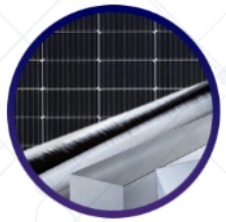

RCT
solutions
One Stop
Photovoltaics
Solutions Partner
Is IBC a good choice
for new cell fabs?
WE ARE HIRING
JOIN RCT TEAM
OPEN VACANCIES
rct-solutions.com/careers
29.11.2023
Hameln, Germany
11th BC Workshop

About RCT Group at a glance

RCT solutions

Owners & Basic Engineering

Installation & Commissioning



Value Chain Consultancy

Conceptual & Basic Design

Feasibility Studies

Training Academy

2012
Founded, privately owned

72 GW
Installation, Owner's engineering worldwide

World's First
Fully integrated 2.2 GW Factory installation

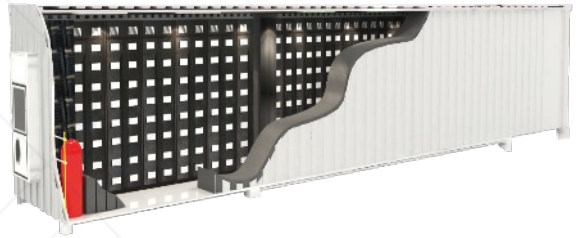
94 GW
Total manufacuring served

24GW / 5 projects
Active projects in North America (USA/Canada)

76 GW
Ingot & Wafer integration

RCT power

RCT Power Residential Batteries



RCT Power Utility Battery Storages

RCT Power inverters

2015
Founded, privately owned

20GWh
production capacity, fully automised

Fully EES manufacturing
Residential, commercial, utility scale (from KWh to MWh)

>10GWh (6GWh USA)
Total shipment

Best Storage
Awarded in Germany

EU&China&USA Based
Battery production & Operation

Speech today
Is IBC a good choice for new cell fabs?

- **Moving forward with frontier technologies**

Solar cell technology roadmaps for the next years to come

- **Comprehensive study of silicon solar cell technologies across the globe**

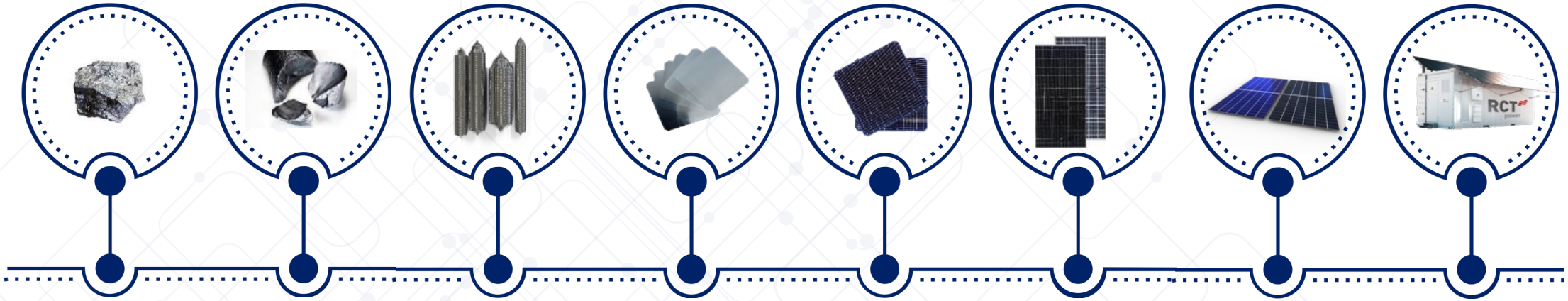
Comperssion of different locations with different cell Technologies, CoO and LCOE differences.

- **Conclution**

Is IBC a good choice for new cell fabs?

Short answer: Yes!!

