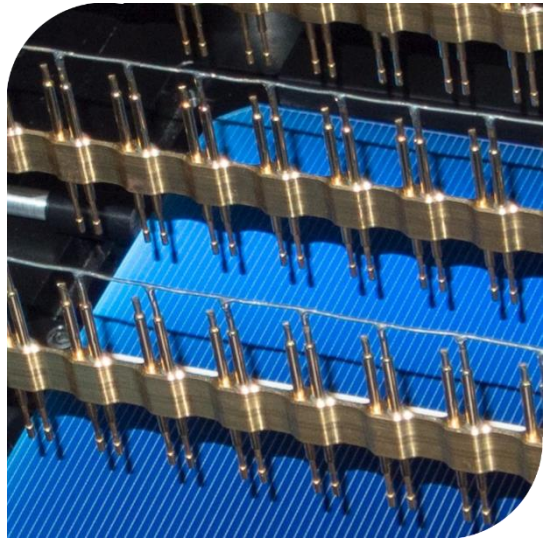



Cu screen printed bifacial XBC for utility scale

Dr. Radovan Kopecek et al.

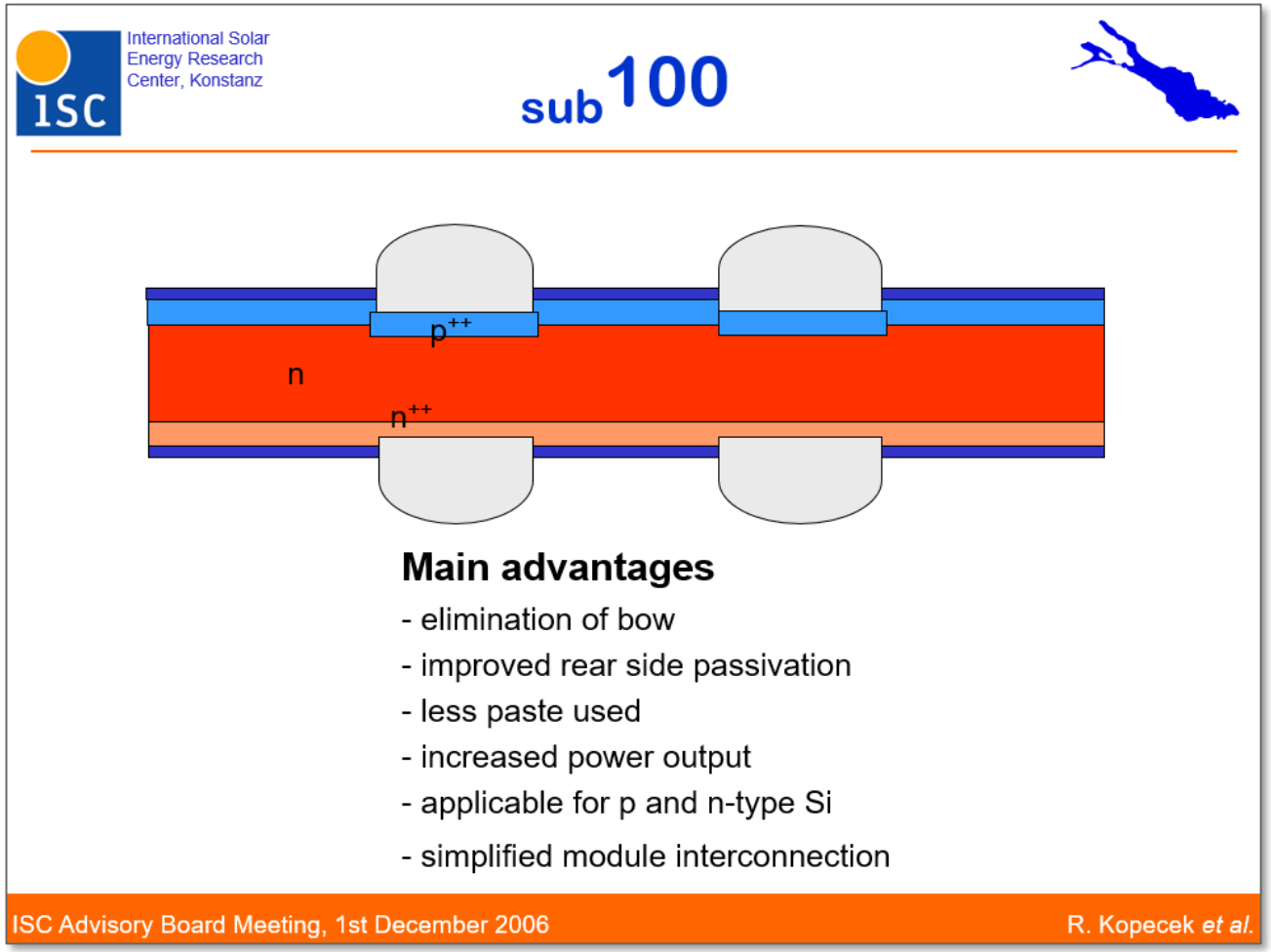
ISC research for a sunny future

International Solar Energy Research Center Konstaz

Agenda

1. Summary and questions of last presentation
2. XBC solar cell technology
3. IBC4EU project /bifacial XBC Cu screen printed tech
4. BCworkshop 2023
5. Summary

ISC Konstanz: 18 years



Summary: 3 takeaways

PV (bifacial PERC) is since 2020 the king of energy markets!

> More 1ct/kWh announcements to come.

Bifacial nPV will be from 2024 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.

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Crystalline silicon solar cell technology

28%
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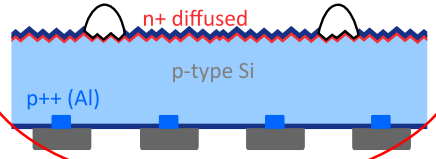
p-type low cost
(2000-2017)

Al-BSF (680 mV)

p-type **bifacial**
(2018-2023)

PERC (690 mV)



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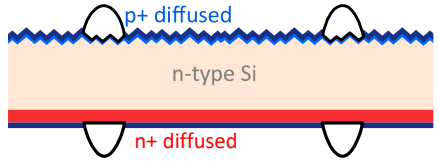

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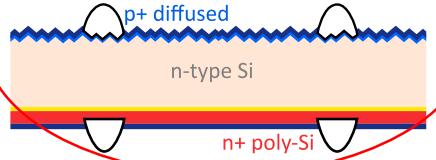
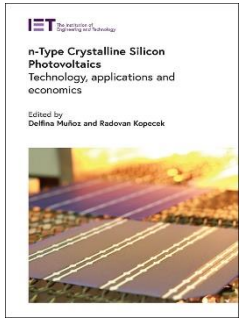
TOPCon-like (720 mV)



2023



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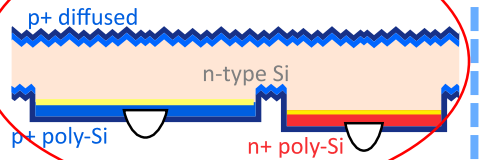
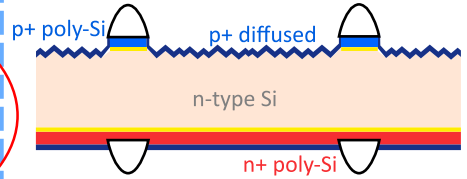
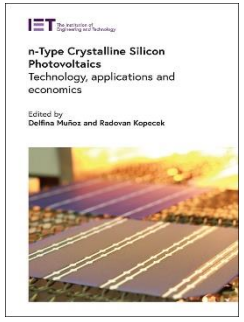
TOPCon-n-IBC (740+ mV)

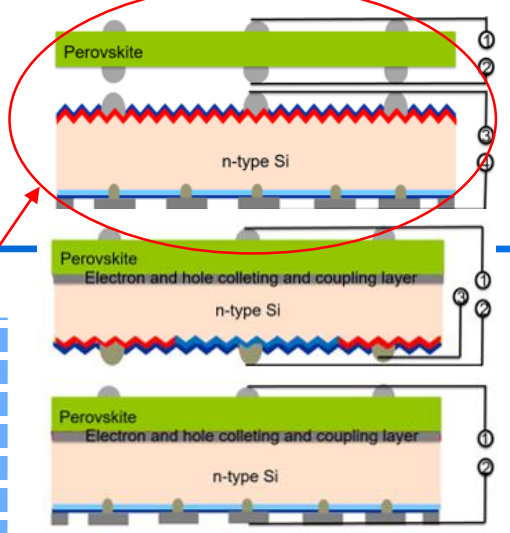


TOPCon-like 2 (740+ mV)



2025





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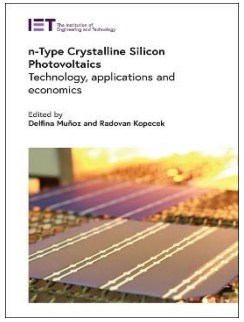
TOUCAN
n+ poly-Si

2023



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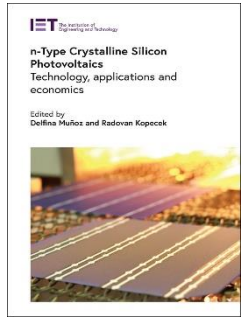

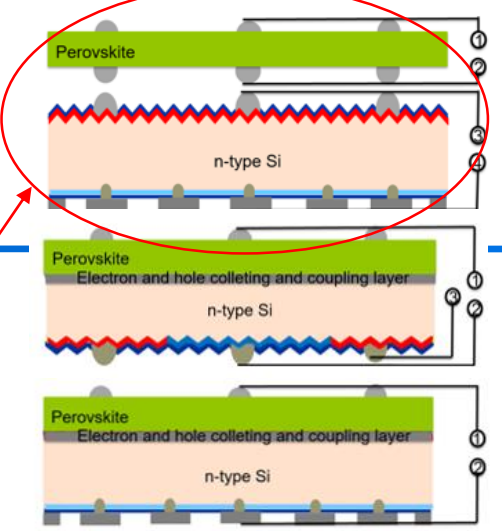

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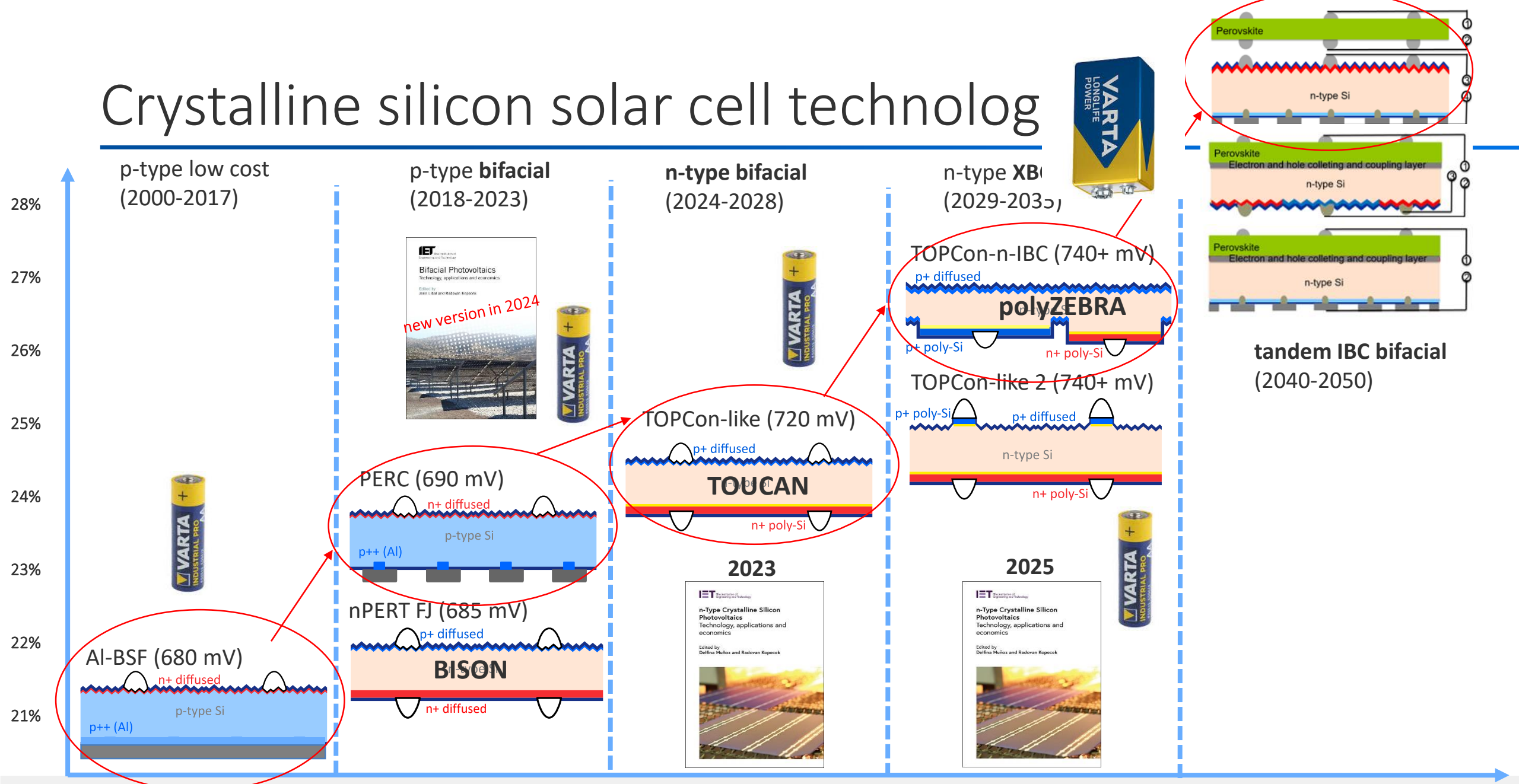
Crystalline silicon solar cell technolog



