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Pilot Production of Bifacial Heterojunction Cells- and Modules

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Hercules Workshop, Berlin – 2016-10-11

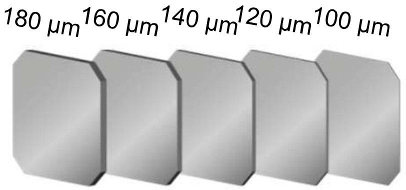
the perfect combination

A

less material consumption

Diamond Wire sawing

Thinner wafer ➔ Lower costs



B

simple, efficient and low CoO cell technology

Si heterojunction cells

high efficiency
high energy yield ➔ Lower costs
low CoO

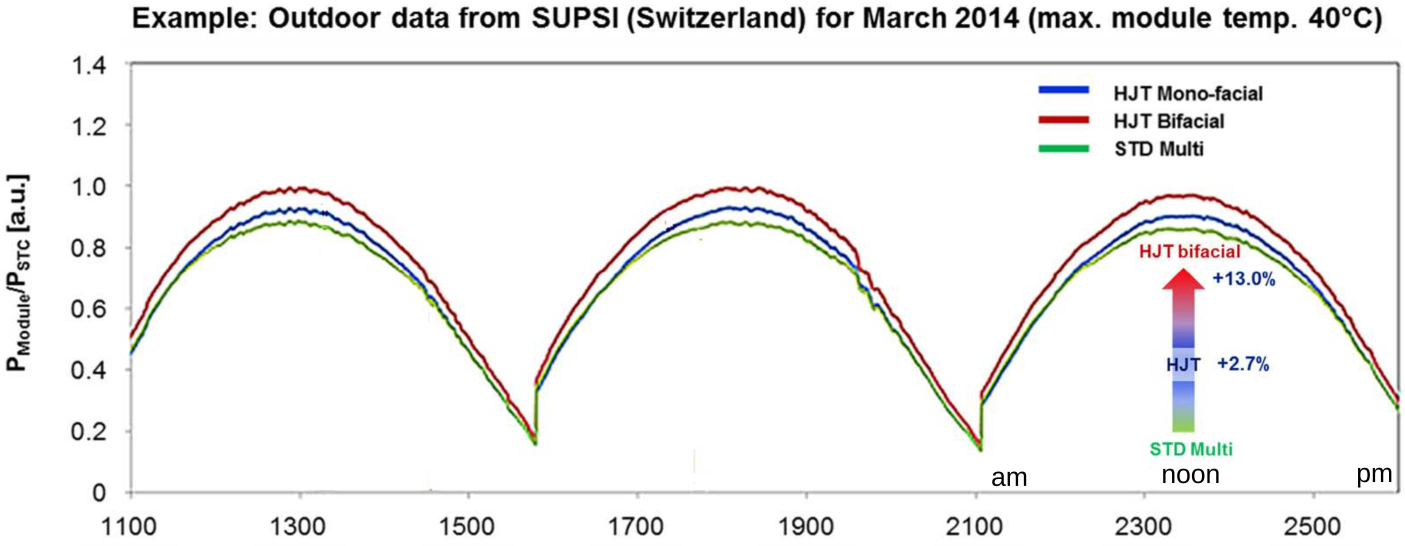
C

high yield, efficient and stable module technology

SmartWire Connection

less silver
bifacial ➔ Lower costs
microcrack resistant

HJT Outdoor Performance



HJT / SWCT

\+ lower Temp. Coeff

\+ Bi-facial **module**

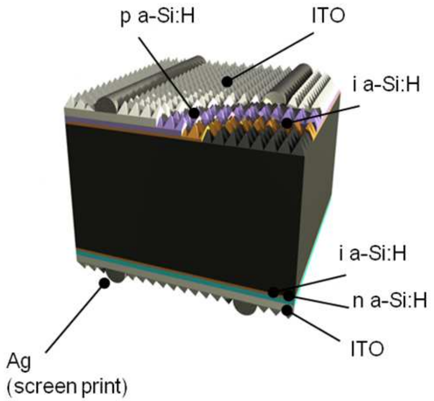
= **higher energy yield**

compared to std. c-Si

kWh/kWp	HJT vs. Multi Module	
	HJT Mono-facial	HJT Bi-facial
All days	+2.7%	+13%
Clear Days	+3.9%	+12.9%
Cloudy	+2.1%	+12.9%

Outline

- Heterojunction Cell Pilot Line
- Measurement of Busbarless and Bifacial Cells
- Bifacial SWCT Module Design
- Summary



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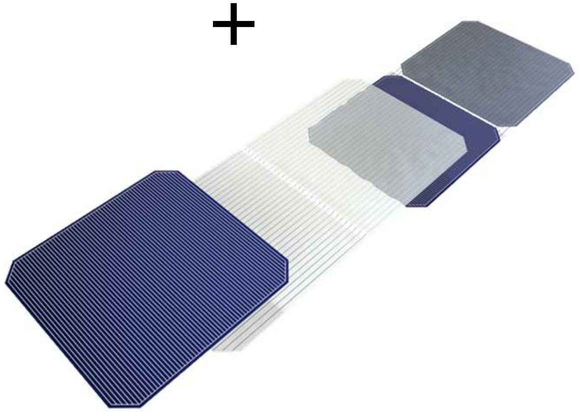

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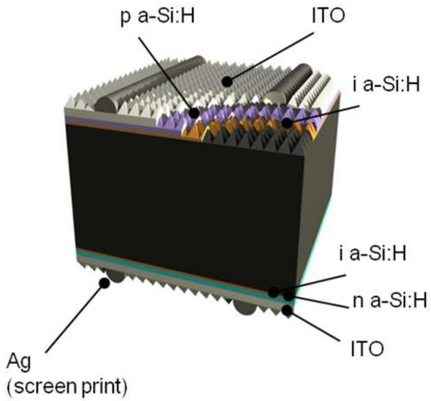

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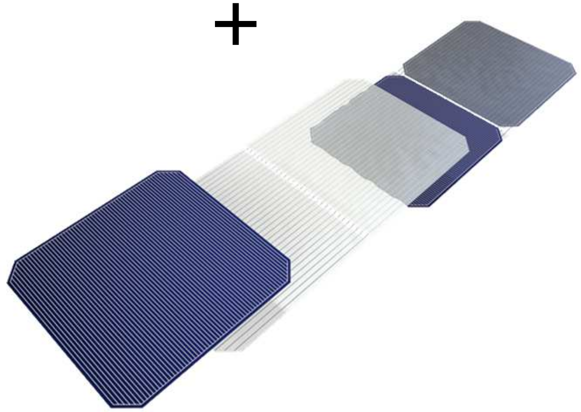
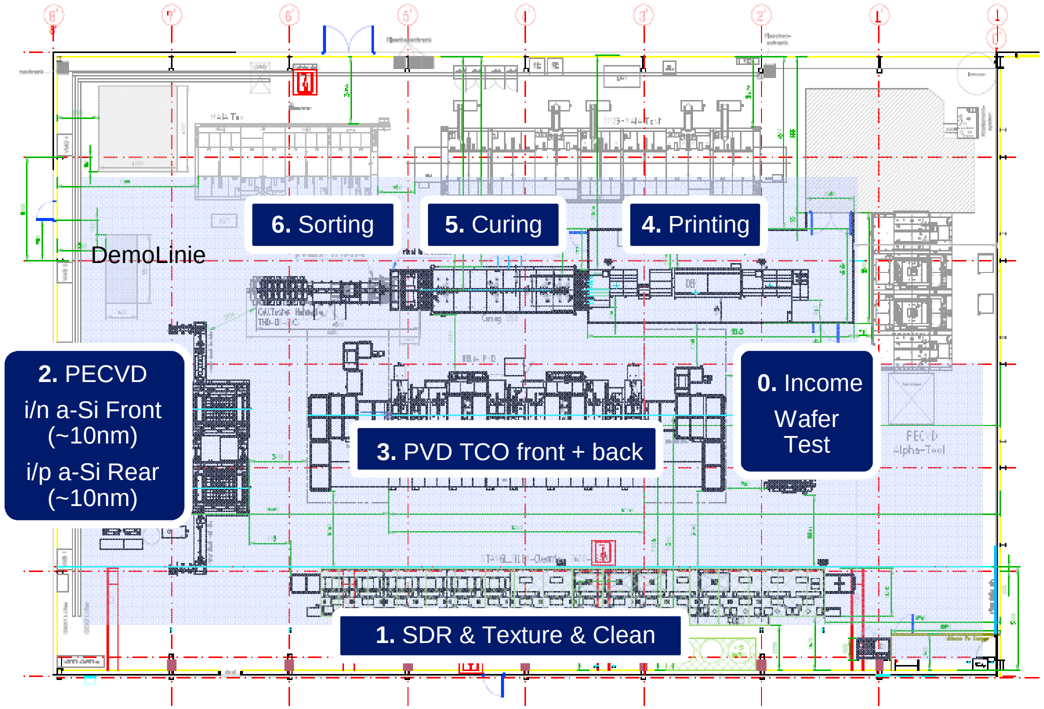
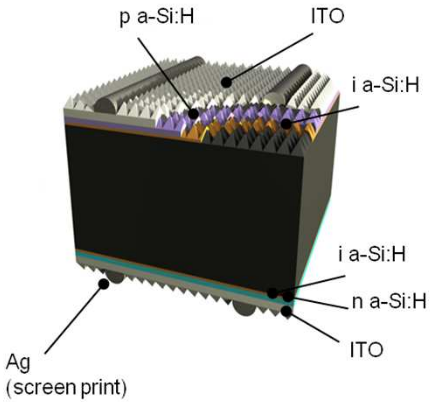


