



Organizers:



# Bifacial Modules – review

Ingrid Romijn

Miyazaki  
29 September 2016

[www.ecn.nl](http://www.ecn.nl)

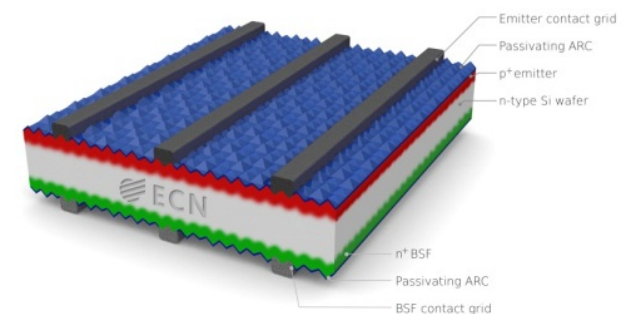
# ECN Solar

---

- Several industrial platforms & programs
  - To develop and benchmark new technologies
  - Pilot manufacturing for extensive field tests
- Development of PV solutions in close collaboration with industry
  - ECN has helped install > 2 GWp worldwide
  - Direct access to industrial (pilot) production lines
- Working from wafer to application/system
  - TRL 4 – TRL 7
  - Turnover 15MEuro/yr
  - 80 people, 10 nationalities



n-Pasha



# Bifacial modules

---

- Overview
  - History, different designs
- Advantages & Challenges
- Outlook



romijn@ecn.nl



# Overview





# Early history of bifacial cells

- 1960: first description of bifacial cell by H. Mori
- 1977: first bifacial lab cells,  $n^+pn^+ / n^+np^+$
- 1980: use of albedo realized

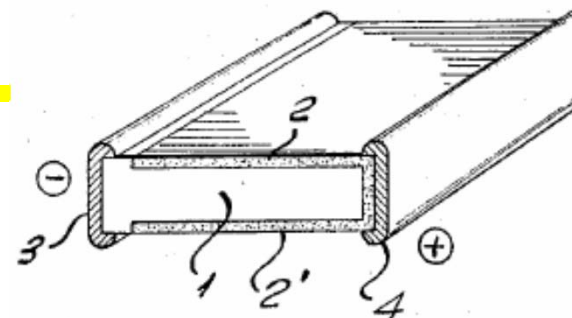


Figure 1. Double junction cell [1]. The numbers indicate 1: n-type silicon, 2 and 2': p-type emitter regions.

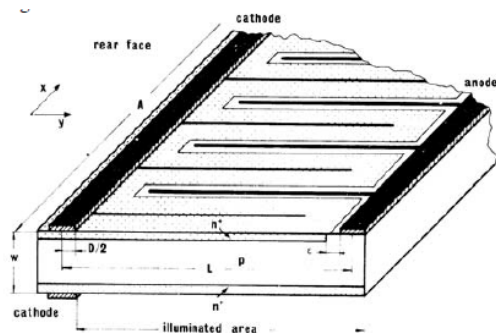


Figure 2. Double-junction solar cell, or Transcell [10].

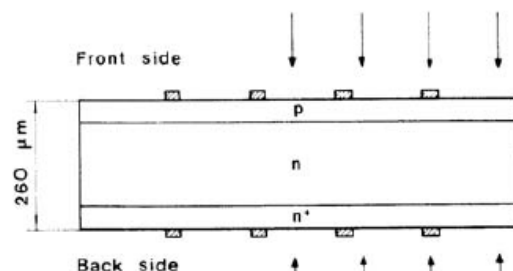
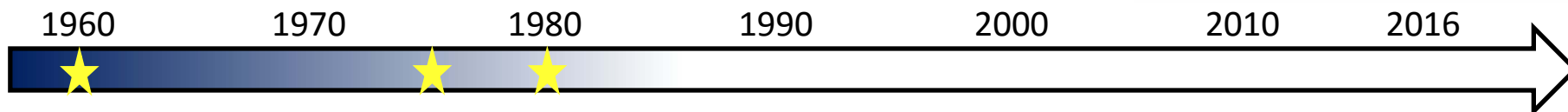
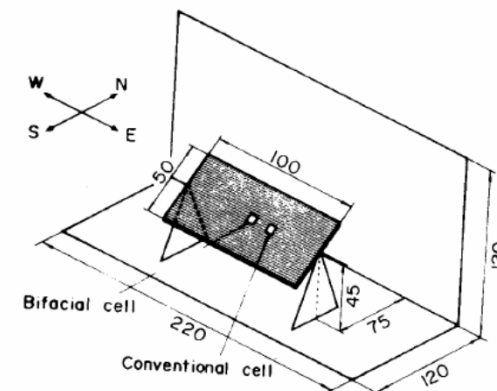


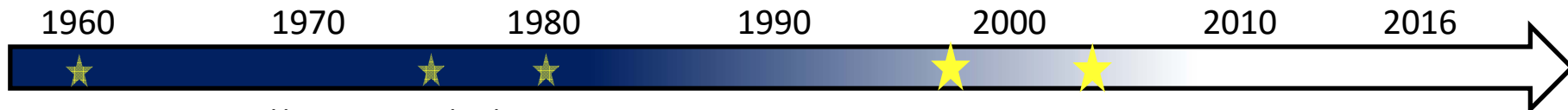
Figure 3. Bifacial Back Surface Field solar cell [26].