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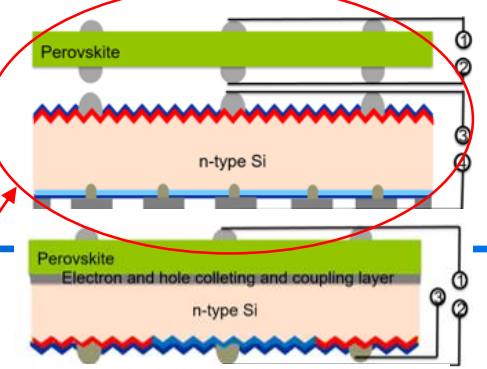
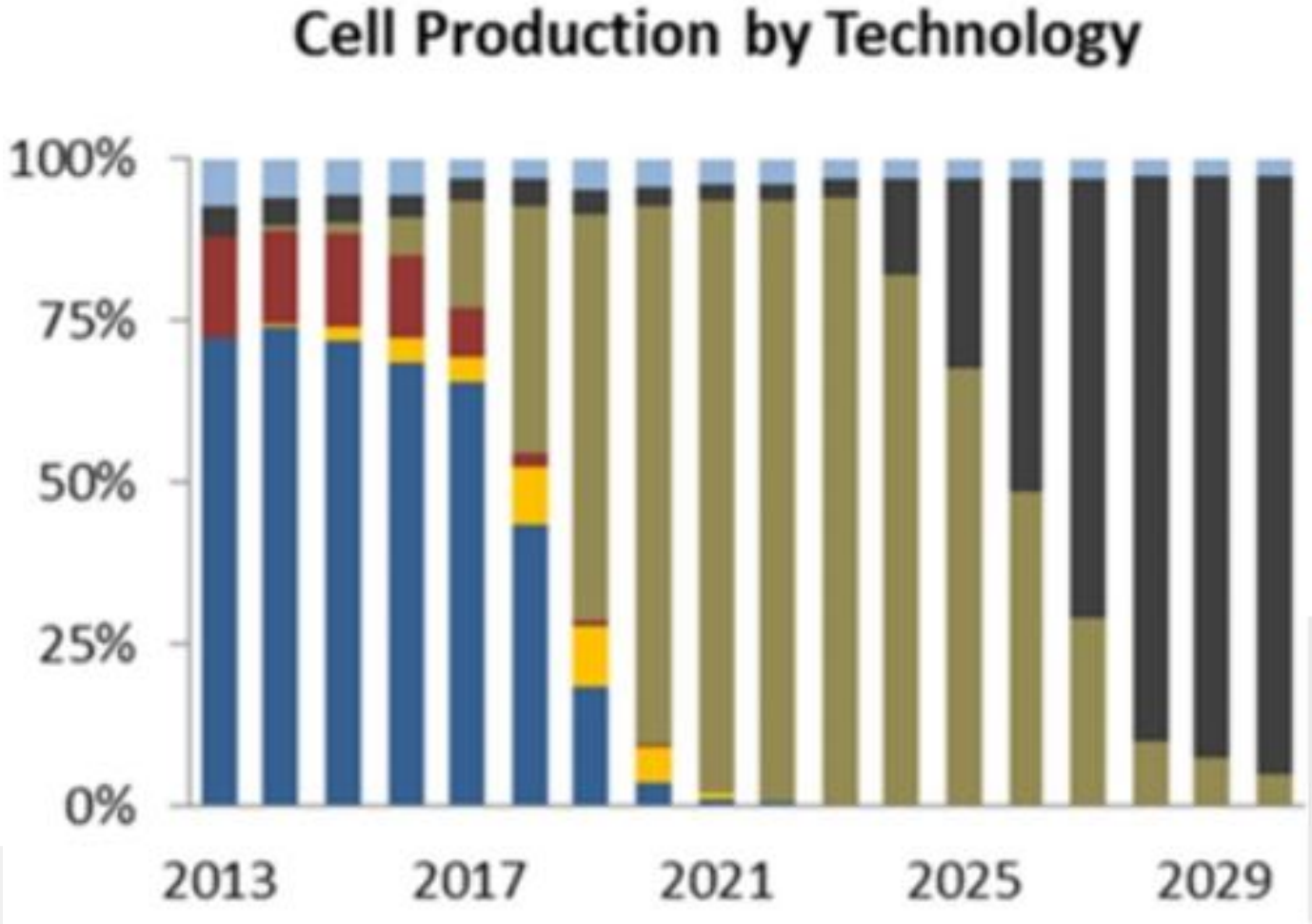
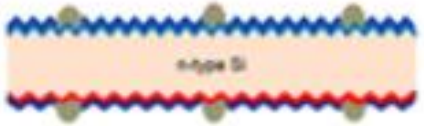




24%+

TOPCon, SHJ

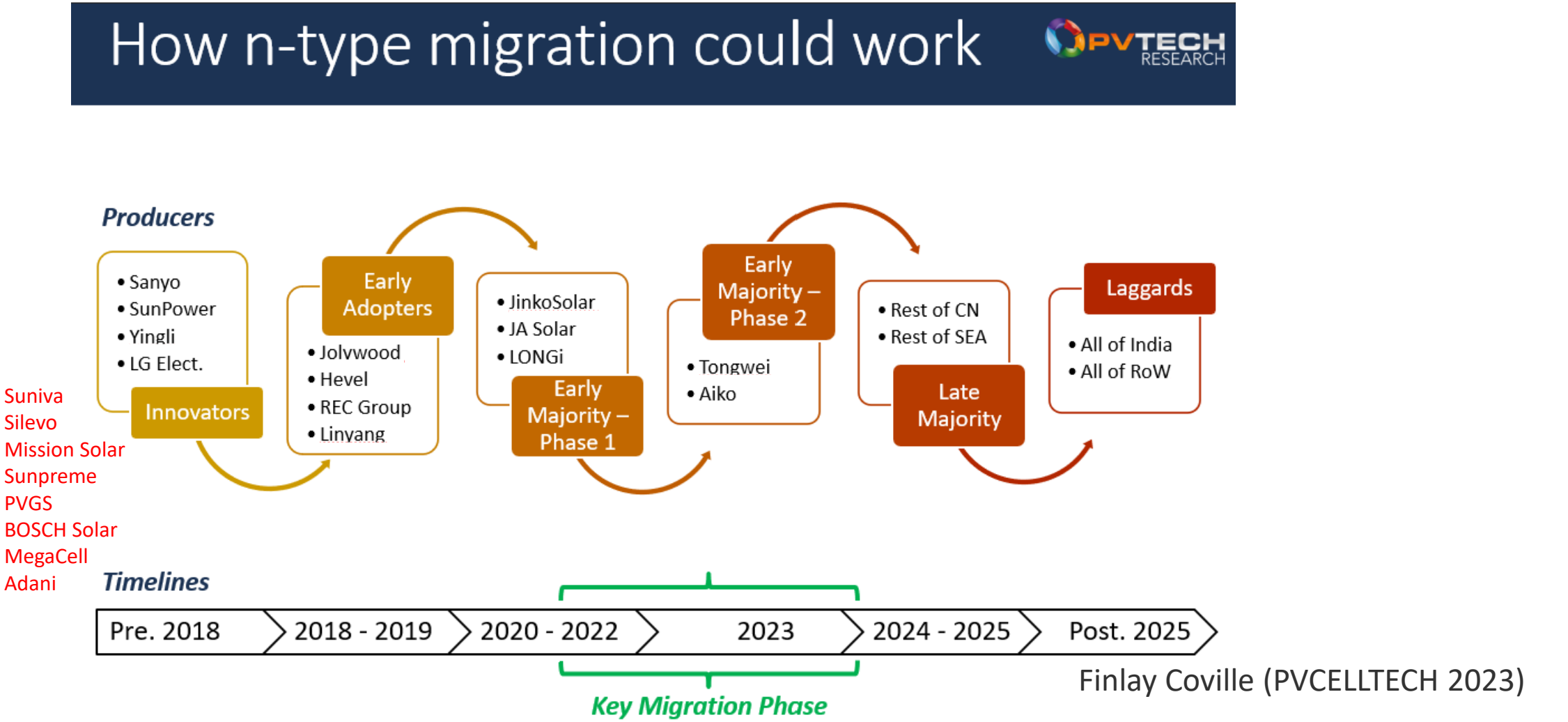


25%+

poly-IBC, SHJ-IBC

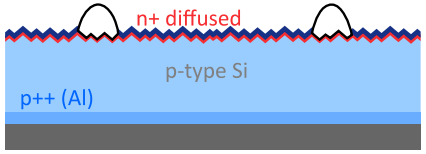
PVTECH RESEARCH

PVTECH Research



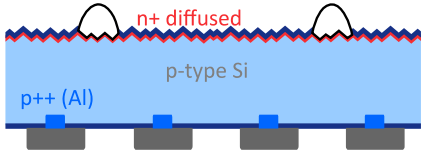
Finlay Coville (PVCELLTECH 2023)

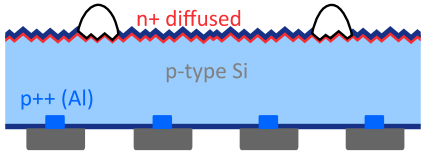
Technology switch: an evolutionary revolution



Selective emitter — PECVD AlOx — Low cost Cz-Si

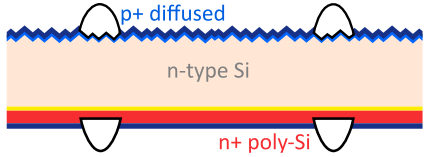
High sheet resistance contacting pastes — Void free Al-paste — Bifacial standard — 2018

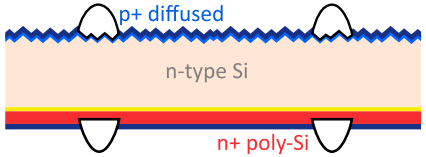




ALD AlOx — LeTID stability — PECVD poly(P)-Si — LECO

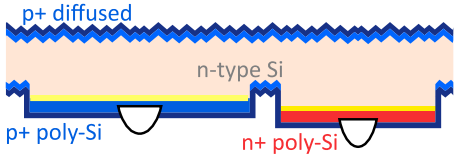
Homogeneous B-diffusion — M10/G12 — 2024

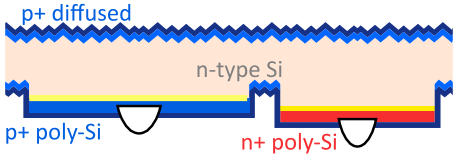




XBC interconnection — low Ag content SP — PECVD poly(B)-Si

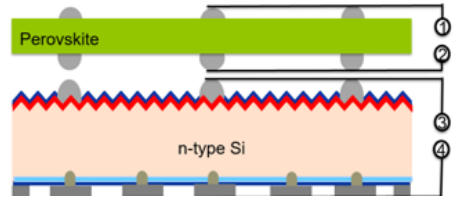
SP metallisation / isolation paste — Cu SP — 2028



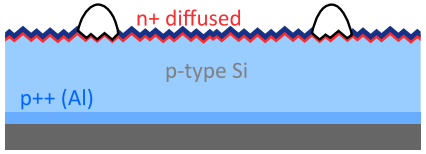


Upscale: homogeneous depositions — Stability — Reverse behaviour

Current matching — Voltage matching — Interconnection — 2035?



Technology switch: an evolutionary **revolution**



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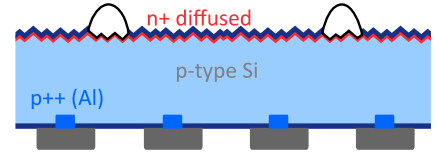

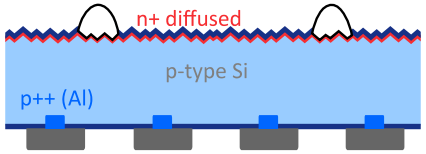

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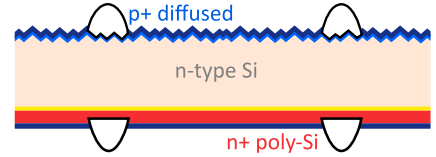

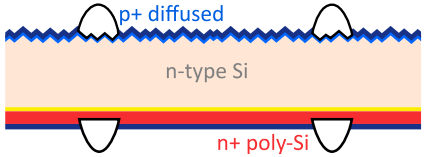

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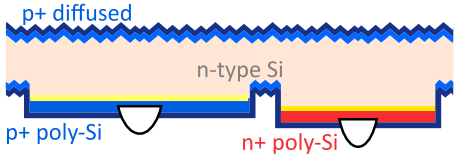

