Photovoltaic

Services & Technology

Solutions Partner

GW IBC-Production: Integration, Technology and Cost

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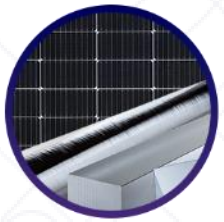
Konstanz, Germany

Agenda

- Integration
- Technology selection
- Cost analysis
- Conclusion

About **RCT Group at a Glance**

Owners & Basic Engineering



Full Value Chain

Conceptual & Basic Design

Feasibility Studies

Training Academy

2012
Founded, privately owned

30 GW
Installation, Owner's engineering worldwide

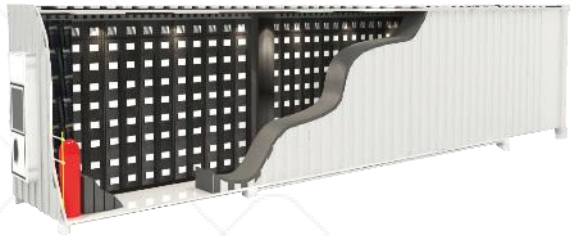
World's First
Fully integrated 1.2 GW Factory installation

20 GW
Pipeline outside of China

12 GW
Active projects in India

5x GW Scale
Factory Project Integrator

RCT Power Residential Batteries



RCT Power Utility Battery Storages

RCT Power Inverters

2015
Founded, privately owned

11.4kWh
Modular concept development

Mass Production
Residential & battery pack for container solutions

>3GWh
Total shipment

Best Storage
Awarded in Germany

EU&USA Based
Battery production & Operation

pv magazine SPOTLIGHT 2020

ENERGY STORAGE Inspection 2021

A new era on

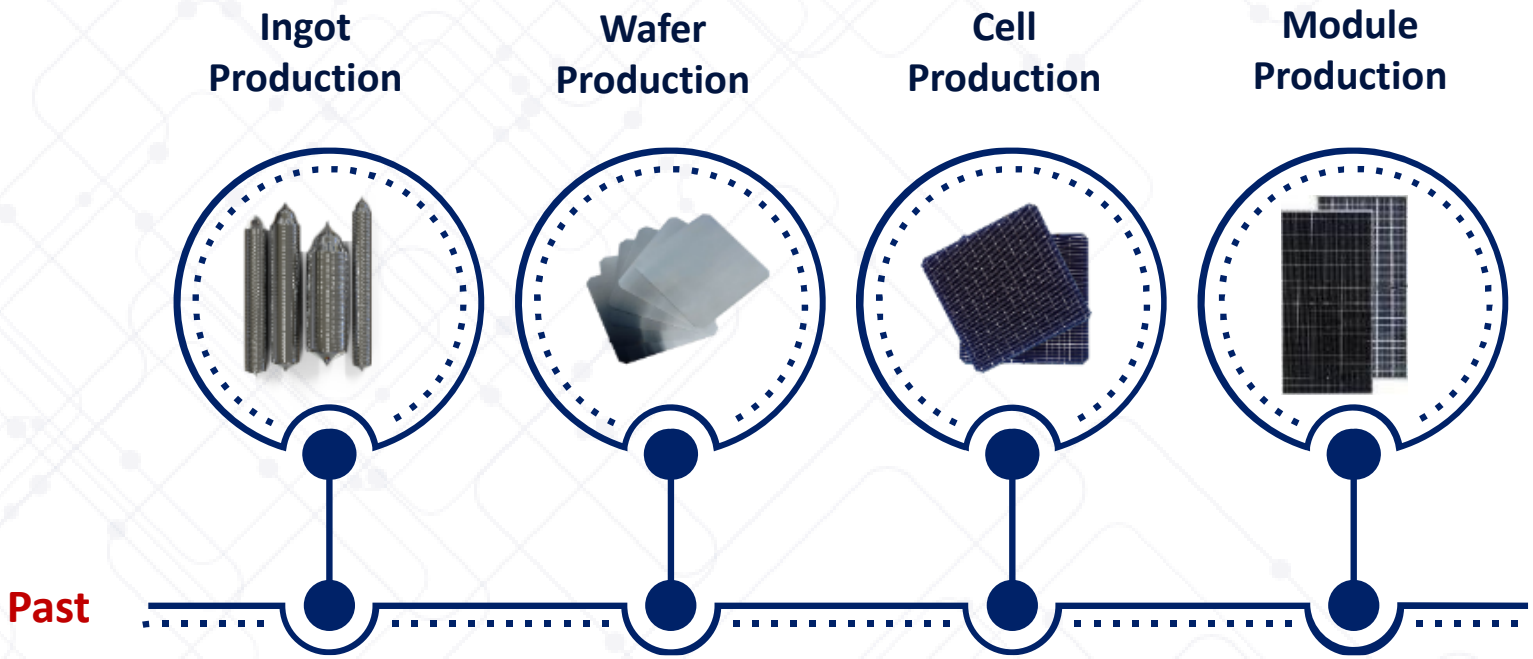
global manufacturing

RCT solutions

Integration: 2.0
Vertical integration into Giga scale PV production

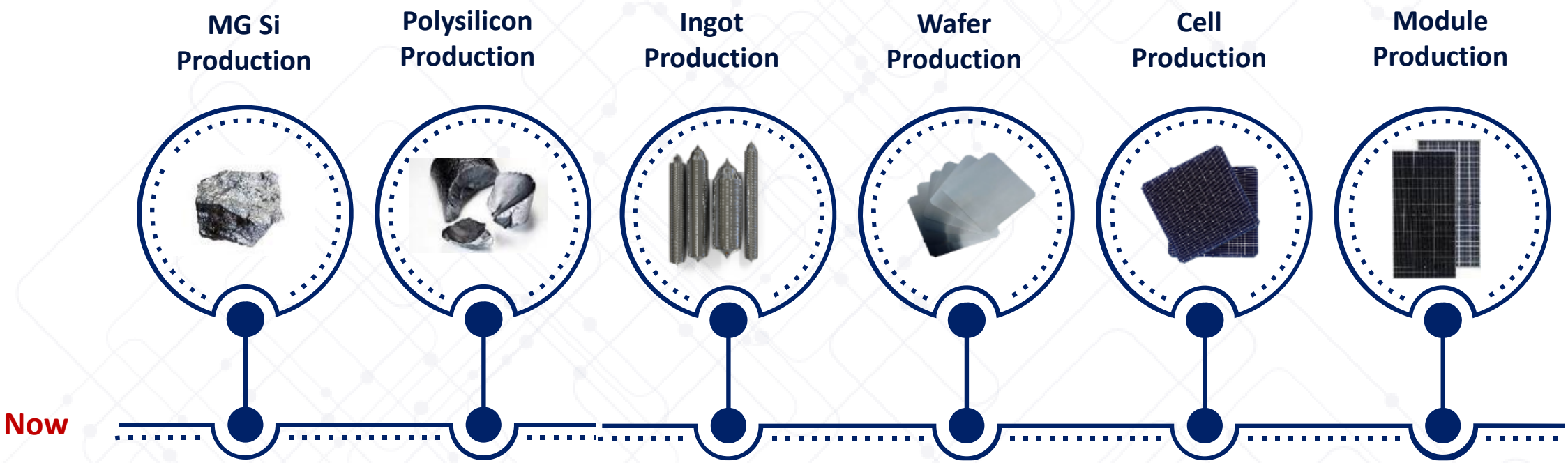
Industry moved forward and we are able to see more and more of integrated ingot, wafer, cell and module production.

Should we stop here?

