Turnkey
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Technologies

Bifiacial Workshop, Konstanz, 2017

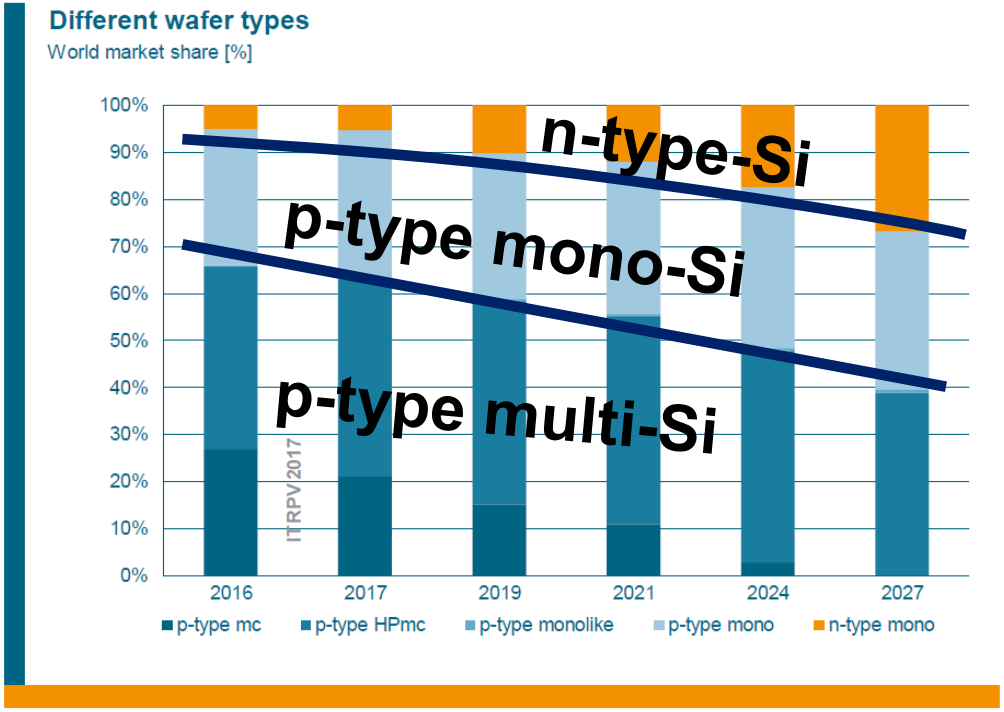
Multicrystalline PERCT Solar Cells and Modules

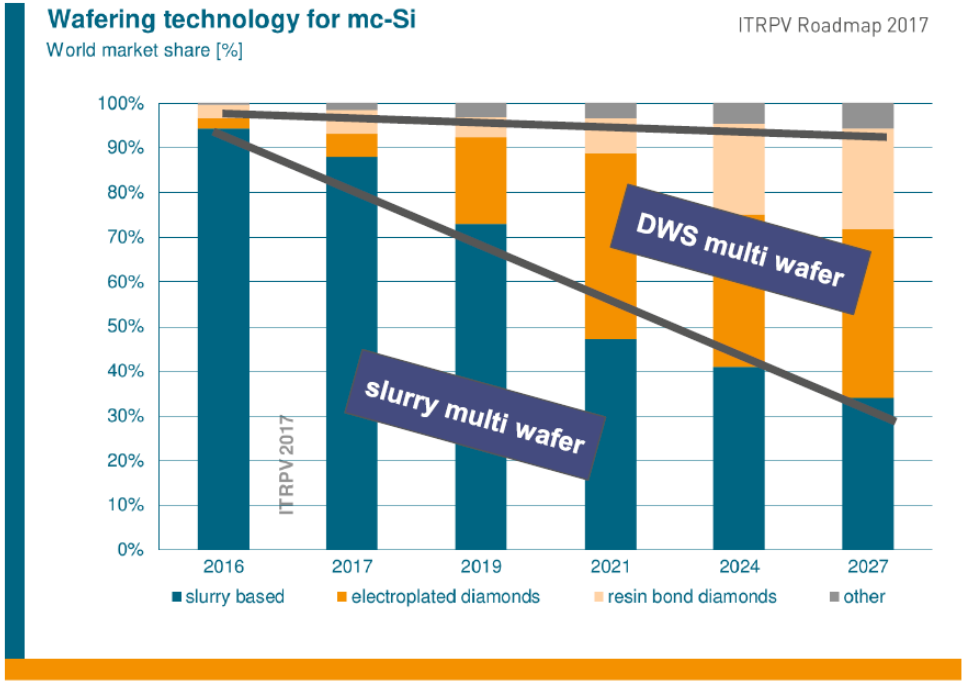
W. Jooss, A. Teppe, O. Voigt, I. Melnyk, F. Binaie, P. Fath

RCT Solutions GmbH, Germany

RCT solutions

Motivation



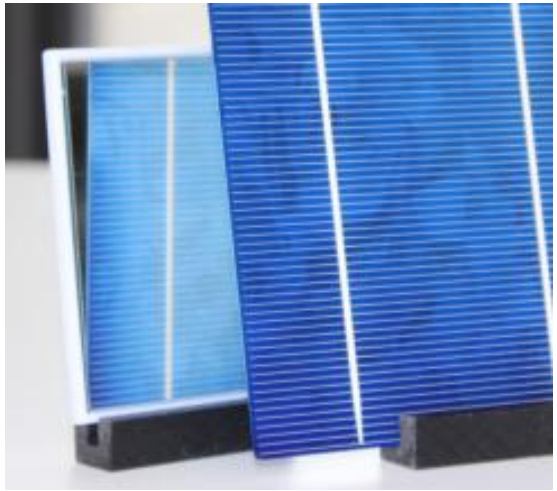


- p-type multi-Si will dominating in future
- p-type wafers and corresponding processes are well established => base for evolutionary solar cell development
- Need for advanced solar cell processes for high efficiency multi-Si solar cells