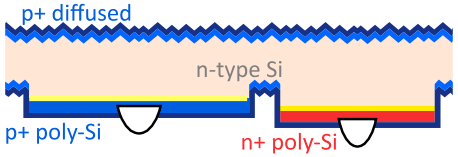

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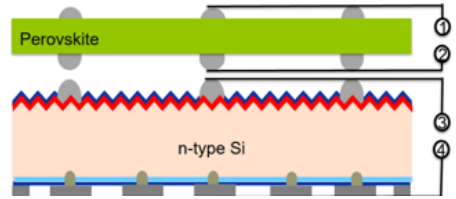
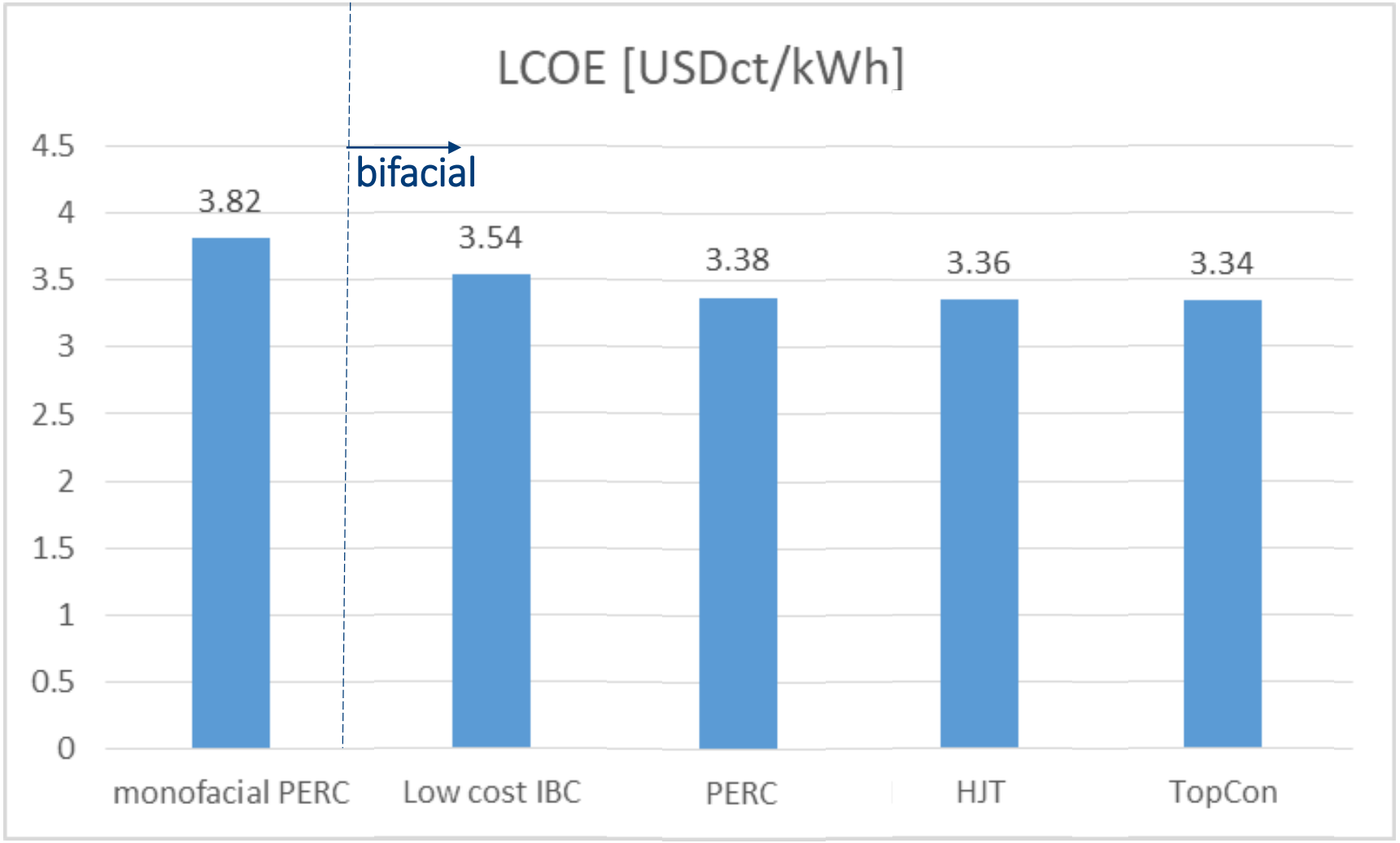


LCOE: results for utility scale ground mounted systems
PERC, TOPCon, HJT, or XBC? What to chose?



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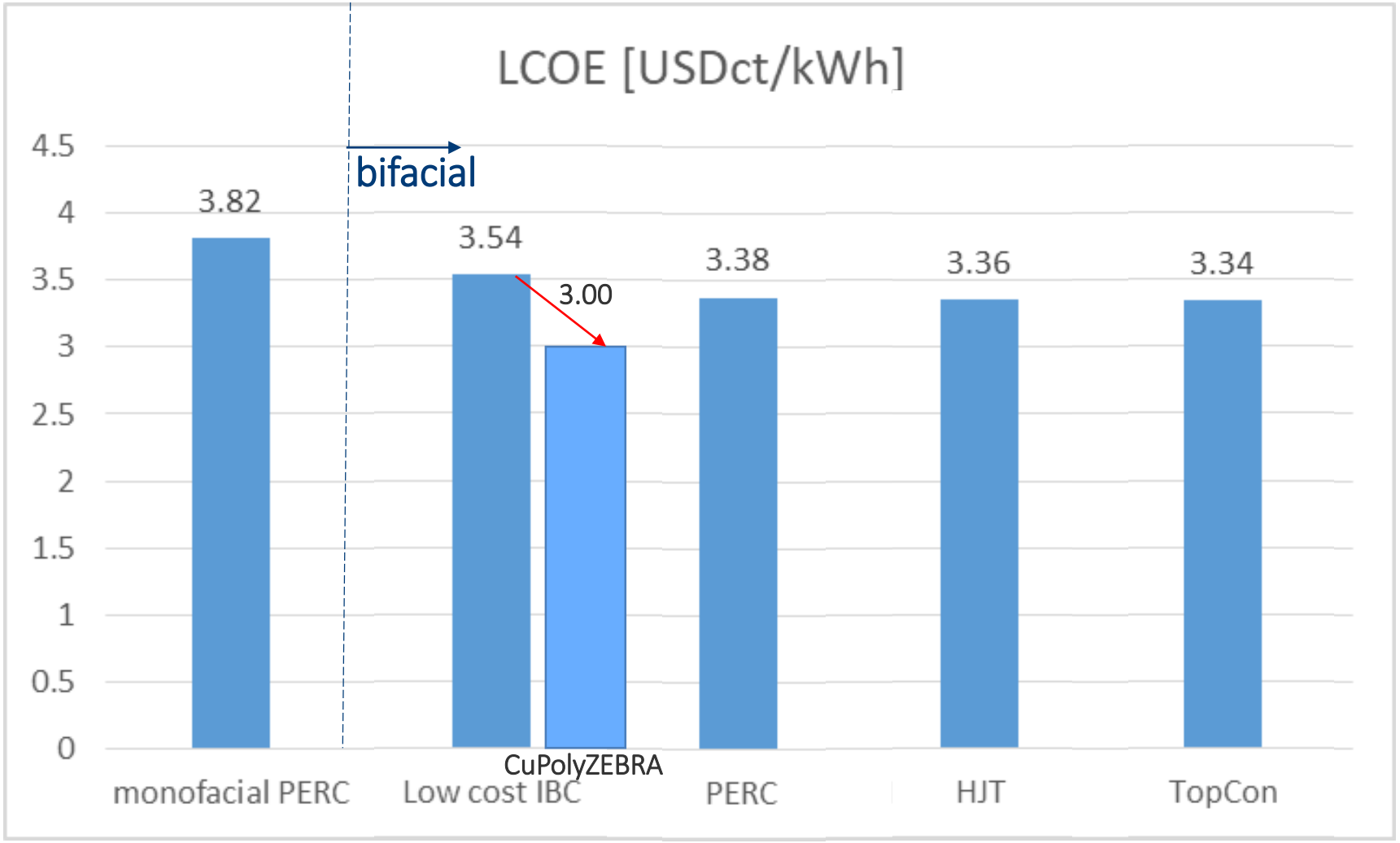


Albedo enhancement (“concentrating”)

Research shows high-albedo ground reflectors increase bifacial solar plant yield by up to 4.5%

Tests conducted by Canadian researchers at the NREL’s testing field in Colorado have shown that ground reflectors based on high-density polyethylene can significantly increase bifacial PV plant performance. They stressed the profitability of this technology is strictly dependent on the location and warned avoiding to combine it with inverter clipping.

MAY 8, 2024 EMILIANO BELLINI

TECHNOLOGY AND R&D | UTILITY SCALE PV | CANADA

Image: University of Ottawa

Trinasolar ABOUT SOLAR PV PV PRODUCTS STORAGE SOLUTIONS

The following figure 1 (on the left) and table 1 mainly compares the data on sunny days. With the fixed-tilt installation method, the generating capacity gain increases gradually with the increase of ground surface reflectance. The generating capacity gain is around 20% in the case of white paint.

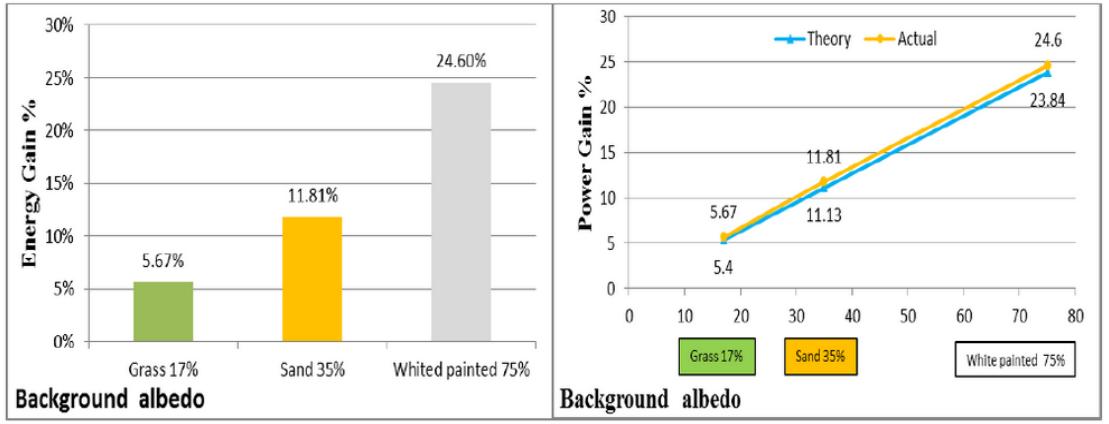


Figure 1. Bifacial gain affection by different albedos (different surfaces)

Types of ground	Albedo (%)	Estimated Bifacial Gain (%)
Grass	17	5.67
Sand	35	11.81
White Painted	75	24.6

Table 1. Measured Bifacial Gain for different albedos (surfaces) on a real PV plant

2. XBC solar cell technology

XBC technology > explanation of different concepts

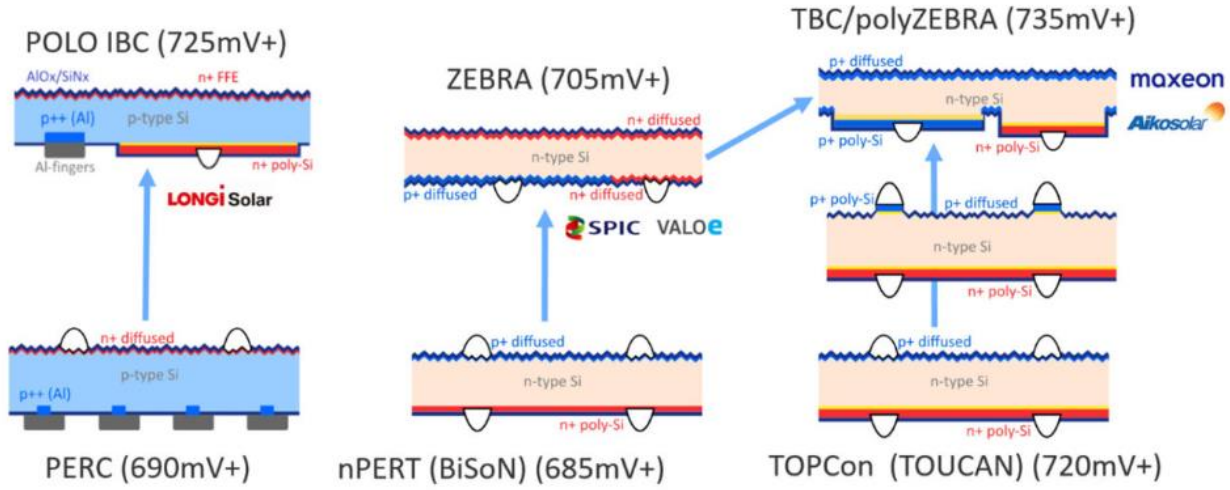
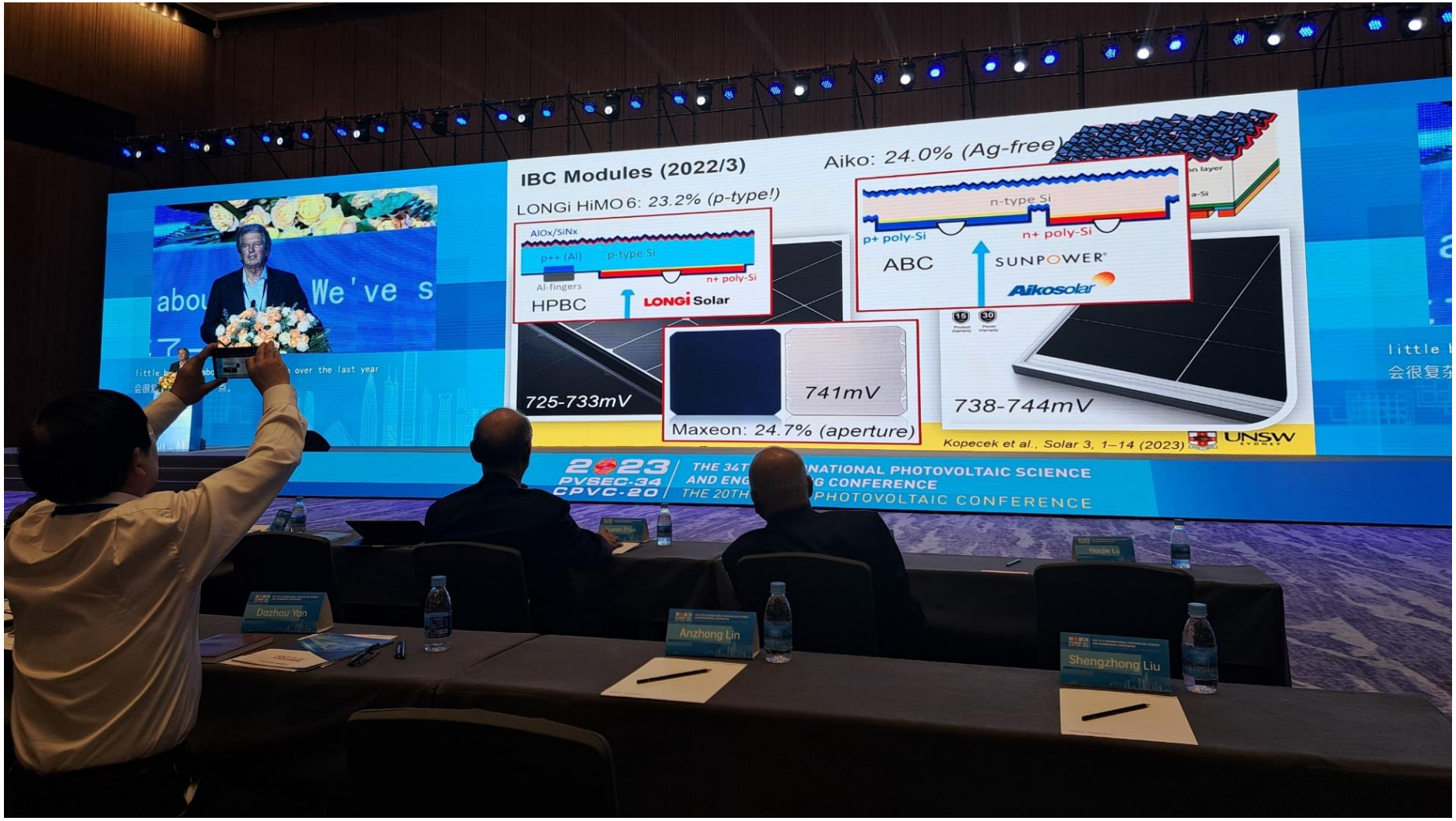


Fig. 4. Three IBC concepts based on different both sided solar cell concepts – PERC, nPERT and TOPCon.