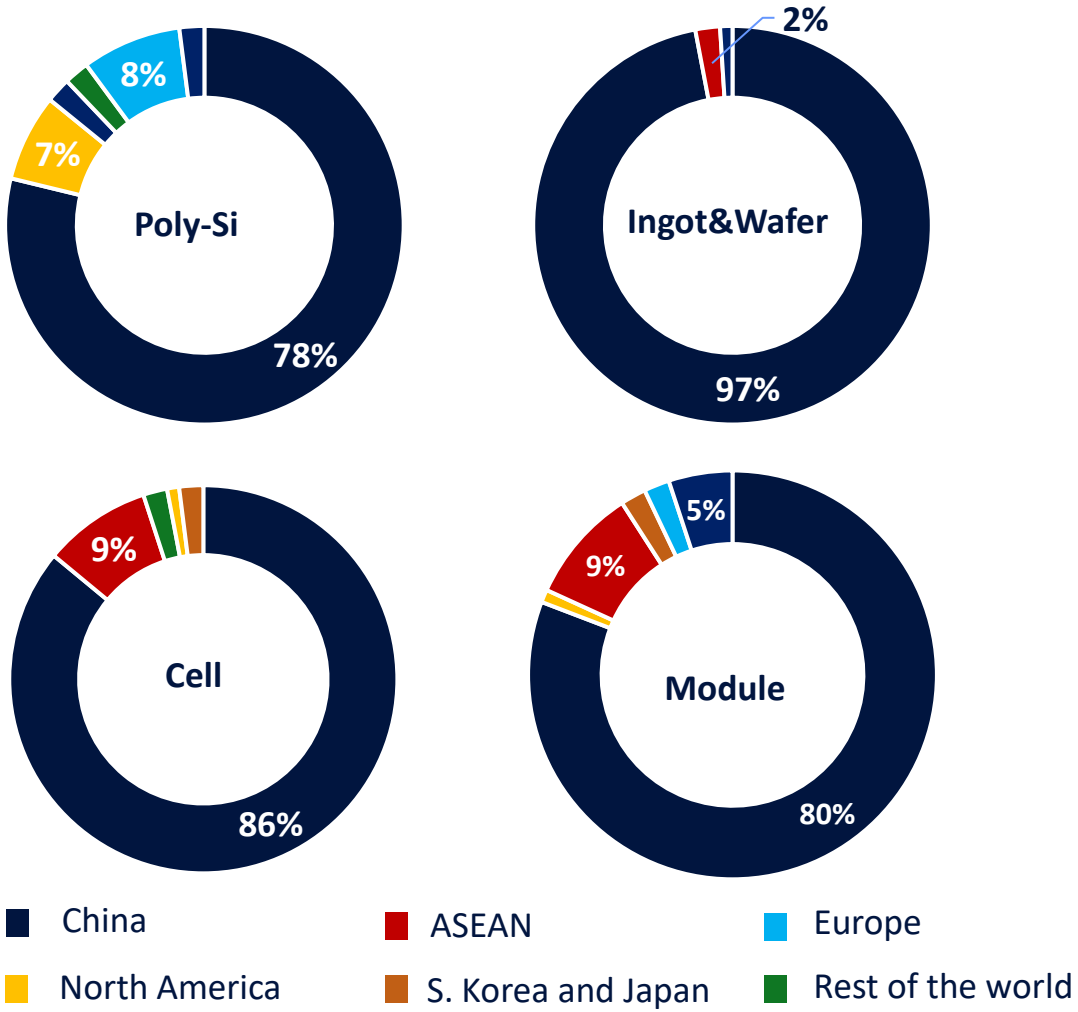


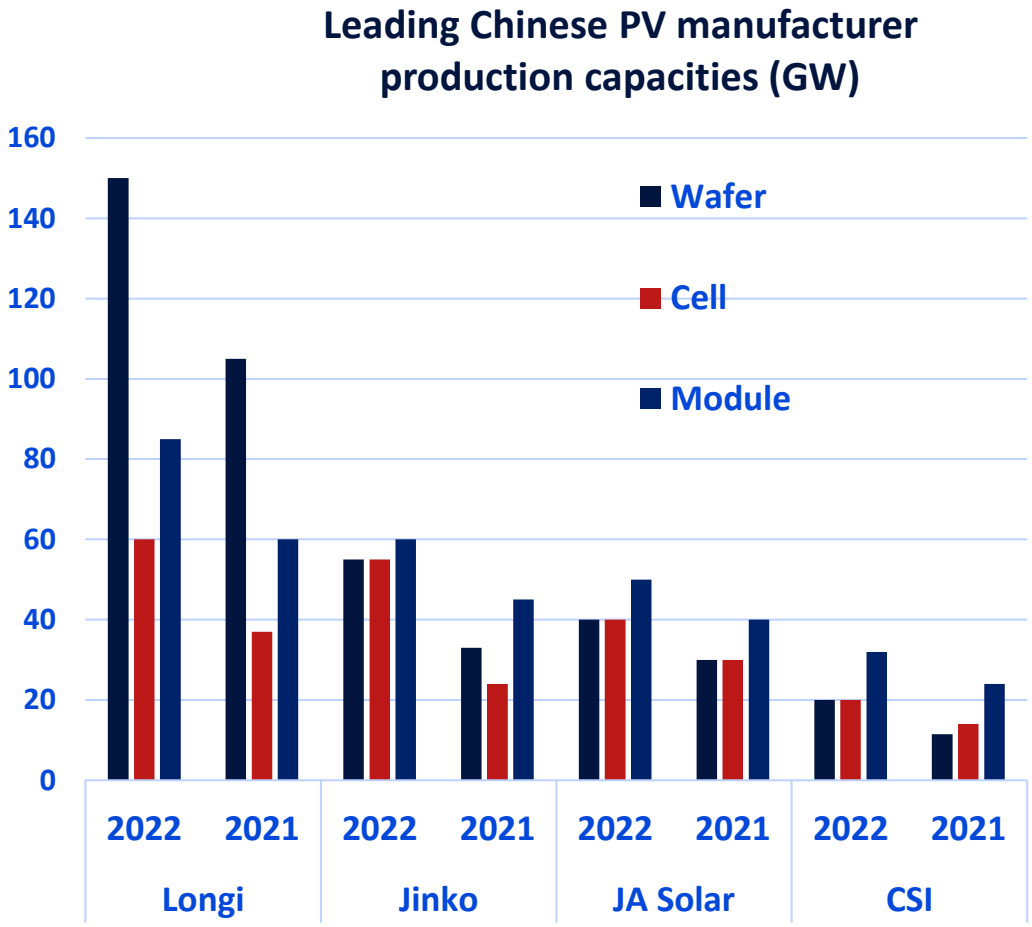
Introducing Integration: 3.0

Vertical full integration into Giga scale PV production



Production locations - Status