- New texturing technology for DWS multicrystalline wafer is required, since acidic isotexturing is not as effective due to different (sub-) surface morphology

Outline

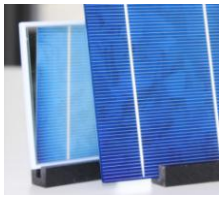
- Multi-Si PERCT Solar Cell Structure
- Production Process Flow
- Pilot Production Results
- Loss Analysis
- MCCE for DWS multi-Si wafer
- Cost-of-Ownership Analysis of Different Technologies



RCT covers the full range of Photovoltaics: from production technology and equipment to PV systems and energy storage

Subsidiary:
RCT Suzhou Ltd China
Equipment Production

Solar Cell Techn.



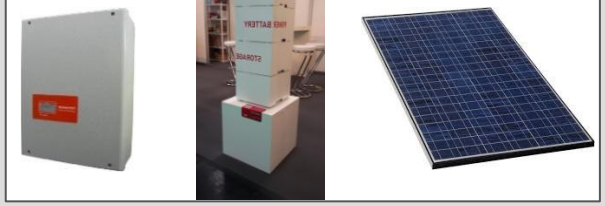
Equipment.

Factory Projects

Joint venture partner:
JJAP Ltd China
100KW to MW Energy
Storage System Production

Solar Power Plant

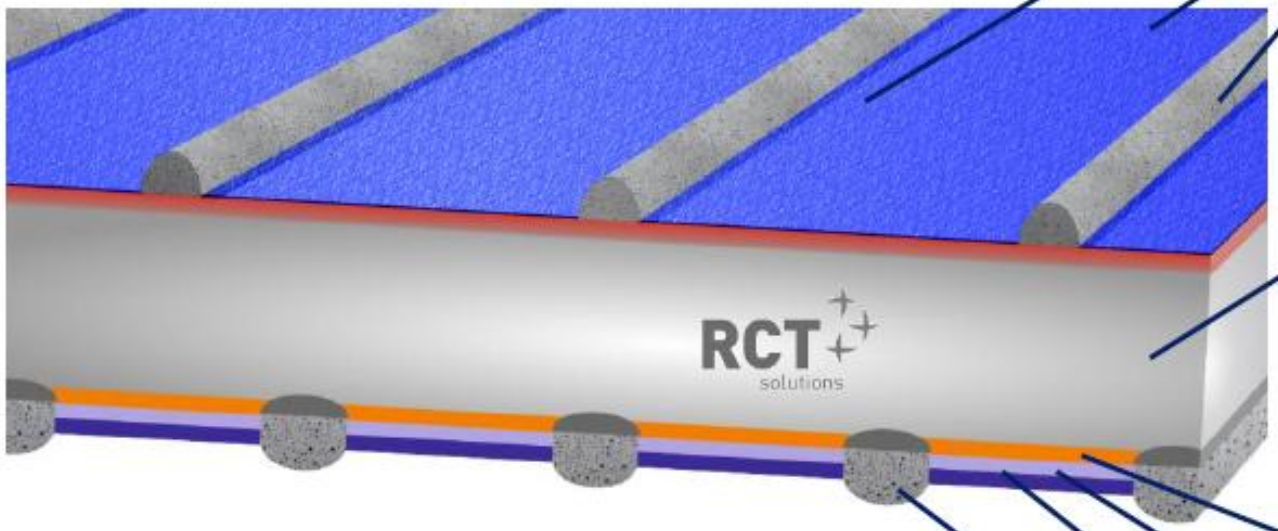
Solar Inverter, Battery, Module



- Established in 2012
- >3 GW RCT black Si wet chemical equipment sold until now
- Setting up of first solar cell factory in Turkey with RCT bifacial multi Si technology
- Technology partner for largest 1GW solar factory in India applying RCT mono PERC technology

- Market launch of highly efficient integrated solar battery inverter
- Novel battery storage tool for up to 9kWh with modular concept developed
- Pilot production in Konstanz, Germany