IBC technology (ZEBRA)
TBC technolohy (polyZEBRA, ABC, Maxeon, PoloIBC…)
HJBC (Meyer Burger´s PILATUS…, 3SUNS BC,…)

Plenary: Asian PVSEC 2023



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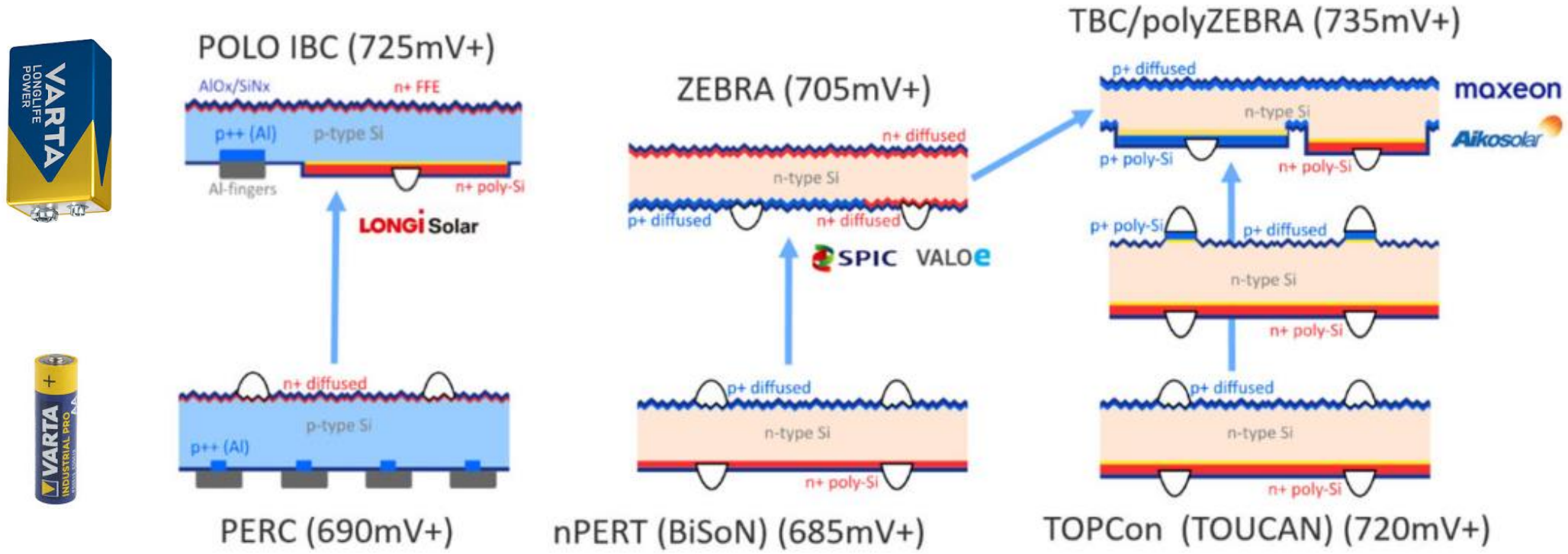

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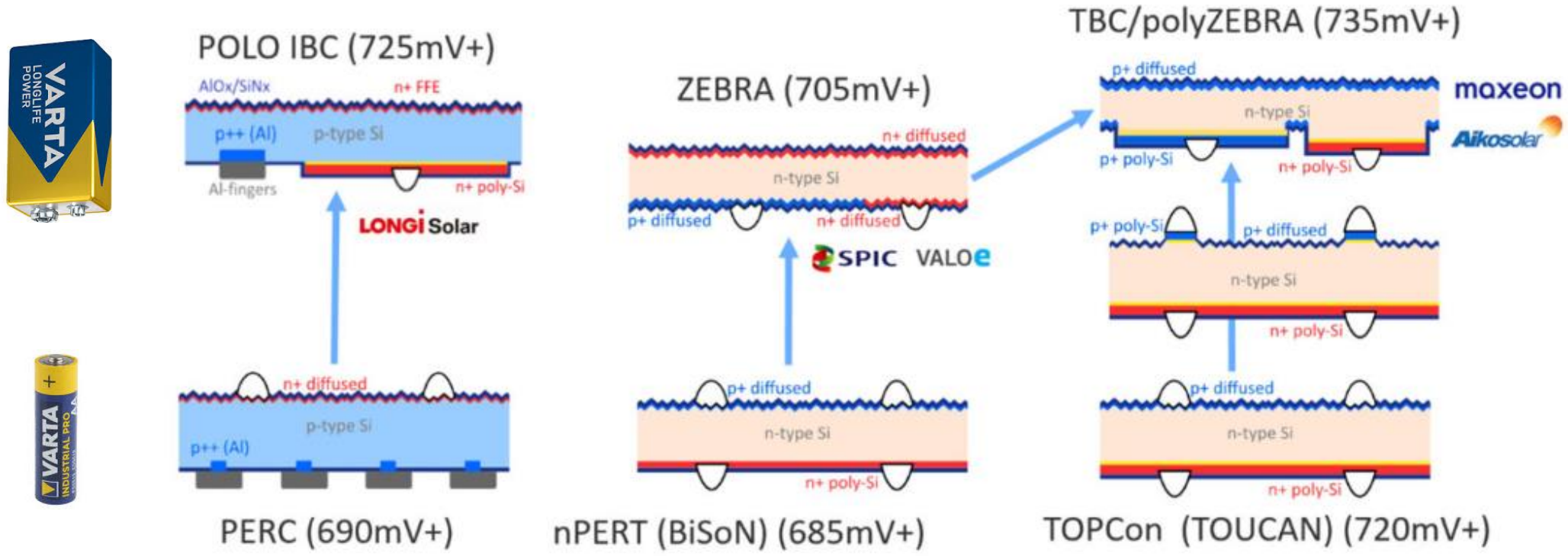
Why TBC will follow shortly after TOPCon
By Radovan Kopecek et al.
September 11, 2023

XBC technology > explanation of different concepts



IBC4EU
Futura Sun
Valoe Cell
SPIC
CARBON

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PVTECH

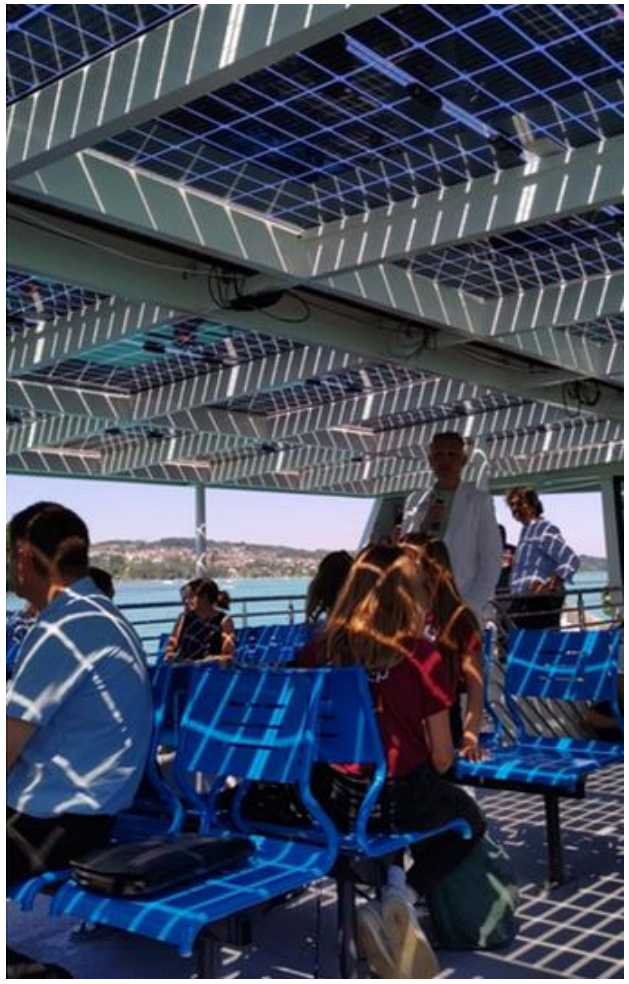
XBC technology > explanation of different concepts

	IBC without passivating contact (0PC)			POLO-XBC (1PC)		XBC (2PC)	
Company/Institute	SPIC/ISC	ipv Stuttgart	Jolywood	LONGi	Maxeon	AIKO	TRINA
Brand-name	ZEBRA/Andromeda2.0	MESA	–	POLO IBC	Maxeon 6	Black Hole	–
Type	n-type	n-type	n-type	p-type	n-type	n-type	n-type
In production	Yes	No	Yes	No	Yes	Yes	No
Efficiency	24.6% [7]	23.3% [8, 9]	23-24%	25% [10]	25.5% [11]	25.5% [12]	25.04% [13]
PERC Related	80%	75%	70%	90%	0% (plated)	10% (plated)	10% (plated)
Module efficiency	22.3%[14] can be bifacial	Unknown	Unknown	23.0% [14]	23.0% [14]	23.6% [14]	Unknown

Table 1. Prominent IBC technologies on the market and their properties.

