PV MODULE TECHNOLOGIES – CONCEPTS AND CHALLENGES

Ulrich Eitner, Sebastian Nold, Max Mittag

Fraunhofer Institute for Solar Energy Systems ISE

Future PV forum 2017
Intersolar Munich, June 1st, 2017

www.ise.fraunhofer.de
www.moduletec.de

© Fraunhofer ISE
FhG-SK: public

Fraunhofer ISE

AGENDA

- LCOE or COO?
- CTM-analysis
- Module concepts

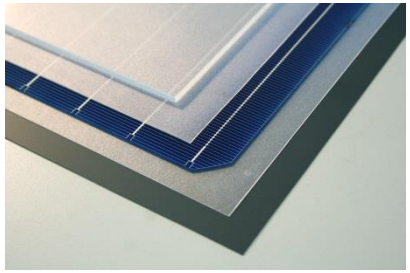
Module Technology Center - ModuleTEC

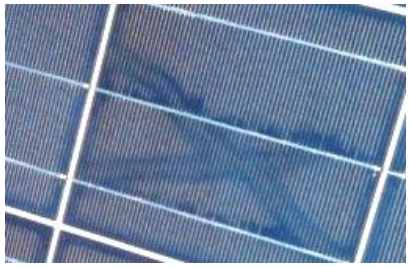
© Fraunhofer ISE
FhG-SK: public
Fraunhofer ISE

LCOE or COO?
Aspects of LCOE

LCOE [€/kWh]

- Manufacturing cost
- Maintenance cost
- Energy
  - Initial power
  - Angular incidence
  - Irrandiance levels
  - Temperature effects
  - Location / weather data
  - Degradation / reliability





© Fraunhofer ISE
FhG-SK: public
Fraunhofer ISE

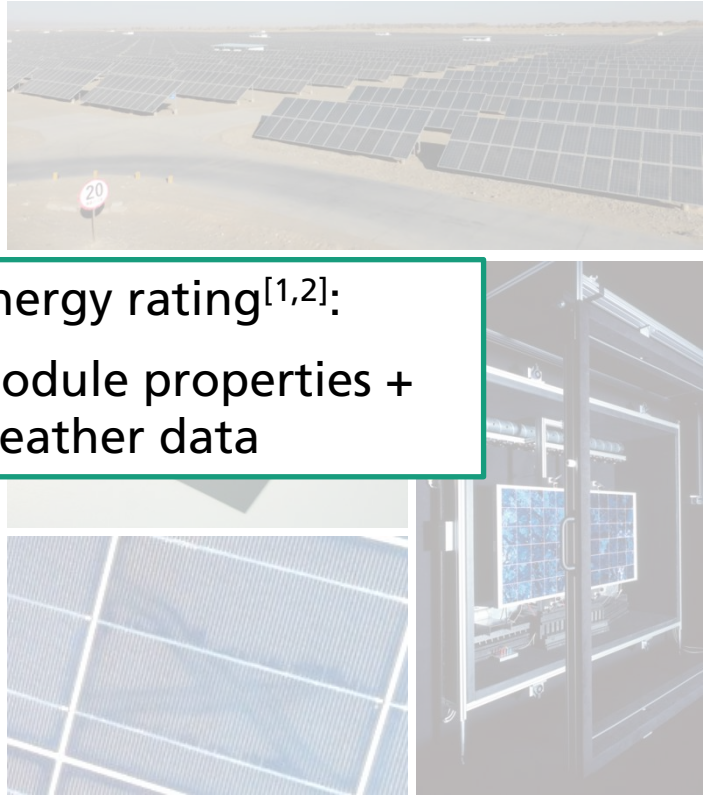
LCOE or COO?
Aspects of LCOE

LCOE [€/kWh]

- Manufacturing cost
- Maintenance cost
- Energy
  - Initial power
  - Angular incidence
  - Irrandiance levels
  - Temperature effects
  - Location / weather data
  - Degradation / reliability

Energy rating[1,2]:

module properties + weather data



[1] Dirnberger et al., Progress in PV 23(12), 2015
[2] IEC 61853 standard, in progress

© Fraunhofer ISE
FhG-SK: public

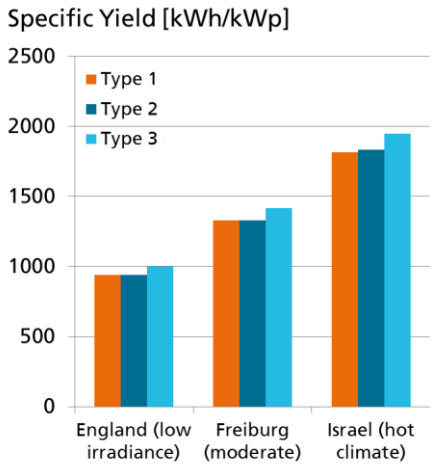
Fraunhofer ISE

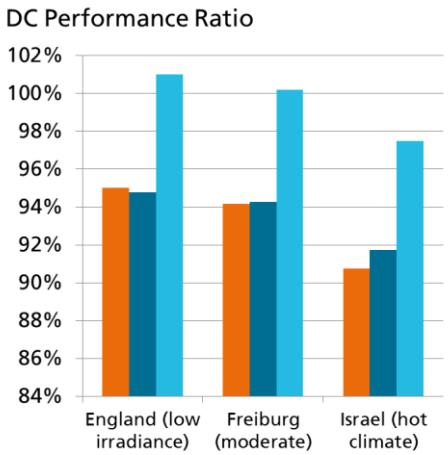
LCOE or COO?
Energy Rating of PV modules

