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module integration for back contact back junction solar cells

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1: International Solar Energy Research Center - ISC Konstanz
2: Eurotron BV

Introduction: IBC module

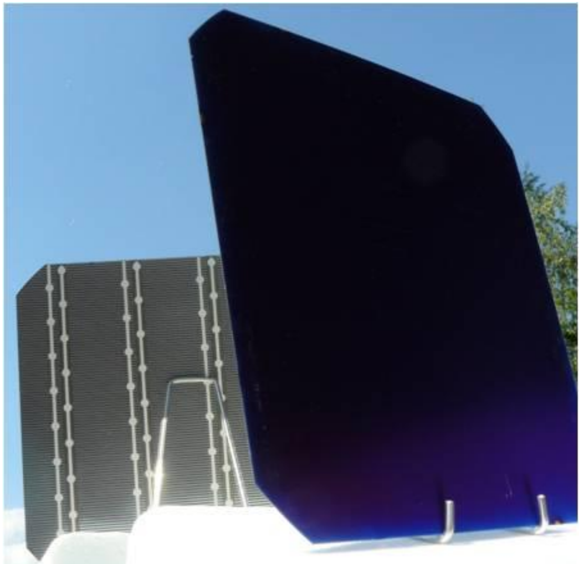
Advantages:

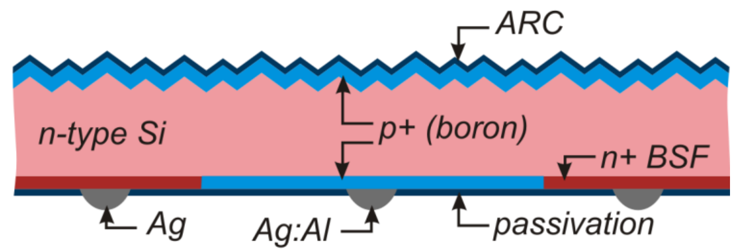
- highest power potential
- uniform optical appearance

Challenges:

- CTM losses
- interconnection method

Introduction: Zebra cell





- Low cost IBC cell
- Screen printed 3D metallization
- 6 inch *n*-type Cz wafer
- Bifacial IBC cell

- Front floating junction
- Industrial processes proven in PERC and PERT fabrication

» Current best efficiency: 22 %

Introduction: main CTM power losses

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standard H-pattern cell

– electrical losses:
  - series resistance → more liberty since all metal is on the rear side

– optical losses and gains:
  - absorption in glass and encapsulant layer → thinner front encapsulation implementable
  - reflection at the interfaces
  - reflection from front metallization → higher CTM loss in Isc
  - reflection from backsheet → increases Isc for bifacial IBC cells

IBC cell

Introduction: interconnection issues

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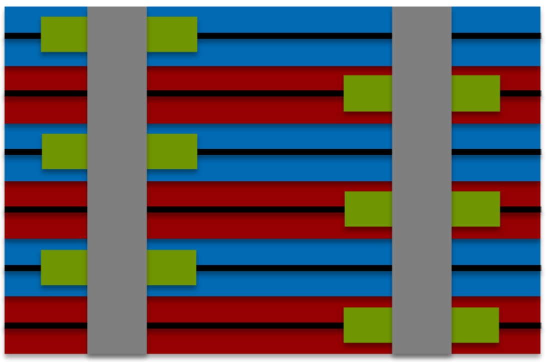
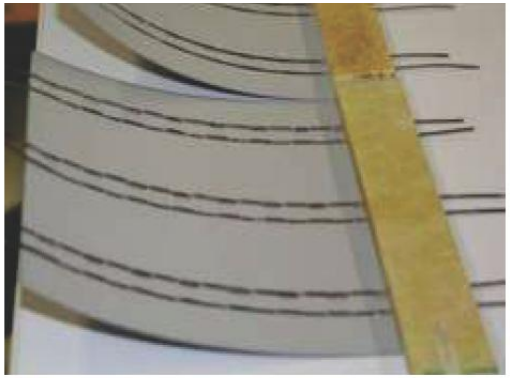
Contacting of both polarities in one plane:



3D metallization of Zebra cell



H. Wirth, Fraunhofer ISE,
2nd MWT Workshop 2010, Amsterdam

-> electrical isolation on cell or module level needed

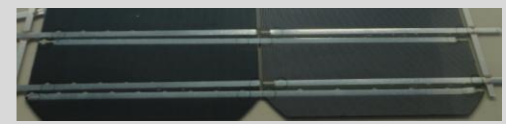
-> compensation of mechanical stress for single sided contacting needed

Introduction: possible interconnection concepts

Classical way: adapted tabber-stringer

Edge stringing (Sunpower)

Continous stringing (e.g. ISC)



new approaches: dedicated equipment

NICE

multi busbar

smartwire

weaving

conductive backsheet

many other great concepts……

Introduction:
possible interconnection concepts

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Classical way:
adapted tabber-stringer

Continous stringing
(e.g. ISC)

new approaches:
dedicated equipment

conductive backsheet

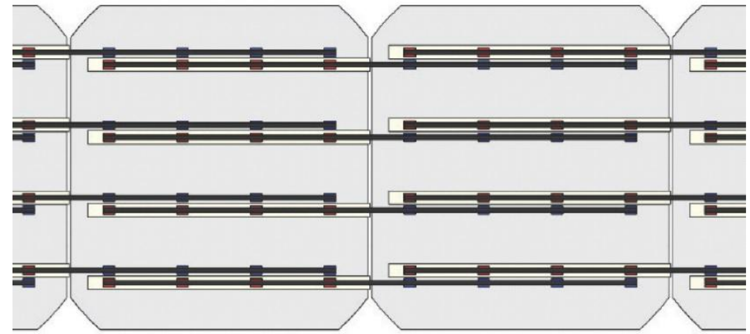
Outline

- ribbon based Zebra modules
  - contacting scheme
  - bifacial module measurements
  - reliability

- Zebra modules assembled with conductive backsheet
  - device optimization
  - results on 60 cell modules
  - cost structure