Integration: 3.0
Vertical & Horizontal full integration into Giga scale PV



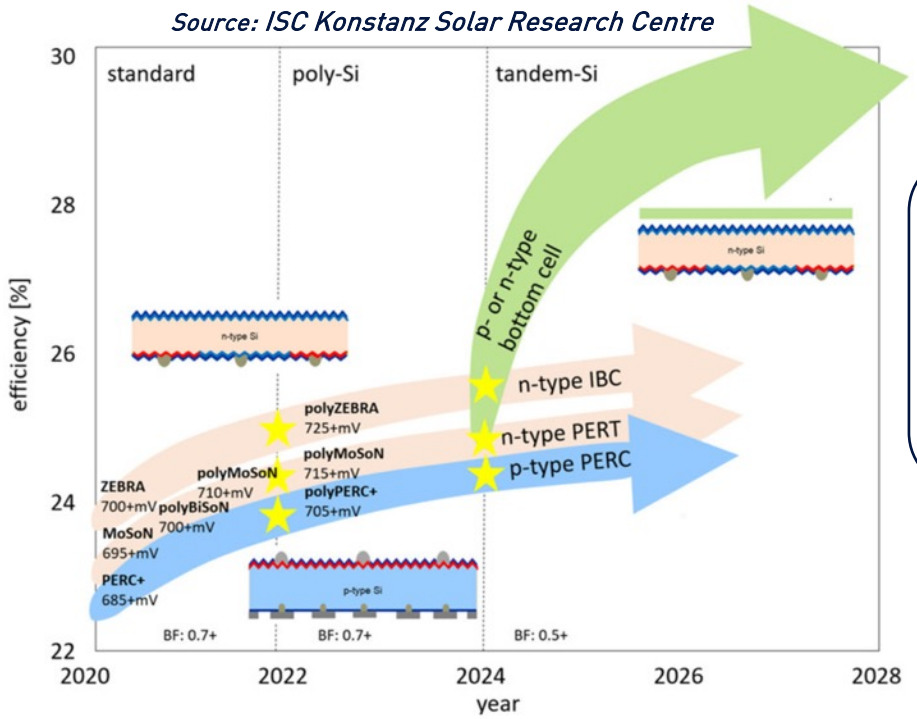
MG Si Production	Polysilicon Production	Ingot Production	Wafer Production	Cell Production	Module Production	SPP Construction	GESS Storage
• Quartz • Prebaked electrode • Coal	• Graphite chuck • Gases (HCl, N_2, H_2, Cl_2)	• Hot zone • Crucible • Ar	• Diamond wire	• Ag paste • Screens • Chemicals • Gases	• Glass • Encapsulation material • Al frames • Junction box& ribbons etc		

Combined regions manufacturing and installations?

Cost of Ownership analysis (CoO) | LCOE

Expected technology roadmap

Source: ISC Konstanz Solar Research Centre



PERT	xBC
HJT	PERC
Tandem	Perovskite
TOPCon	IBC

Economic analysis required!

Technologies

Locations

2. CoO

3. LCOE

Summary

KPI's of Different Cell Technologies for Energy Yield

Technology	PERC SE	TOPCon SE	HJT	TBC / IBC
Wafer Size	G12 (440.96 cm^2)	M10 (330.15cm^2)	G12 half-cut (220.48 cm^2)	M10 (330.15cm^2)
Cell Efficiency	23.2%	24.5%	25.0%	25.5%
P_{mpp} Temperature Coefficient	-0.34 %/°C	-0.29 %/°C	-0.26 %/°C	-0.27 %/°C
Bifaciality +-5%	70%	80%	90%	60%
First Year Degradation	2%	1%	1%	1%
Second Year Ongoing Degradation	0.45%	0.40%	0.40%	0.40%
Comments	• No significant difference in low light intensities expected • Second year ongoing degradation mostly dependent on module packaging • Only PERC affected by LID			

Technology roadmap throughout the value chain
with different cell technologies

Ferro-silicon

mg-silicon

Direct chlorination

hydro chlorination

FBR

Siemens

Multi

HP multi

Cz- mono

Mono-like

p-type (B)

p-type (Ga)

n-type (P)