Benefits of Integrated Production

long term predictable production costs

Quality Assurance

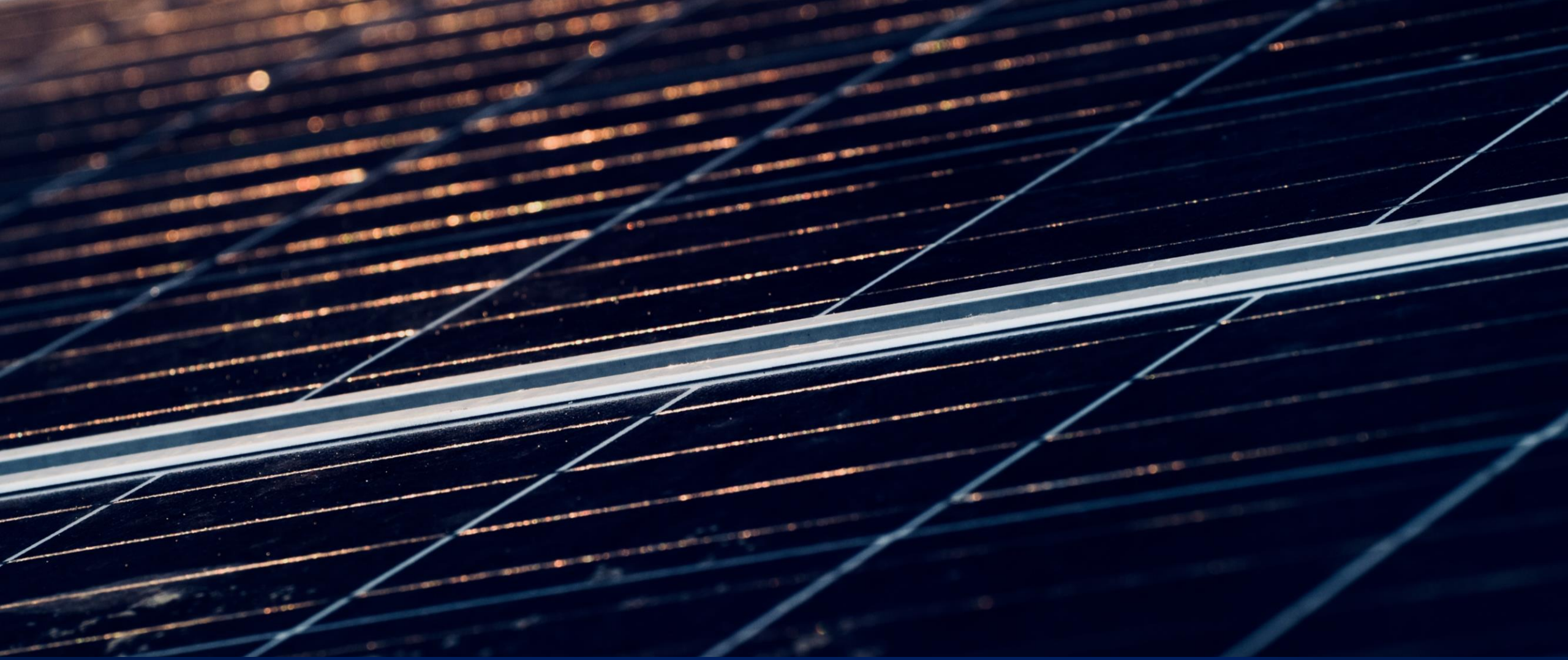
Packaging & shipping

Product Optimization

Process Optimisation

Cost Reduction (OPEX)