R. Kopecek et al., „Why XBC will follow shortly after TOPCon", PV International 50, 2024

BC TECH: ZEBRA technology







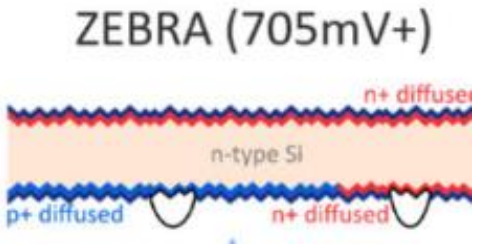


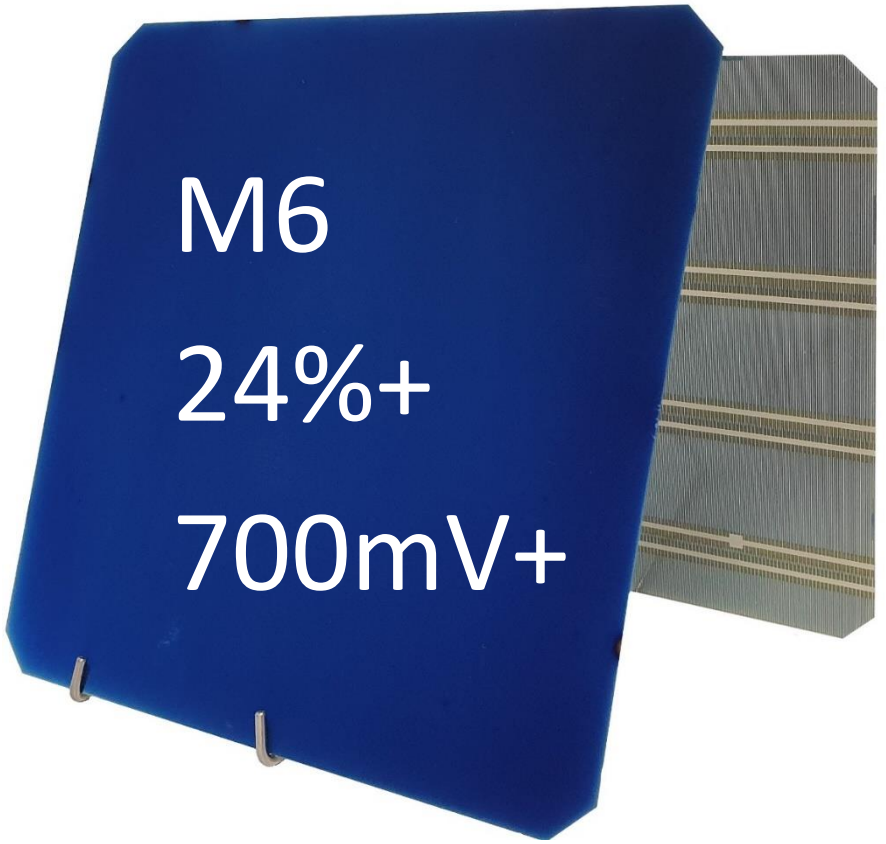

- VIPV
- BIPV
- Balcony
- Roof
- Utility

ZEBRA cell technology

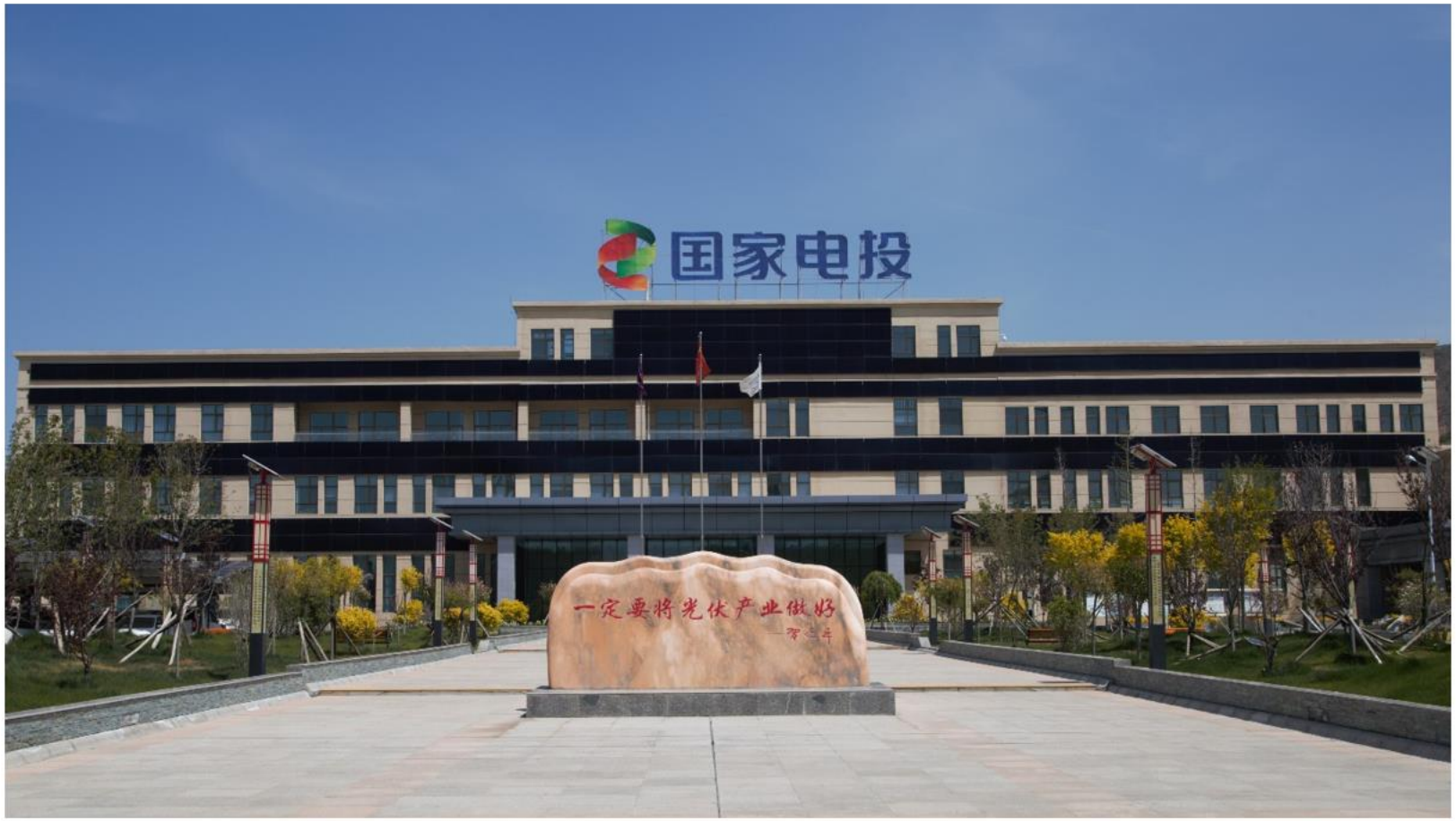
A low-cost, high efficiency, n-type back contact back junction solar cell

- No metallization on front side
- Regular stripes of n+ and p+ doping on the rear
- Screen printed Ag-paste metallization
- Busbars on flexible positions
- Developed by ISC Konstanz in 10+ years of R&D

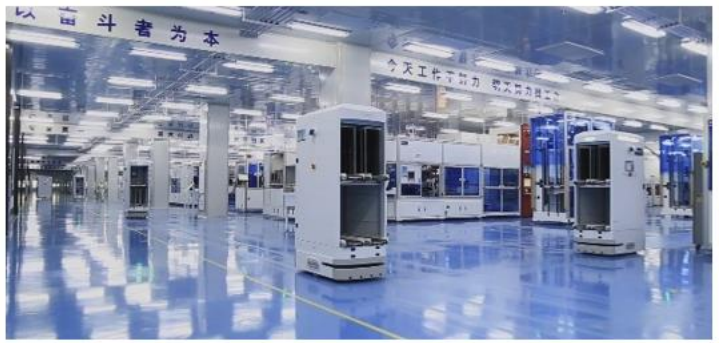




Introduction of SPIC Solar: IBC production



ISC research for a sunny future



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**

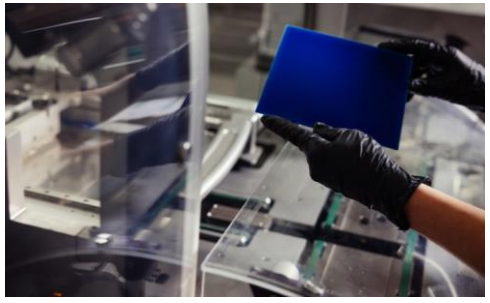
24+% ZEBRA IBC

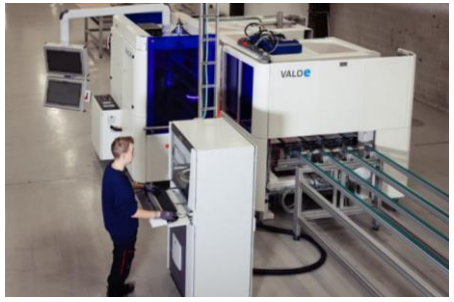
PERC mainstream 2020: 22.8%

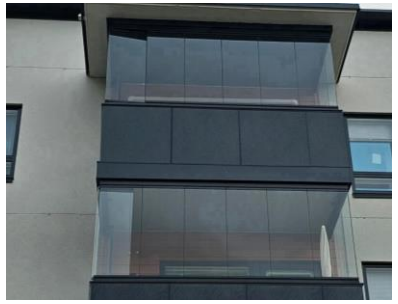
Only IBC production in EU at ValoeCell in Vilnius

VALOE

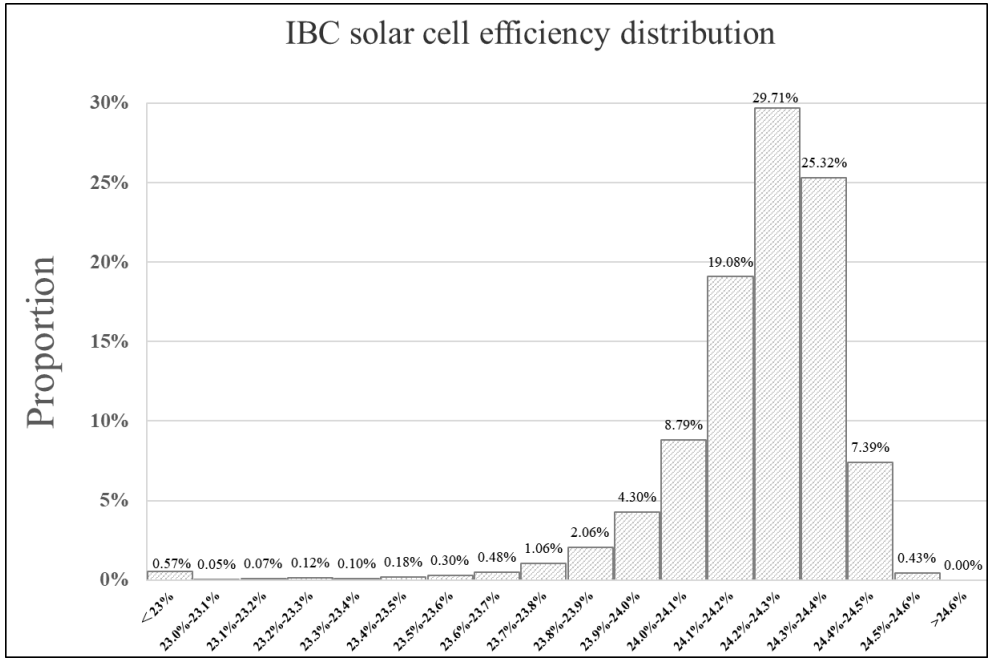
ISC research for a sunny future

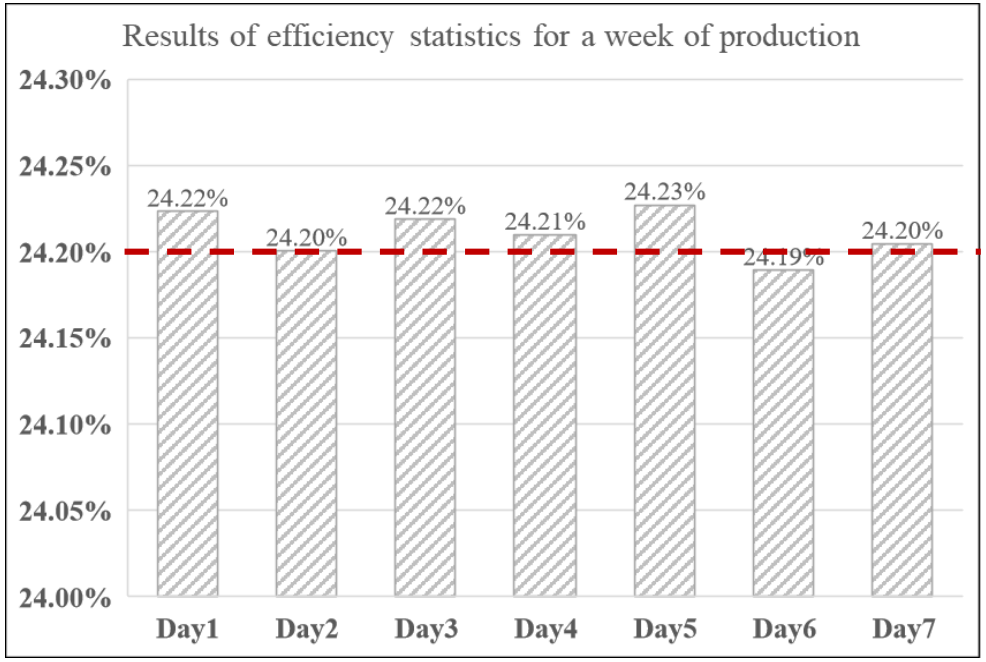






ZEBRA cell technology: cell parameters from production



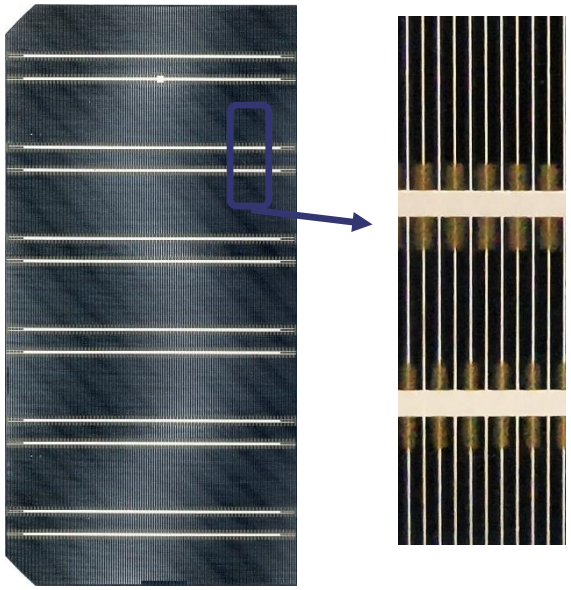


	Voc (mV)	Isc(A)	FF(%)	Eta(%)
average	700	11.83	80.15	24.21
Best cell	704	11.86	80.64	24.60

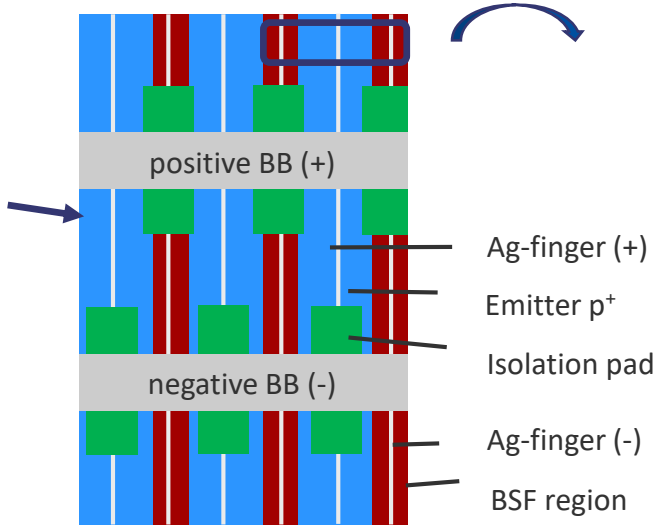
IV data for a week of production, 4/2022