Pilot Line Cell Process Hohenstein-Ernstthal





- Pilot line with 15MW capacity was installed in Q1 2015,
- In 2016 line stability, tact time, handling and yield was improved, more than 500000 cells manufactured
- Tool equipment is combined with Process Intelligence from Meyer Burger (Testing & MES)
- only 6 process steps, up to 25% reduced line footprint

HJT Pilot Production Cell Line Performance

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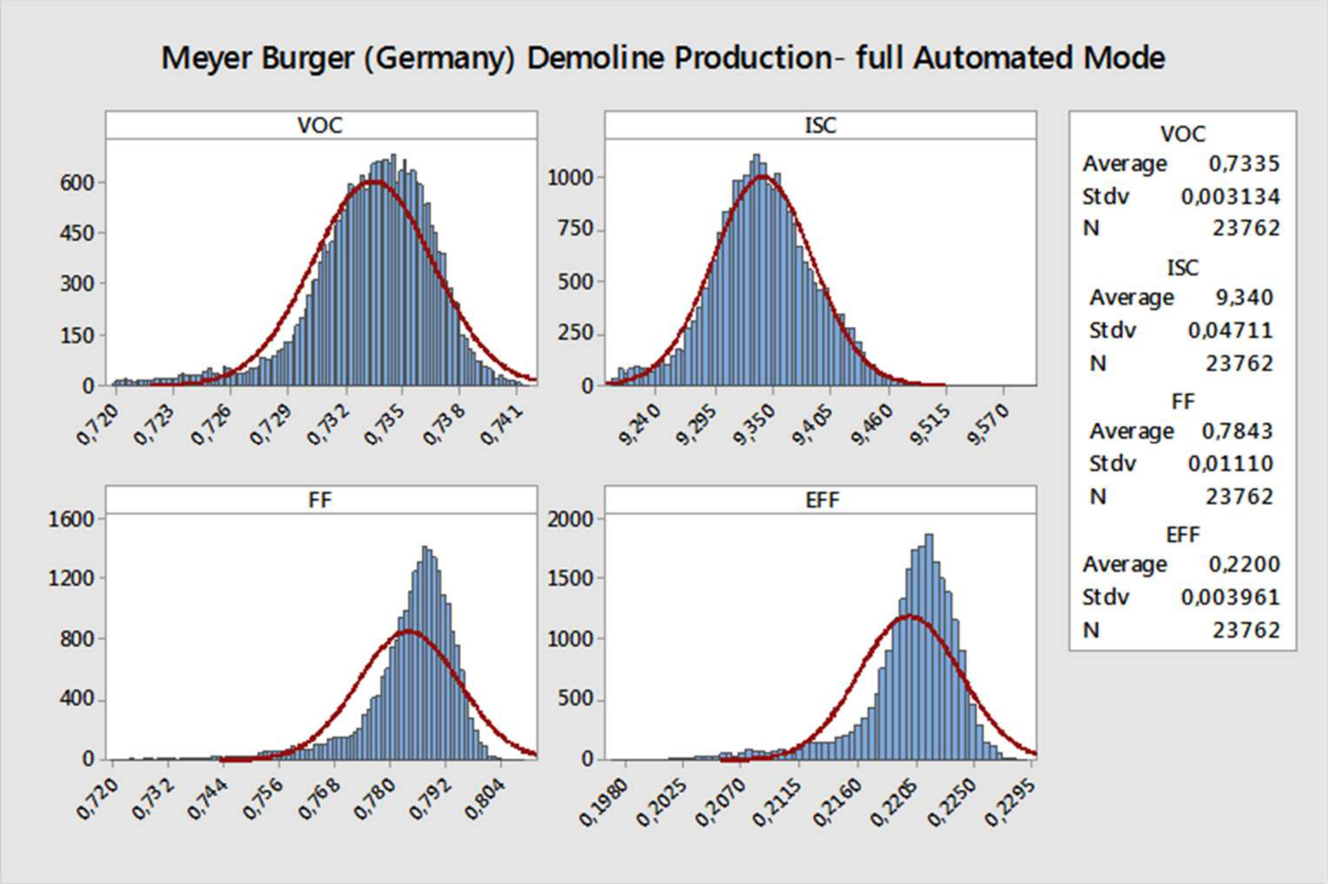
- Weekly production: ~25.000 cells, median efficiency 22 - 22,5%, full automation
- Roadmap 2017 >23% median in production



HJT key technology

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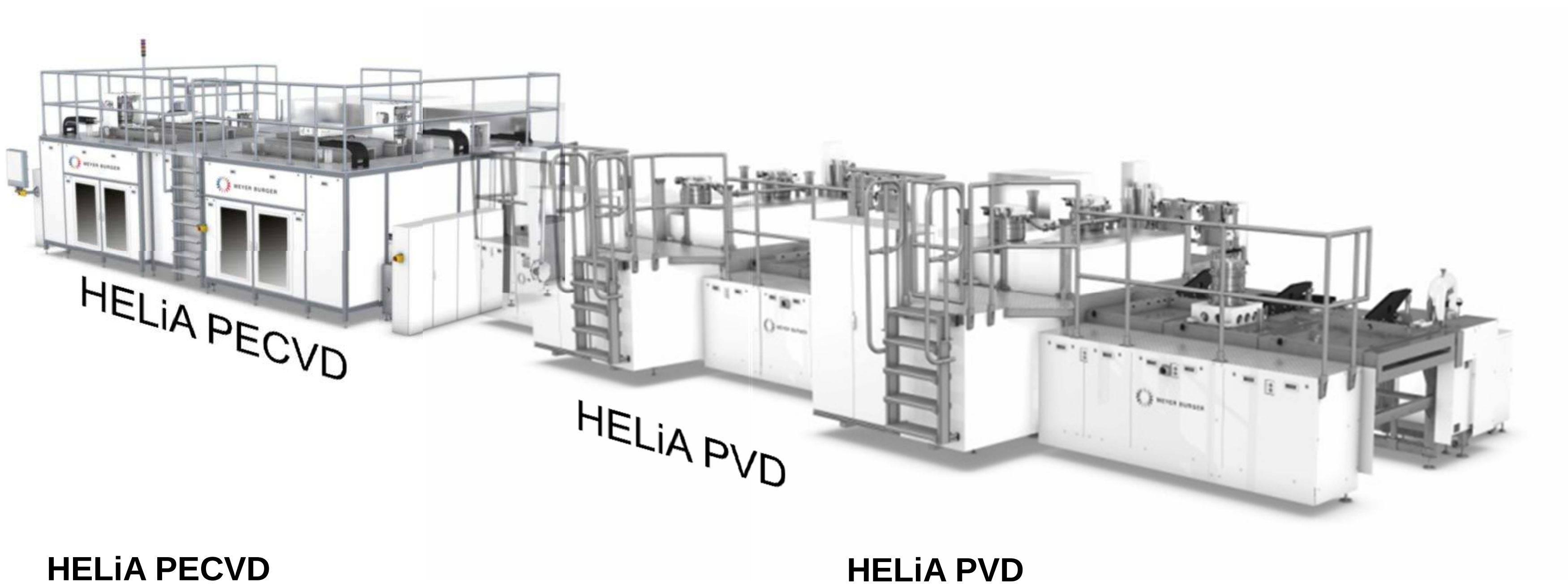

HELiA PECVD

- Gross throughput: 2400 w/h
- 56 wafer/tray
- 84 s tact time
- Process pressure: 0.5…10 mbar

HELiA PVD

- Gross throughput: 2400 w/h
- 24 wafer/tray
- 36 s tact time
- Process pressure: 1E-2…5E-3 mbar

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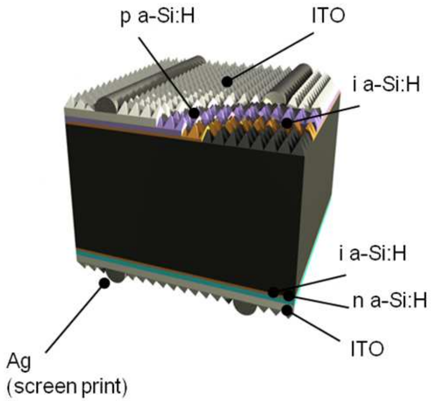