Recycling



Technology selection

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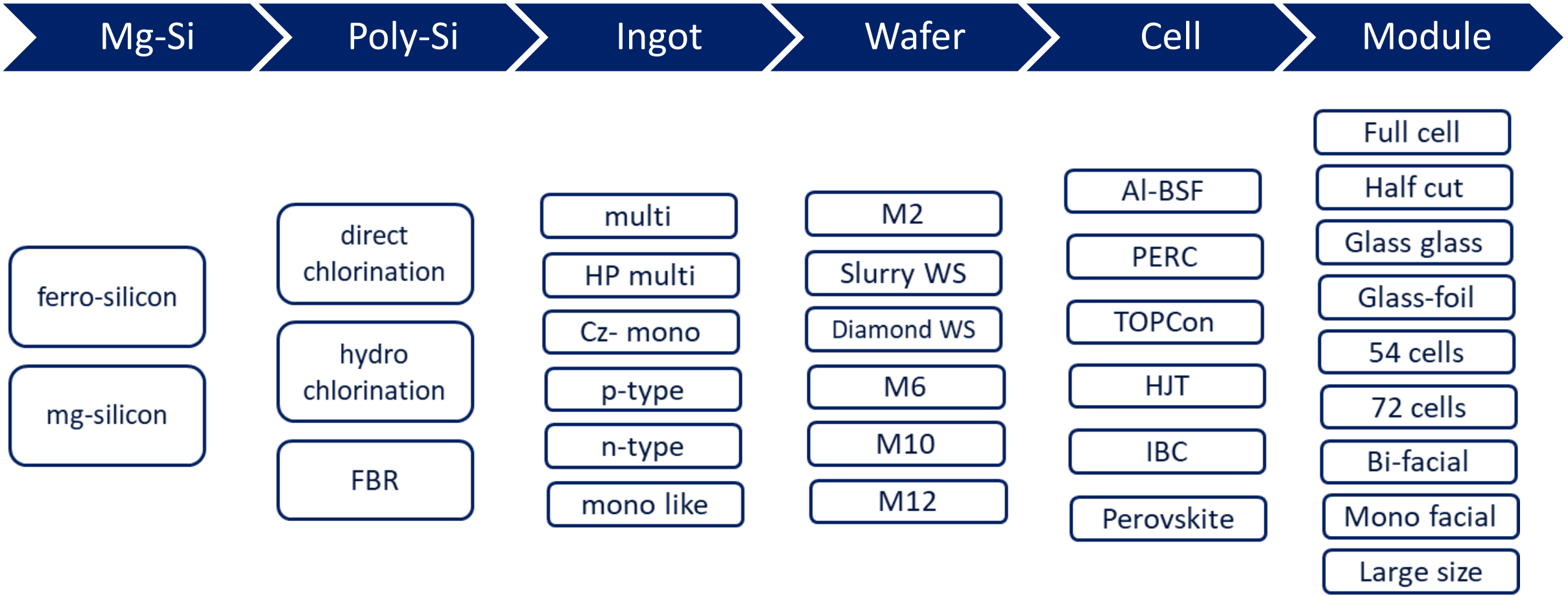
Technology options



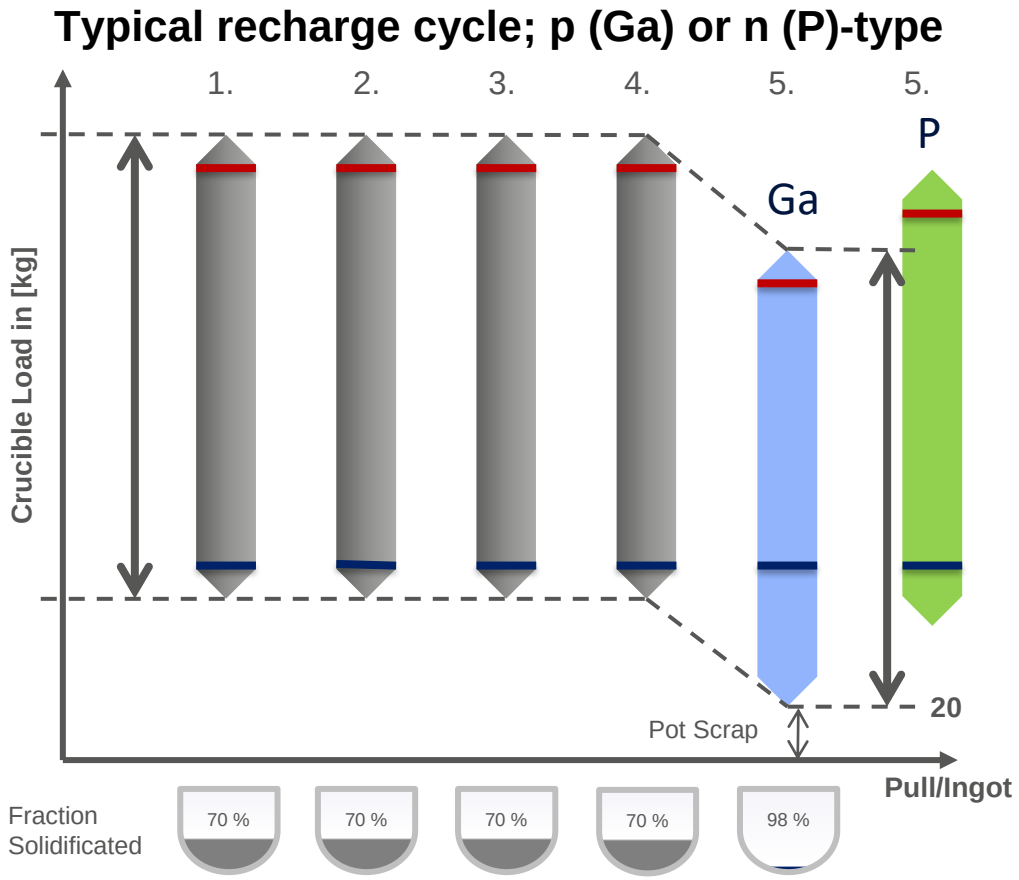
How to select the right technology for your PV factory?

1. What are your target markets?
2. Required product portfolio: utility, C&I or residential market
3. Factory size
4. Time to market expectation
5. Investor profile: low risk versus higher risk but front runner
6. Upgradeability – is important when a technology is at the end of its cycle
7. Access to technology and engineering staff
8. Availablity of equipment, material supply chain and technology provider (for new entrant)

Various technologies are available!