mc-Si PERCT Solar Cell

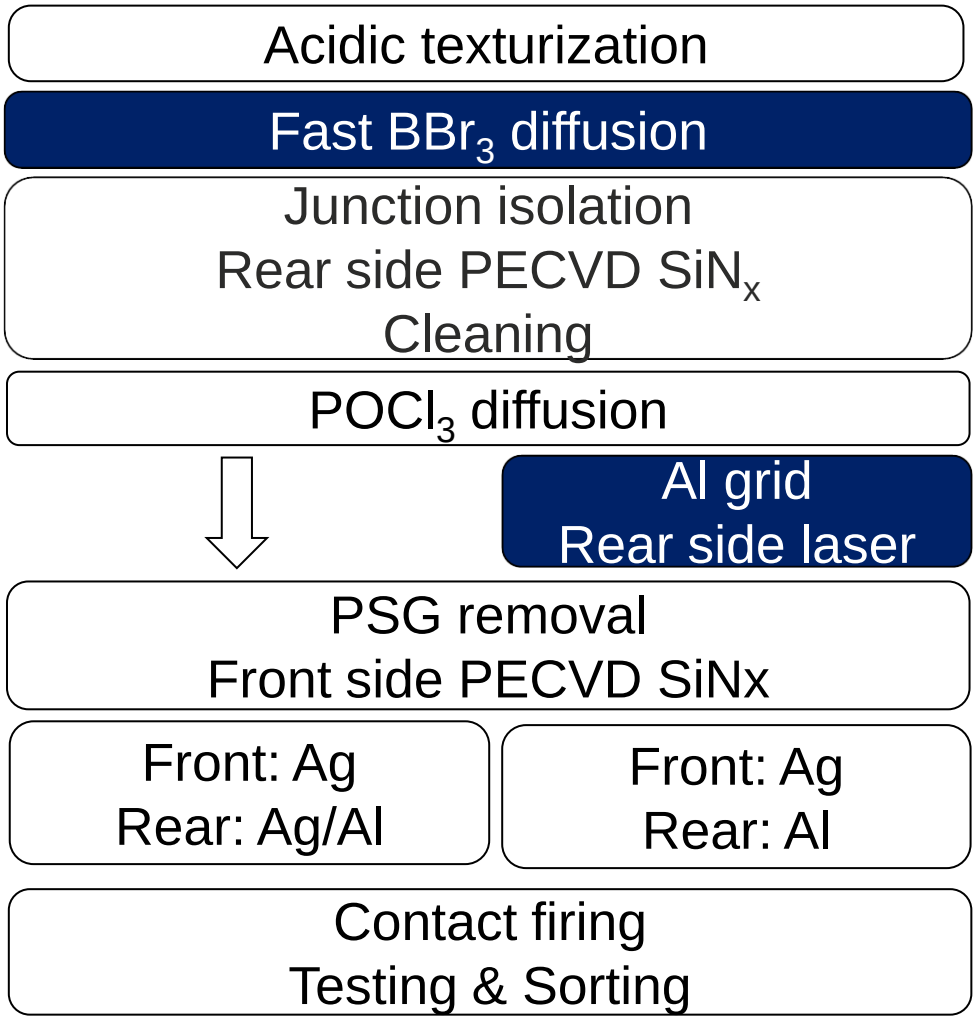


- High performance emitter
- Anti-PID SiN_x
- Screen print Ag front grid
- Standard multi crystalline wafer
- p^+ boron BSF, full area
- BSG passivation layer
- PECVD dielectric layer
- Ag/Al contact grid

Effective rear passivation
(< 40fA/cm²) by B-BSF and BSG

Solar Cell Process Flow and Production Equipment

PERCT bifacial process flow



Additional standard equipment for bifacial production

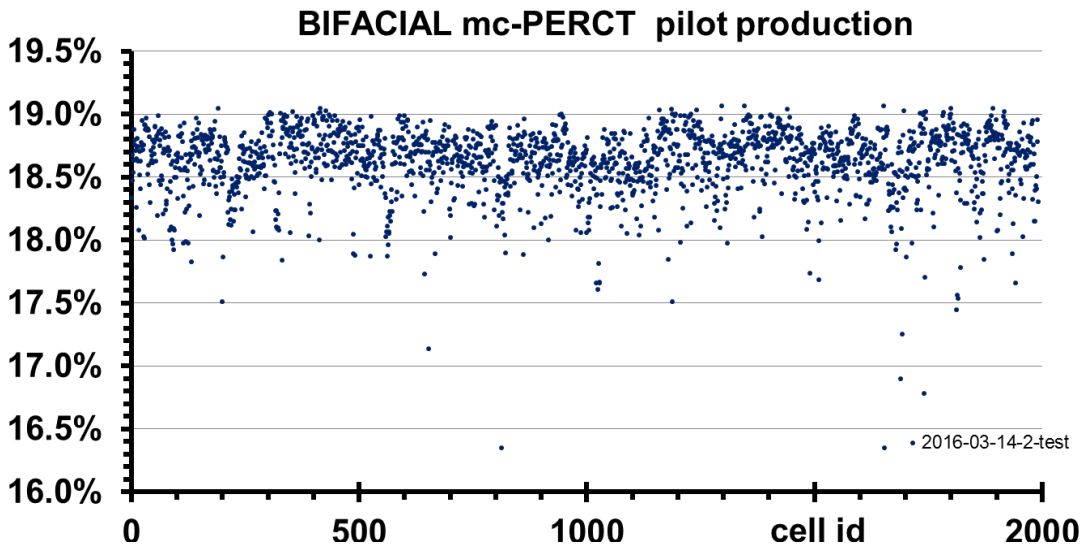
- Rear side PECVD SiN_x
- Wet bench
- BBr_3 diffusion