Ref: A. Cuevas, "early history of bifacial solar cells", 20<sup>th</sup> EUPVSEC 2005, Barcelona, Spain)

# First bifacial modules

- 1997: first application of bifacial PV modules in sound barriers<sup>1</sup>
- 2003: novel applications of bifacial solar cells in sun-shading elements<sup>2</sup>



1: <http://www.tnc.ch/en/power-instead-noise-photovoltaic-noise-barriers-1>

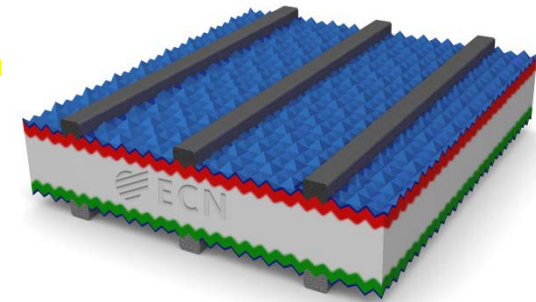
2: R. Hezel, "Novel Applications of Bifacial Solar Cells", *Progress in PV: Res and Appl.* **11**, p549-556, 2003

# Commercial bifacial cells

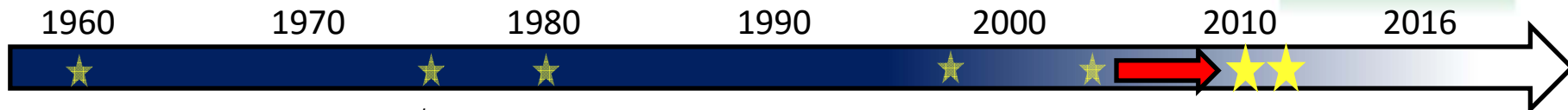
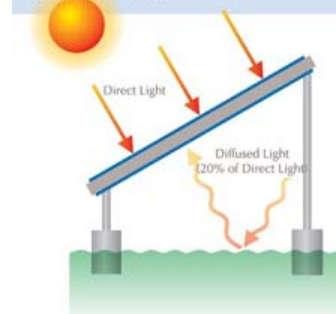
- 2004 - 2008: large scale PV industry takes off....
  - With monofacial modules

→ Wait for right cell to come along

- 2010: **Yingli** commercializes ECNs n-Pasha cells → 300 MW<sup>1</sup>
  - Applied in monofacial modules
- 2011: **PVGS** starts with EarthOn technology → 35 MW<sup>2</sup>
  - Applied in bifacial modules



Power generation characteristic ex. of EarthON Cell



1: A.R. Burgers, 26<sup>th</sup> EUPVSEC, Hamburg, Germany (2011)

2: S. Goda, 11<sup>th</sup> CSPV, Hangzhou, China (2015)

# Commercial bifacial modules

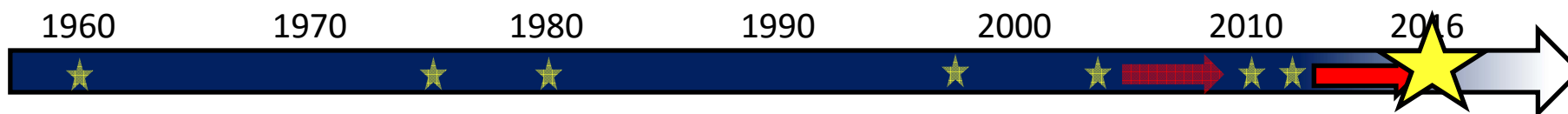
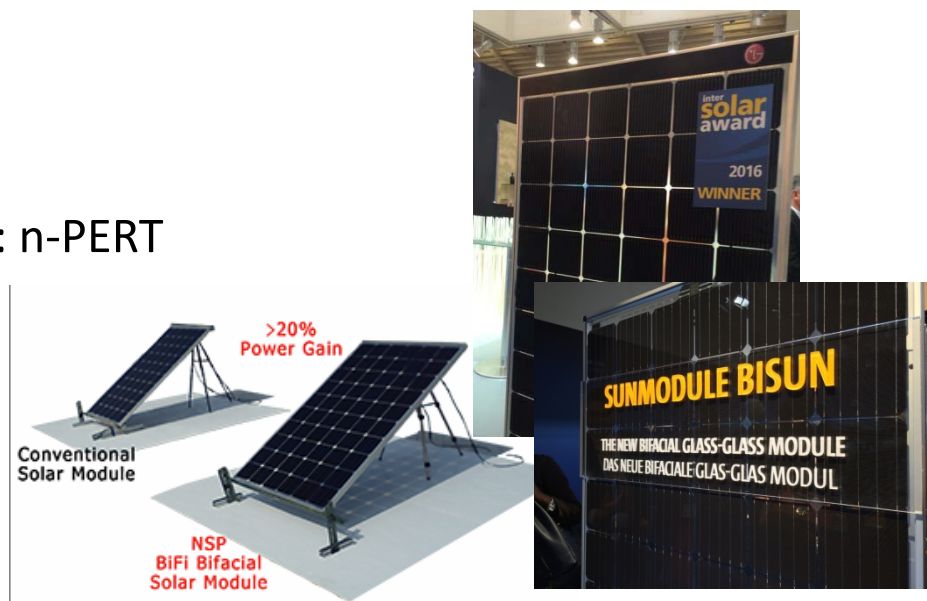
- 2012 – 2016: Strong increase research on different bifacial cells
  - Many publications