Select the right technology from the bunch of choices and move forward

Ingot & Wafer Manufacturing – p- vs n-type



Difference in segregation coefficient leads to different qualifying ratio

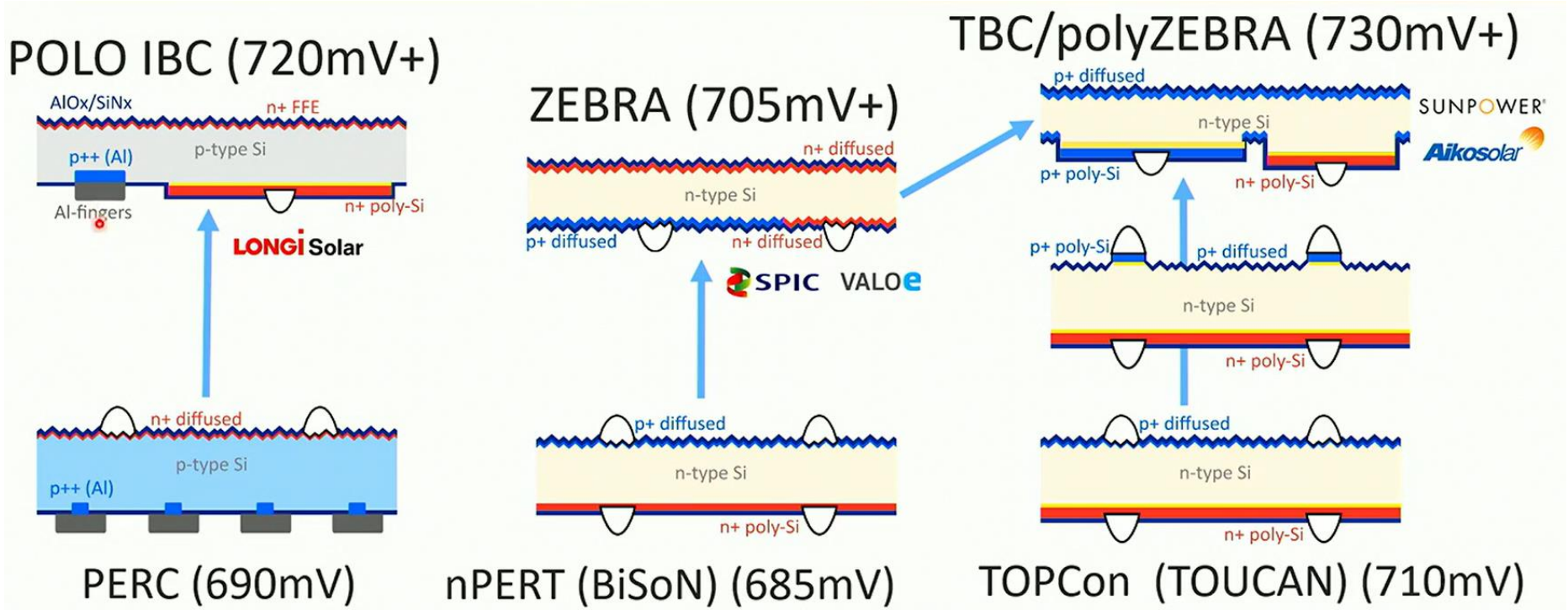
Key cost contributors

1. Wafer specification (qualifying ratio: lower for Ga)
    1. Lifetime MCLT
    2. Base doping range
    3. Impurity concentration
2. Wafer thickness
3. High lifetime requires good poly-Si quality (virgin and recycled)

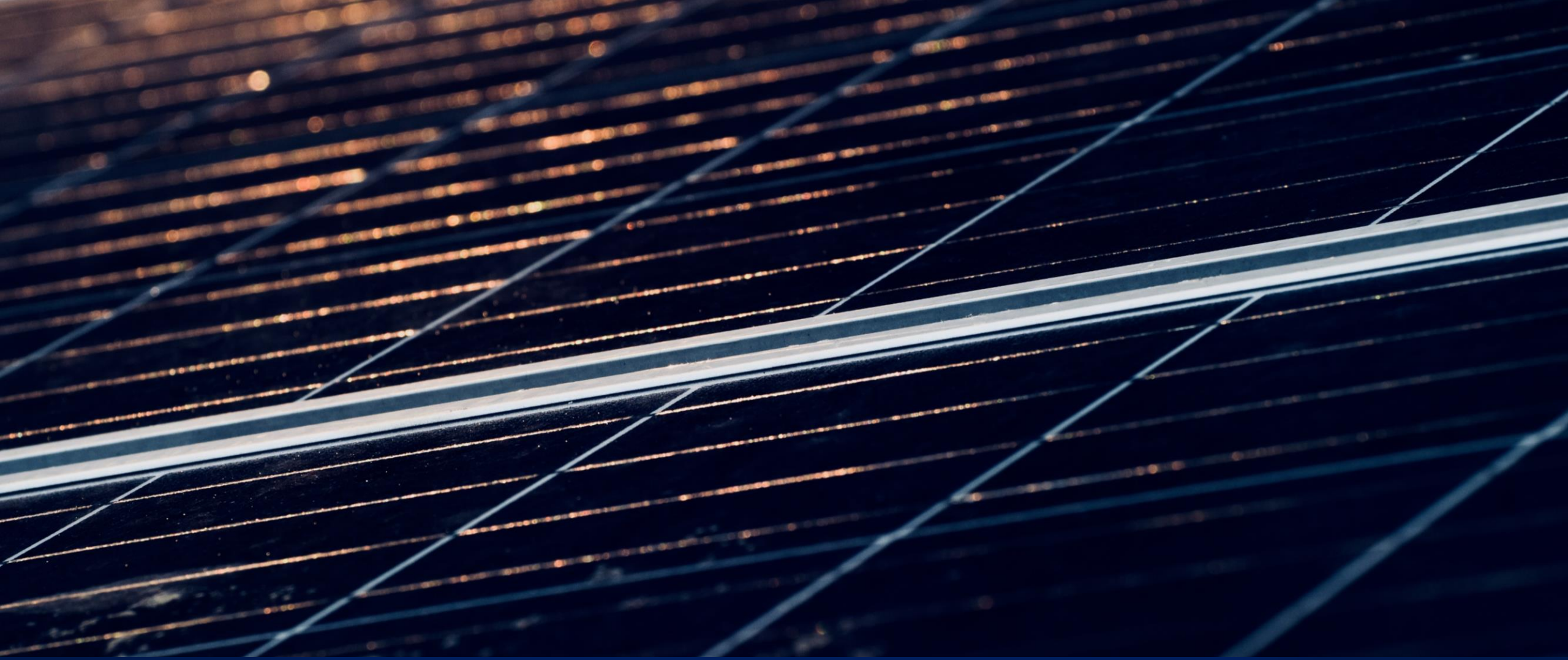
Cell design allowing thin wafer is advantageous to lower wafer cost