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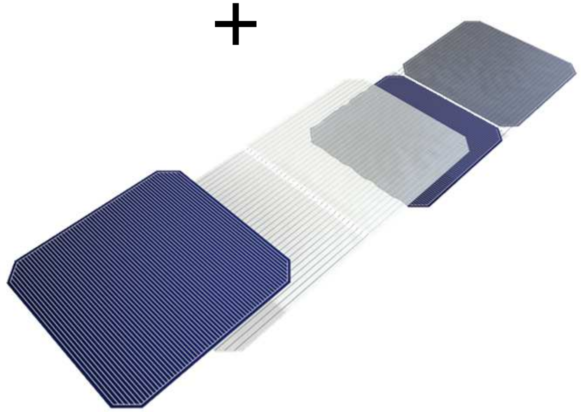

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Certified Busbarless Cells

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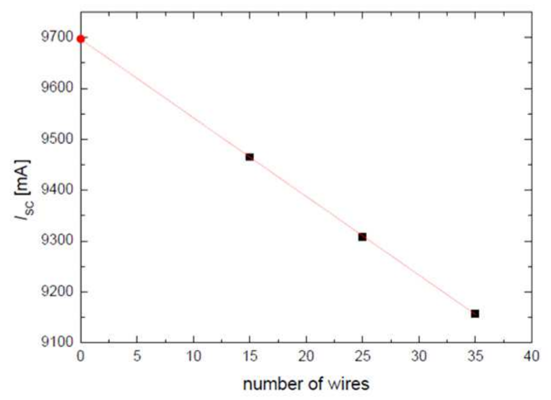
- GridTOUCH is now established at ISE Callab
- Shading-free I_{sc} extrapolation by different wire configurations → 15, 25, 35 wire
- calibration report for busbarless cell



4. Messergebnis
Measurement results

Fraunhofer
ISE
CalLab
PV Cells

Mismatch-Faktor / *Mismatch factor* : = 1.0089

(Spektral-Korrektur / *spectral correction*)

Fläche / Area (t)[1]: = (244.25 ± 0.24) cm²

[1] : *(t) = total area, (ap) = aperture area, (da) = designated illumination area /7/*

Kennlinienparameter des Messobjektes unter Standardtestbedingungen (STC) / *IV-curve parameter under Standard Testing Conditions (STC)* :

V_{OC}	= (	741.2	±	2.5	) mV
I_{SC} (Ed.2 - 2008)/3/	= (	9.24	±	0.18	) A
J_{SC}	= (	37.82	±	0.72	) mA/cm²
I_{MPP}	=	8.71			A
V_{MPP}	=	641.8			mV
P_{MPP}	= (	5.59	±	0.11	) W
FF	= (	81.62	±	0.53	) %
η	= (	22.88	±	0.46	) %

Cell Performance

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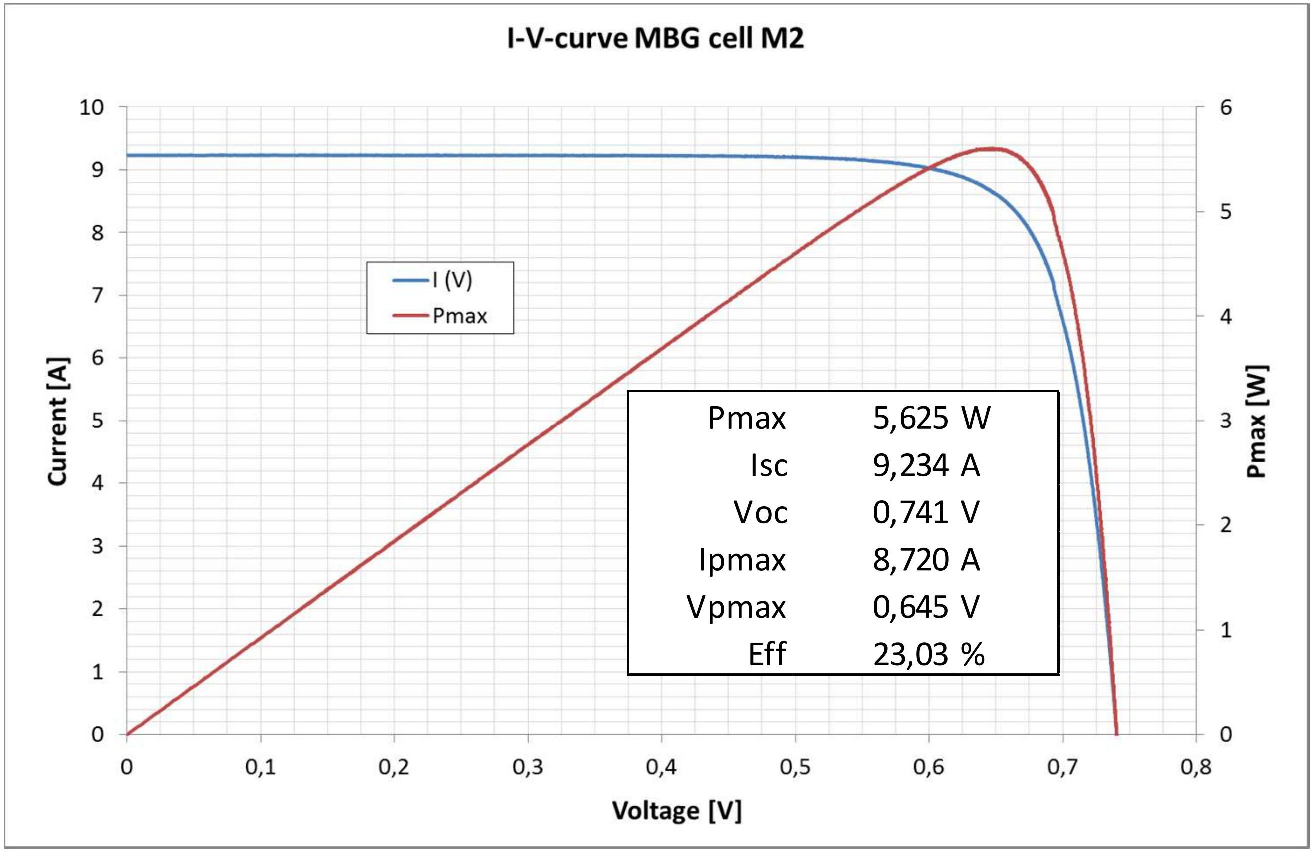
- Internal measurement shows 23,0% efficiency (22,9% confirmed independently)
- Excellent temperature coefficients