Additional equipment for Al rear finger

- Rear side laser

All equipment and technologies proven in PV industry

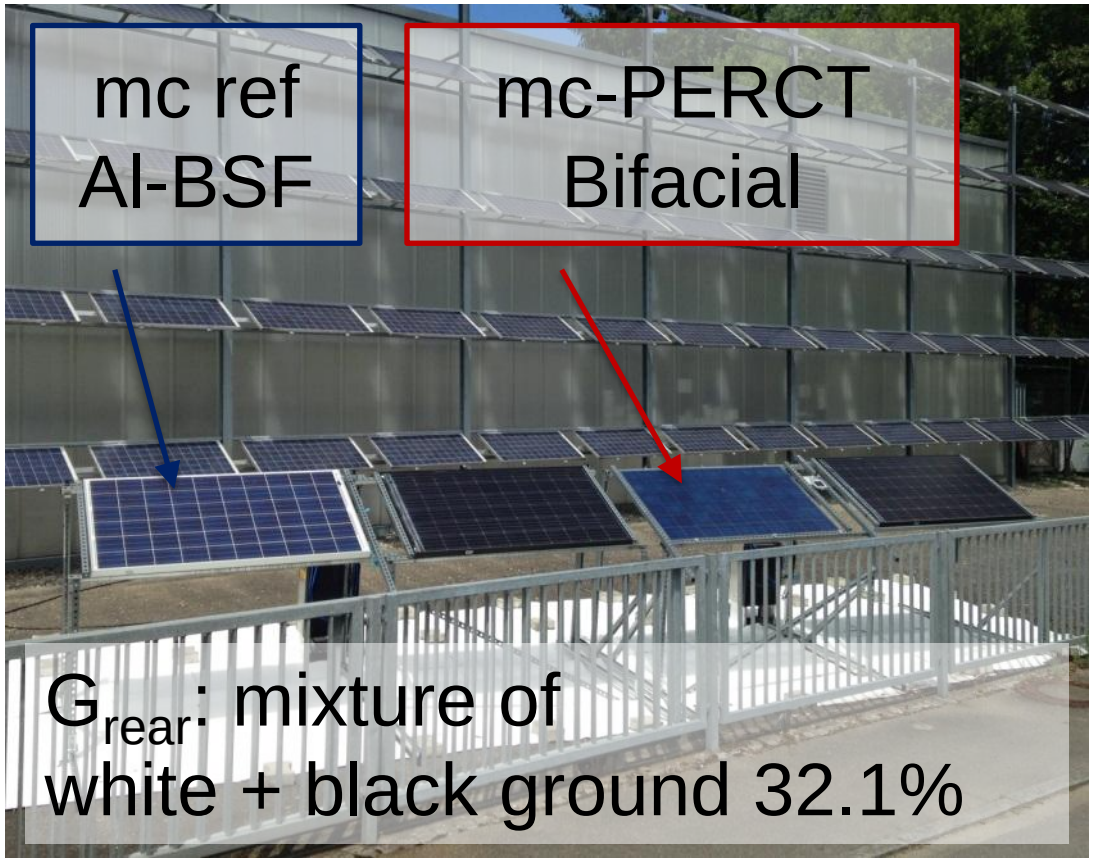
Results on Bifacial PERCT: Solar Cells and Modules in Industrial Pilot Line

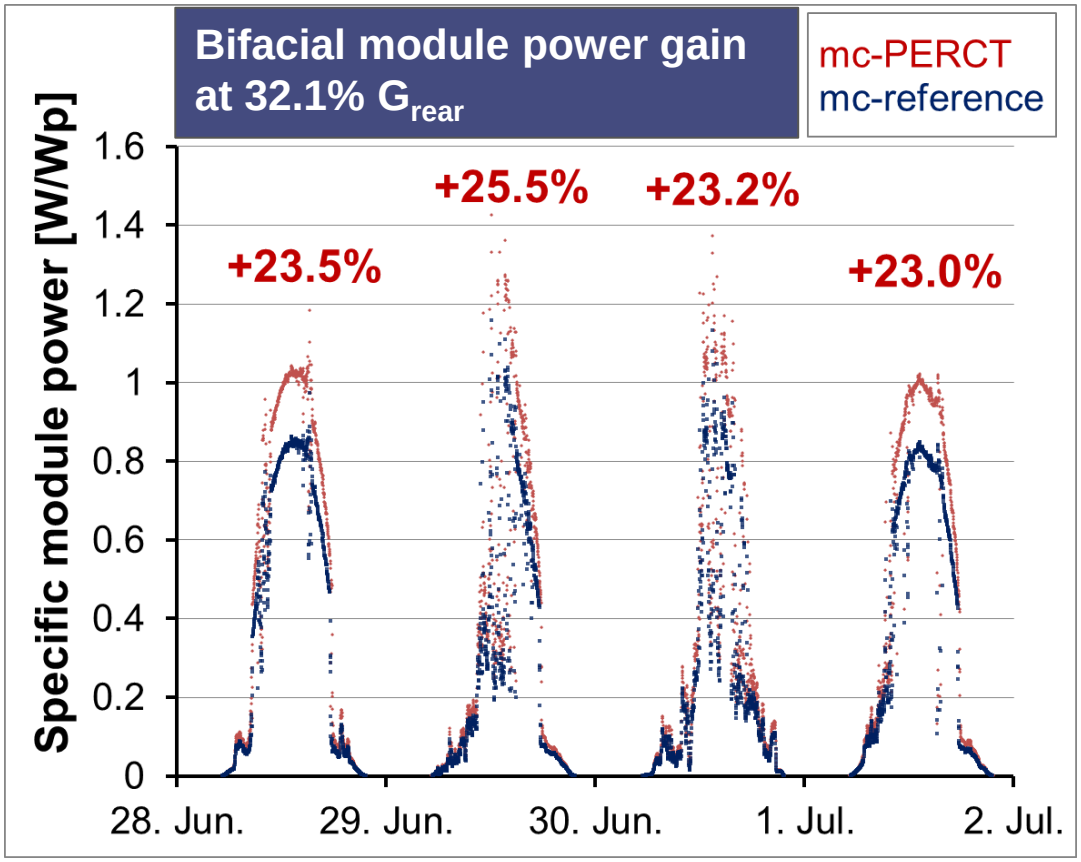


- Average solar cell efficiency
  - Front side: 18.7%
  - Rear side: 16.1%
- Top efficiency: 19.1%
- Bifaciality: 86%