## Bifacial n-type modules<sup>1</sup>:

- PVGS, Yingli, LG, NSP, REC, Trina: n-PERT
- Sunprime, Panasonic, MB: HJT
- First Solar: Tetrasun

## Bifacial p-type modules<sup>1</sup>:

- RCT, SolarWorld: bifacial PERC

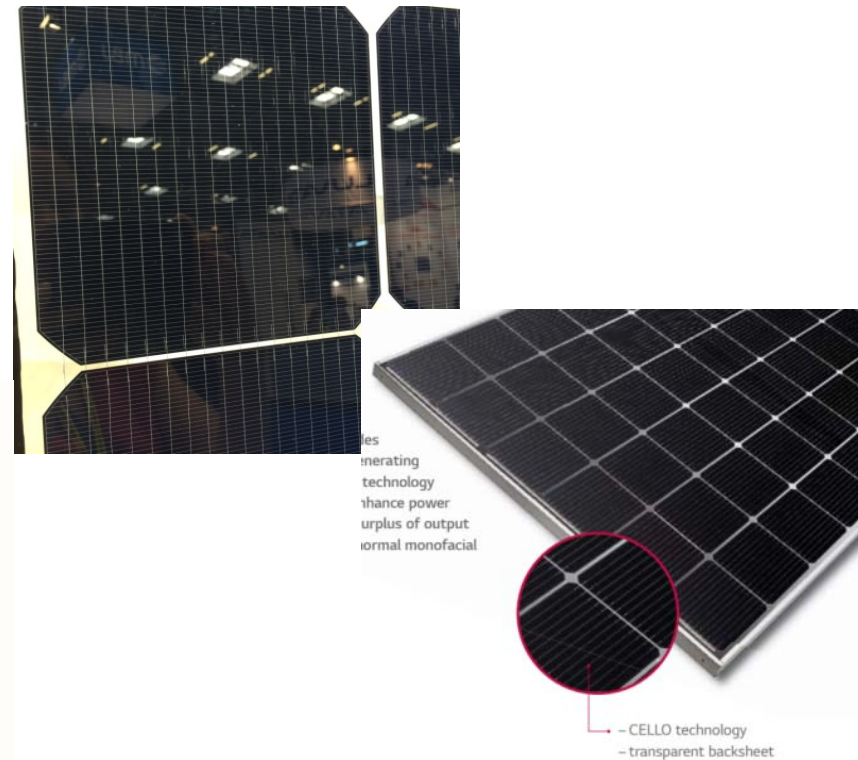
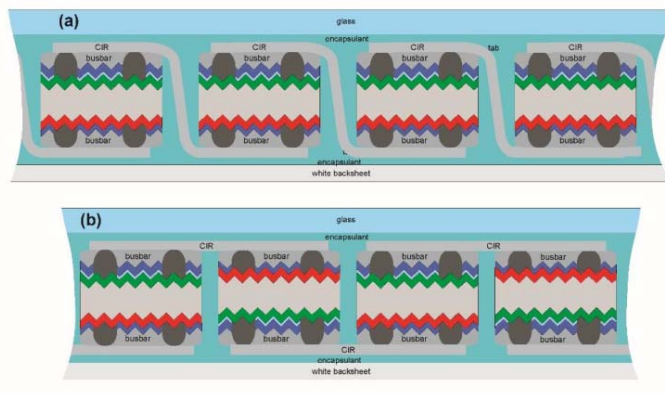


<sup>1</sup>: This and previous sessions of today, pictures from InterSolar Munchen, 2016



# Alternative interconnection designs

- Smartwire: Meyer Burger<sup>1</sup>
- Multiwire: production by LG
- Flip-Flop module<sup>2</sup>

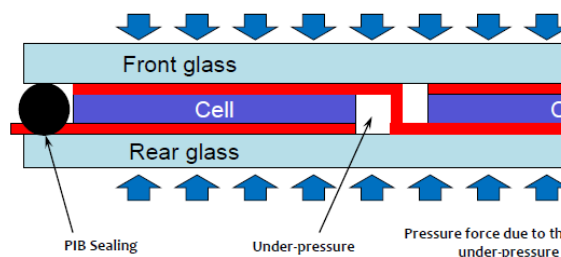


1: picture from Intersolar Munich, 2016

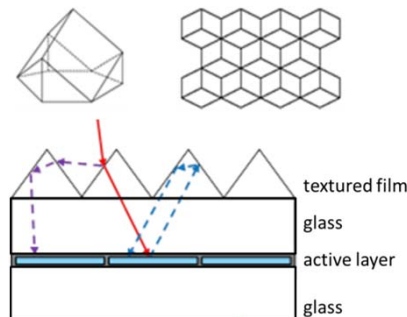
2: Peibst et al., EUPVSEC, Munich, Germany, 2016