IBC Solar Cells

Unlike other solar cells (PERC, TOPCon), various device designs are available with different process flows and complexities



Source: R. Kopecek, WCPEC 2022



Comparison of true costs and different cell technologies

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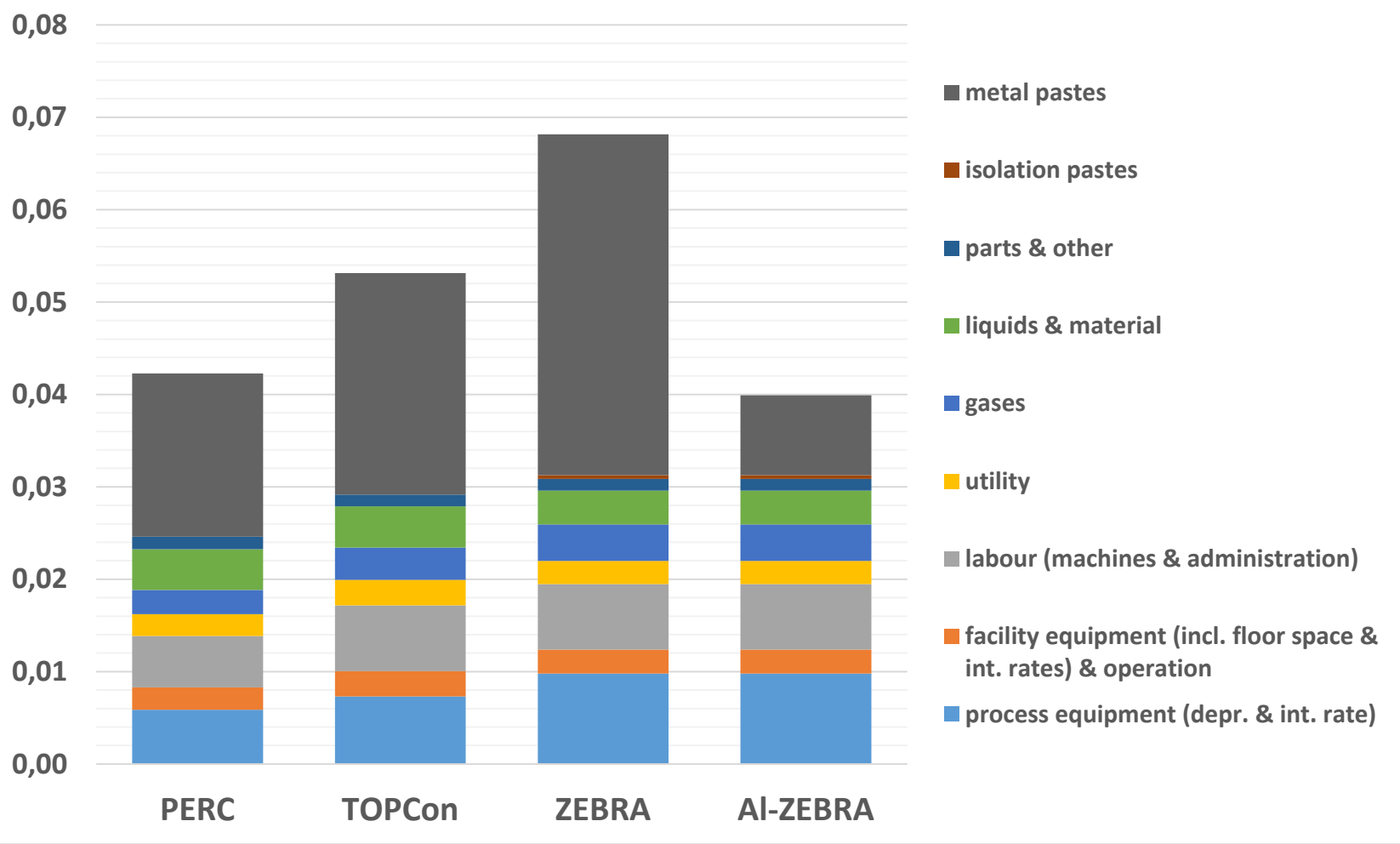
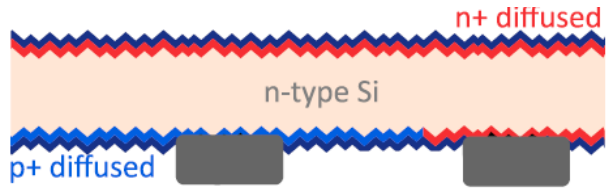
Solar cell – Step costs for different solar cell designs



Al-ZEBRA cell design



700mV+ only Ag dots

- TCO provided by ISC Konstanz, as part of a joint funded project „FlexFab2“
- Manufacturing location: Europe (high)
- Al-ZEBRA at same level as PERC