- Laboratory measurements (Fraunhofer CalLab PV modules)
  - STC (1.5% measurement accuracy)
  - Power Rating (15-75°C, 100-1100 W/m²)
  - Spectral response
  - Reflection
  - NOCT

$$Y_{DC} = H_{POA}\, \eta_{STC}\, A_{module}\, f_{AOI}\, f_{spectral}\, f_G\, f_T\, f_{stability}$$

- Comparison of module performance by energy rating for diffent locations



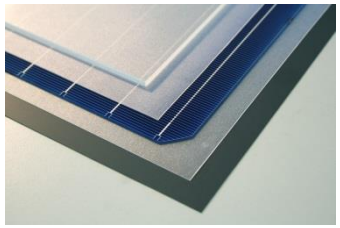


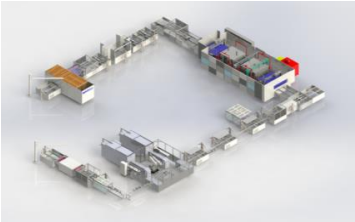
© Fraunhofer ISE
FhG-SK: public
Fraunhofer ISE

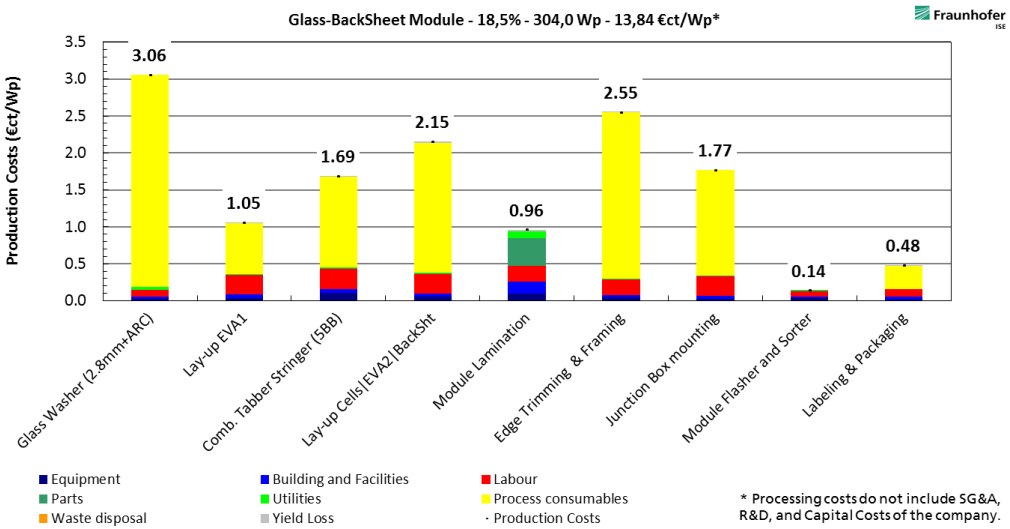
LCOE or COO?
Aspects of COO

COO [€/W_p]

- Manufacturing cost
  - Process cost
  - Material cost
  - Labour
- Module Power
  - STC