# Alternative interconnection designs

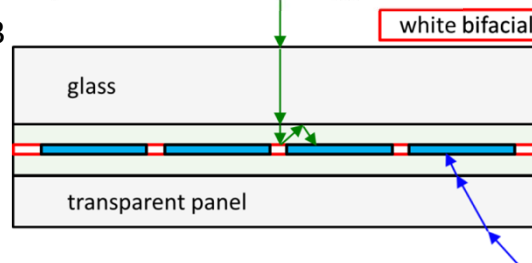
- NICE module – Apollon<sup>1</sup>
  - Glass-glass modules
  - Ideally suited for bifacial use



- LTF – DSM<sup>2</sup>
  - Additional light trapping



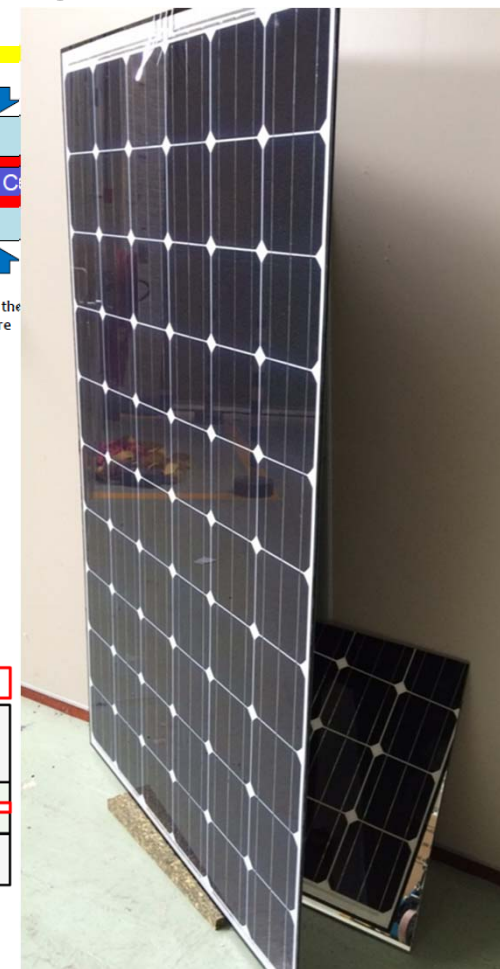
- White bifacial module – ECN<sup>3</sup>
  - +5% energy yield vs st bifacial



1: bifacial workshop Chambery, 2014

2: This session

3: B. van Aken EUPVSEC, Munchen, Germany, 2016



# Different design and applications



romijn@ecn.nl



# Bifacial modules: Advantages





# Advantages

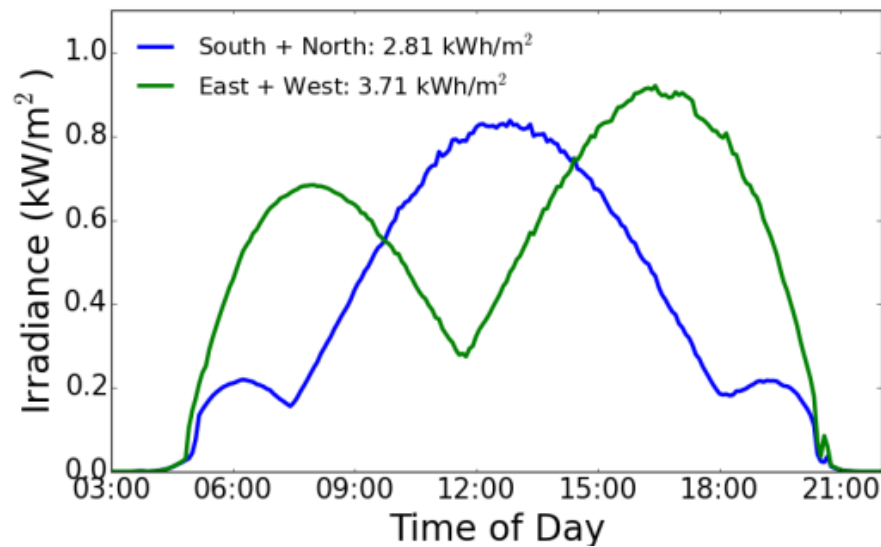
---

- Additional energy yield
  - Reported by many, ranging from 10% – 50%
  - Both modelling and measurements on cells, modules and systems confirm the additional gains
- Temperature effect
  - Less IR radiation is trapped in the module → lower T → higher  $V_{oc}$  potential
  - But: also more irradiation in bifacial modules? How does the balance tip?
- Less soiling for vertical modules → dusty area's
- PV in otherwise not-accessible or not-feasible locations
- Modules generate energy even when front side is covered!