3D printed ZEBRA cell technology: device architecture

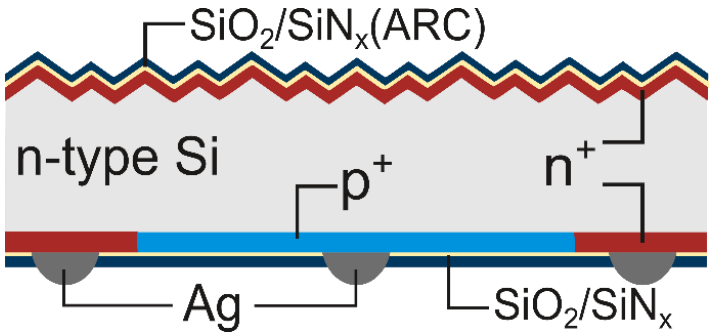
Photo of rear side



Schematic drawing



Drawing cross section



The stripes are p+ and n+ doped regions of optimum width

25mg Ag/W

ZEBRA cell technology: properties

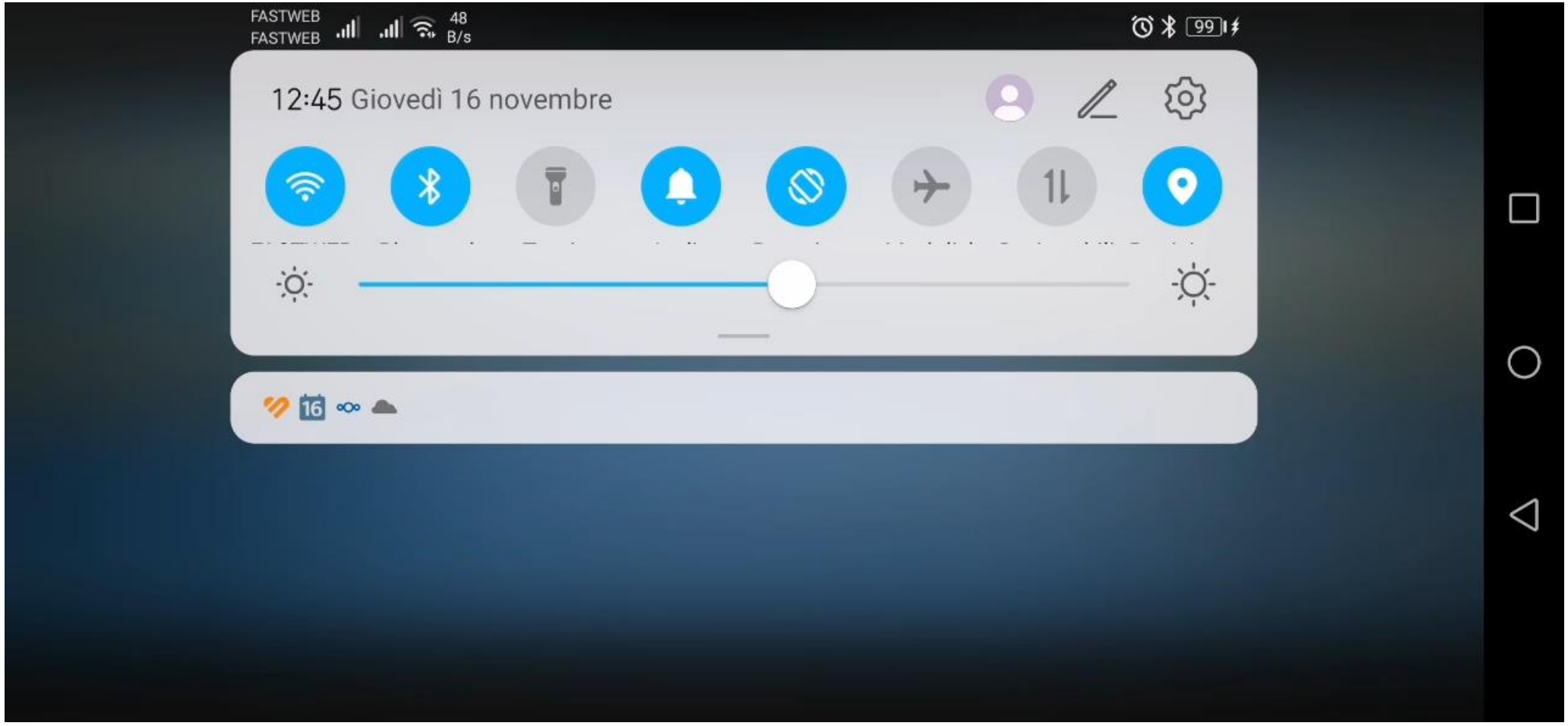
- M6 wafers >> G12 possible
- 9 BB technology
- No passivating contacts
- No AlOx passivation
- Simple module interconnection
- No PID, No LeTID, No UV degradation

Future:
- Lean upgrade to poly-ZEBRA
- Easy implementation of Cu and Al

25mg Ag/W

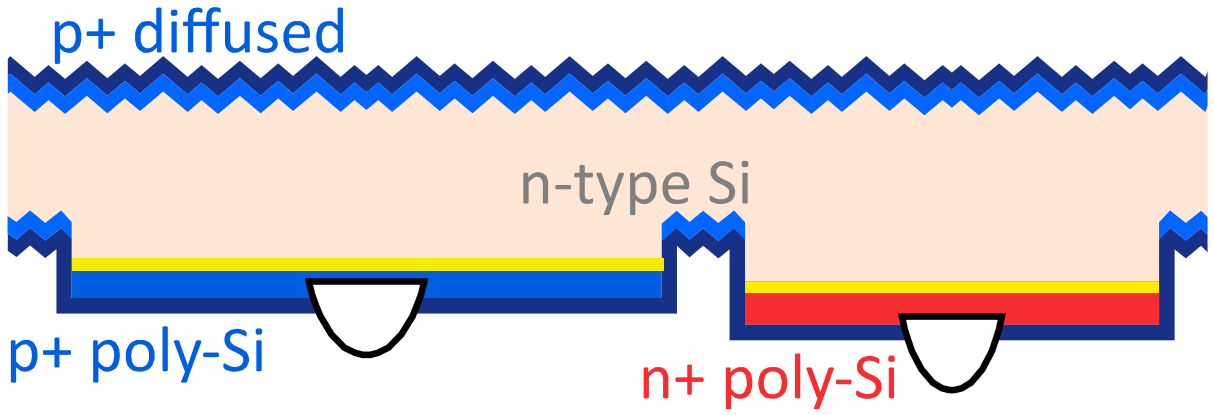
ZEBRA cell technology: properties

IBC TECH: ZEBRA technology

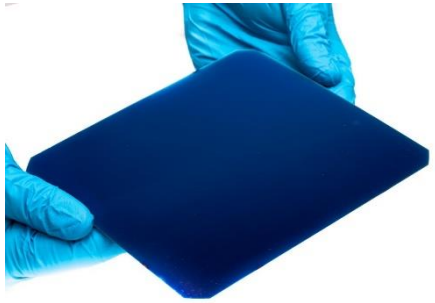


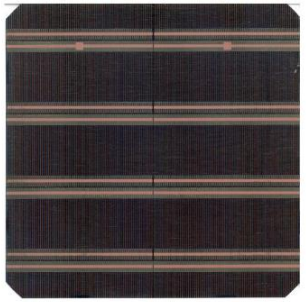
IBC TECH: ZEBRA technology

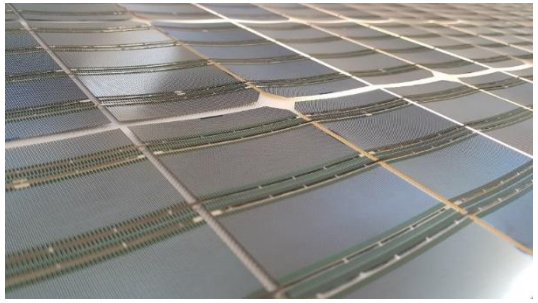
XBC technology: why will it win?

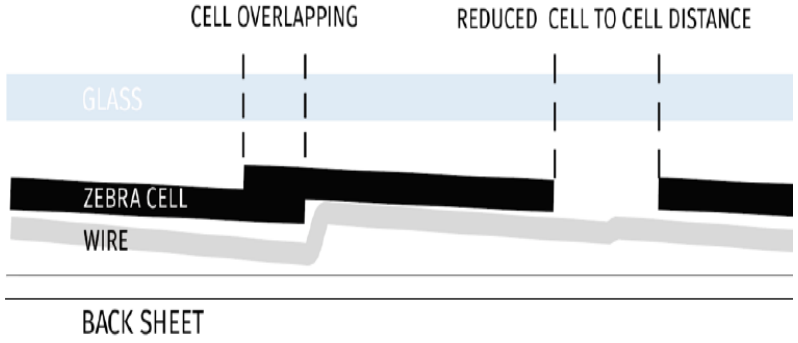


1) Perfect front side
2) UV degradation stable
3) poly-Si on rear
4) **Cu/Al on rear**
5) Easy module interconnect

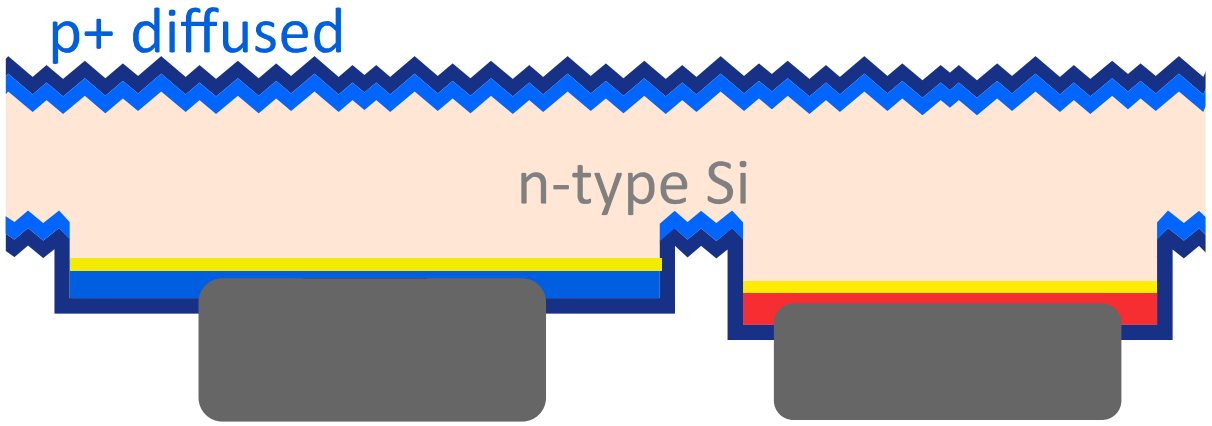








XBC technology: why will it win?



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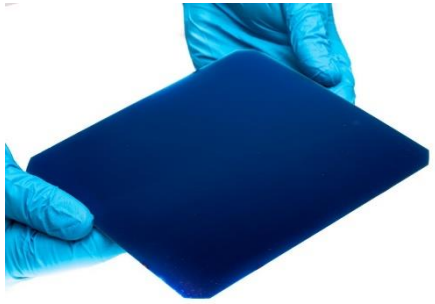

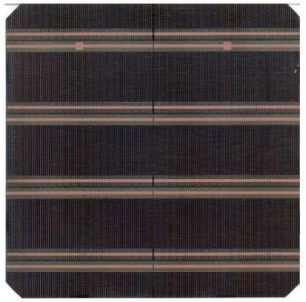

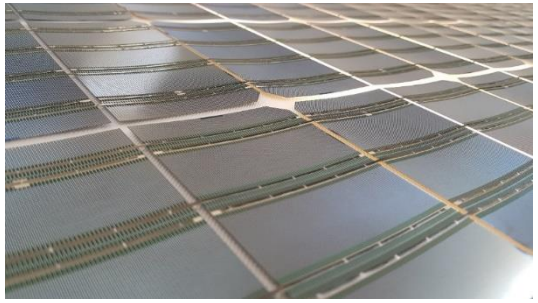

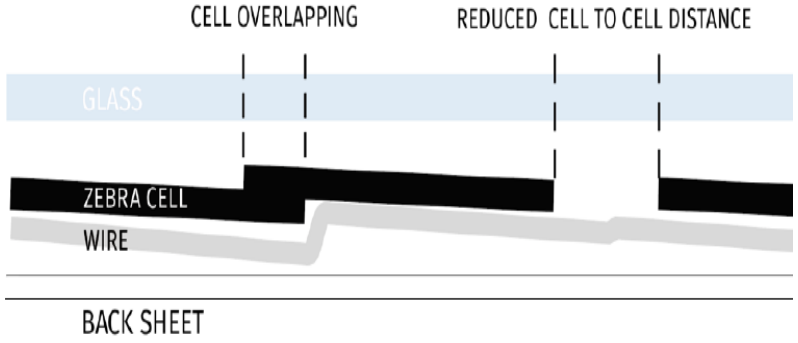

3. IBC4EU project

IBC4EU (Horizon Europe project with 17Mio budget)

EURECA: EUropan REar Contact Alliance

EURECA

R|E|N|A centrotherm LPKF Toyal

NorSun VALOE kalyon FuturaSun anticipate tomorrow ENERGYRA

ISC research for a sunny future ISFH TNO innovation for life imec Copprint

proTECH BECQUEREL INSTITUTE WIP cea ines INSTITUT NATIONAL DE L'ENERGIE SOLAIRE HIGHLINE TECHNOLOGY LuxChemtech

IBC4EU

Piloting novel cost-competitive bifacial IBC technology for vertically integrated European GW scale PV production value chain

Call: HORIZON-CL5-2021-D3-03
(Sustainable, secure and competitive energy supply)

Topic: HORIZON-CL5-2021-D3-03-13

Type of Action: HORIZON-IA

Proposal number: 101084259

Proposal acronym: IBC4EU

Type of Model Grant Agreement: HORIZON Action Grant Budget-Based

Bringing bifacial Cu/Al XBC from roof top to utility scale

IBC4EU (Horizon Europe project with 17Mio budget)