Slurry WS

Diamond WS

M6

M10

M10L

G12R

G12

150 µm

130 µm

110 µm

Al-BSF

PERC

TOPCon

IBC

HJT

TBC

Perovskite

Full cell

Half cut

Glass glass

Glass-Backsheet

54/108 cells

72/144 cells

78/156 cells

60/120 cells

66/132 cells

Bi-facial

Mono facial

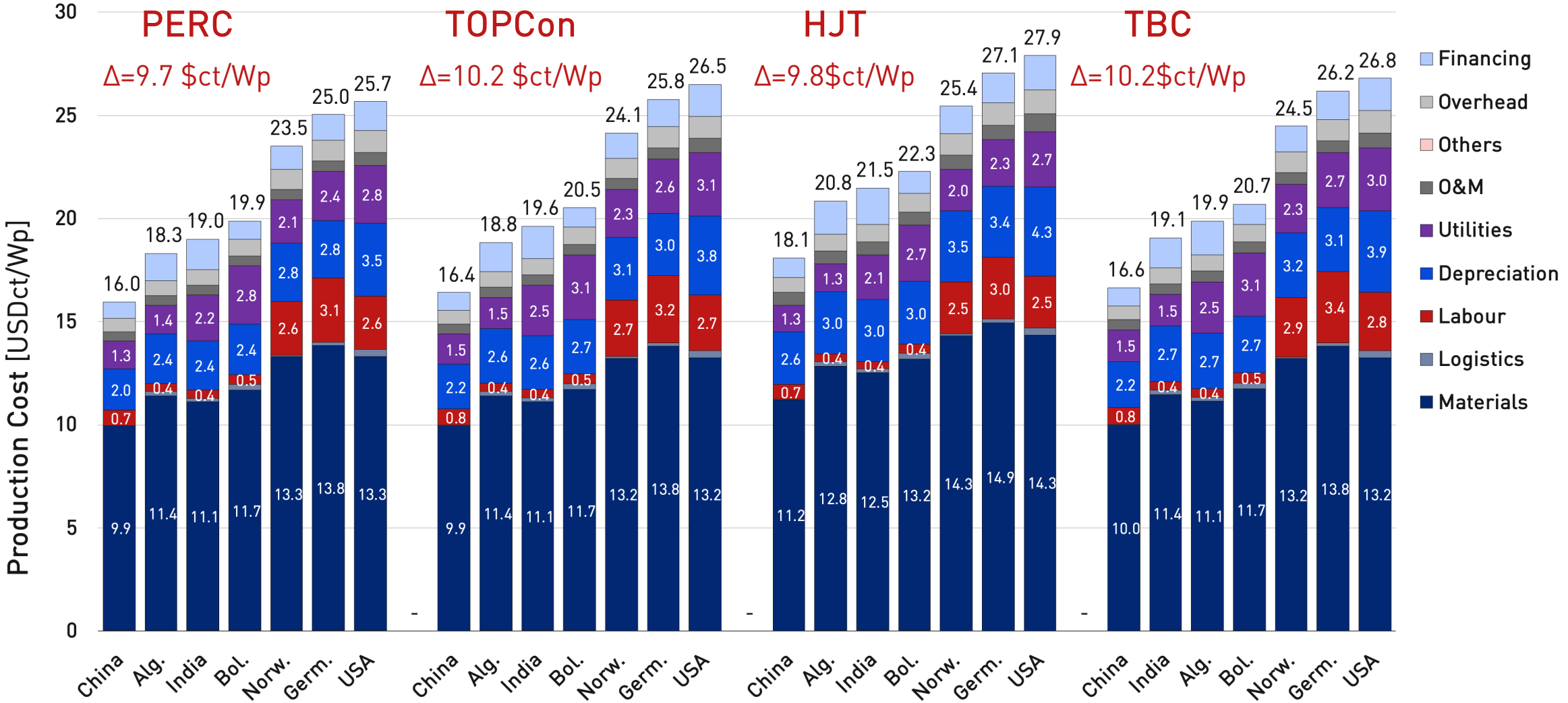
PERC Route

TOPCon Route

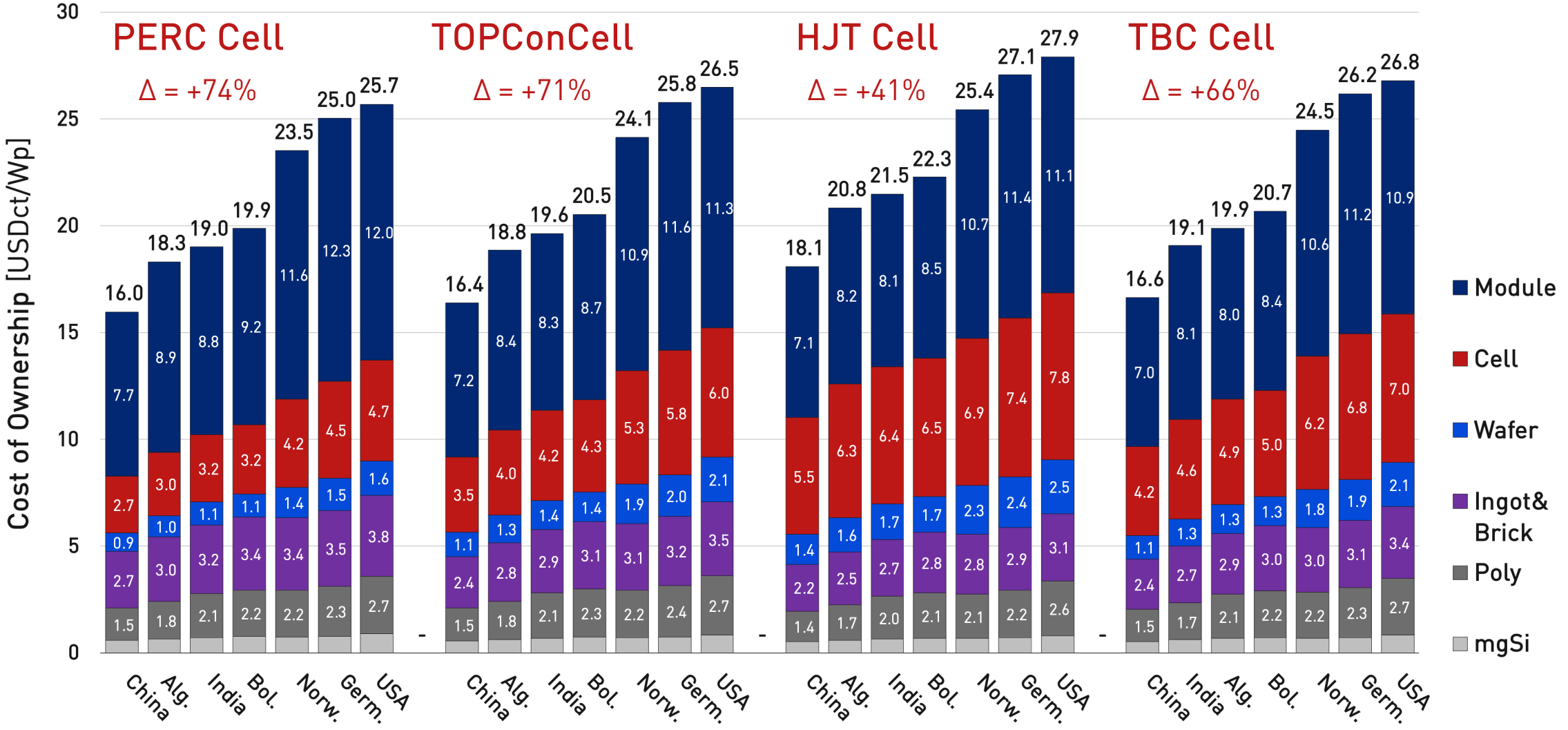
HJT Route

TBC/IBC Route

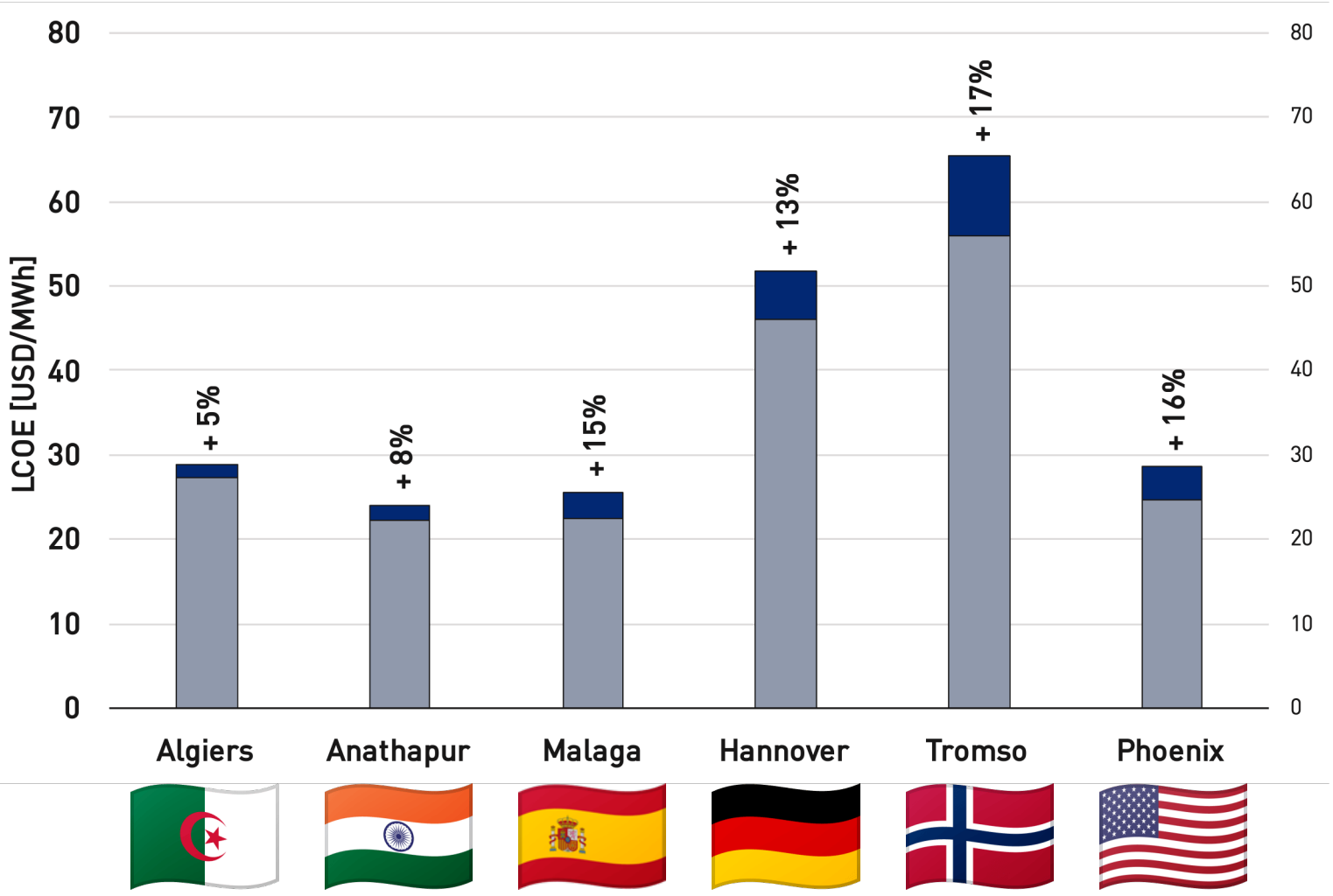
Component Wise COO – 10 GW Factory Breakdown



Location Wise COO – 10 GW Factory Breakdown



LCOE for modules from China vs. locally produced equivalent



- Manufacturing cost differences of ca. 60% reduces to about 15% on LCOE level
- Better financing conditions (e.g. reduction of wacc by about 2% reduces significantly the difference

Levelized Cost of Electricity Impacted by Cell Parameters

I_0: Investment costs

- Module Price
- BOS
  - BOS "power related"
  - BOS "area related" (higher module efficiency benefits)
- Land costs (higher module efficiency benefits)

$$LCOE = \frac{I_0 + \sum_{t=1}^{n} \frac{A_t}{(1+i)^t}}{\sum_{t=1}^{n} \frac{M_{t,el}}{(1+i)^t}}$$

M_{tel}: Energy Yield: produced amount in electricity in kWh

- Prop. GHI (site dependent)
- Thermal loss (Indicated by the temperature coefficient)
- Bifacial gain
- Degradation loss
- Others

At: Annual total cost (O&M)

- Minor for PV power plants (1%)