TC Isc	≈	+ 0.035 %/K
TC Voc	≈	- 0.241 %/K
TC Pmax	≈	- 0.239 %/K

Bifacial Behavior

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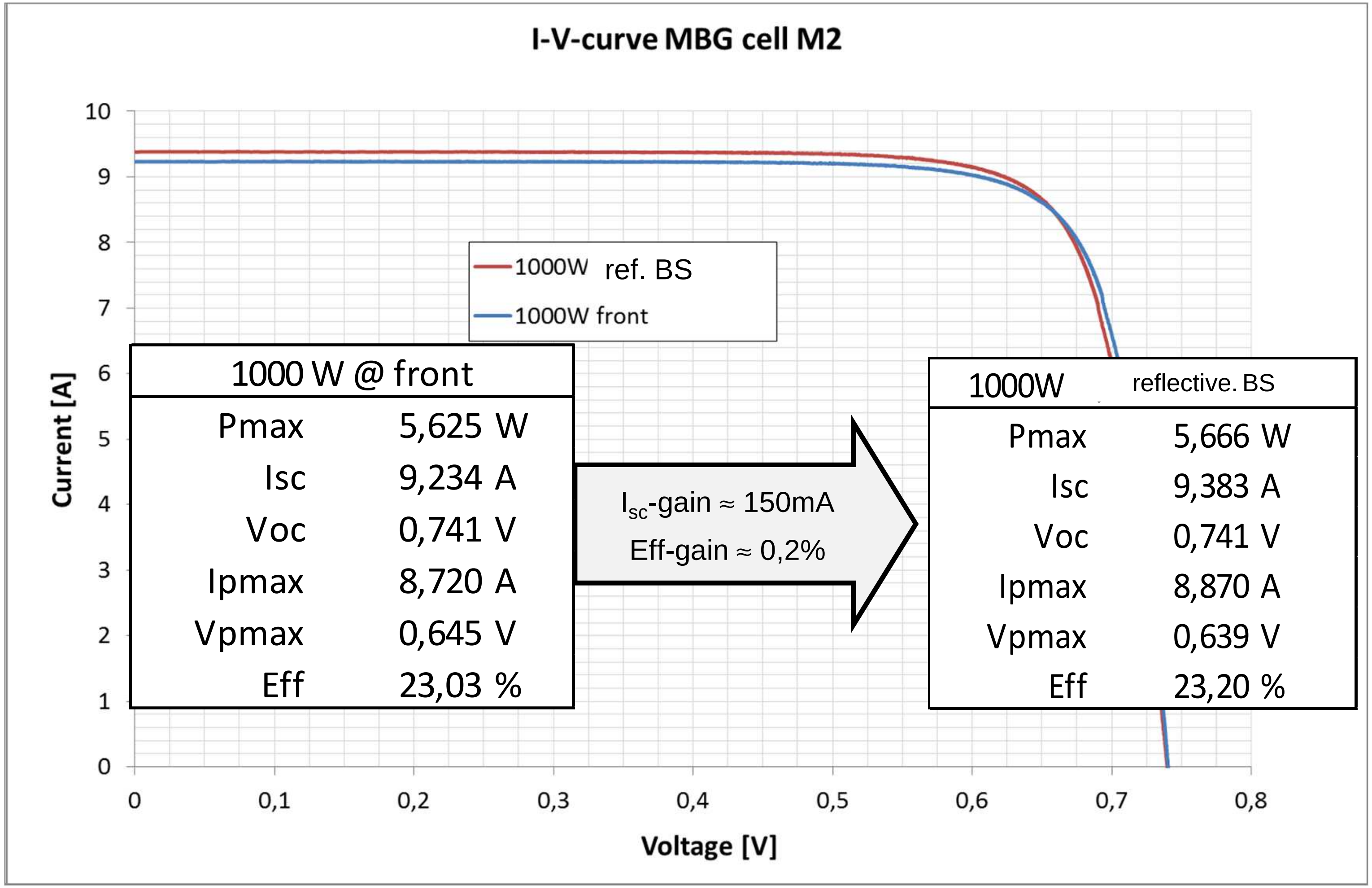
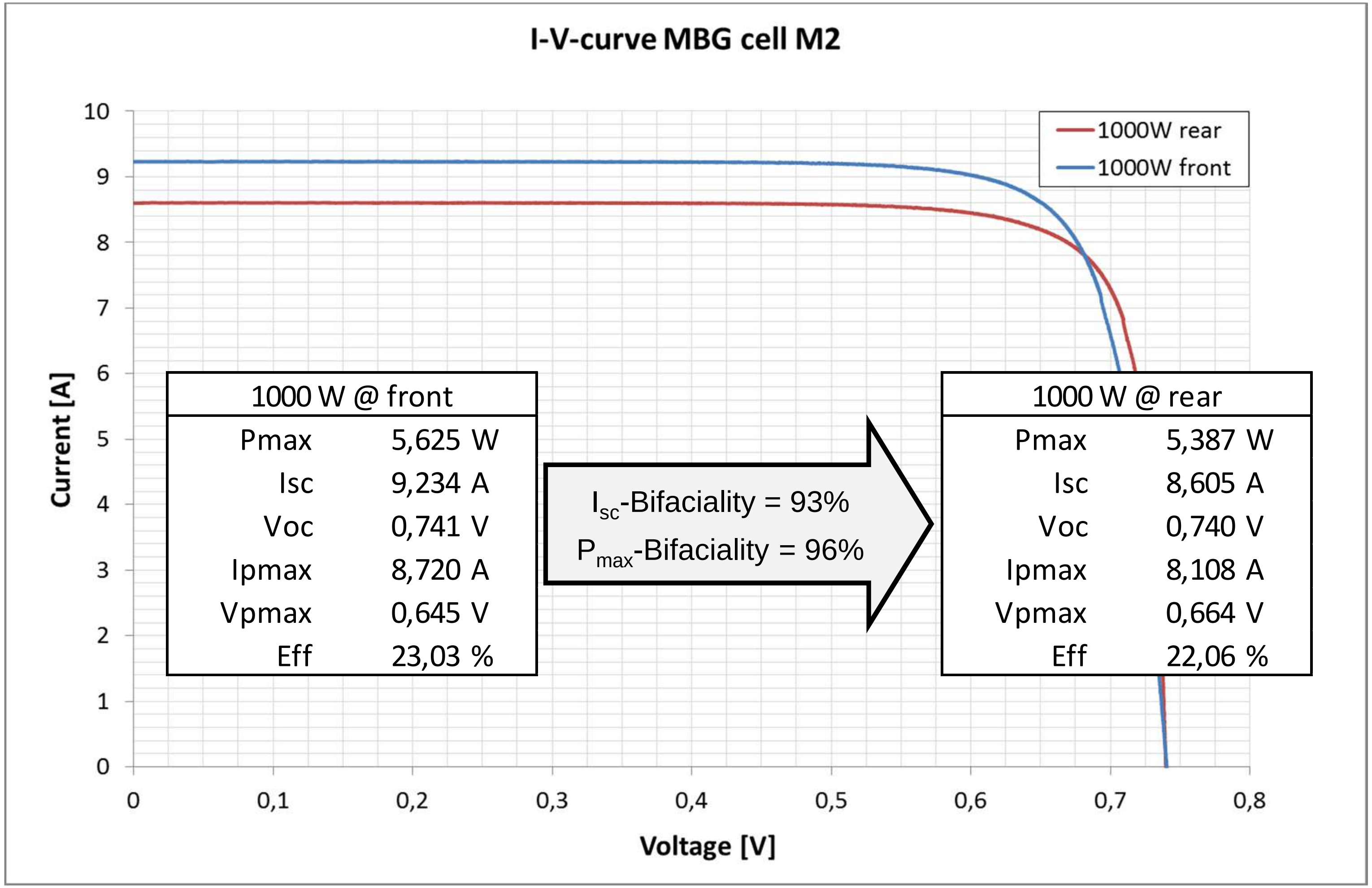
- What happens in a backsheet module?



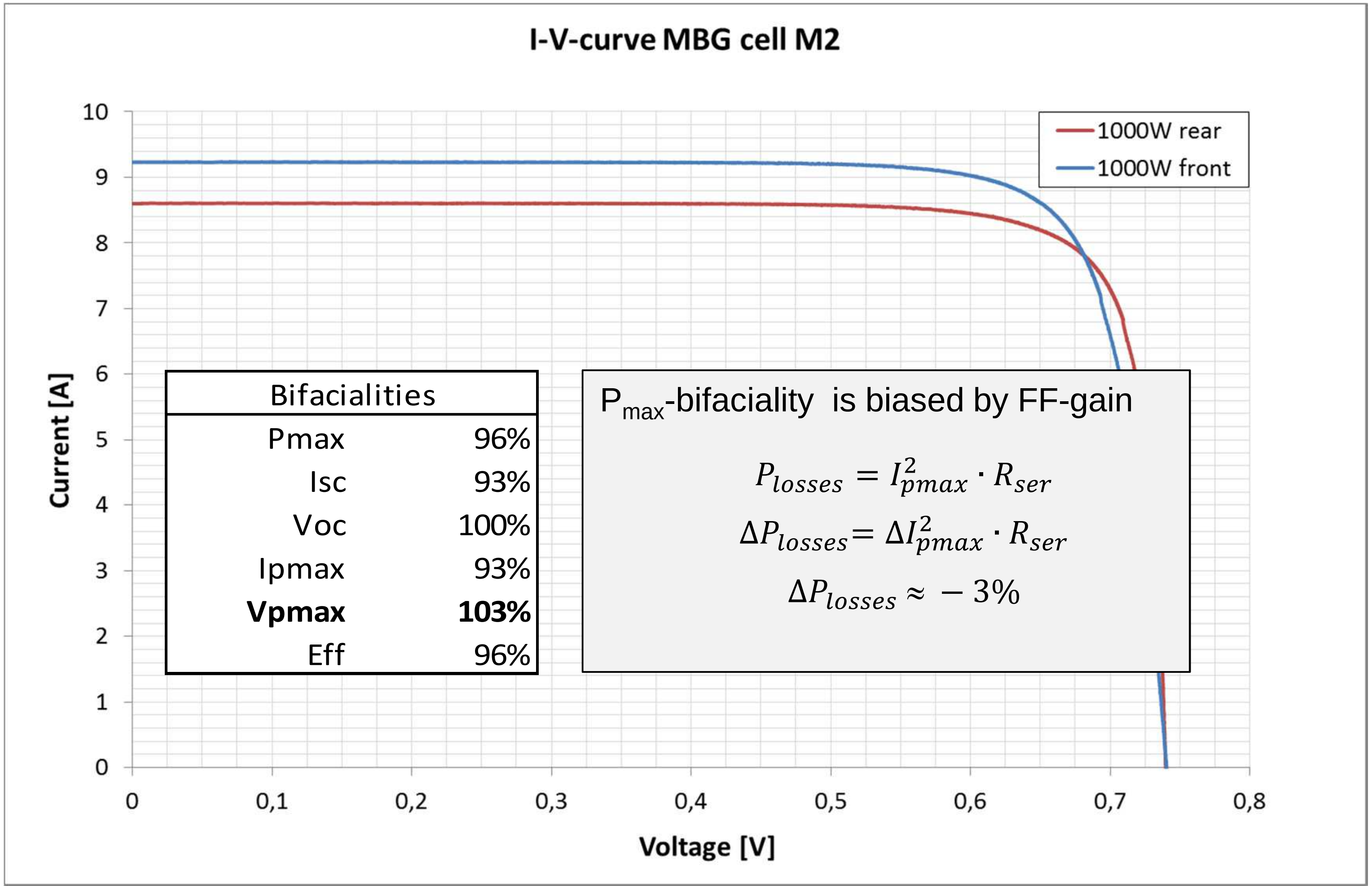
Bifacial Behavior

- What`s the right bifaciality factor?