Module ID	average cell Eff.	back sheet	CTM loss	Module power front (1sun) [W]	Module power rear (1 sun) [W]	technical power 1.0 sun front + 0.2 sun rear [W]
P6016SY087	18.47	transparent	2.4%	265.8	167.5	299
P6016SY088	18.47		2.0%	266.9	165.6	300
P6016SY089	18.57		2.5%	267.0	163.4	300
60 cell	18.5	transparent	2.3%	266.6	165.5	300

Bifacial Module Energy Harvest





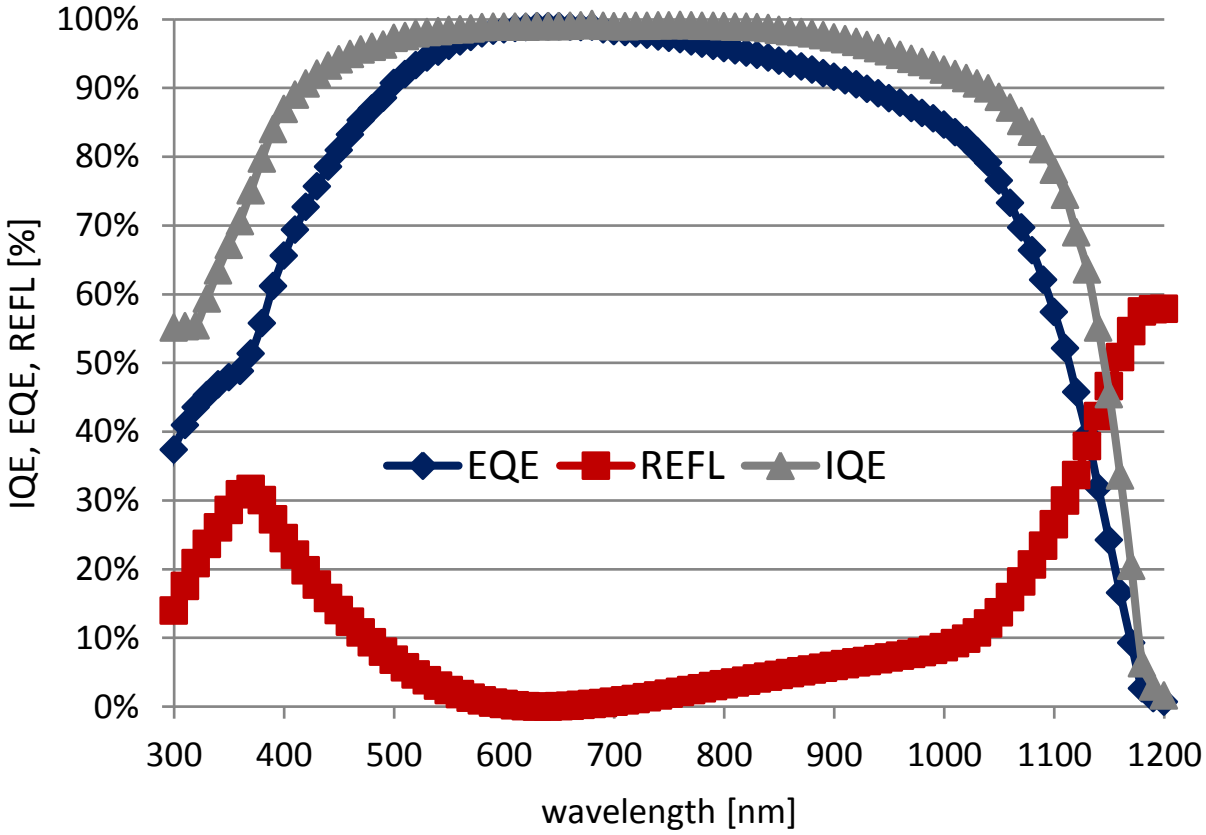
Estimation of bifacial gain
32.1% G_{rear} * 80% bifaciality = 25.7%

Experimental data:
+23.0%...25.5%

V_{oc} and I_{sc} nearly unchanged after 4 months of outdoor exposure

Loss Analysis of typical mc-PERCT solar cell

- Quantum Efficiencies of a solar cell with J_{sc} = 37.3 mA/cm²



Optical losses	5.16 mA/cm²
▸ Shadowing	2.05 mA/cm²
▸ Rear absorp.	0.29 mA/cm²
▸ **Primary refl.**	**2.41 mA/cm²**
▸ ARC abs.	0.01 mA/cm
▸ FCA	0,41 mA/cm²
Electrical losses	1.26 mA/cm²
▸ **Emitter**	**0.63 mA/cm²**
▸ Bulk	0.63 mA/cm²
▸ Rear	0.01 mA/cm²

- J_{sc} is limited by high primary surface reflectivity (improve texturing), bulk (better material) and emitter recombination (better emitter: reduce N_{peak} + passivation)

Enabling DWS Multi Texturing and Efficieny Inrease:
Black Silicon by Metal Catalyst Chemical Etching