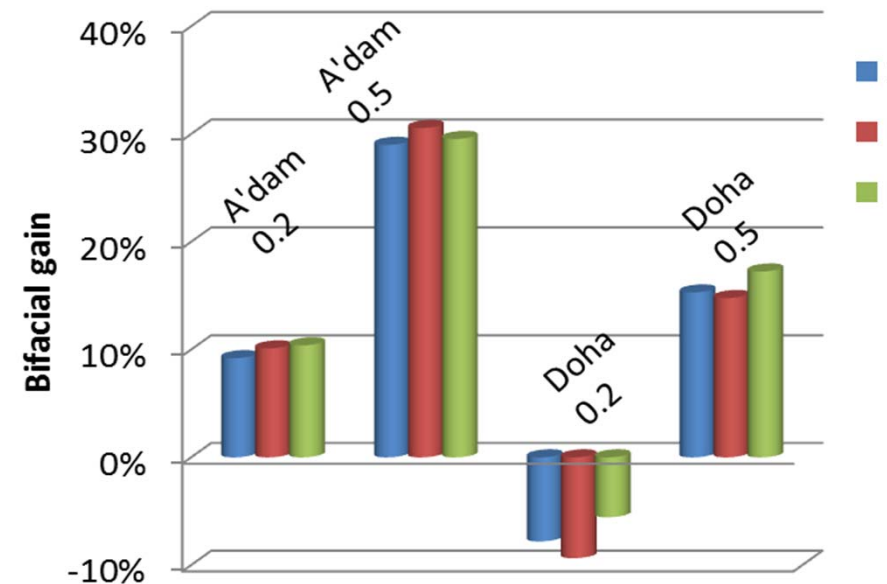


# Advantages

- Additional energy yield
  - Reported by many, ranging from 10% – 50%
  - Both modelling and measurements on cells, modules and systems confirm the additional gains