- outlook and summary

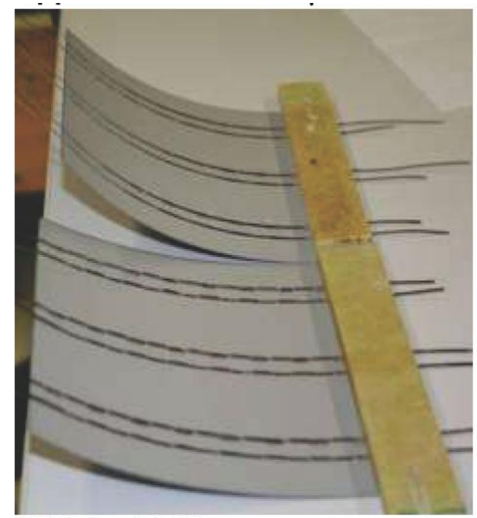
ribbon based interconnection


S. Kaufmann, 4th MWT WS, Amsterdam, 2012

advertages and challenges:

+ easy built-up for cells with asymmetric BB structure
+ existing technology with long term experience
+ bifaciality implementable
+ EI inspection of string possible

- special upgrade for stringer needed
- bowing problem


H. Wirth, Fraunhofer ISE,
2nd MWT Workshop 2010, Amsterdam

ribbon based interconnection: contacting scheme

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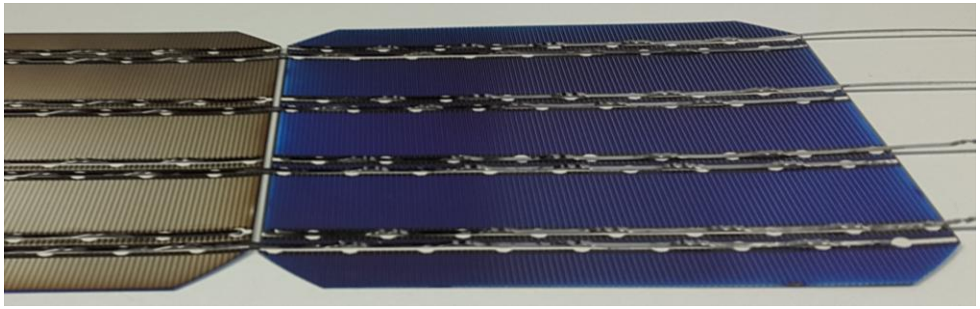
assembly process at ISC to overcome excessive bowing

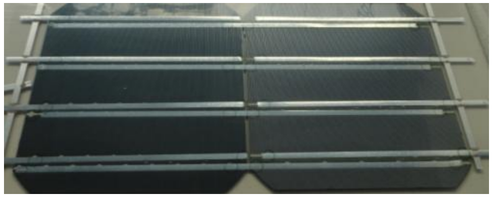
a) soldering of stress relieved ribbon

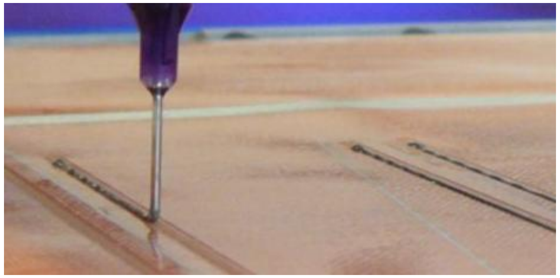
+ long term stability
- high mechanical stress



b) gluing of electrically conductive adhesive (ECA)

+ low mechanical stress
- reliability ?





ribbon based interconnection: performance

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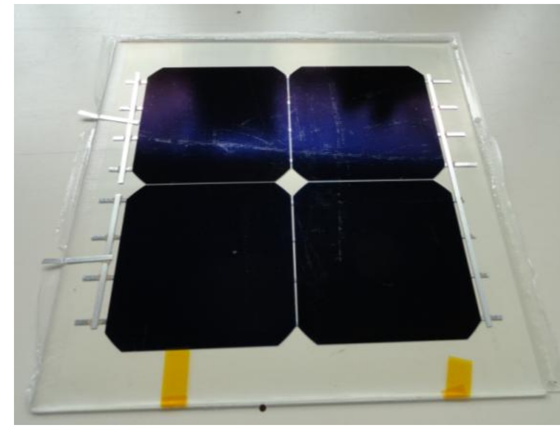
Both techniques yield similar results !

- > choice of ribbon main factor for series resistance losses



best results so far:

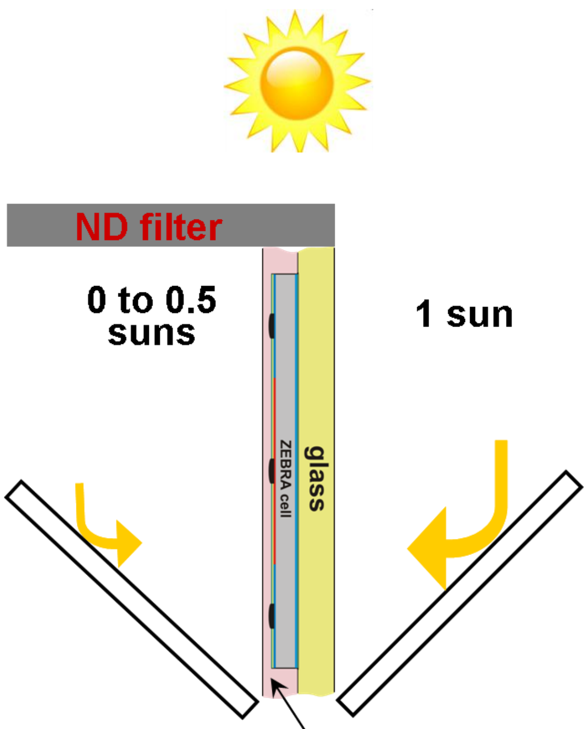
module	Voc (V)	Isc (A)	FF (%)	Pmpp (W)	Eta (%)	CTM power (%)
bifi module front side	2.65	9.85	76.8	20.0	20.2*	1.5
bifi module rear side	2.62	7.03	78.0	14.3	14.4*	