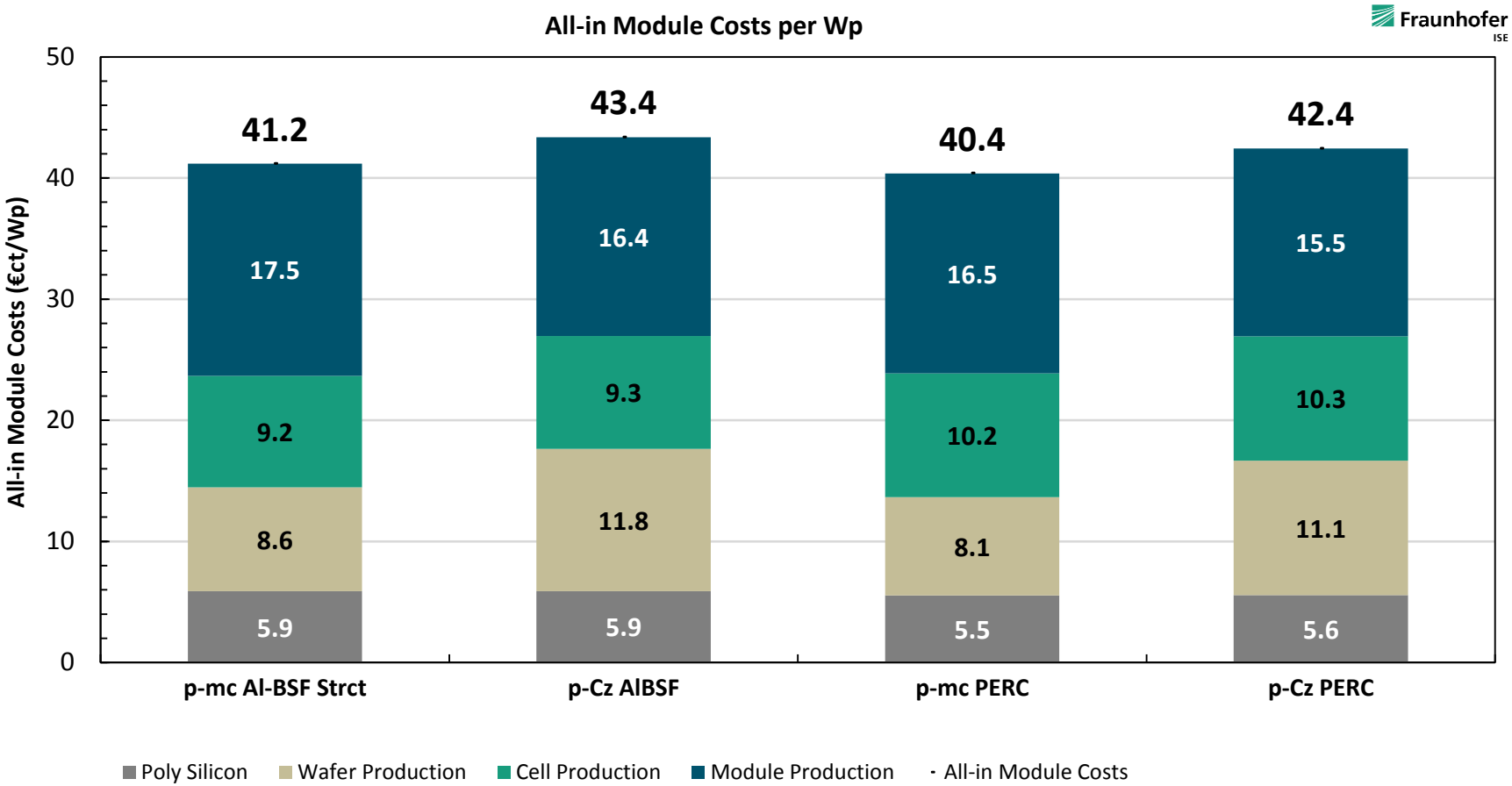


Nold et al., Proc 27th EUPVSEC, 2012

© Fraunhofer ISE
FhG-SK: public

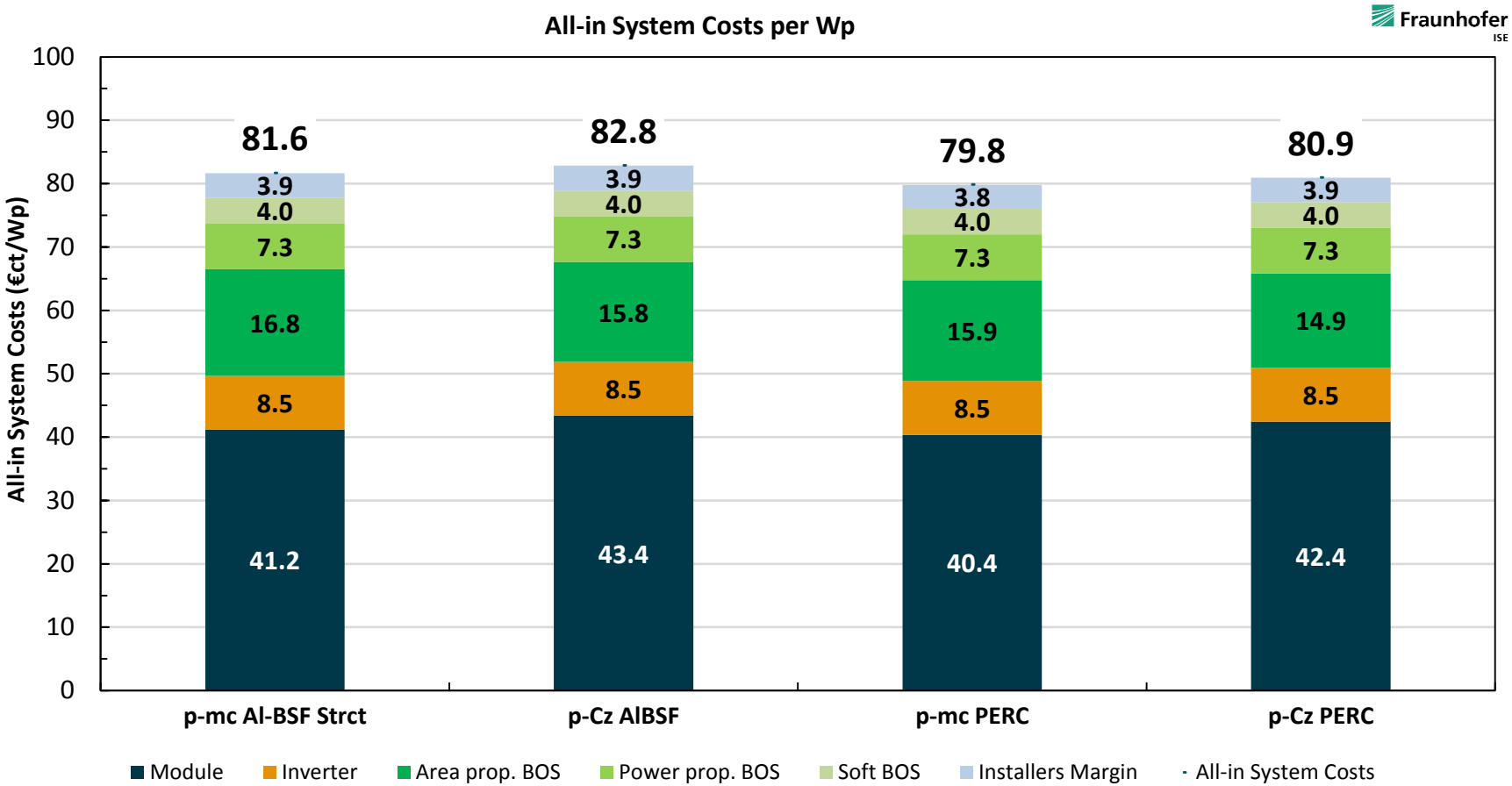
Fraunhofer ISE