E-W vertical bifacial vs south – oriented mono facial

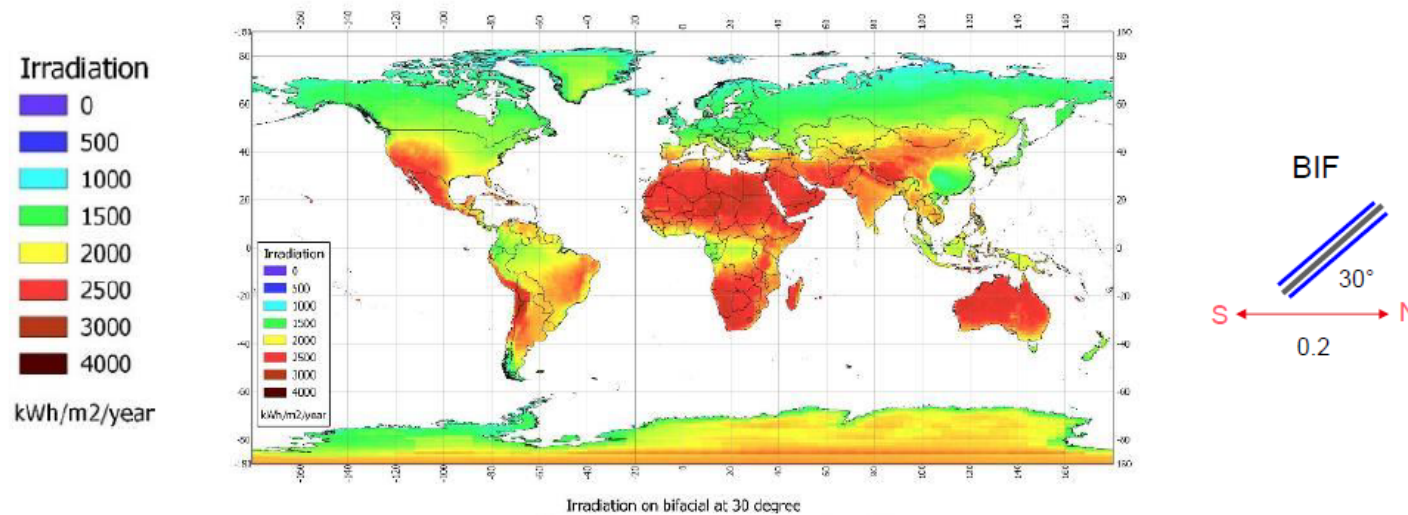


# Irradiation on bifacial module

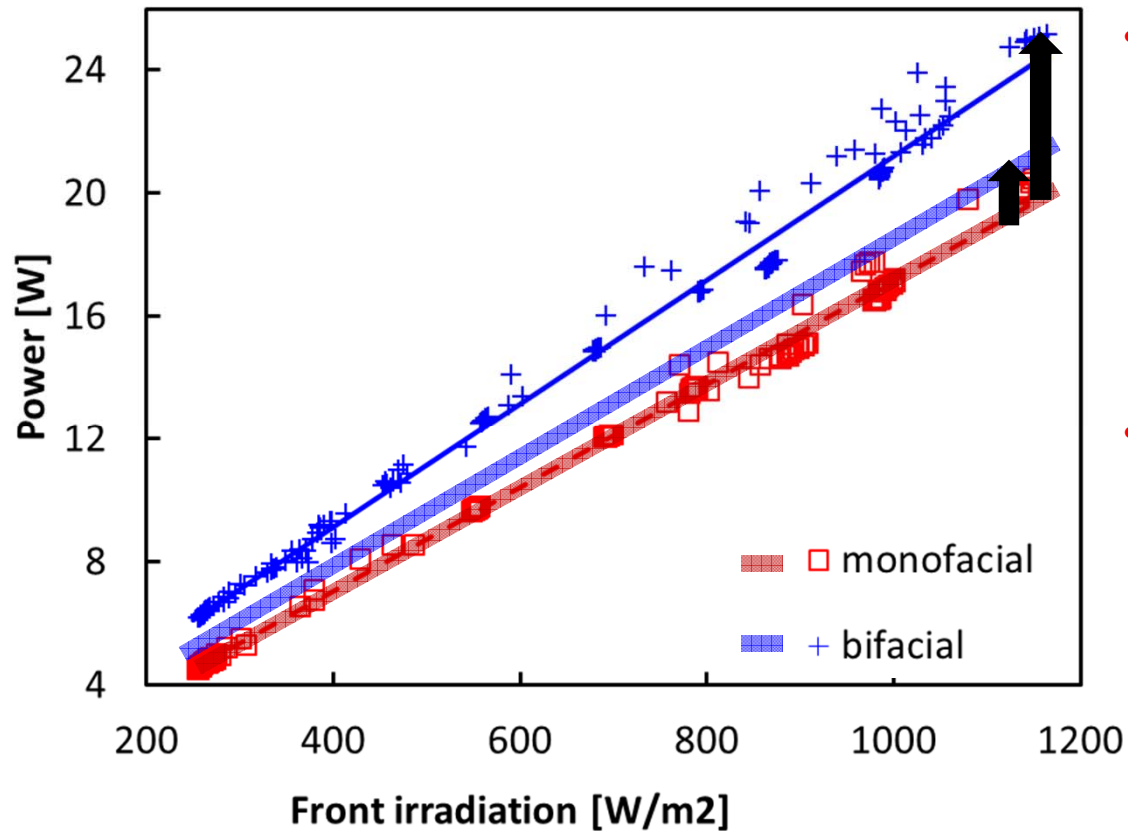
- Increase in irradiation : dependent on placement on earth and on tilt angle



**EXAMPLE: BIFACIAL N/S ORIENTED\* : EFFECT OF TILT ANGLE & ALBEDO**  
 30° TILT @ ALBEDO: 0.2



# Bifacial gain: measurements



- Concrete floor:

5% higher output for bifacial



- White background:

20% higher output for bifacial



romijn@ecn.nl



# Bifacial modules: challenges



# How to measure ?

- Nameplate rating for manufacturers

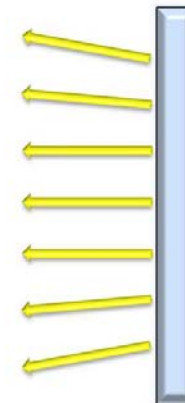
- Session on Friday



Non-illuminated side blocked by absorbing black plate



- Other options:

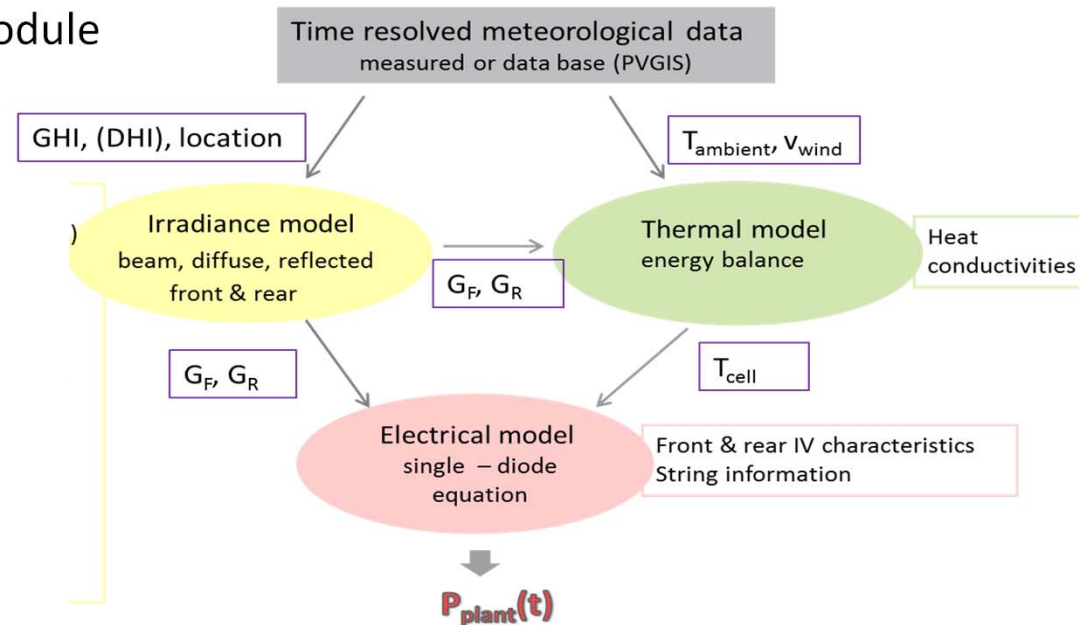


Well defined reflector with known properties / albedo



# Prediction of annual energy yield

- Modelling of energy output design for modules & systems
  - 2 sessions on Friday
- ECN model: correlate STC measurements with outdoor performance of the bifacial module



# Shading at the rear

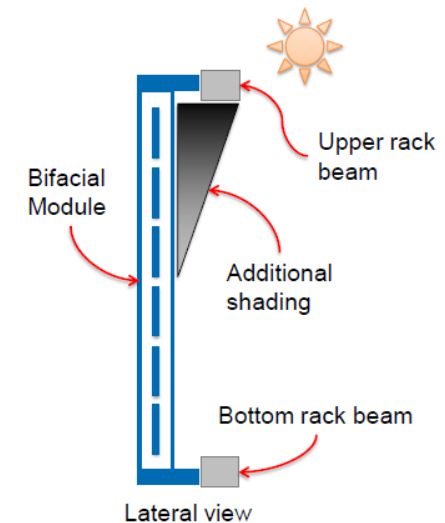
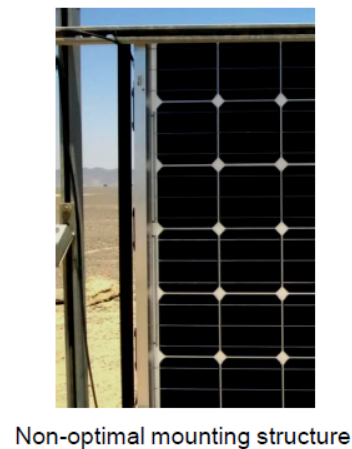
- How does it effect the energy yield
- Issues with hotspots ??

Shading effects for south oriented bifacial modules



*J. Abarach et al., EUPVSEC, Munich, Germany, 2016*

Shading effects for vertically mounted bifacial modules



# Shading south oriented

---



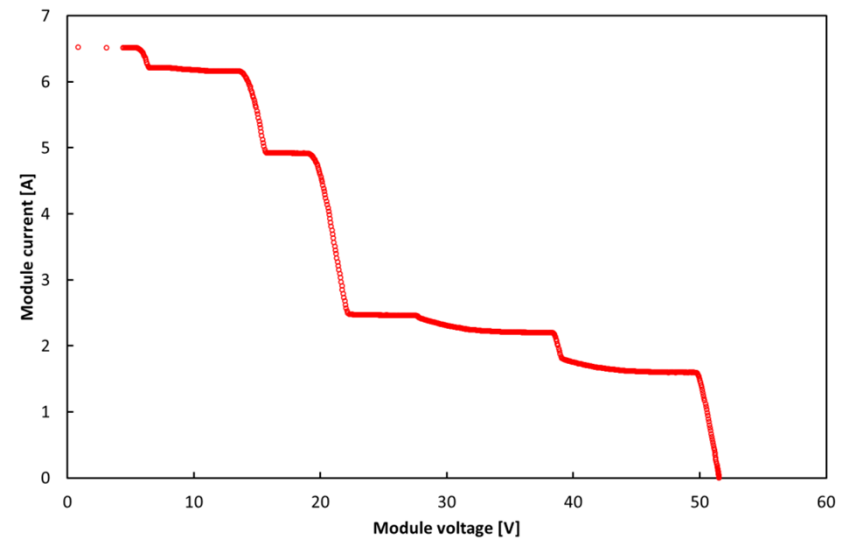
Research questions:

- How does the shade affect the energy yield
- Issues with hotspots ??

- Measurements & analysis ongoing at ECN
- Results to be published soon

# Shading vertical highway sound barriers

- Very broad support beams
- Shade is cast more or less severe over the rear of the module
- 6 horizontal strings  $\rightarrow$  6 bypass diodes
- Dangerous: **NO**, yield loss: YES