Bifacial Behavior

- What`s the right bifaciality factor?
- P_{max}-bifaciality is a function of I_{pmax}-bifaciality and R_{ser}



Bifacialities	
Pmax	96%
Isc	93%
Voc	100%
Ipmax	93%
Vpmax	**103%**
Eff	96%

P_{max}-bifaciality is biased by FF-gain

$$P_{losses} = I_{pmax}^2 \cdot R_{ser}$$

$$\Delta P_{losses} = \Delta I_{pmax}^2 \cdot R_{ser}$$

$$\Delta P_{losses} \approx -3\%$$

Bifacial Behavior

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- Equivalent Irradiance method according Pasan for Albedo factors of 0,1 and 0,2

1. **Bifaciality determination at STC:**

$$\varphi_{Isc} = \frac{Isc_{rear}}{Isc_{front}};$$

2. **I-V characterization vs. backside illumination:**

   Equivalent 1-side irradiance levels

   $G_{total} = 1000Wm^{-2} + \varphi_{Isc} \cdot G_{rear}$

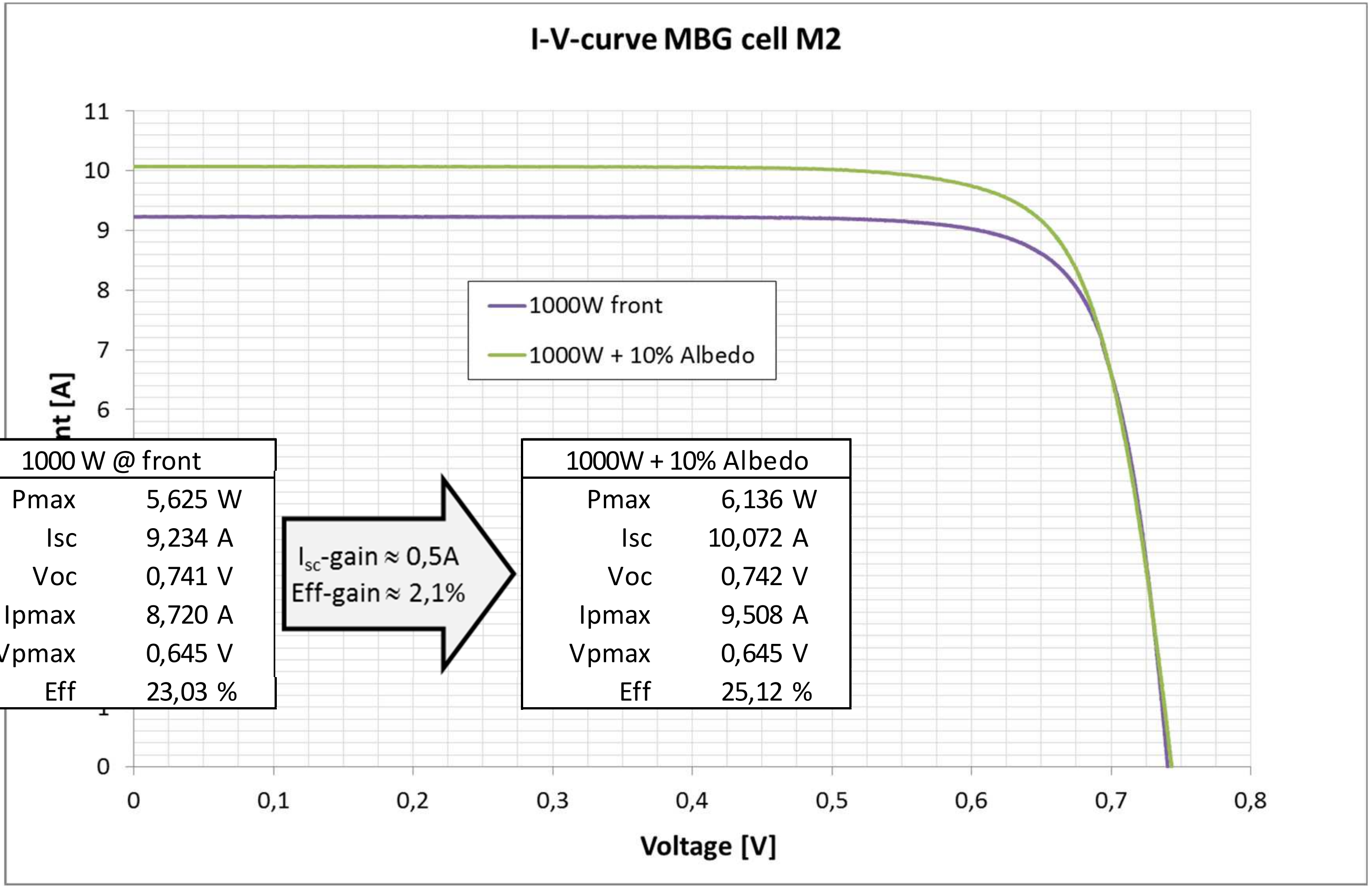
3. **Specific Pmax reporting:**

$$P_{max\_Bifi10} = P_{max} \; with \; G_{rear} = 100Wm^{-2}$$
$$G_{total} = 1000Wm^{-2} + \varphi_{Isc} \cdot 100Wm^{-2}$$

ground material	albedo
snow	0,45-0,9
desert	0,3
greenfield	0,18-0,23
asphalt	0,15

Bifacial properties

- Equivalent Irradiance method according Pasan for Albedo factors of 10% and 20%

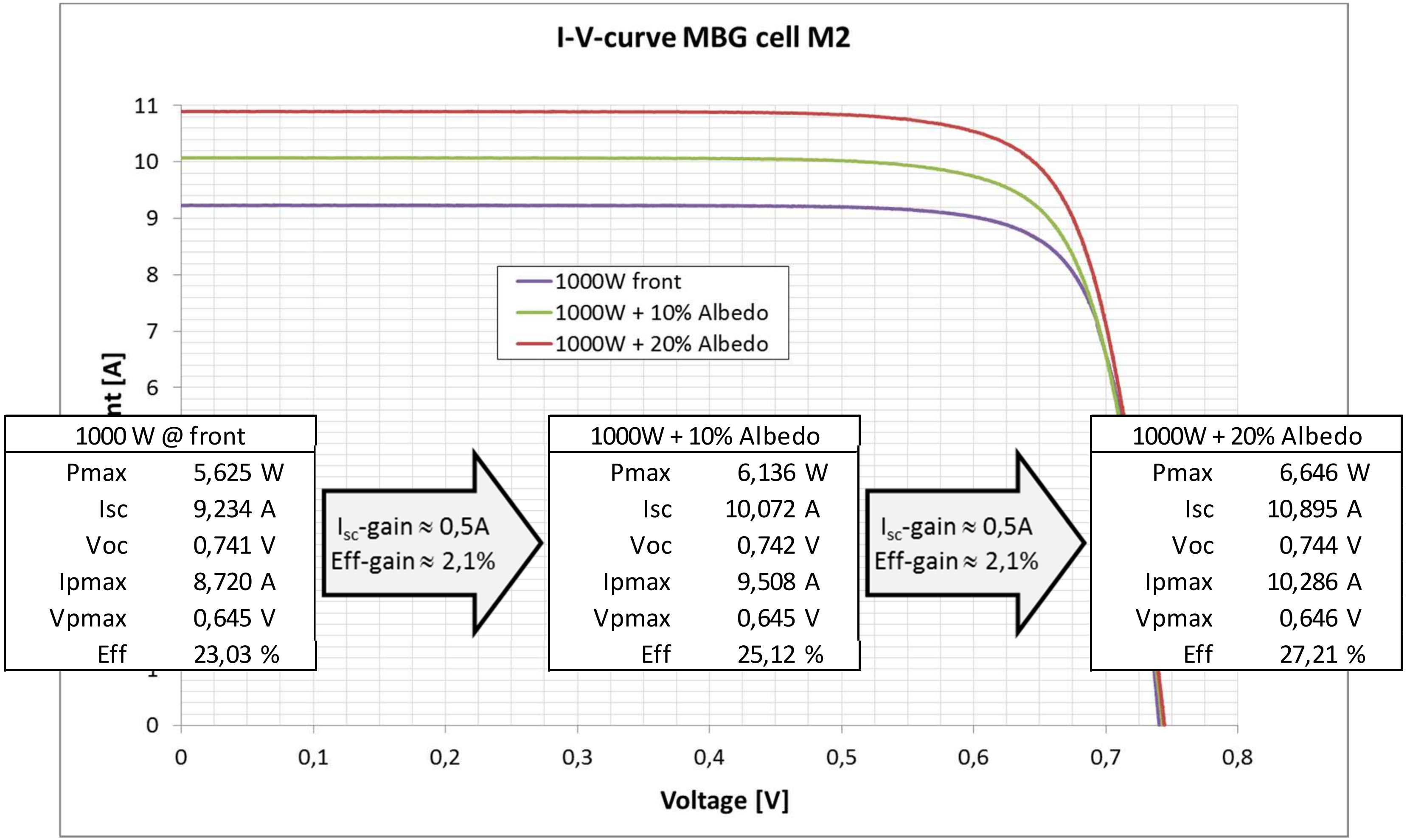


1000 W @ front	
Pmax	5,625 W
Isc	9,234 A
Voc	0,741 V
Ipmax	8,720 A
Vpmax	0,645 V
Eff	23,03 %

1000W + 10% Albedo	
Pmax	6,136 W
Isc	10,072 A
Voc	0,742 V
Ipmax	9,508 A
Vpmax	0,645 V
Eff	25,12 %