- Generic process flow

Saw damage removal

↓

Ag nanoparticle deposition

↓

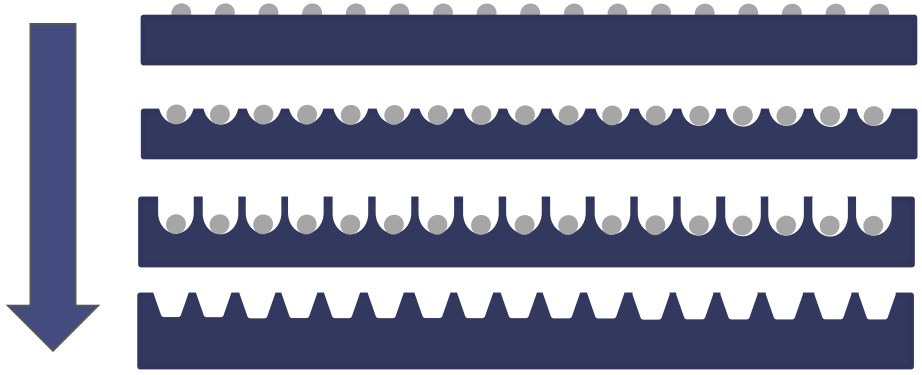
Metal Catalyst Chemical Etching

↓

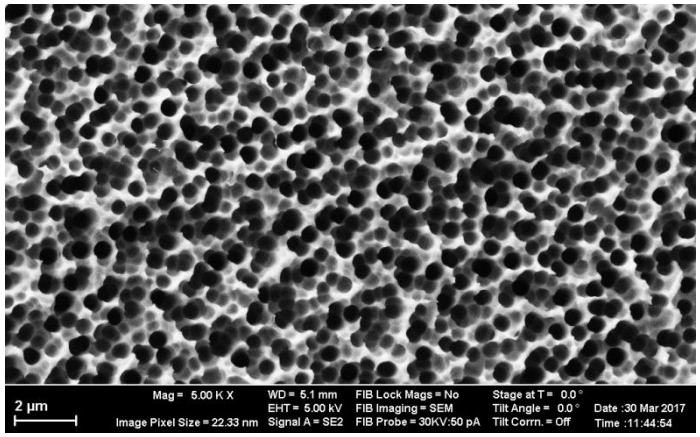
Acidic / alkaline post treatment (opt)

↓

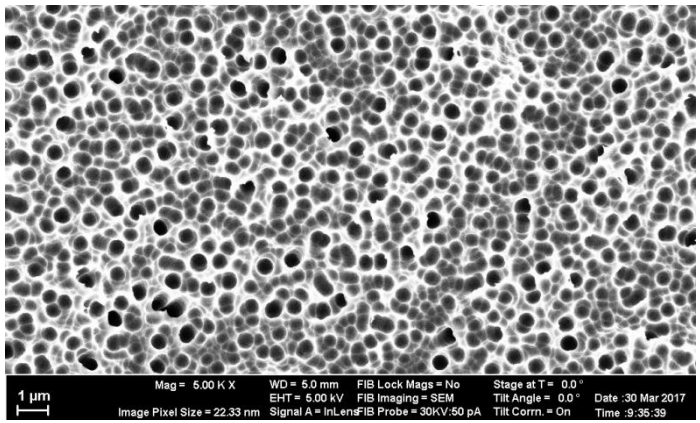
Metal removal and cleaning



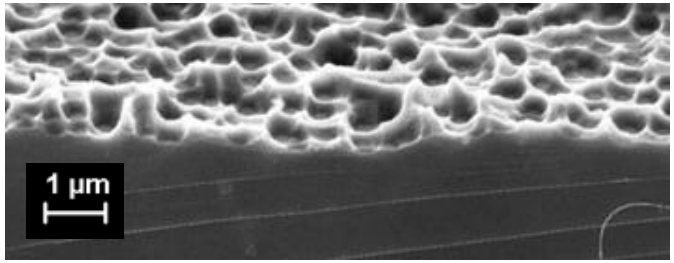
R_{ave} = 12%



R_{ave} = 20%



R_{ave} = 22%



Tool Layout i-BlackTex

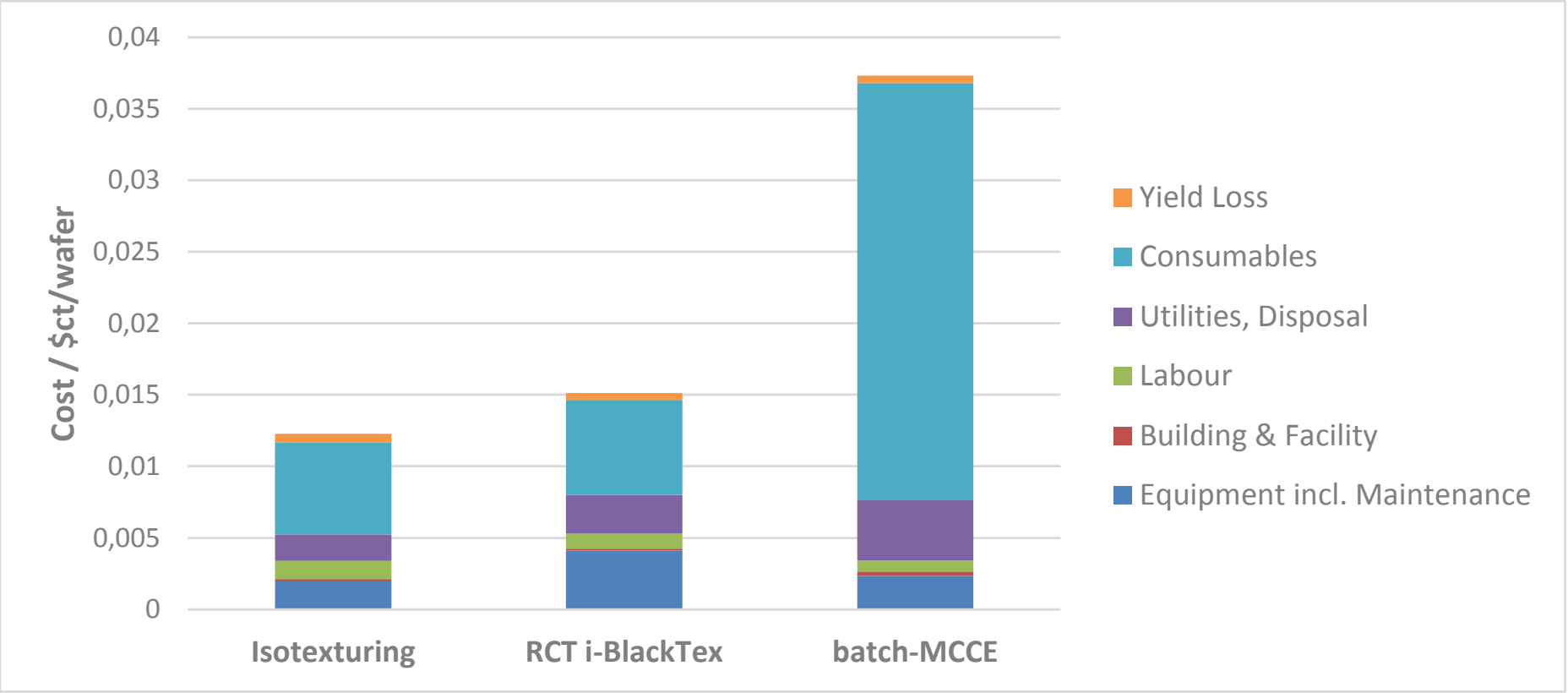
- Based on RCT inline family (i-Tex, i-Side, i-Clean) with proven design and components

