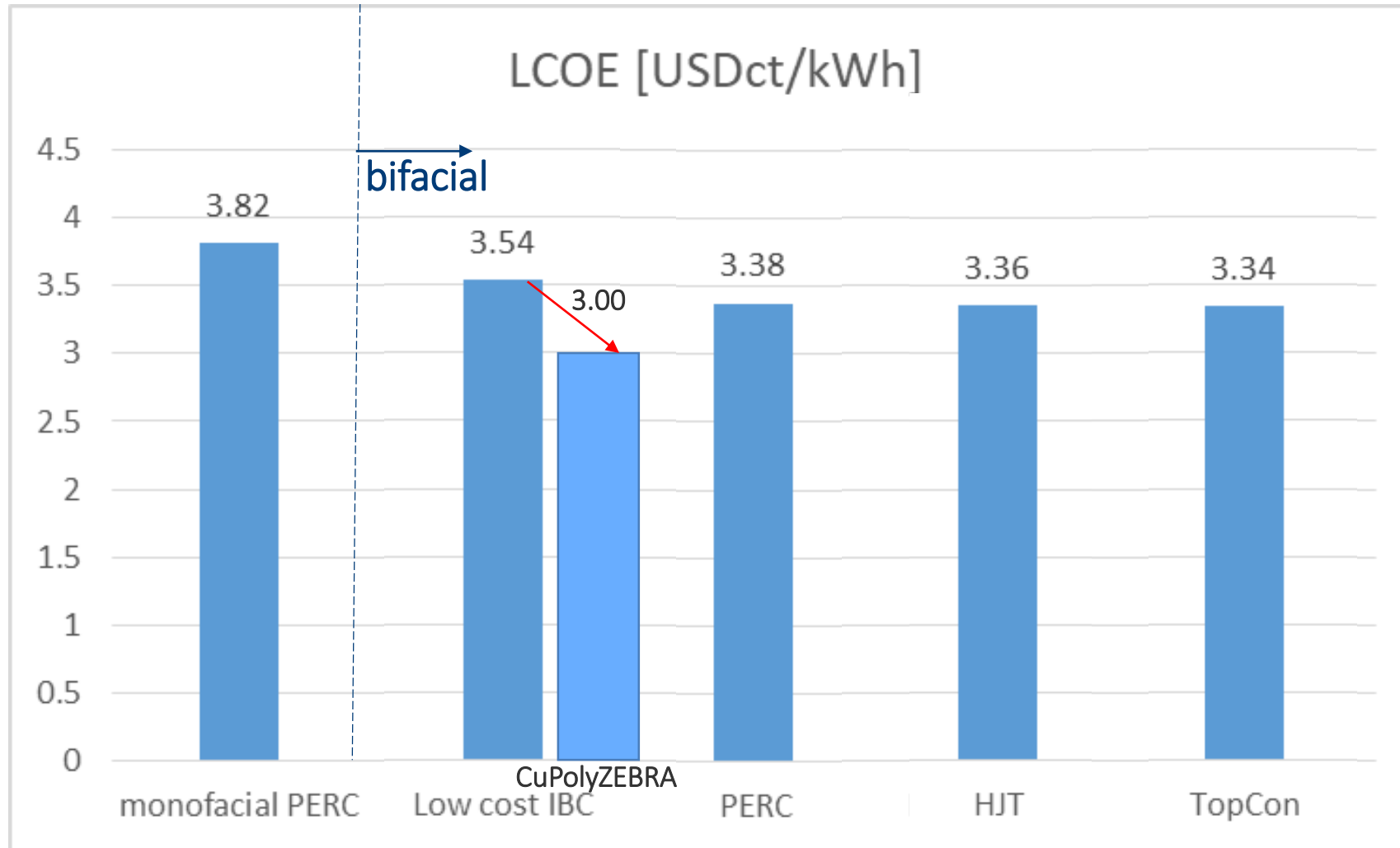
Desert HSAT systems: Ibri II / Jolywood's TOPCon modules



LCOE: results for utility scale ground mounted systems



LCOE: results for utility scale ground mounted systems



2025+: nPV will become the emperor of energy markets

24%+ efficiency
TC well below -0.3%/K
BF of 70-95%
Lower degradation
COO: 15ct/Wp and less
LCOE below 1ct/kWh



Summary: 3 takeaways

PV (bifacial PERC) is the king of energy markets!

> More 1ct/kWh announcements to come.

Bifacial nPV will be the new emperor.

> TOPCon and HJT will be used for utility scale.

TBC to come later on utility scale as well.

Sustainable development will be key (e.g. Cu instead of Ag).

More albedo enhancements will be used

> Bifacial gain optimisation will become more important in utility scale.



Upcoming bifiPV workshops 2024 and 2025

bifiPV2024 in November 27/28 at AIKO in China



bifiPV2025 in January in Antofagasta, Chile



Thank you for
listening!



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TW era

WE THANK GERMANY FOR BMWK Projects and EU FOR IBC4EU FUNDING

More information: www.isc-konstanz.de