Power or efficiency?
COO-study: Al-BSF vs PERC



© Fraunhofer ISE
FhG-SK: public
Fraunhofer ISE

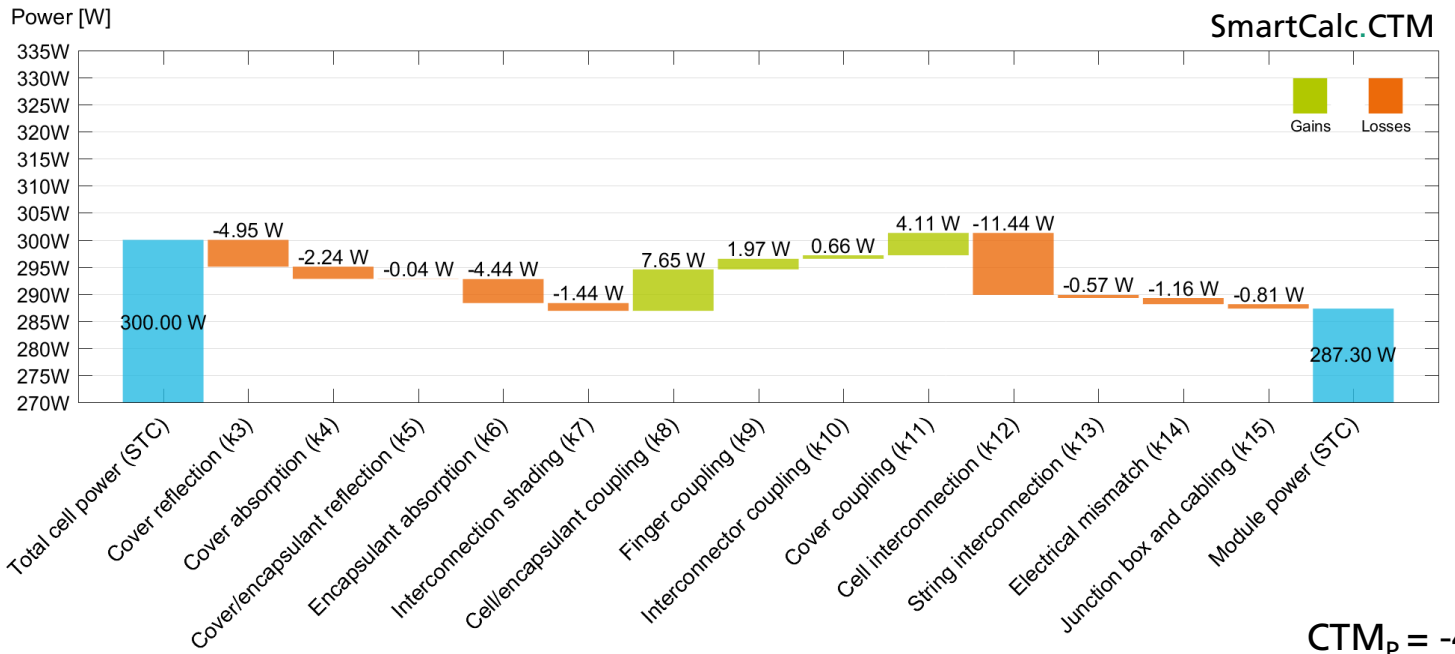
Power or efficiency?
COO-study: Al-BSF vs PERC