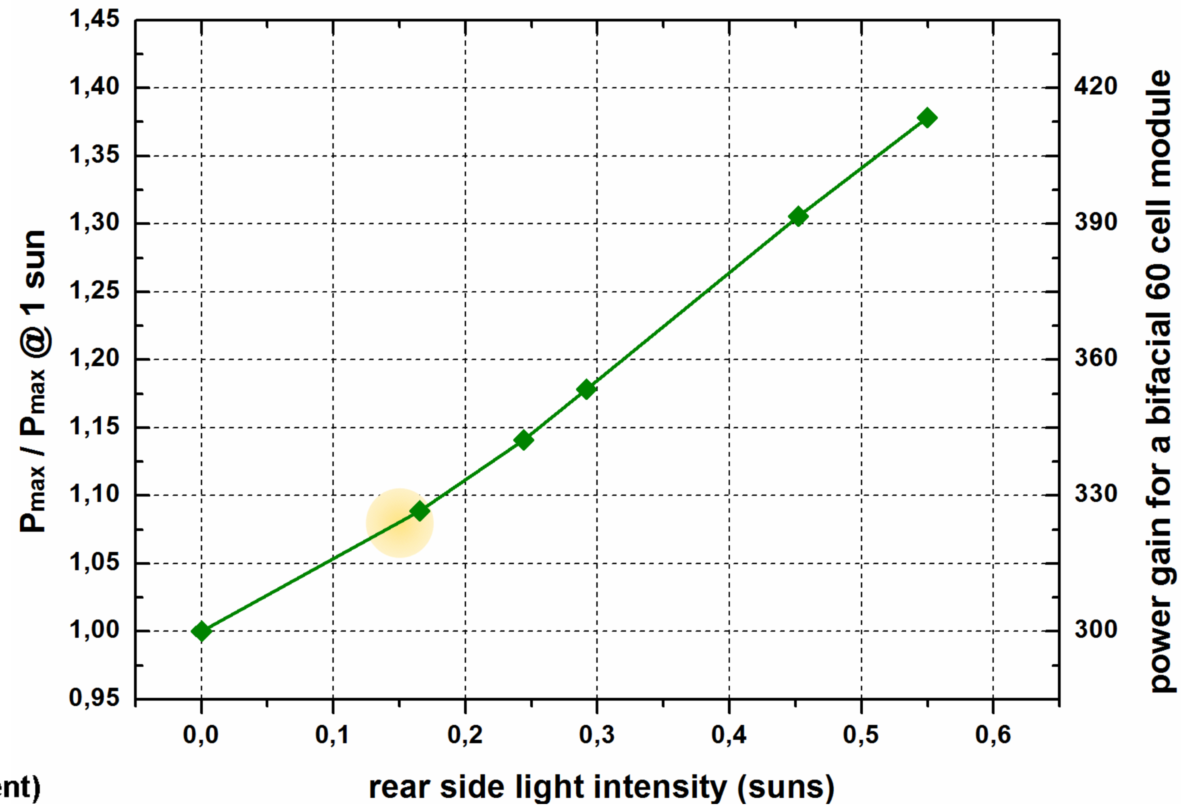
bifi factor: P rear / P front = 0.71

*measured with black frame in 1 mm distance to edge cells

ribbon based interconnection: bifacial measurements

both side illuminated IV measurements on a one-cell-module:

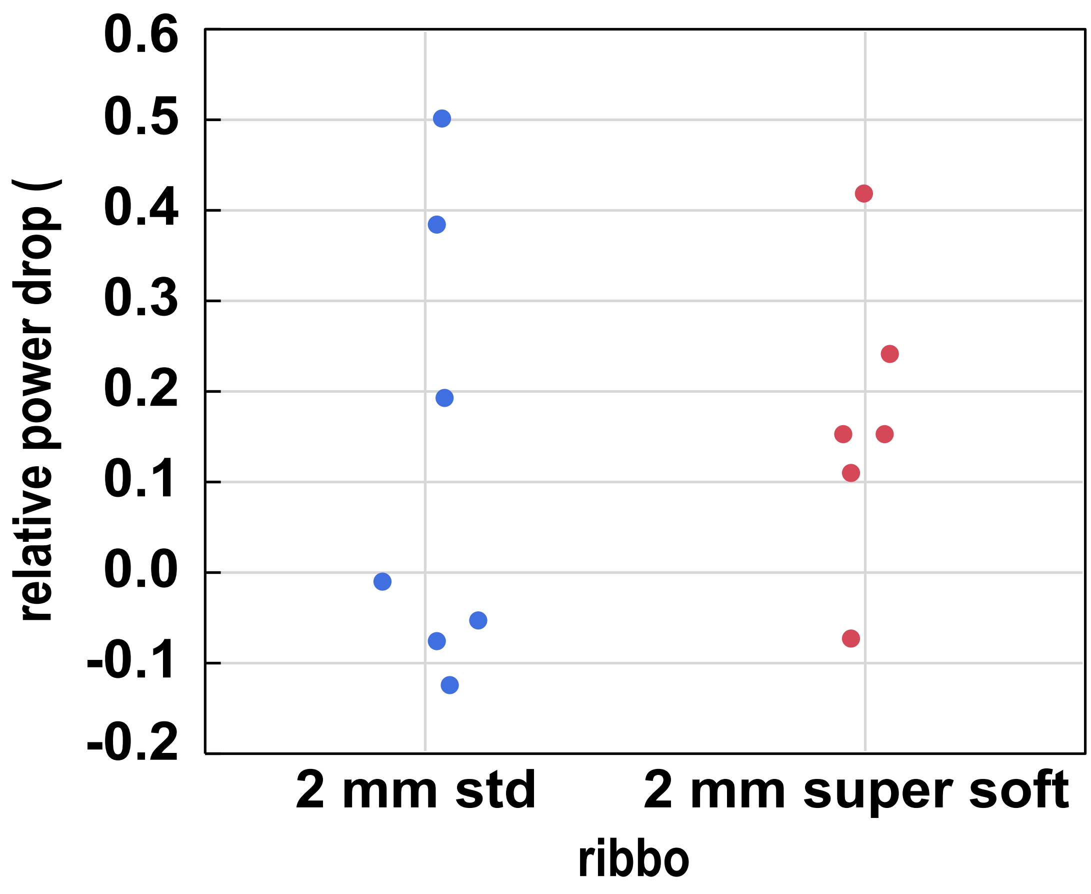




bifaciality factor: $P_{REAR} / P_{FRONT} = 0.77$

ribbon based interconnection: reliability

TC 200 testing of soldered one-cell-modules:



ribbon based interconnection: reliability

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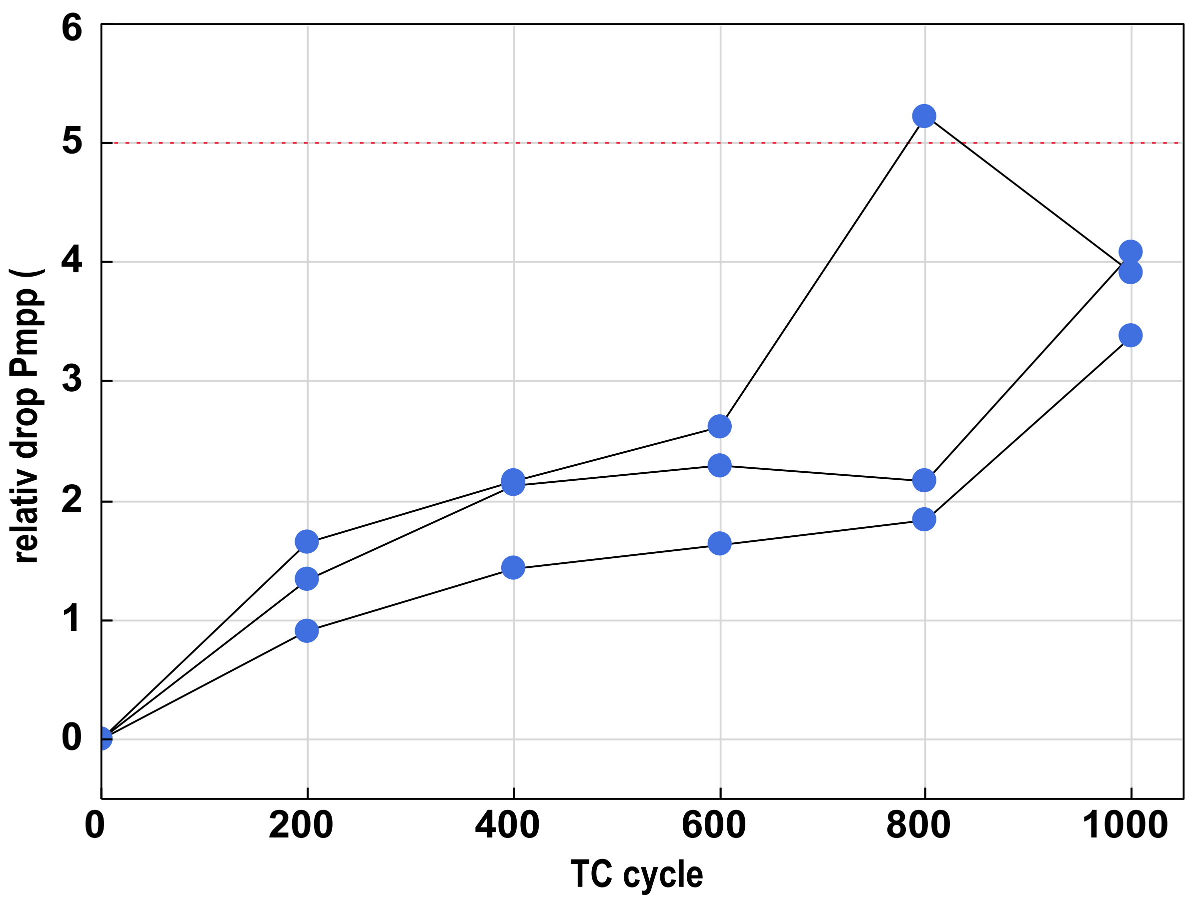
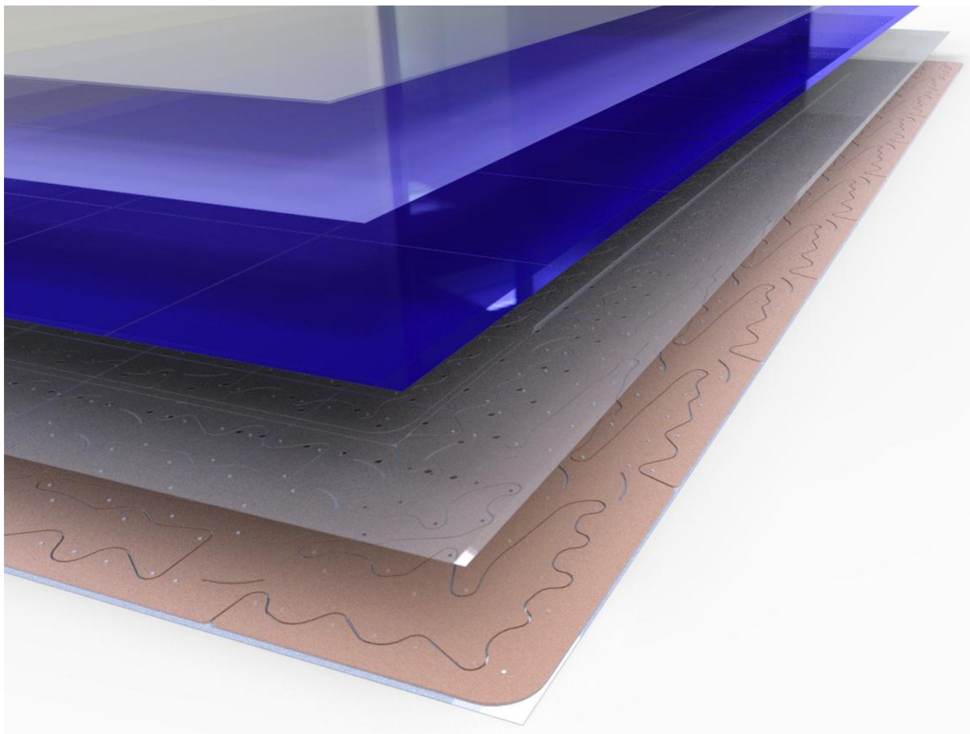
temperature cycle testing up to TC 1000 for ECA glued one-cell modules:



conductive backsheet (CBS) approach

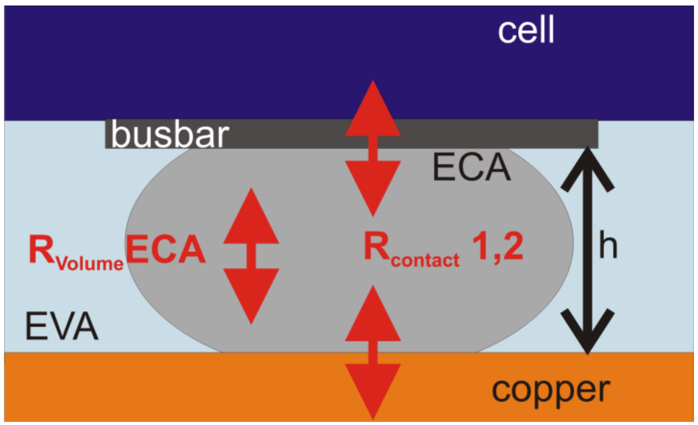


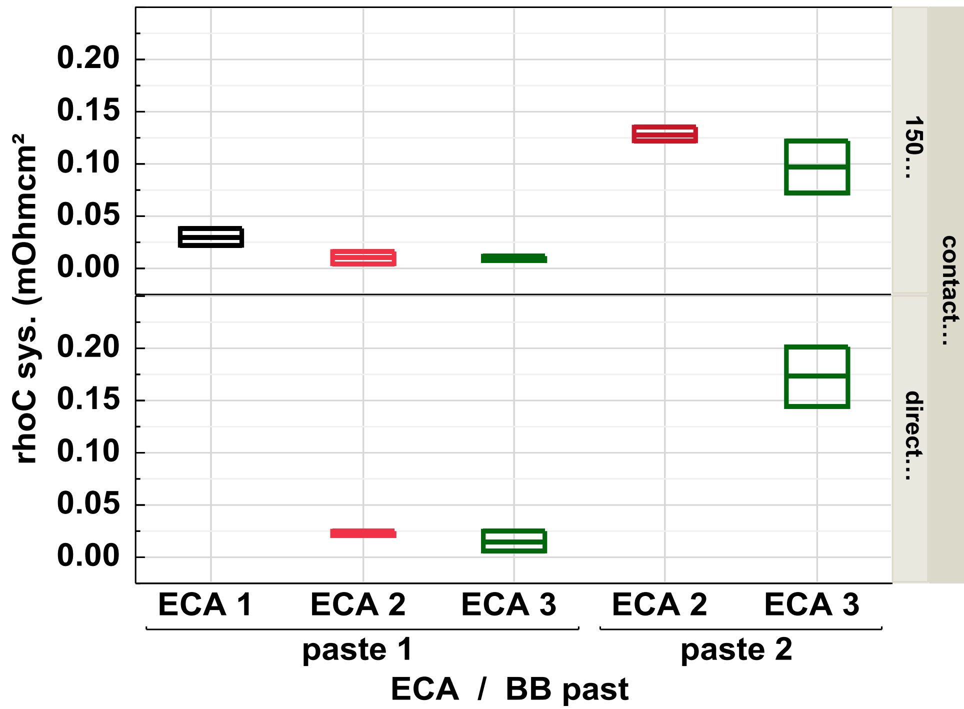
- Pick and place: low stress on cell
- Cu backsheet: low R_{series}
- Small cell spacing
- Flexible rear design
- Proven in mass production

» Good candidate for fast transfer to industry

CBS: contact optimization with ECA

Contact resistance measurements:





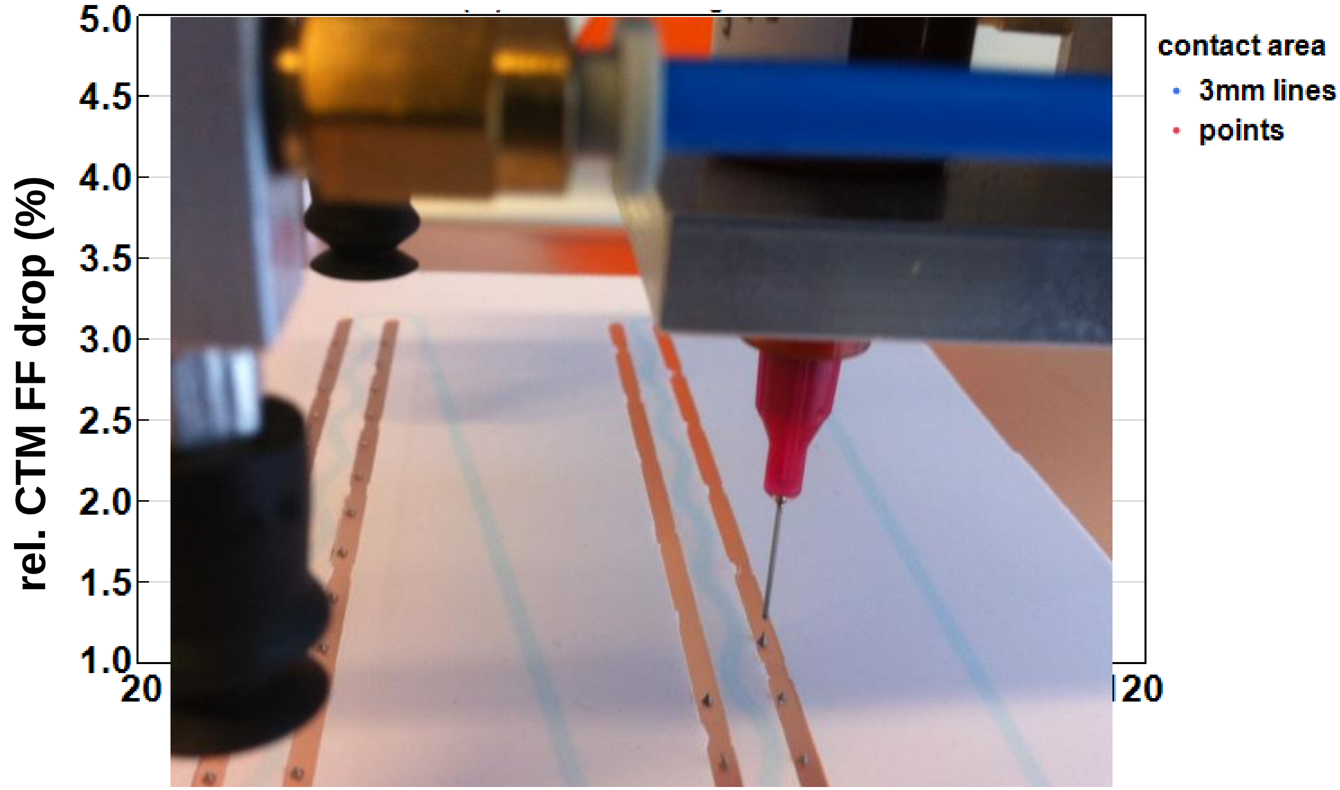
Measured quantity:

R_C system = $R_{C1} + R_{C2} + R_{Vol}$ (h)

h : contact height

CBS: optimization of contact pattern

optimization on ECA layout: **points** versus **3mm lines**



-> quantity of contact points more significant that contact area

CBS: reliability

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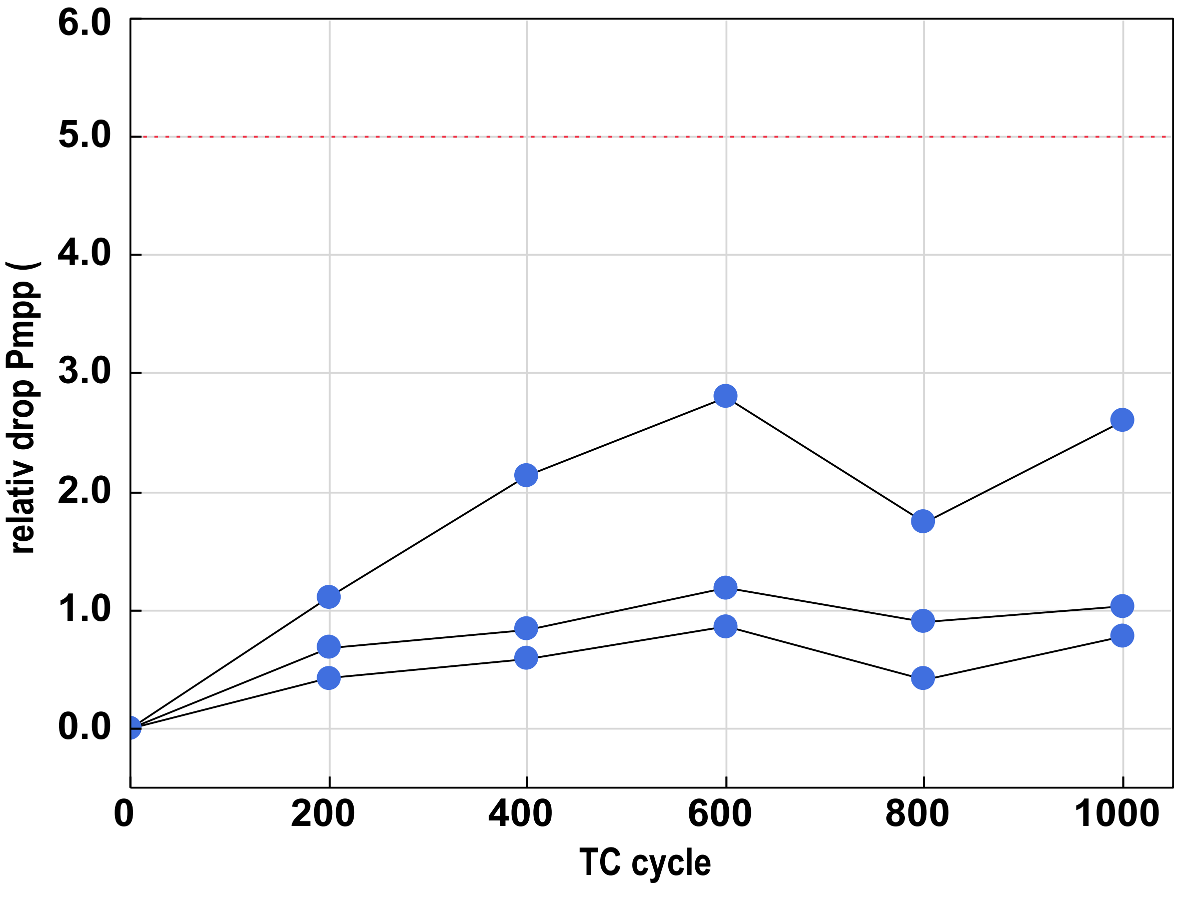
temperature cycle testing up to TC 1000:



CBS: 60-cell Zebra modules

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Cell preparation at ISC Konstanz during Hercules pilot line experiment:

Group	I_{MPP} (A) Mean	Std. Dev.	P_{MPP} (W) Mean	Std. Dev.	Σ P_{MPP} (W)
A	9.18	0.016	5.10	0.026	306
B	9.13	0.016	5.06	0.03	304
C	9.07	0.019	4.99	0.037	299

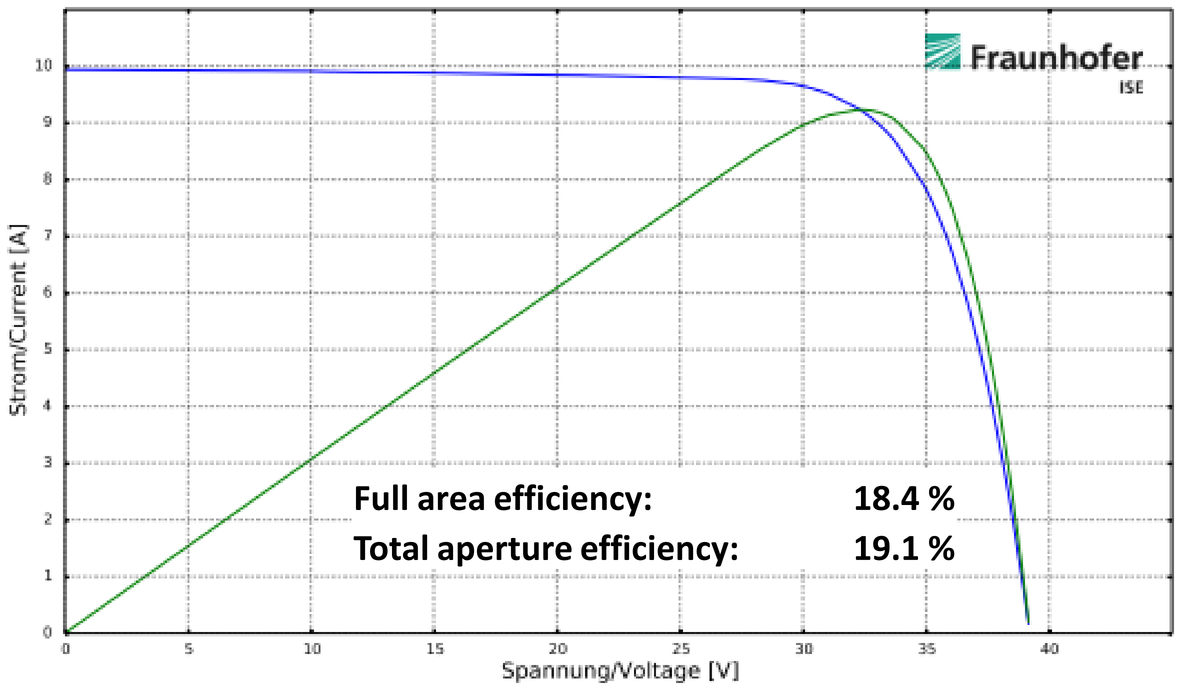
Module production at Eurotron´s competence center:

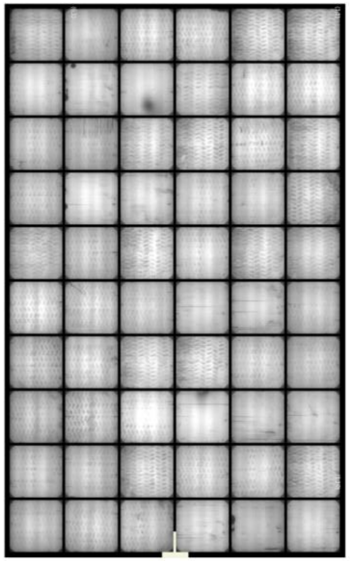
		Isc (A)	Voc (V)	FF (%)	P_{MPP} (W)
Module	**A**	**9.97**	**39.3**	**77.1**	**303**
CTM (%)		-0.6	0.00	1.8	1.1
Module	**B**	**9.94**	**39.2**	**76.5**	**298**
CTM (%)		-0.7	-0.05	2.4	1.7
Module	**C**	**9.84**	**39.1**	**76.3**	**294**
CTM (%)		-0.6	0.04	2.3	1.8

CBS: certified module measurement

ISE Callab measurement:

	Module	I_{SC} (A)	V_{OC} (V)	FF (%)	P_{MPP} (W)
IV @ Callab	B	9.94	39.24	76.5	298.3





CBS: Short term improvements

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Calculated power increase with identical cell and module process:

Module configuration	Power (W)
Current status	**303**
Use 22 % cell efficiency instead of 21.4 %	**311**
Introduce M2 wafers (now M0)	**319**
Increase cell spacing from 1.25 to 4 mm	**322**

Comparison to example high end c-Si modules on the market:

	Module	Technology	Area (m^2)	Cells / Size	Power (W)
	SunPower	*N* IBC	1.66	96 / 5 inch	345
next week:	***Zebra***	***N* IBC**	***1.68***	***60 / 6 inch***	***322***
today:	***Zebra***	***N* IBC**	***1.62***	***60 / 6 inch***	***303***
	Yingli	*N* PERT	1.63	60 / 6 inch	300
	Solarworld	*P* PERC	1.68	60 / 6 inch	295
	Trina	*P* PERC	1.63	60 / 6 inch	290

CBS: CoO calculation

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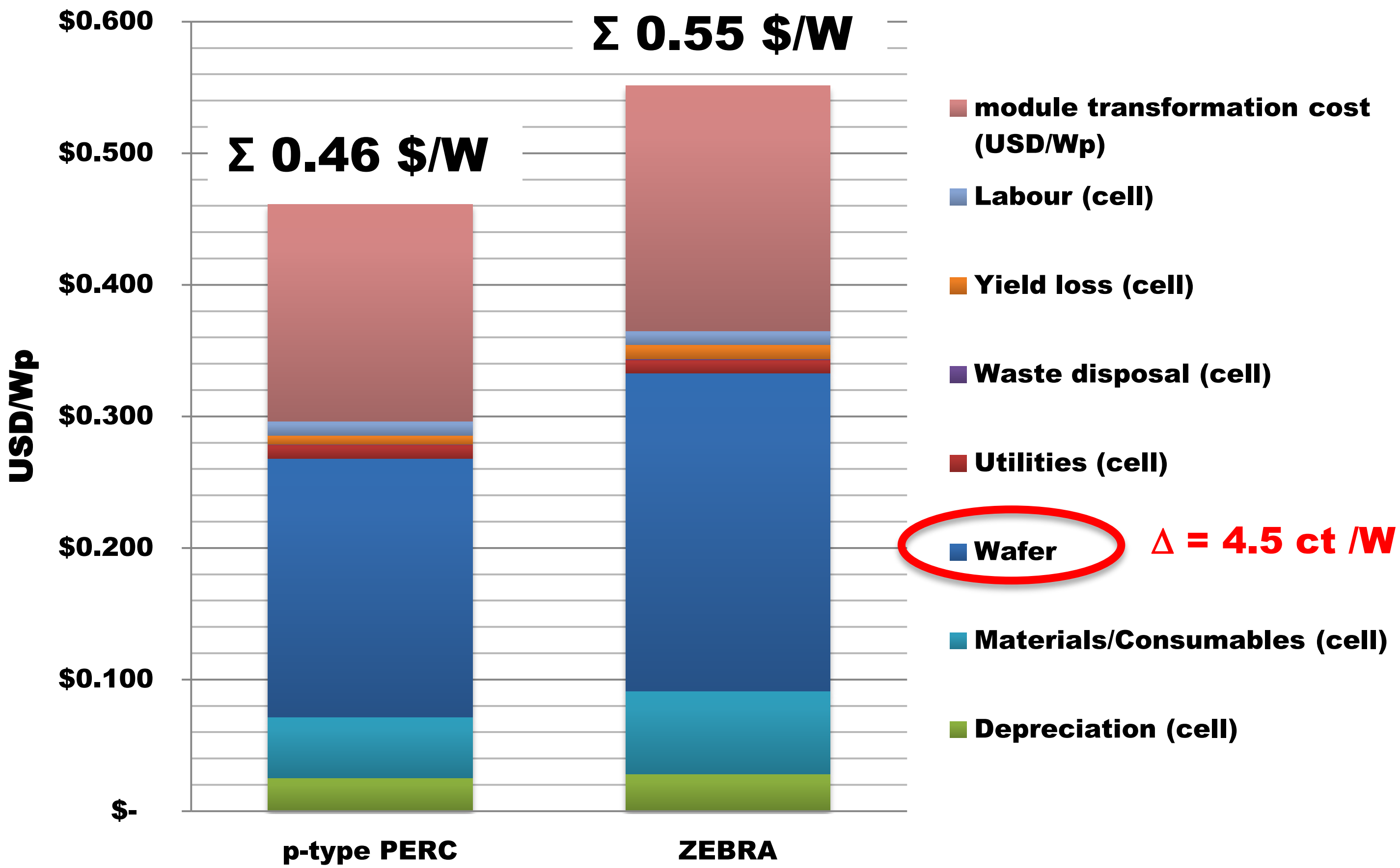


	p-type PERC	ZEBRA
Cell efficiency:	**20.5%**	**22%**
Module power:	**300 W**	**322 W**