Bifacial properties

- Equivalent Irradiance method according Pasan for Albedo factors of 10% and 20%
- $Pmax_{Bifi10}$ = 6,136W (@1093W/m^2) and $Pmax_{Bifi20}$ = 6,646W (@1186W/m^2)



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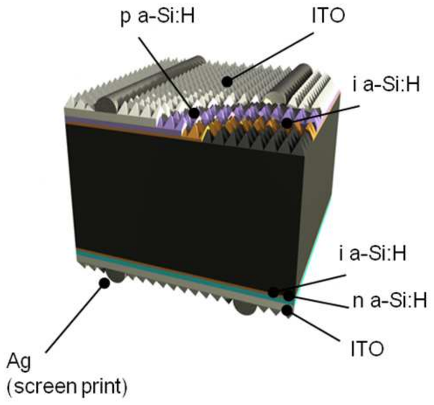
Pmax	6,136 W
Isc	10,072 A
Voc	0,742 V
Ipmax	9,508 A
Vpmax	0,645 V
Eff	25,12 %

1000W + 20% Albedo	
Pmax	6,646 W
Isc	10,895 A
Voc	0,744 V
Ipmax	10,286 A
Vpmax	0,646 V
Eff	27,21 %

- Heterojunction Cell Pilot Line
- Measurement of Busbarless and Bifacial Cells
- **Bifacial SWCT Module Design**
- Summary



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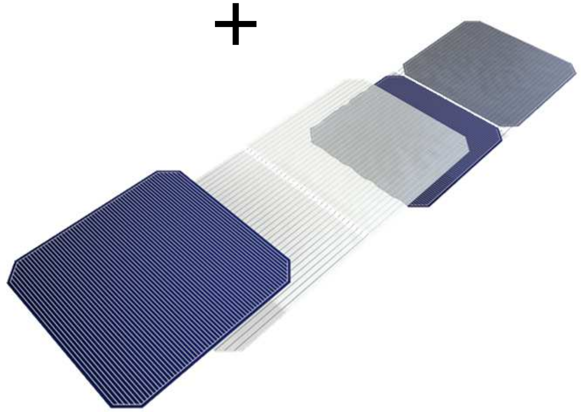
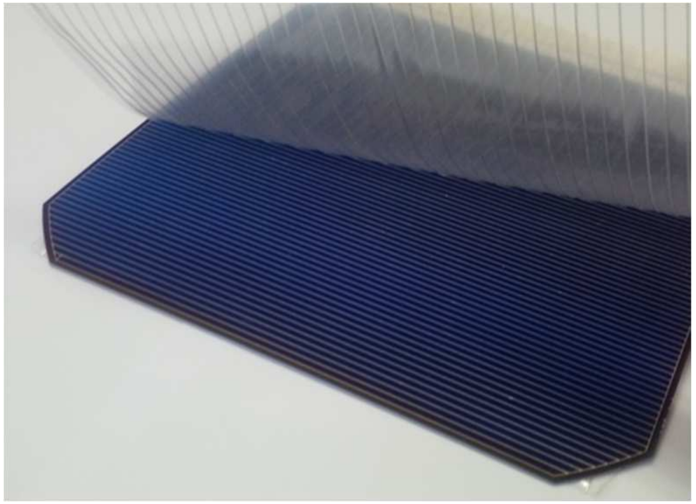


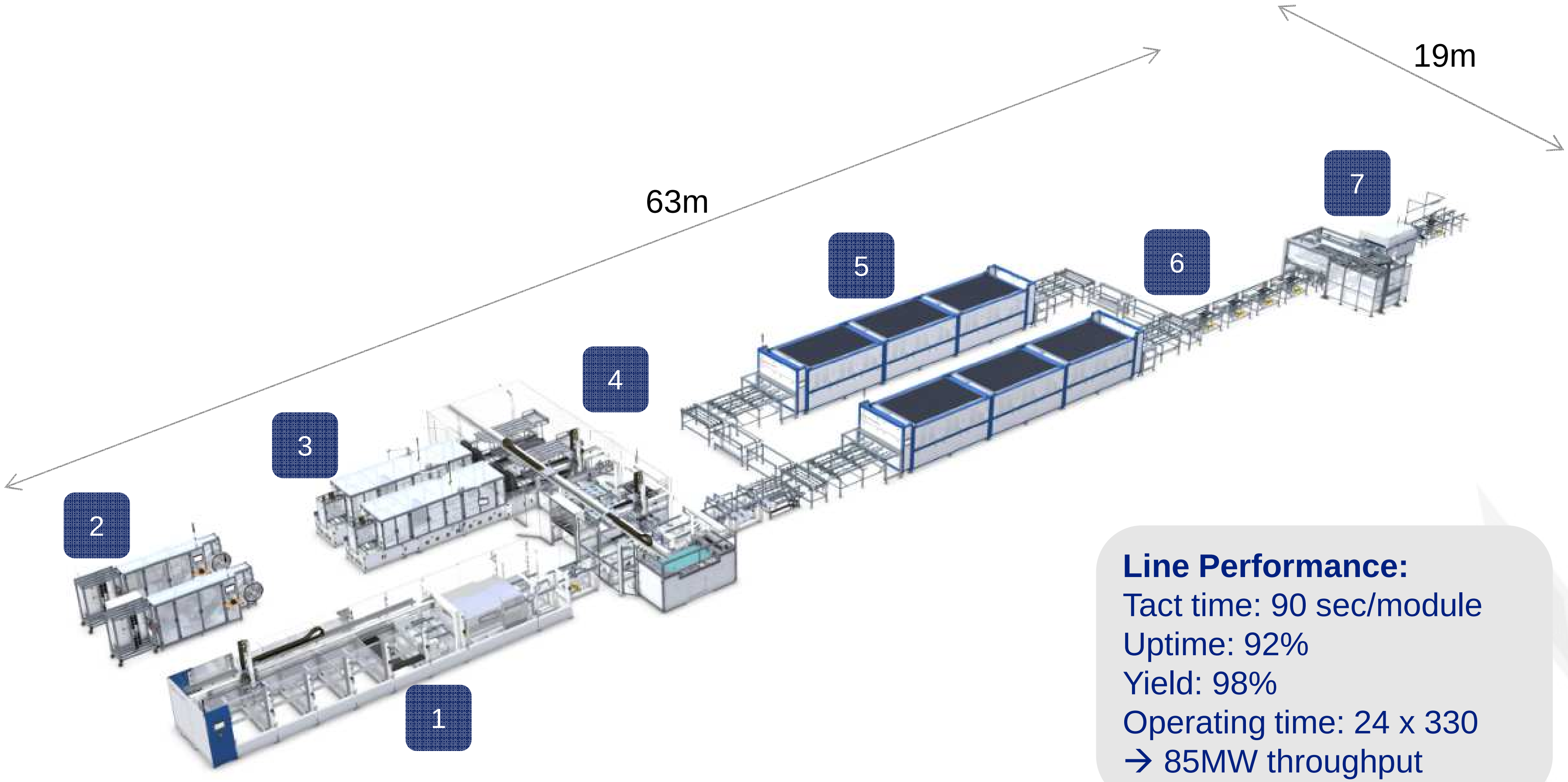
Busbarless Cell Connection



- compatible with very thin wafers
- compatible with all wafer technologies
- up to 7%* more module output power
- over 80%* savings in silver.