© Fraunhofer ISE
FhG-SK: public

CTM-analysis
Method

- Module example
  - Cell 20.35%, 5 W_p
  - 3BB, Glass-Backsheet



CTM_P = -4.2 %

[1] Haedrich, I. et al., SOLMAT 131, 2014

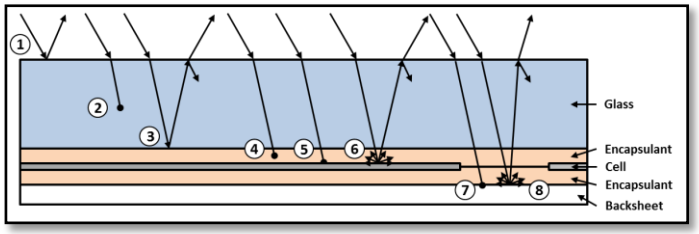
www.cell-to-module.com

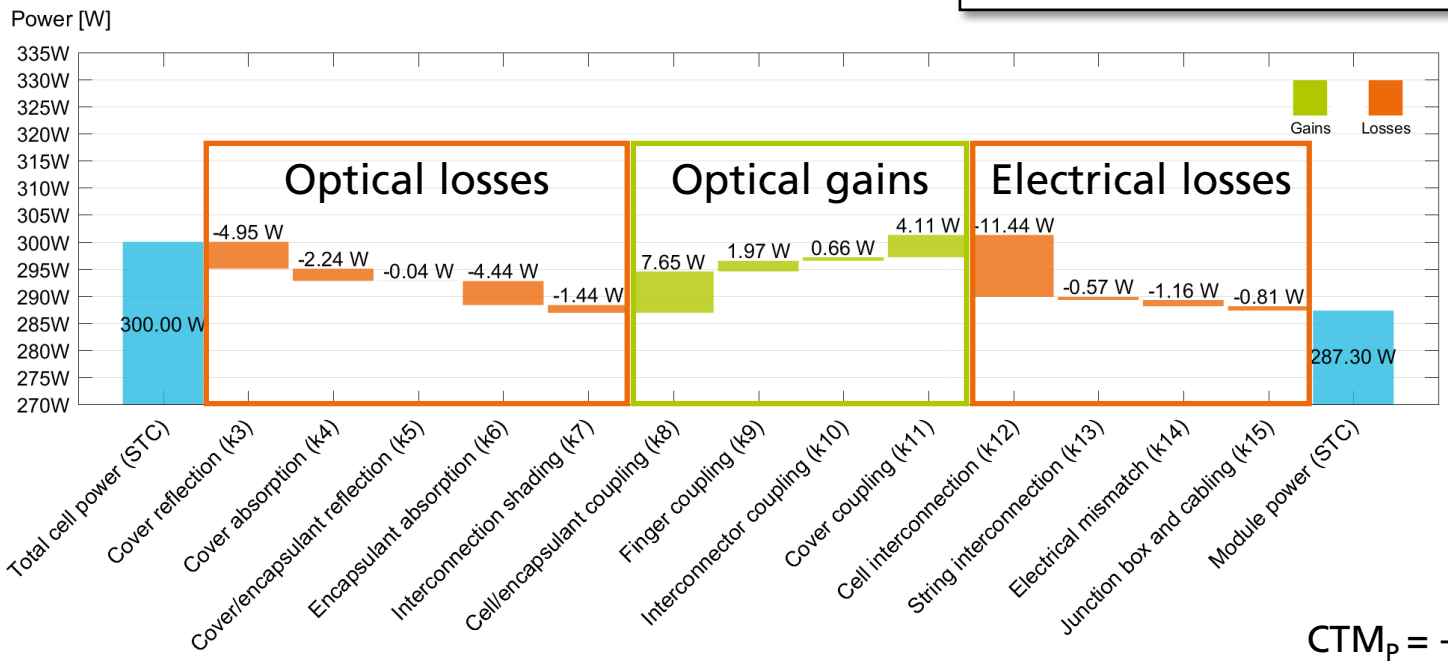
© Fraunhofer ISE
FhG-SK: public

Fraunhofer ISE

CTM-analysis
Method

- Module example
  - Cell 20.35%, 5 W_p
  - 3BB, Glass-Backsheet





CTM_P = -4.2 %

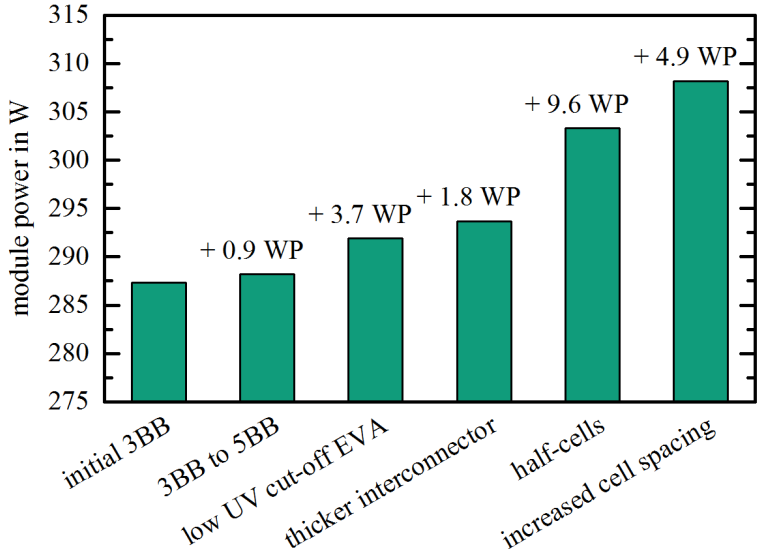
[1] Haedrich, I. et al., SOLMAT 131, 2014

© Fraunhofer ISE
FhG-SK: public

Fraunhofer ISE

Module concepts
Current developments

- Current developments
  - 4BB, 5BB standard today
  - Half cells
  - Highly transparent EVA
  - 250 µm ribbon
  - Reflective ribbon