Outlook: Zebra half cell module

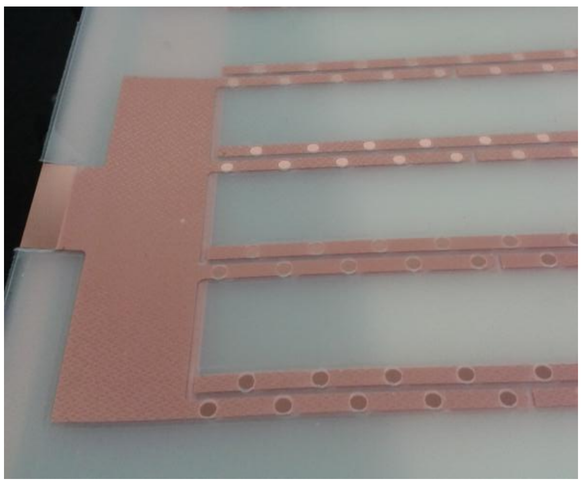
	Isc (A)	Voc (V)	FF (%)	P_{MPP} (W)
Module*	**5.0**	**79.0**	**77.3**	**308**
CTM (%)	-2.8	0.05	0.4	**-3.2**

* measured at EDF

Outlook: new concept

Bifacial conductive backsheet - proof of concept :

Transparent rear backsheet
with copper tracks:



(designed by ISC Konstanz
produced by Coveme)

Bifacial Zebra module:

First prototype P_{front} = 18.1 W, bifaciality factor = 0.7
(produced at ISC Konstanz)

Outlook: outdoor performance 4 cell modules

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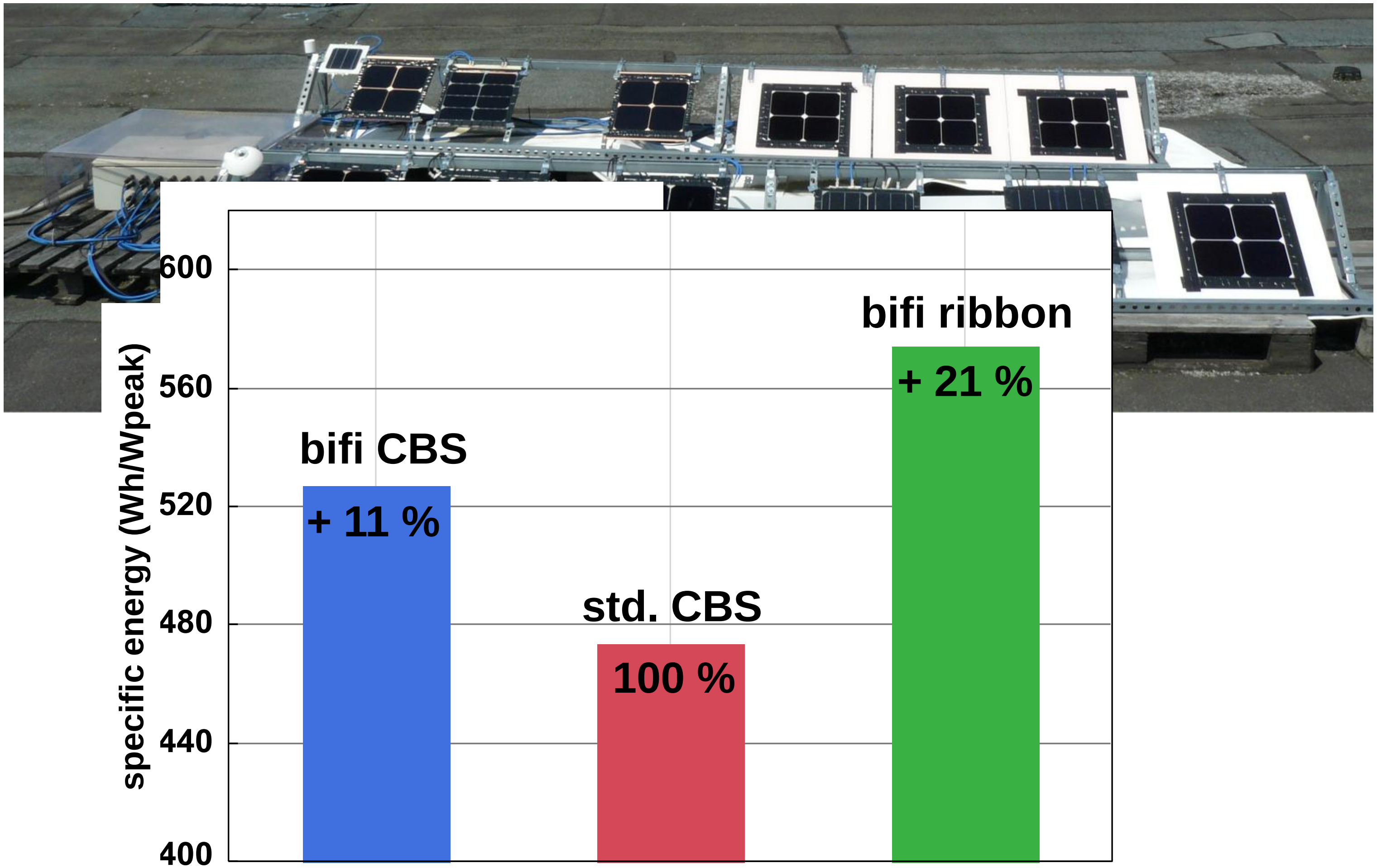

Outdoor performance Zebra modules measured between 12-2015 and 05-2016

Summary

- ribbon interconnection possible for Zebra cells soldered or ECA glued
- bifacial 4-cell module with 20.2 % front efficiency and 71 % bifi factor
- Assembly of Zebra cell in conductive backsheet module possible
- 60-cell module with 303 W power output based on industrial cell and module processes and 308 W module with 120 half cells
- Short term improvements up to 322 W feasible with competitive cost structure

Acknowledgement

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Thank you for your attention !