< 12m length (excl. automation)

Black Texture	Rinse	Post Treatment	Rinse	Alkaline Cleaning	Rinse	Acidic Cleaning	Rinse	Dryer

Cost of Ownership Comparison

- $AgNO_3$ cost are much lower than additive cost in batch type processes
- $AgNO_3$ cost only 10% of total cost, < 0.5mg / wafer, even without recycling
- Inline uses chemicals more efficient than batch due to longer bath lifetime

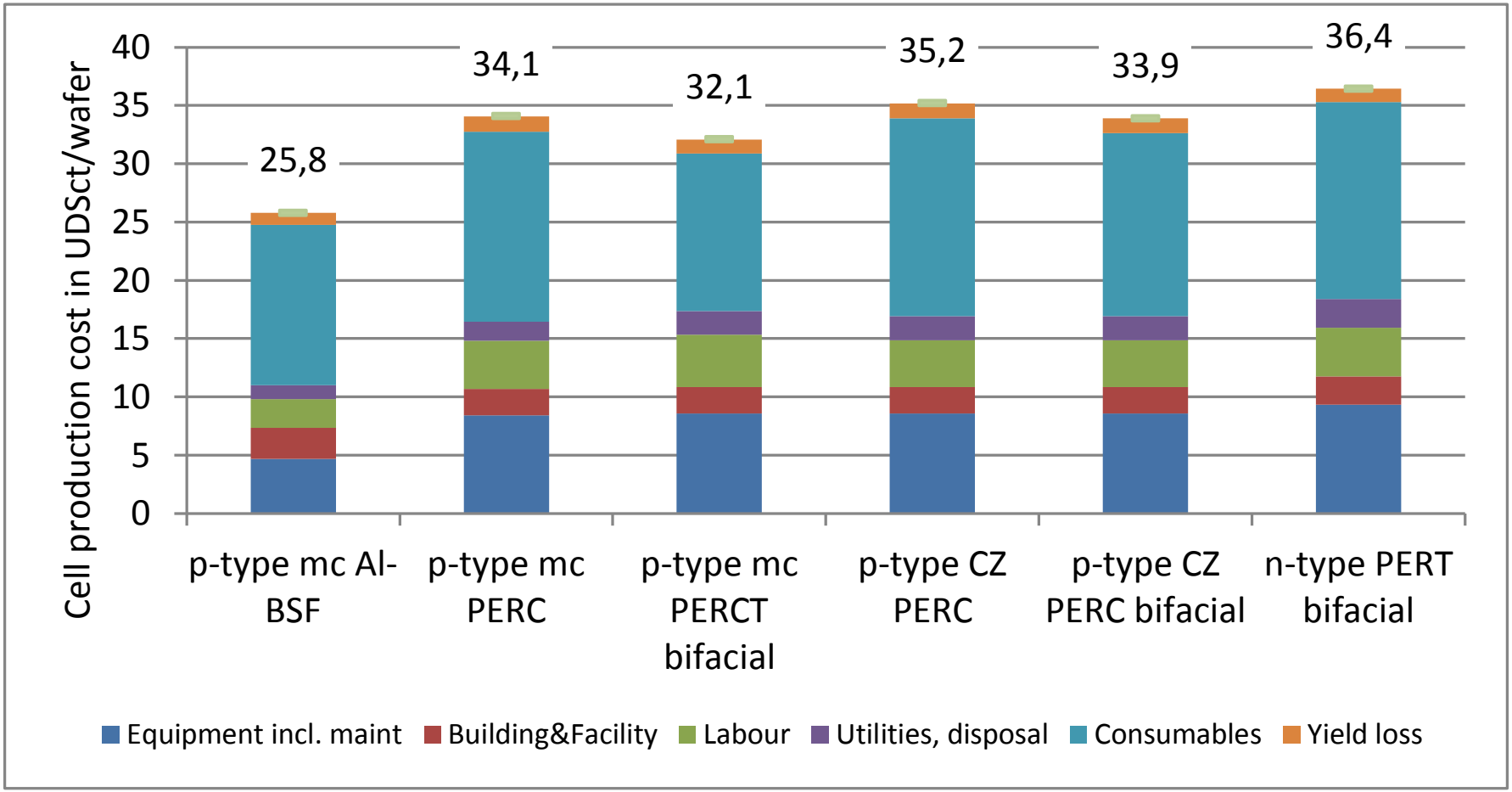


CoO Comparison of Different Technologies

Key Assumptions

	p-type mc Al-BSF	p-type mc PERC	p-type mc PERCT bifacial	p-type CZ PERC	p-type CZ PERC bifacial	n-type PERT bifacial
Cell efficiency	18.8%	19.5%	19.5%	21.2%	21.2%	21.2%
Cell power [W]	4.62	4.79	4.79	5.5	5.15	5.15
Module power[W]	276	286	280	303	297	297
Bifaciality	0%	0%	75%	0%	75%	90%
Technical Power at G_{rear}=25%	276	286	332	303	353	364
Wafer price [USDct]	60	60	60	75	75	80