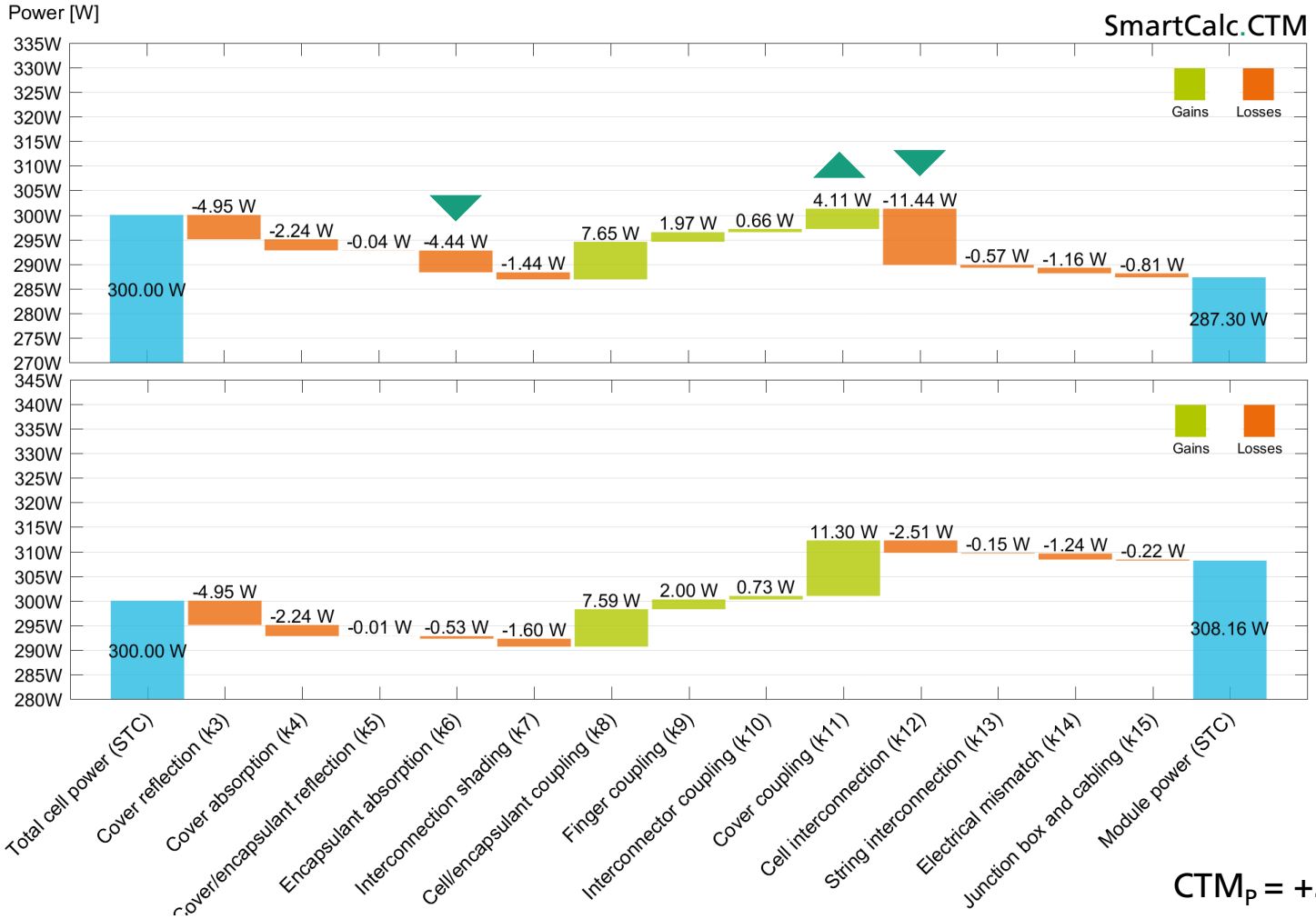


[1] Mittag, M. et al., Photovoltaics International 36, 2017

© Fraunhofer ISE
FhG-SK: public

Fraunhofer ISE

Module concepts
Current developments



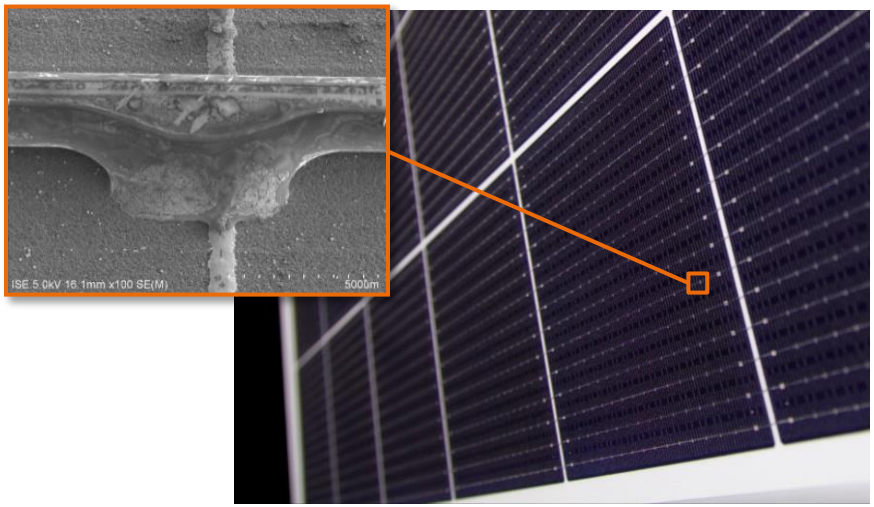
$CTM_P = +2.7\ \%$

© Fraunhofer ISE
FhG-SK: public

Fraunhofer ISE

Module concepts
Multi-wire interconnection

- Multi-Busbar
  - Soldering wires onto micro solder pads
  - Close to standard processing using MBB-stringer