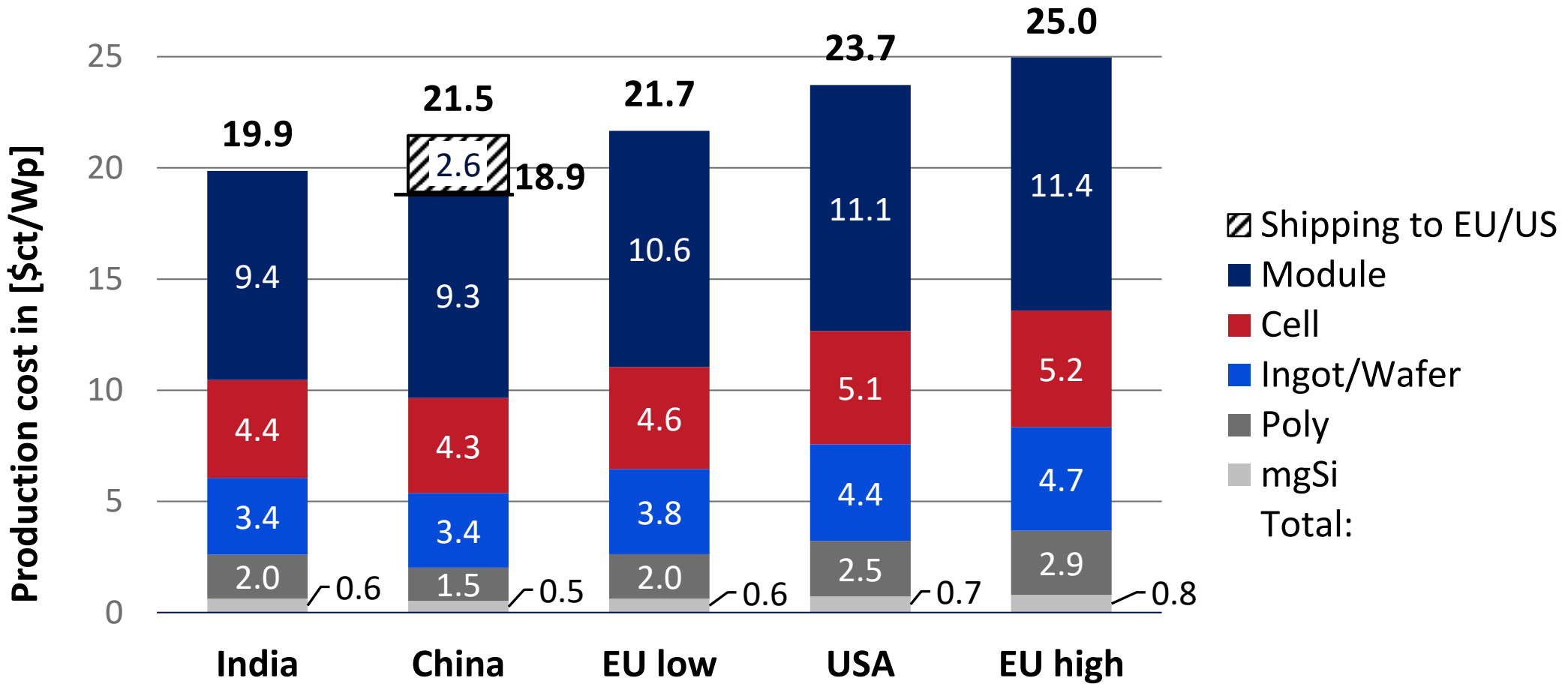
Technology options and selected technology for following TCO modelling

Mg-Si	Poly-Si	Ingot	Wafer	Cell	Module
ferro-silicon	direct chlorination	multi	M2	Al-BSF	Full cell
mg-silicon	**hydro chlorination**	HP multi	Slurry WS	PERC	**Half cut**
	FBR	**Cz- mono**	**Diamond WS**	**TOPCon**	**Glass glass**
		p-type	M6	IBC	Glass-foil
		n-type	**M10**	HJT	54 cells
		mono like	M12	Perovskite	**72 cells**
					Bi-facial
					Mono facial
					Large size

Selected path for TOPCon

The real costs of PV manufacturing for different locations

Factory wise (for TOPCon, similar for Al ZEBRA)