Module costs [USD]	47	47	51	47	51	51

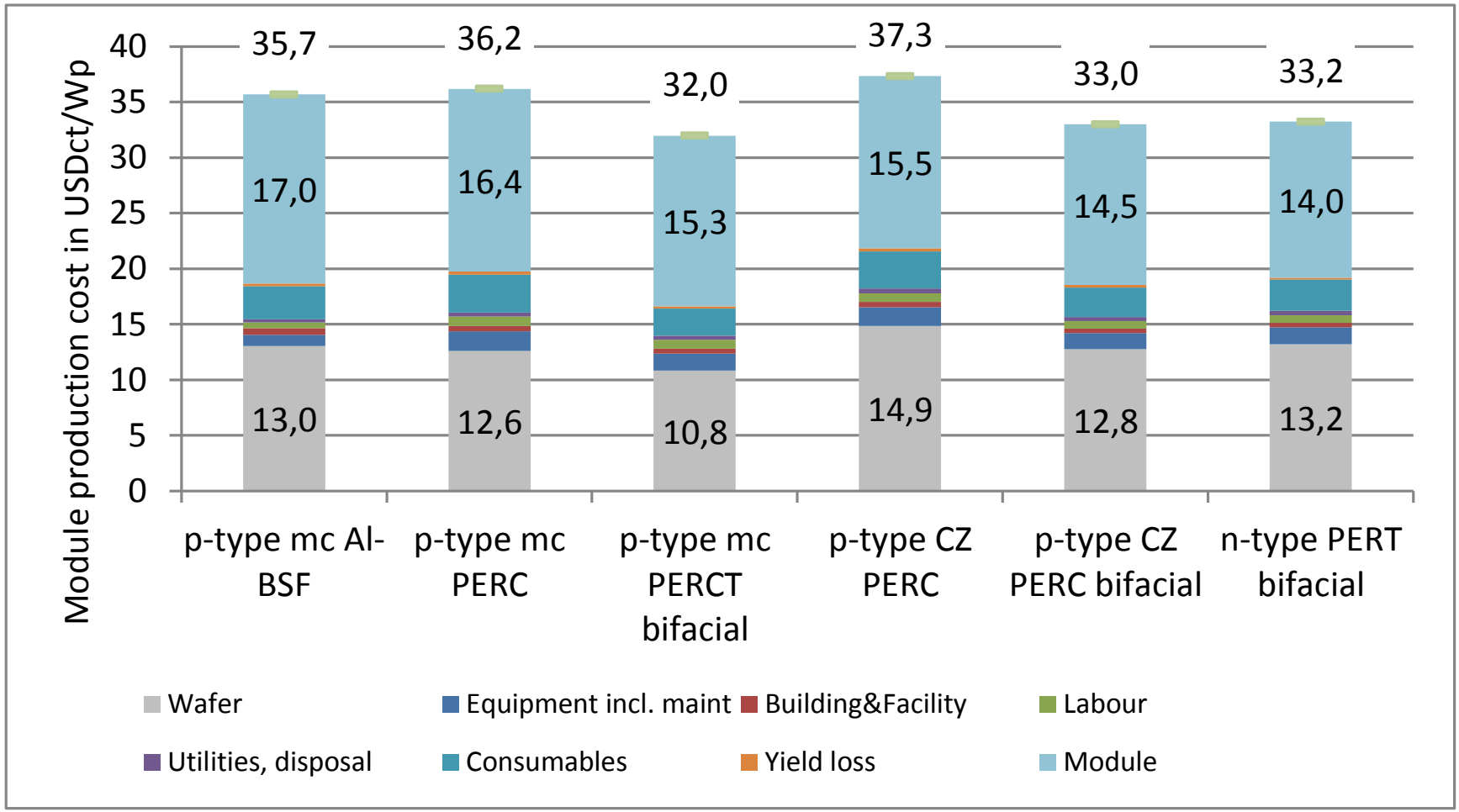
Cell Production Costs



Note: mc-PERCT is based on Al-finger on rear

Module Production Costs

- Bifacial gain is considered in production costs



Summary

- Bifacial multicrystalline silicon PERCT solar cells are an attractive alternative to their monocrystalline counterparts
- Solar cells and modules have been processed in an industrial pilot line
  - Average front side efficiency of 18.7%, top efficiency of 19.1%
  - Bifaciality >85%
  - Outdoor tests confirm bifacial gain as expected
- MCCE texturing enables the use of DWS multi wafer and reduces reflectivity
- CoO analysis further demonstrates the benefits of bifacial applications. Mc-Si PERCT leads to slightly lower CoO than mono bifacial concepts.

Thank you for your attention!

RCT Solutions GmbH
Line-Eid-Strasse 1
78467 Konstanz
GERMANY