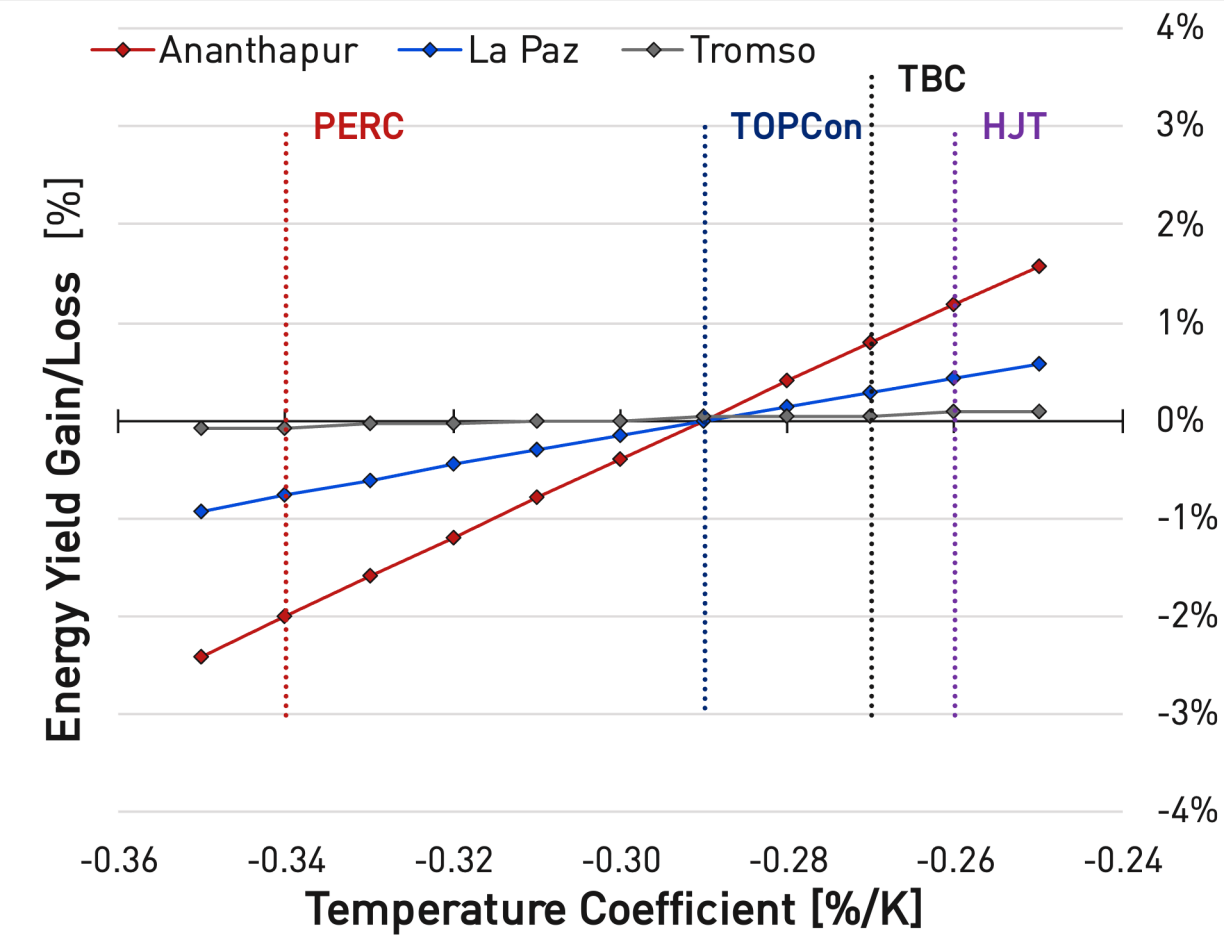
wacc: Weighted average cost of capital

- Taken worldwide with 6% or country dependent

n: Economic lifetime (taken as 25 years)