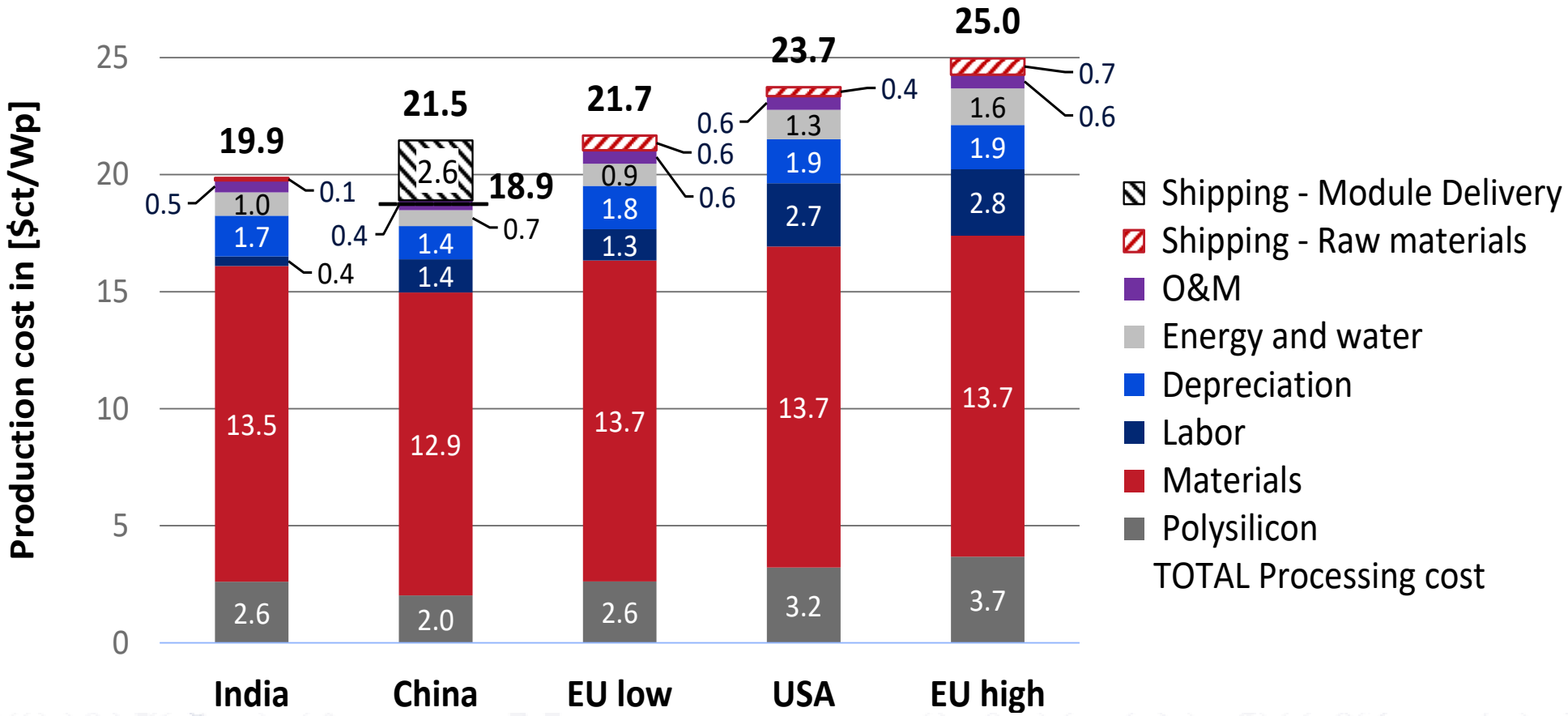


Differences in real costs between various economic regions are between 10 to 15%.

Pricing based on US cents

The real costs of PV manufacturing for different locations

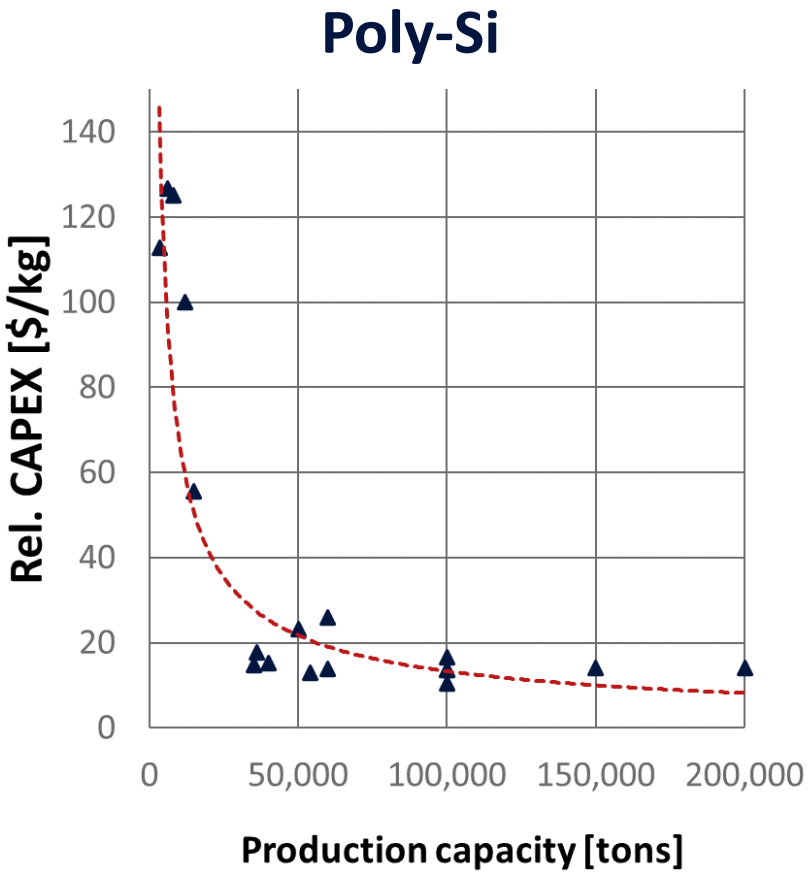
Component wise (only ingot to wafer, for TOPCon, similar for Al ZEBRA)



Major cost differences from electricity, labor and CAPEX.

Pricing based on US cents

Optimum factory sizing



	mgSi (tons/y)	Polysilicon (tons/y)	Ingot/Wafer (MW/y)	Solar Cell (MW/y)	Solar Module (MW/y)
Downstream oriented scenario	18,000	15,000	5,000	5,000	5,000
Full integration scenario: high CAP	48,000	40,000	13,200	13,200	13,200
Selling Poly, module	72,000	60,000	5,000	5,000	5,000
Selling Poly-Si, wafer, module	72,000	60,000	10,000	5,000	5,000

Legend (Plant size): Excellent Medium suitable Non appropriate

- CAPEX per unit decreases with capacity, especially for upstream manufacturing.
- Lowest dependency for module manufacturing

- Finally selected sizes will depend on investor‘s preferences and financial capability (markets, products to be sold, achievable margins along value chain, etc.)

Governmental support around the globe
Different policies, one major objective in common

REPowerEU
20 GW
Production in EU untill 2025

1 TW
By the end of 2030

€210 billion
By 2027

40% to 45%
Increase in renewable energy targets

33% to 67%
Doubling the production capacity of renewables

IRA
50 GW
Production capacity

$30 Billion
Investment in production

$2 Billion
National Labs / R&D

100%
Manufacturing credit for solar supply chain

100%
Clean Energy by 2035

New Energy
450 GW
Solar's share

$63 Billion
Government fund

20%
China's market share increase

71%
Amount of subsidies for all sectors

YEKA (1)
1+1 GW
Installed power on a single site

$1 Billion
Investment

20%
Increase of renewable share

20 Million m²
Dessert Area

Superincentives
Energy, labor, tax, customs

PLI
45 GW
Capacity

$3.2 Billion
Investment Combined

55 GW
Modules

250 GW
In 5 years

90%
Local production

Common goal

Integrated manufacturing

Conclusion

- Local manufacturing is required to accomplish TW manufacturing by 2030. Various countries are initiating support mechanisms to kick-start.
- Integrated manufacturing is a must, offering key advantages:
  - Supply chain independency and reliable module supply
  - Lowest cost
- Cost analysis for Al-ZEBRA shows lower TCO compared to PERC and TOPCon => high potential
- Integrated manufacturing can be realised in any economic region, requiring
  - > 5 GW manufacturing capacity
  - Availability of competitive electricity, local supply chain, qualified labour
- Differences in “true costs” for different economic regions are less than 15%, and differences in “published” can be a consequence of different support schemes
- Manufacturing needs to run on CO_2-neutral energy, be socially responsible and include green manufacturing

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Thank you