* compared to a 3BB cell design

SmartWire Module Line



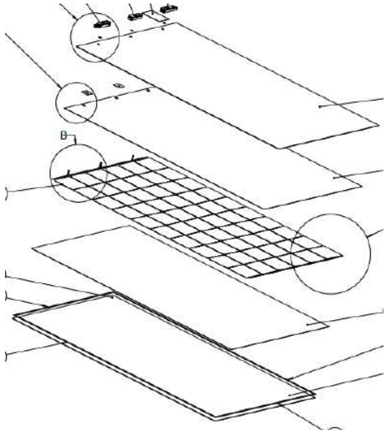
Line Performance:
Tact time: 90 sec/module
Uptime: 92%
Yield: 98%
Operating time: 24 x 330
→ 85MW throughput

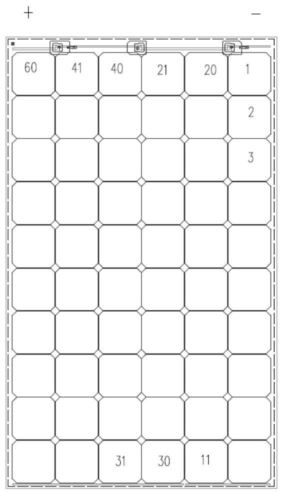
1. Glass Preparation → 2. Foil Wire Assembly → 3. Cell Connection → 4. Matrix, layup & IC → 5.Encapsu-lation → 6. Final Assembly → 7. Testing

*Cell efficiency: 22% (MB HJT Gridtouch measured)
** Indicative value

Module Design in Pilot Produktion

- 2,5mm glass-glass with FS-ARC
- PO based encapsulent
- 60 x M2 size bifacial HJT cells
- SWCT interconnecting (18x 300µm dia.)
- decentralized jbox





Module Production in Thun

- On-going production of about 2200 glass-glass modules with heterojunction cells from MB until week 45
- About 200 produced, including ~30 modules produced with cell efficiency class from 22.2%-22.4%

	Pmax	Voc	Isc	FF
Average power with very low reflective backsheet	309.1	43.8	9.1	77.5%

- When measured with a white backsheet, this is equivalent to a 318.5W module (+3.0%)

Golden Module in Pilot Production
(standard bill of material)

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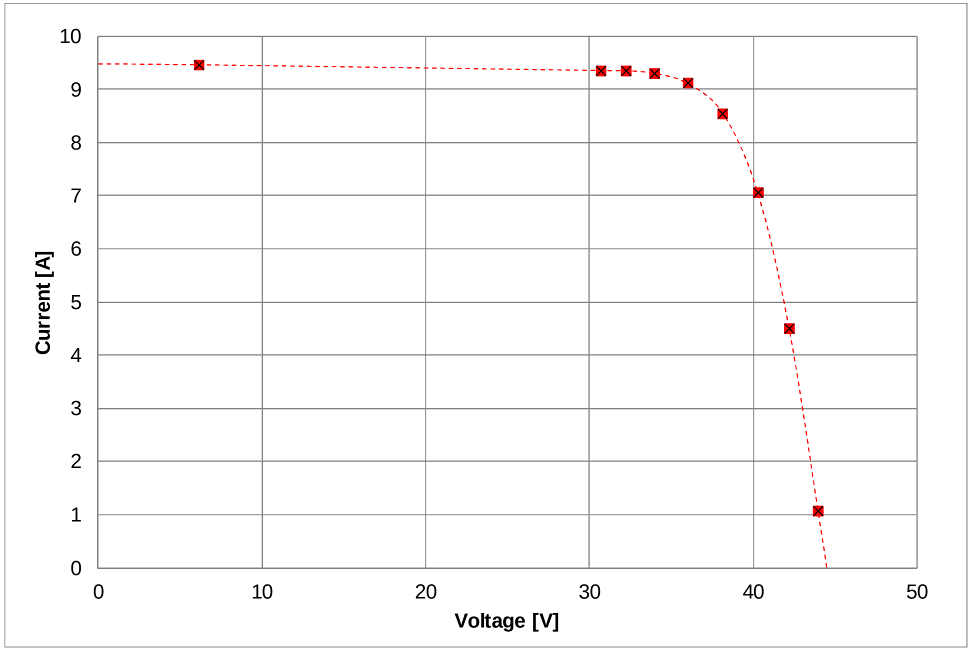
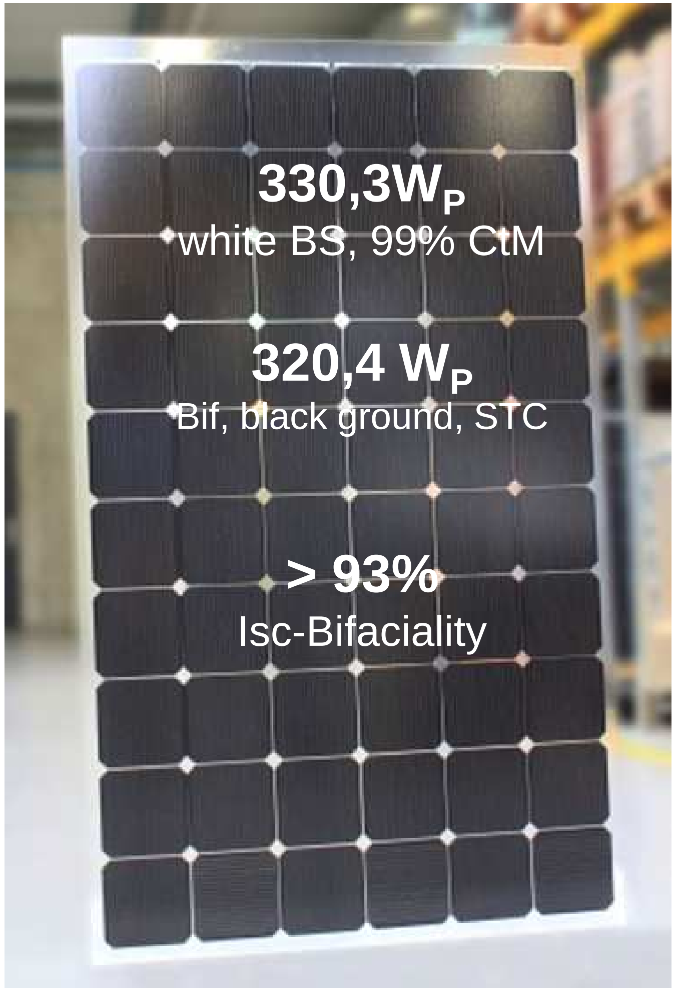


	Pmax[W]	Vmp [V]	Imp [A]	Voc [V]	Isc [A]	FF [%]
front_white BS	330,29	36,90	8,95	44,49	9,46	78,45%
back_white BS	302,24	36,48	8,28	44,40	8,74	77,91%
front_black BS	320,42	36,92	8,68	44,42	9,07	79,52%
back_black BS	296,09	36,88	8,03	44,35	8,45	78,98%



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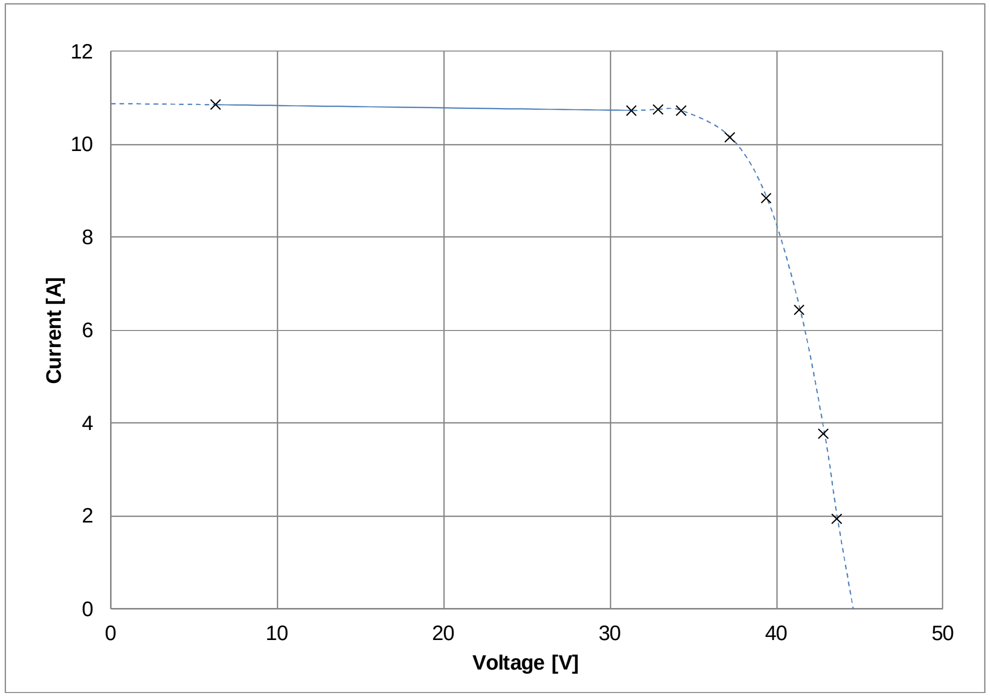

$P_{eq.\ \mathbf{BiF\ 20}} = 379{,}85\ W_p$

60 x 6inch cell module

Measurement conditions						
DUT's temperature:	25,47	[℃]				
Average Irradiance:	1.175,03	[W/m²]				
Electrical performance at STC summary						
Pmax[W]	Vmp [V]	Imp [A]	Voc [V]	Isc [A]	FF [%]	h[%]
379,85	36,59	10,38	44,61	10,85	78,47%	0,23

Summary

- Meyer Burger has successfully combined high efficient cells with a novel interconnection technology
- Since 2015 more than 500.000 HJT busbarless cells were produced (Eta $_{med}$ >22%)
- HJT & SWCT is preferred for **bifacial module** design
- **J_{sc}-bifaciality of 93%** has been achieved