- Reliable product are required

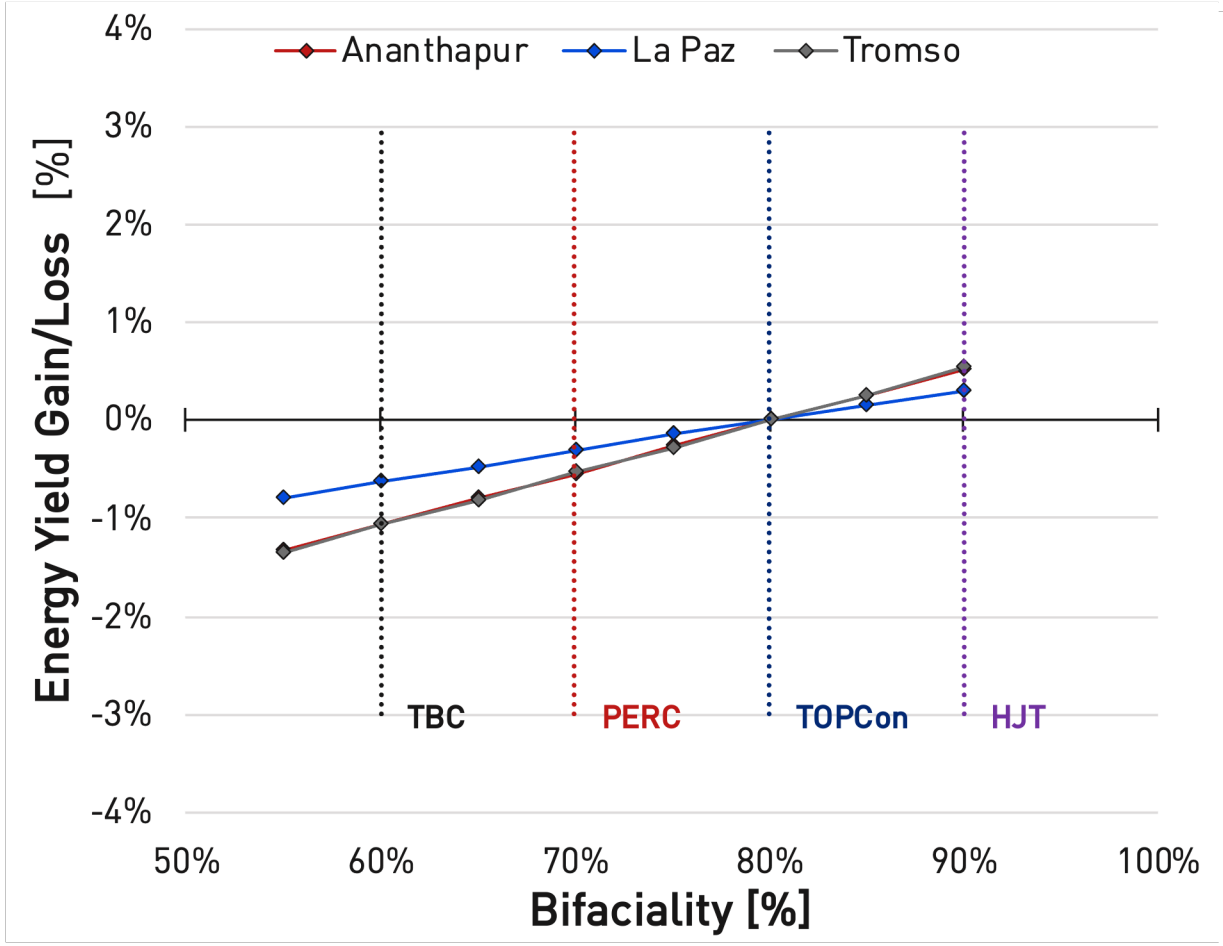
Higher Temperature Coefficient Increases Energy Yield



Simulation by PV-Syst and meteo data of Meteonorm 8.1, NREL, NASA and PVGIS

- Efficiency of PV modules reduces under high operating temperatures, this is indicated by temperature coefficient
- PERC cells have the lowest temp. coefficient, highest losses
- HJT cells have the highest temperature coefficient, lowest losses
- Yield gain between PERC and HJT:
  - 3.0% for Ananthapur, India
  - 1.3% for La Paz in Bolivia
  - Negligible for Tromso, Norway