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EURECA

R|E|N|A | centrotherm | LPKF | Toyal

NorSun | VALOE | kalyon | FuturaSun | ENERGYRA

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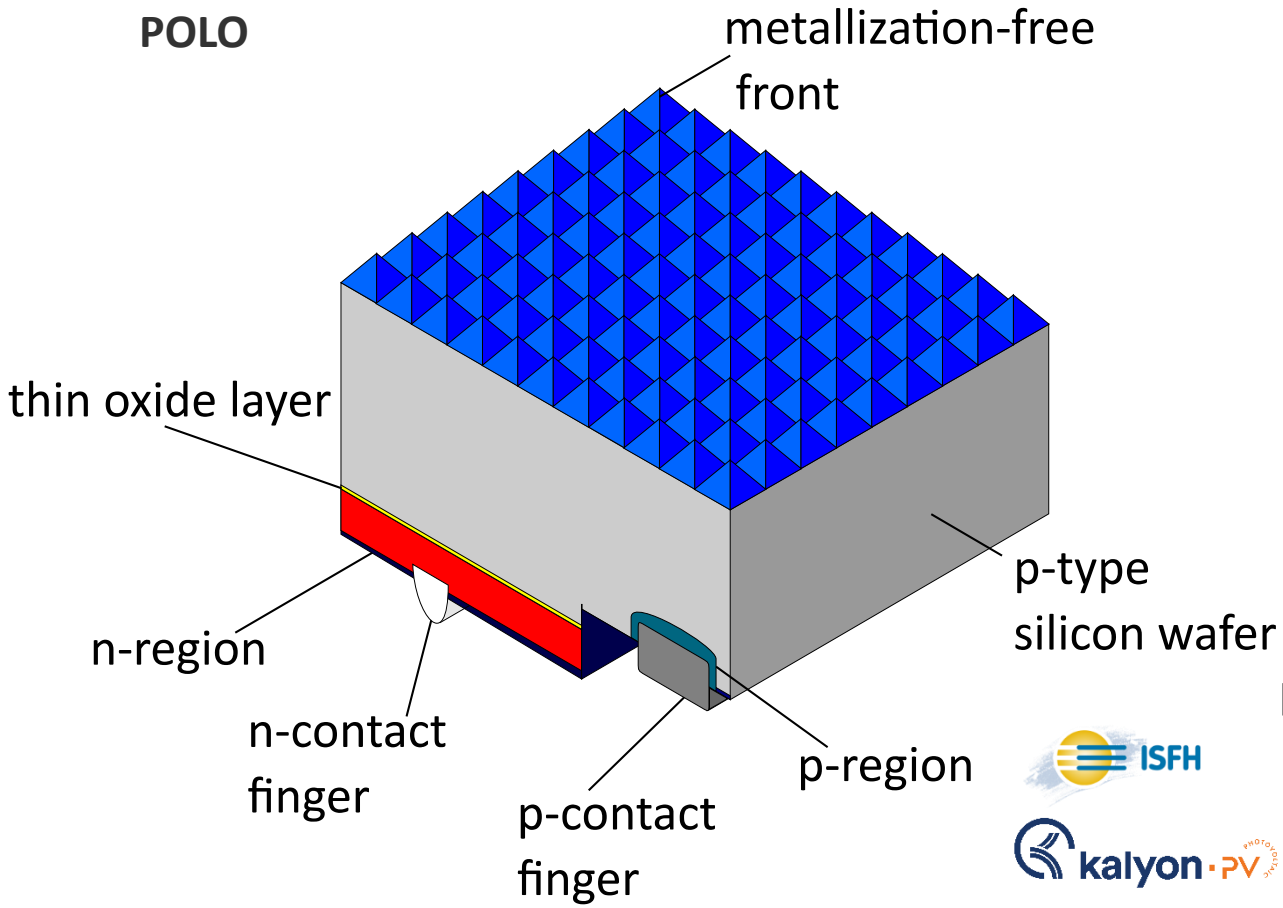
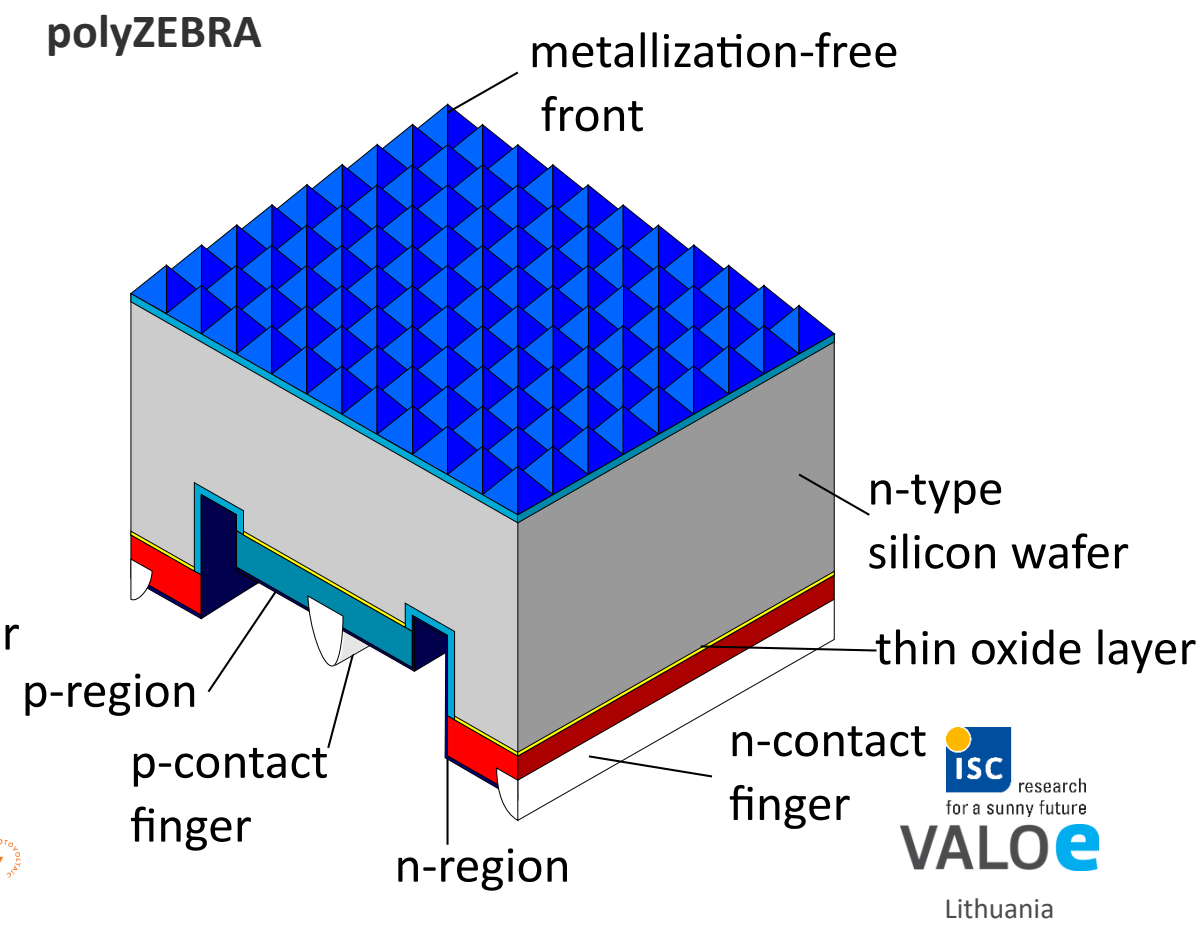
TBC Tech





ISFH

kalyon PV

ISC research for a sunny future

VALOE

Lithuania

IBC4EU´s 2 XBC concepts

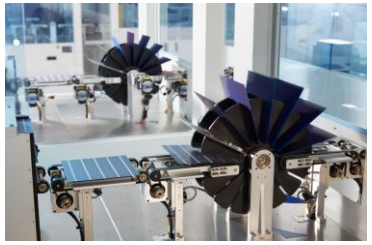
POLO

- Largely based on PERC+ production equipment
- Very lean process sequence*[1,2]
- Efficiency goal: 25% (725mV)

Innovations:

- Local deposition of poly-Si by shadow mask PECVD
- Reduction of silver content

*[1]: EE. Bende et al., 7th Metallization and Interconnection Workshop, Konstanz, Germany (2017).
*[2]: F. Haase et al., Proc. of the 46th IEEE PVSC, Chicago, IL, USA, 2200-2206 (2019).



ISFH
kalyon
Toyal
ENERGYRA

polyZEBRA

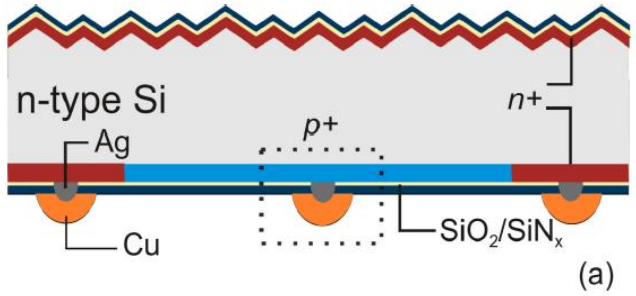
- Upgrade (100% compatible with ZEBRA back-end)
- Developed in Highlite (H2020)
- Efficiency goal: >25% (740mV)
- IP secured

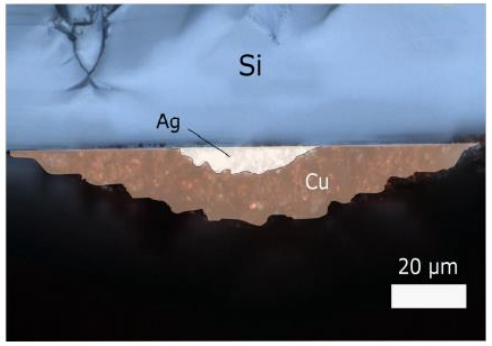
Innovations

- Streamlined process for pilot production
- PECVD-based poly-Si depositions
- **Hybrid metallization based on Cu screen printing**

Coppprint
ISC research for a sunny future
VALOE
Lithuania
FuturaSun anticipate tomorrow

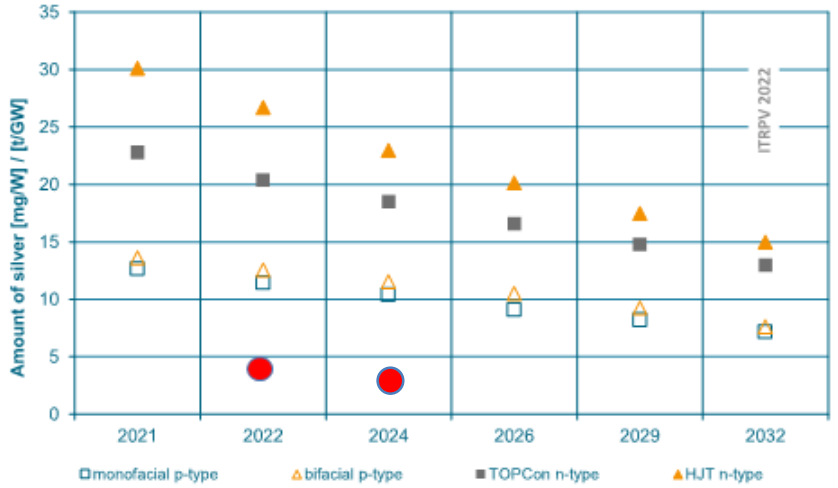
IBC4EU´s Cu-concept (ZEBRA1.5)





Copprint

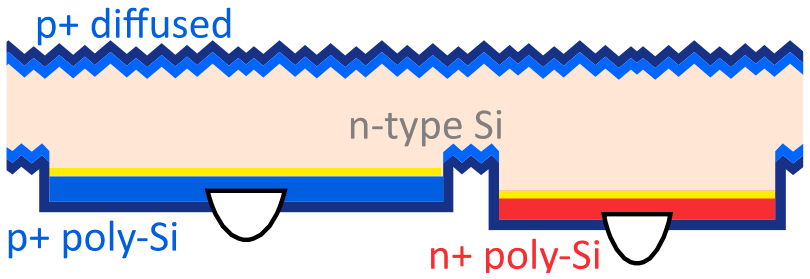
Trend for remaining silver for metallization per Watt (front + rear side)
(Values for M6 + M10 cell size, average)



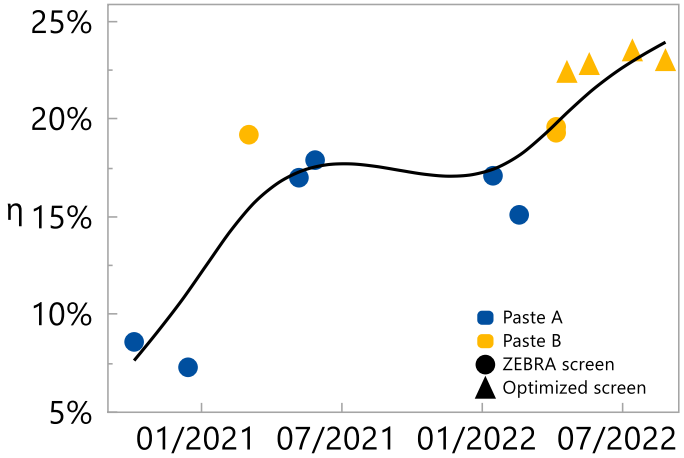
- All screen printing based
- Longterm stability has been demonstrated
- Current status of Cu-polyZEBRA: Solar cells (M6): 24%

N. Chen et al. Solar RRL 7.2 (2023):2200874
Buchholz, PVCellTech 2023
D. Rudolph, MIWS 2023

IBC4EU´s 25%+ cell: polyZEBRA (ZEBRA2.0)



- IP secured
- 2 patent applications pending

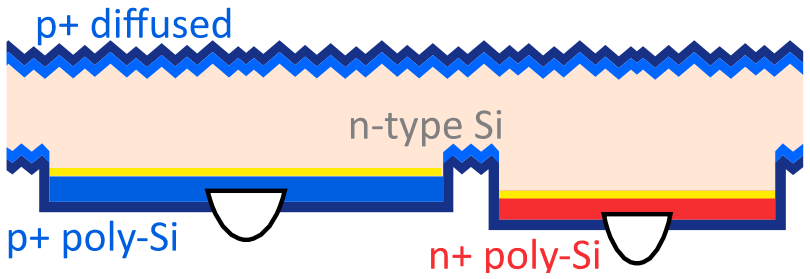


Status Q3/2023:
baseline+0.5%

	ZEBRA		poly ZEBRA	
1	wetbench		wetbench	1
			SiO2+a-Si(n)	2
2	B-diff		SiNx	3
3	wetbench		Laser (abl)	4
			wetbench	5
			SiO2+a-Si(i)	6
4	SiNx		B-diff	7
5	Laser (abl)		wetbench	8
			Laser (SE)	9
6	wetbench		TEX	10
7	P-diff		B-diff	11
8	wetbench		wetbench	12
9	SiNx front		AlOx+SiNx front	13
10	SiNx rear		AlOx+SiNx rear	14
11	SP + FF		SP + FF	15
12	IV+sorting		IV+sorting	16

Linke et al. Fully Passivating Contact IBC Solar Cells Using Laser Processing. WCPEC 2022

IBC4EU´s 25%+ cell: polyZEBRA (ZEBRA2.0)