Move in to the 1st european cell line customer in Jan. 2017

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Competitive Production costs

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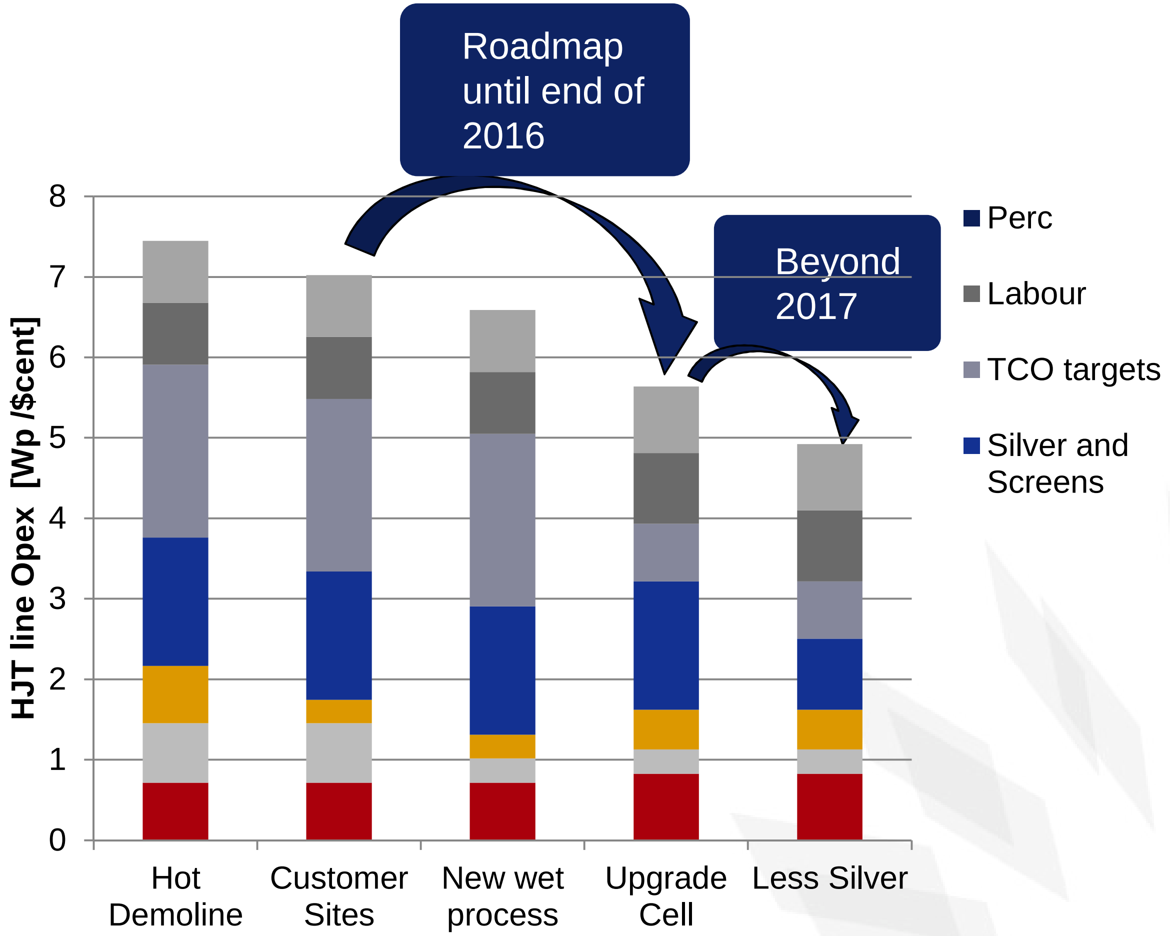
Cost per WP

Cell line Opex*

- Current cell conversion cost below 7$Cent/Wp
- 5$Cent/Wp in 2017
- Opex cost down applicable to current equipment

*95% yield, Opex only



$/Wp

Note:
- CoO depending on region and assumptions
- Capex not included
- M2 wafer size 22,5% cell efficiency

Levelized cost of electricity

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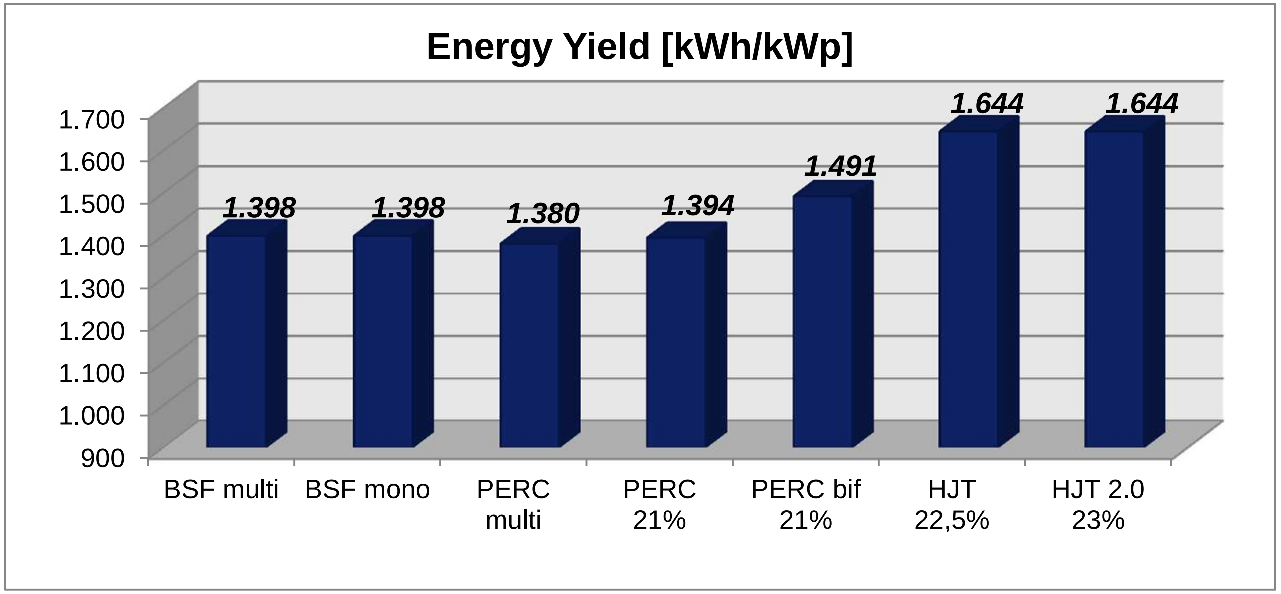

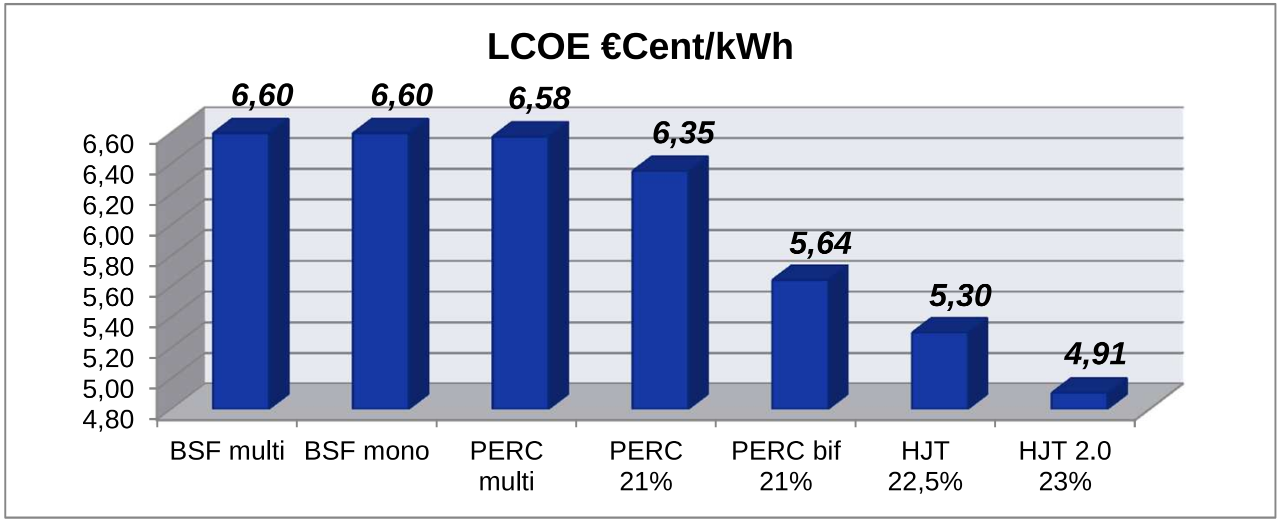

Assumptions

- **1600 kWh/m2** yearly irradiation
- **55℃** average module working temperature
- **25 years** system lifetime
- 1-2% LID for PERC
- **10%** albedo effect for **HJT bifacial**
- **6%** albedo for **PERC/PERT/L** bifacial