Higher Bifaciality Factor Increases Energy Yield



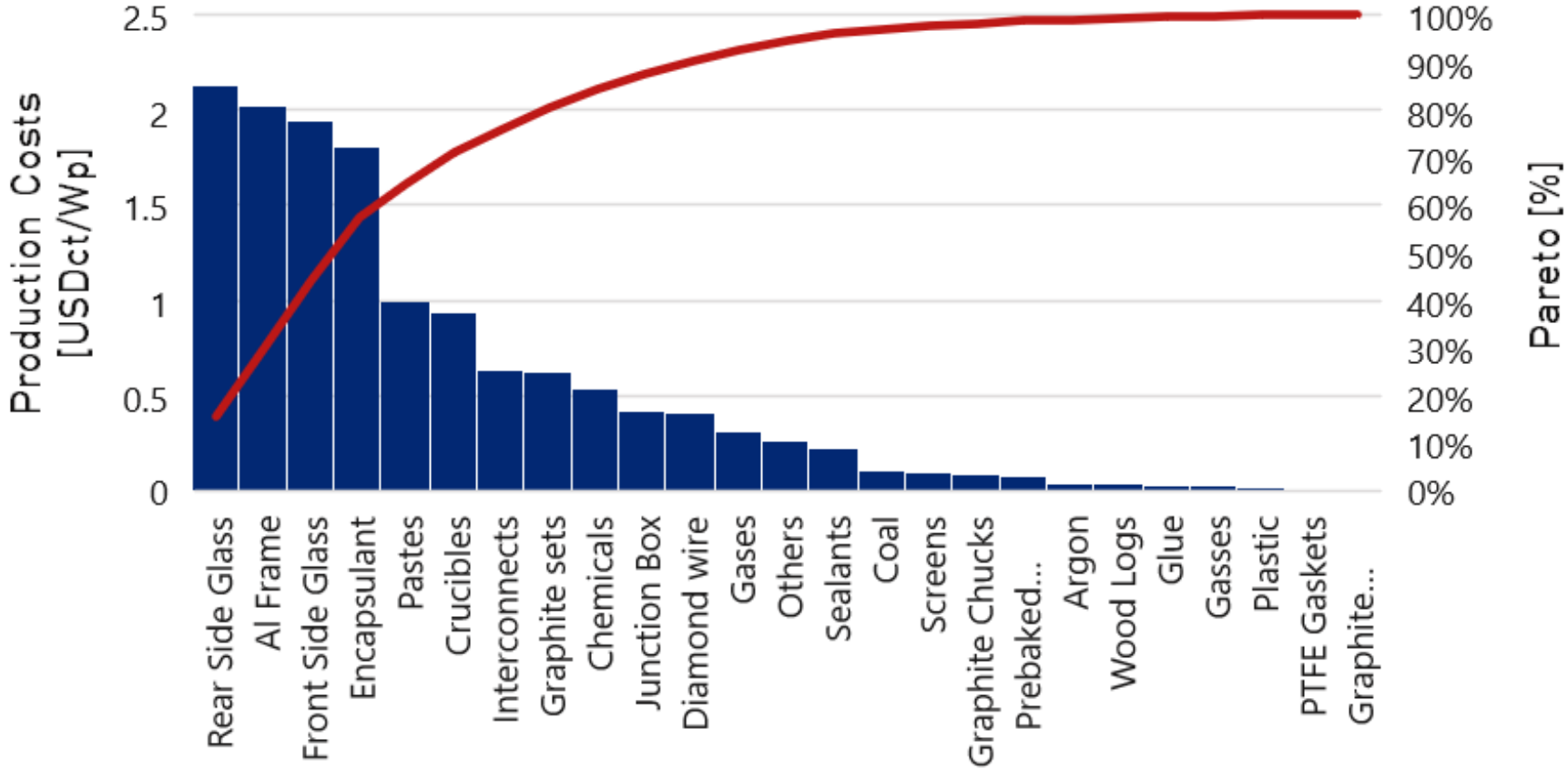
- HJT have the highest bifaciality, whereas TBC cells have the lowest, since both contacts are on rear-side
- Yield gain between PERC and HJT with an Albedo of 20%:
  - 1.9% for Ananthapur and Tromso
  - 1.1% for La Paz in Bolivia
  - Diffused light contribution as root cause

Result temperature coefficient and bifaciality:

- Norway: Bifaciality more important
- Bolivia: Balanced influence
- India: Temp. coefficient more important

Simulation by PV-Syst and meteo data of Meteonorm 8.1, NREL, NASA and PVGIS

Pareto for materials (mgSi to module for TOPCon)



- Local supply chain partly not existing
- Generally, it can be built-up in parallel with production (no roadblocker)

Conclusion

Yes!!

- **10 GW Manufacturing of solar modules at different locations: CoO $\Delta_{avg.}$ = 10ct/Wp (US → China)**

Location differences - material, labor, electricity and wacc

- **10 GW Manufacturing of four different solar cell technologies: CoO $\Delta_{avg.}$ = 10% (PERC → HJT)**

Cell technology differences - Ag consumption and equipment CAPEX

- **Differences in LCOE for 10 MW Project:**

Energy yield – Bifaciality and Temperature coefficient up to 4% gain compared to PERC

n-type solar cell structures, with differences in-between of 2%, show better LCOE than out phasing PERC technology

Low System Cost + High wacc → TOPCon and TBC lowest LCOE (e.g. India and Algeria 3-4% lower)

High System Cost + Low wacc → TBC and HJT lowest LCOE (e.g. Europe and US 3-5% lower)

TBC applicable on both markets

PV enables lowest LCOE at serval location options worldwide to enable clean electricity/hydrogen production

Now, more than ever, we need to start the establishments. TBC is on necessary step for further improvement.

RCT Solutions GmbH
Line-Eid-Strasse 1
D-78467 Konstanz, Germany

Phone +49 7531 58470 12
info@rct-solutions.com
http://www.rct-solutions.com

Regd. HRB 708952,
Executive Board: Dr. Peter Fath

rct-solutions.com/careers

Thank you