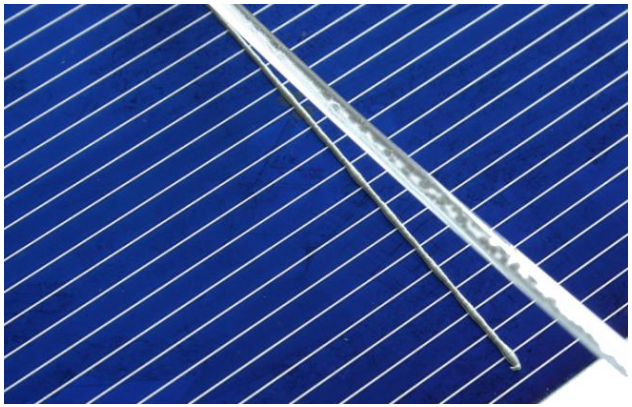


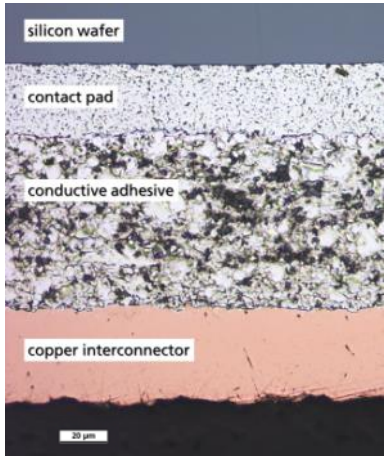
- SmartWire
  - Wires embedded in foil
  - Stringing foils to cells
  - Well-suited for temperature-sensitive cells (e.g. HJT)

© Fraunhofer ISE
FhG-SK: public
Fraunhofer ISE

Module concepts
Conductive adhesives

- Conductive tapes
- Screen-printable ECAs
- Applications
  - Temperature-sensitive cells (e.g. HJT)
  - Busbar-free cells
  - Back-contact modules with conductive backsheet

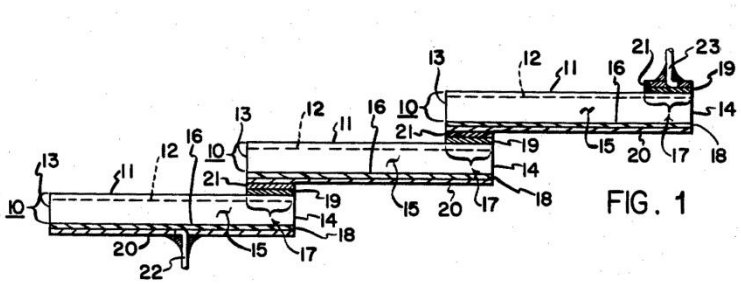


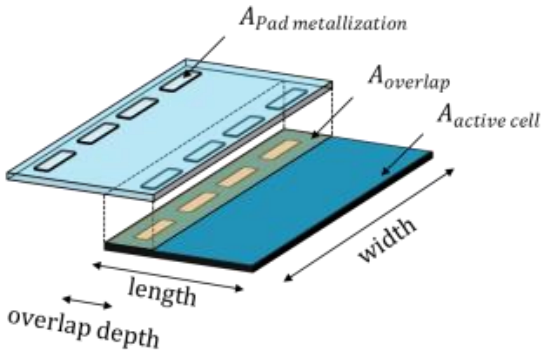


© Fraunhofer ISE
FhG-SK: public
Fraunhofer ISE

Module concepts
Shingling interconnection

- Reduction of inactive areas in module, designed for high module efficiencies
- Overlapping busbar-free cell stripes (6-8 per wafer)
- Use of conductive adhesives
- Concept first published in 1960s[1], current activities at major PV players
- R+D effort at Fraunhofer ISE to combine bifaciality and cell shingling for highest efficiencies[2]