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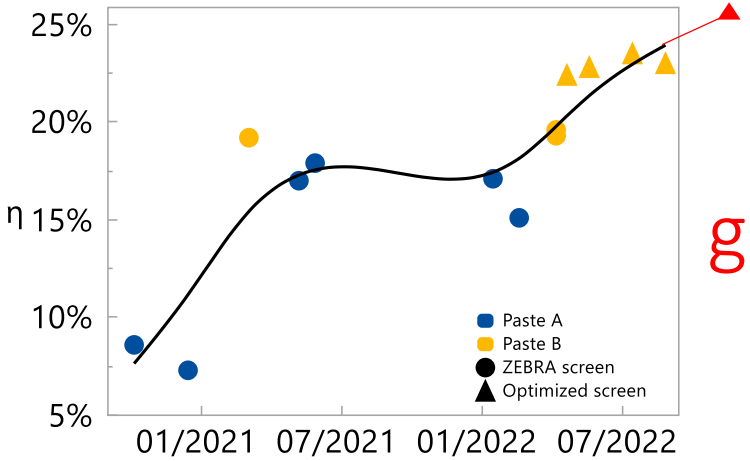
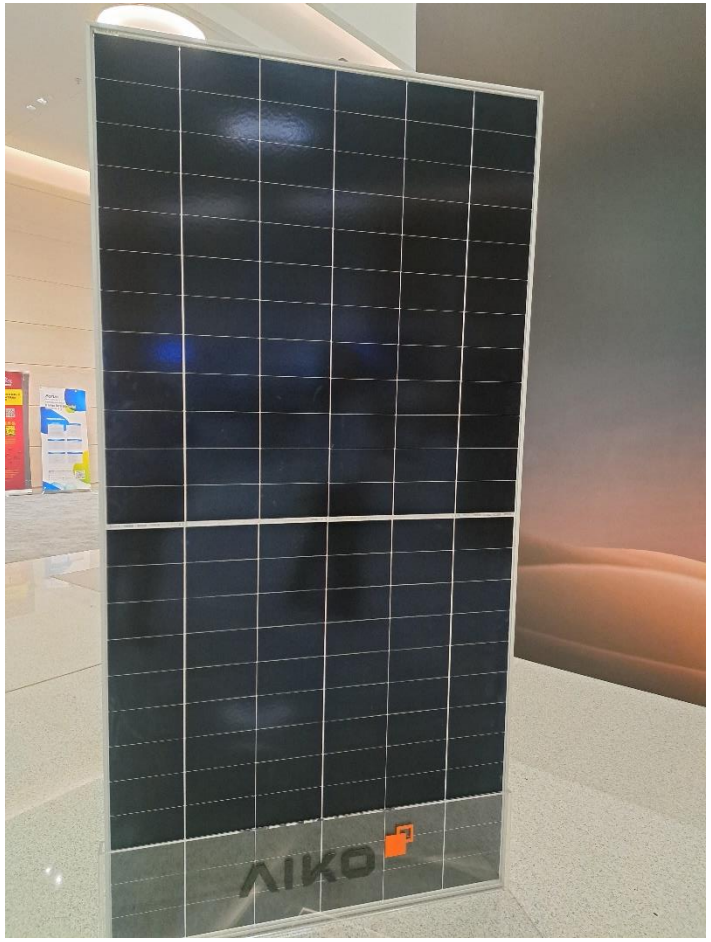


goal > 740mV

	ZEBRA	poly ZEBRA	
1	wetbench	wetbench	1
		SiO2+a-Si(n)	2
2	B-diff	SiNx	3
3	wetbench	Laser (abl)	4
		wetbench	5
		SiO2+a-Si(i)	6
4	SiNx	B-diff	7
5	Laser (abl)	wetbench	8
		Laser (SE)	9
6	wetbench	TEX	10
7	P-diff	B-diff	11
8	wetbench	wetbench	12
9	SiNx front	AlOx+SiNx front	13
10	SiNx rear	AlOx+SiNx rear	14
11	SP + FF	SP + FF	15
12	IV+sorting	IV+sorting	16

Linke et al. Fully Passivating Contact IBC Solar Cells Using Laser Processing. WCPEC 2022

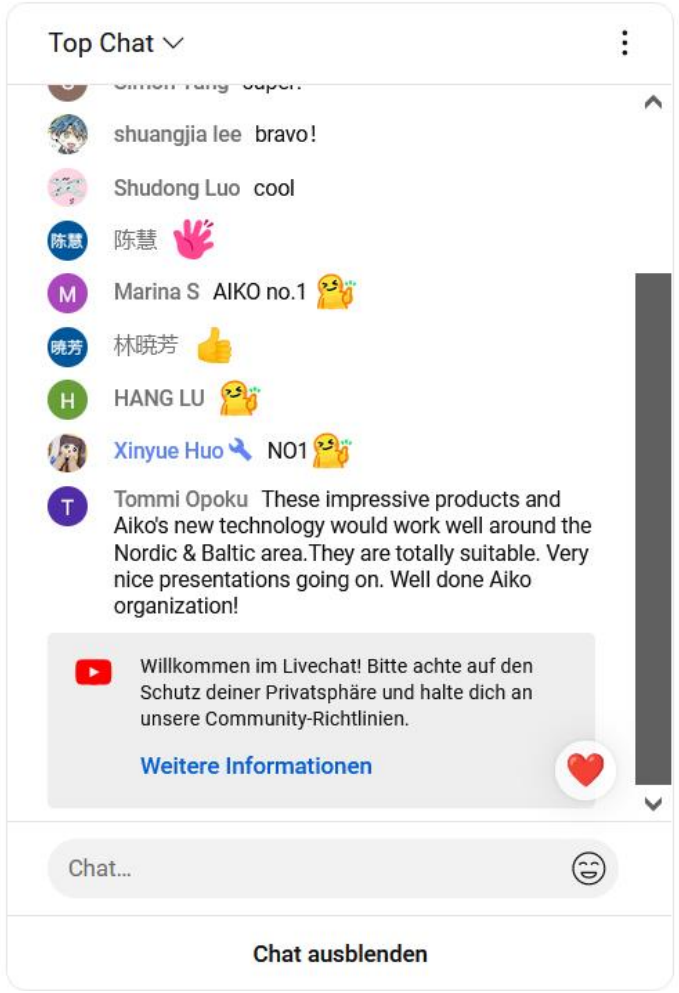
Bifacial XBC



Bifacial ABC: https://www.youtube.com/live/DHyMOQC0fUg?si=GJULGBhQgCC7YCbF

AIKO ABC Bi-Facial Module Launch Ceremony

Aiko Energy
109 Abonnenten
Abonnieren
18
Teilen
Speichern



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'

Facebook Twitter LinkedIn Reddit Email

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

Solarserver Das Internetporta

STROM WÄRME MOBILITÄT THEMEN Termine Branchenverzei

Solarinstitut ISC Konstanz unterzeichnet Lizenzvertrag mit Futurasun

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

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).

3. BCworkshop 2023

BCworkshop 2023 in Hameln

BCworkshop 2023 in Hameln

- XBC community getting bigger
- Still too many concepts out there
- XBC will come on 2 digit GW scale
- First rooftop market and XIPV
- From 2028 utility scale market
- There are cases already now where utility scale makes sense

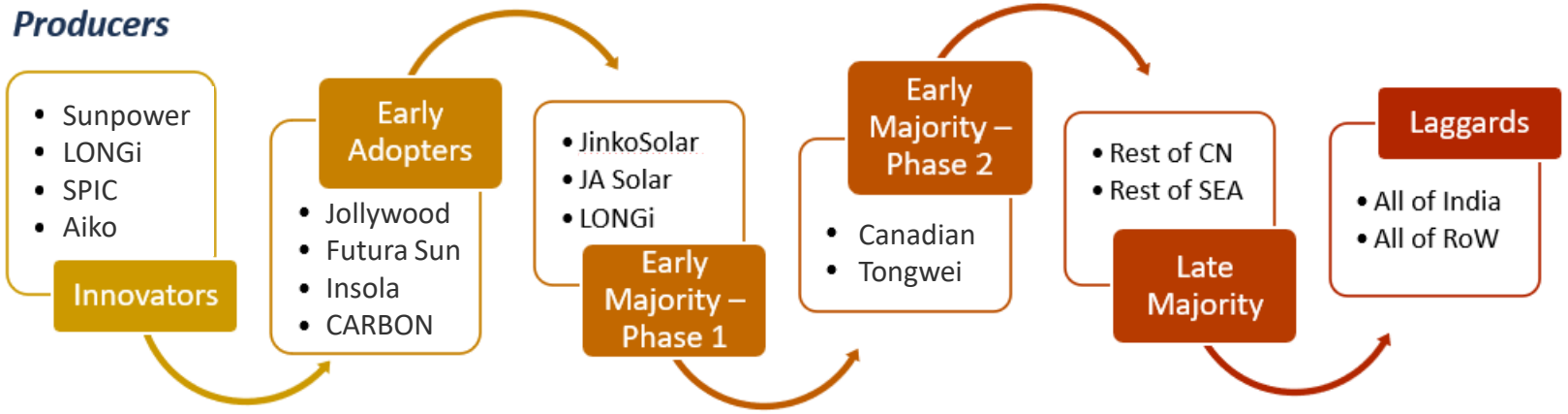
PV companies going nPV

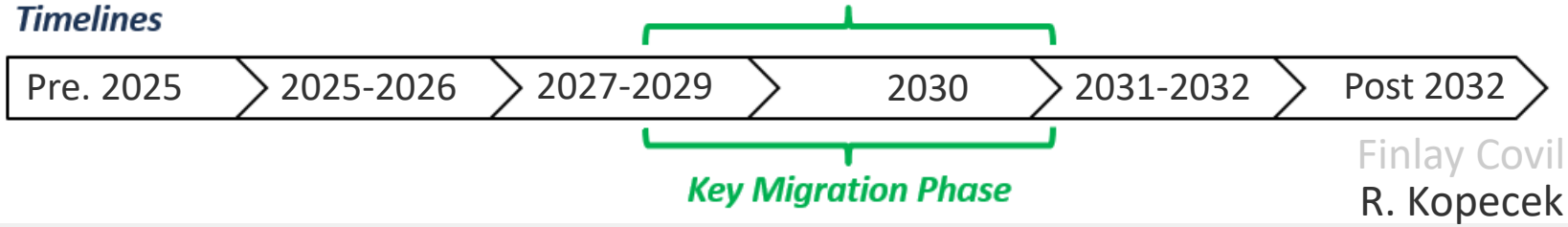
TOPCon/HJT >> 2TT/4TT	XBC >> 3TT/4TT
Qcells	LONGi
Jinko	AIKO
TRINA	SPIC
	Sunpower
	Gold Stone
	Futura Sun
many more	**few more**
	ValoCell

ISC Konstanz Research

How XBC migration could work

isc research for a sunny future

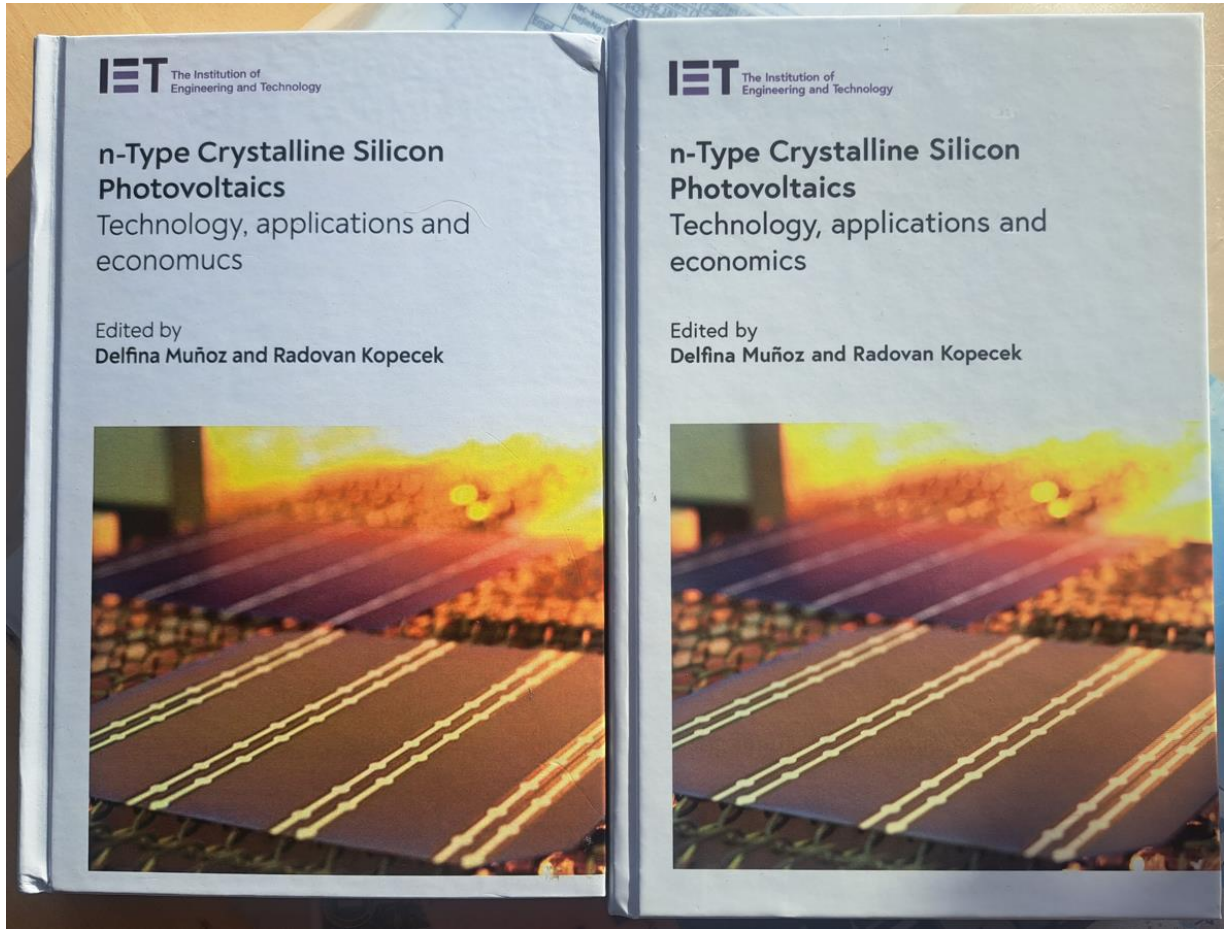




Finlay Coville (PV Cell Tech 2023)
R. Kopecek (this presentation)

Summary

- PV is entering bifacial nPV era
- nPV book is being copied ☺
- **TOPCon is the next mainstream**
- HJT, XBC take rooftop first
- **XBC will be the coming mainstream**
- LET´S GO TOWARDS TW PV ERA!!!



Upcoming bifiPV workshops 2024 and 2025

Upcoming bifiPV workshops 2024 and 2025

Upcoming bifiPV workshops 2024 and 2025

Cu screen printed bifacial XBC for utility scale

ISC research for a sunny future

Thank you for listening

More information: www.isc-konstanz.de