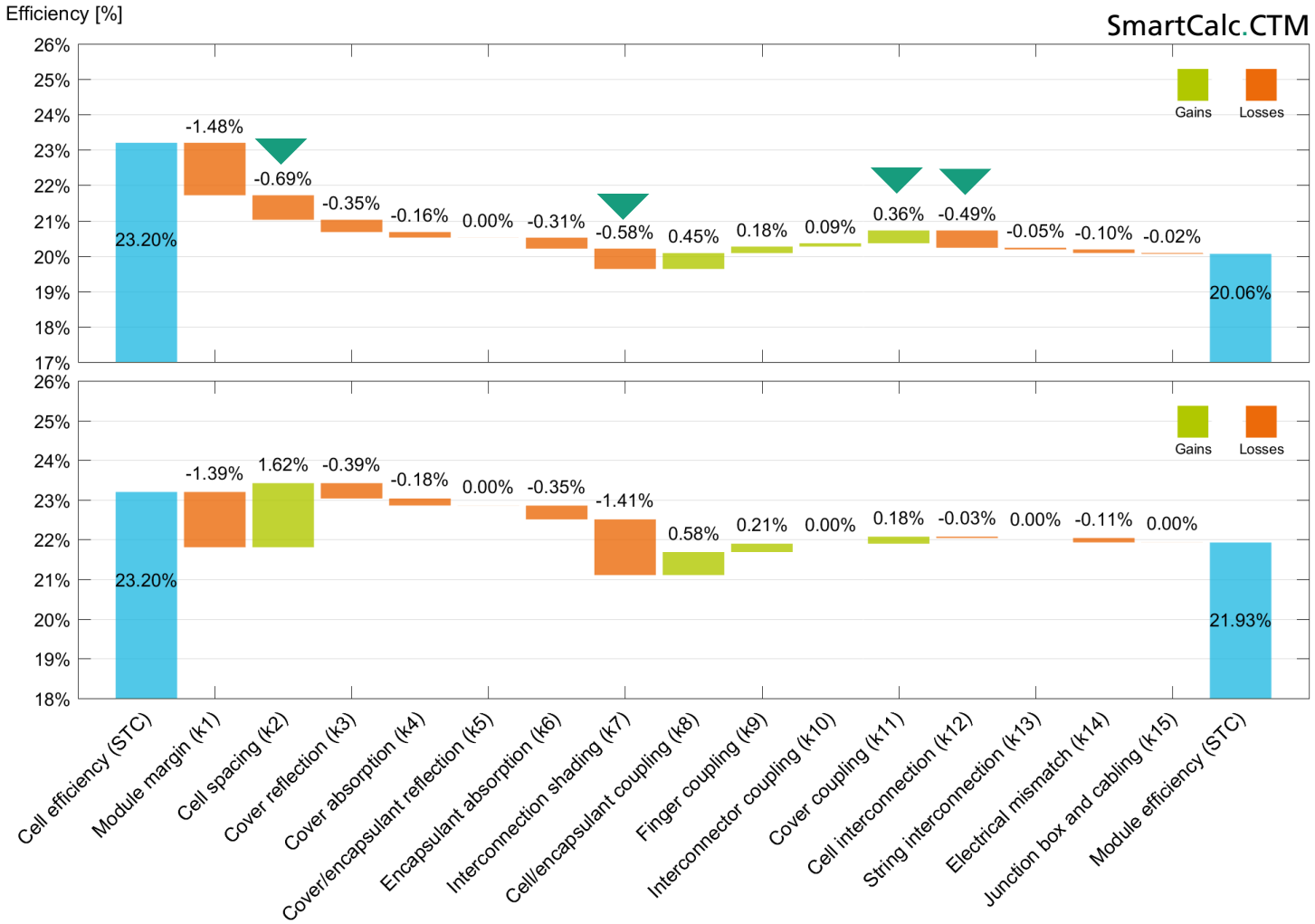


[1] Dickson, D.C. jr., US Patent 2938938, 1960
[2] Wöhrle, N. et al., Photovoltaics International 36, 2017

© Fraunhofer ISE
FhG-SK: public

Fraunhofer ISE

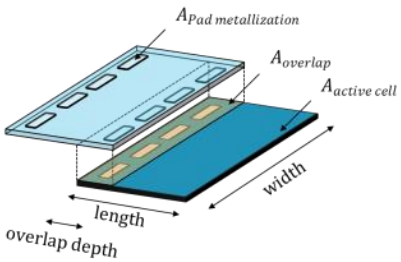
Module concepts
Shingling interconnection



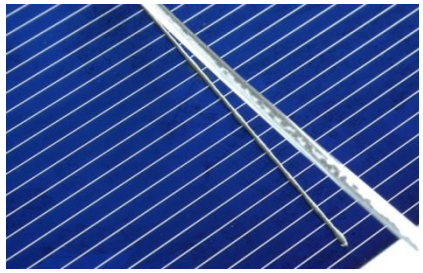
© Fraunhofer ISE
FhG-SK: public
Fraunhofer ISE

Challenges

- Half cells, shingling
  - → cutting process for low edge recombination
  - → Processing throughput



- Temperature-sensitive high-efficiency cells, shingling
  - → Cost-effective solder alloy / conductive glue

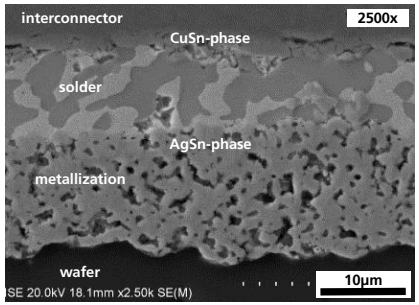


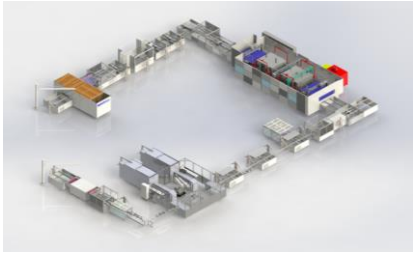
- Multi-wire, XBB
  - → Cell metallization < 10 mg Ag

© Fraunhofer ISE
FhG-SK: public
Fraunhofer ISE

Challenges

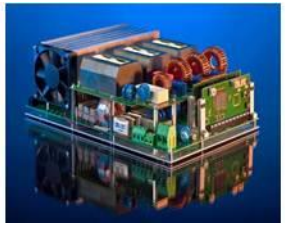
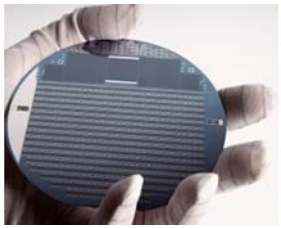
- Lead-free solder alloy
  - → Triggered by legislation
- BIPV-modules
  - → Automated mass-production of customizable modules
- General
  - → Standards for optimization towards energy (energy rating)
  - → Drivers for high efficiencies, special applications?





© Fraunhofer ISE
FhG-SK: public
Fraunhofer ISE

Thank you for your attention!

Fraunhofer Institute for Solar Energy Systems ISE

Ulrich Eitner

www.ise.fraunhofer.de

www.moduletec.de

ulrich.eitner@ise.fraunhofer.de

© Fraunhofer ISE
FhG-SK: public

Fraunhofer ISE