romijn@ecn.nl



# Outlook





# Future for bifacial modules

---

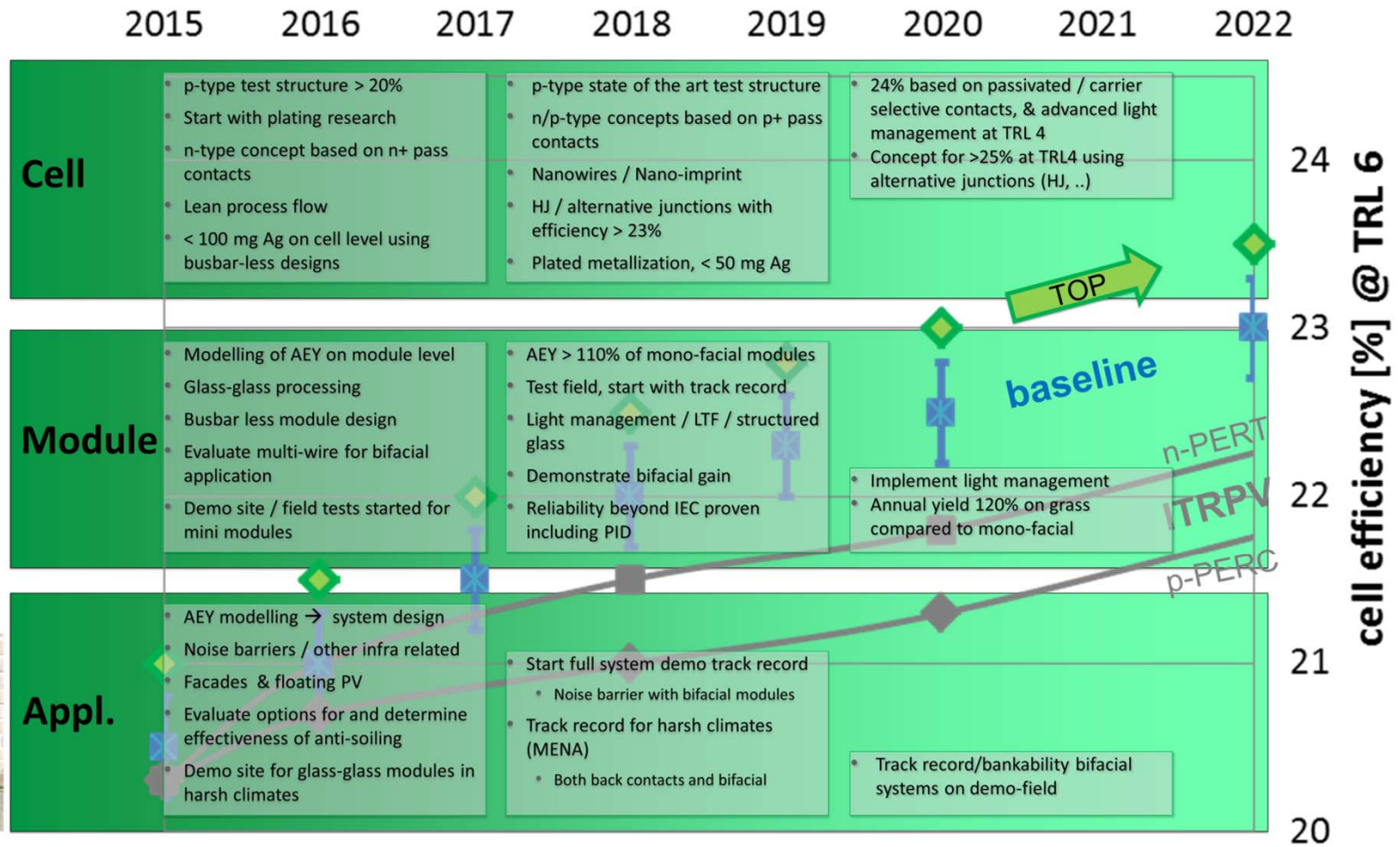
- YES !
- Industry is realizing the potential of bifacial modules
- Two distinct applications:
  - Large fields optimized for bifacial modules & systems
  - Infrastructure - integrated modules / applications
- Main issues to be solved:
  - Standardization of measurements / name-plate power rating
  - Annual Energy Yield predictions
  - Reliability & Bankability to be (further) proven → field tests

## PowerPlants / Infrastructure Integrated

### Bifacial modules

#### Requirements / drivers:

- Low LCOE
- PID resistant
- (very) long lifetime
- Semi-transparent
- Maintenance free
- High T performance
- Optimal and fast installation
- Smart modules for infrastructure or specific



**Thank you!**

**For further discussion contact me: [romijn@ecn.nl](mailto:romijn@ecn.nl)**

Thanks to the ECN bifacial team: Bas van Aken, John Anker, Evert Bende, Paula Bronsveld, Anna Carr, Bart Geerligs, Astrid Gutjahr, Gaby Janssen, Martien Koppes, Eric Kossen, Ji Liu, Jochen Loffler, Bonna Newman, Nienke Riezebos, Maciej Stodolny and Kees Tool



# nPV WS: April 5/6, 2017 in Freiburg

romijn@ecn.nl



**npworkshop Freiburg 2017**

Organizers: Fraunhofer ISE, ines, ISC, Imec, ECN, csem

Imprint

Main | nPV Chairman's Message | Abstracts | Program | Registration | Contact | Freiburg | Previous WSs

**Announcement: nPV WORKSHOP April 5/6 2017 in Freiburg, Germany**

Dear PV-scientists,

because of its... will... in time organise the nPV workshop with the participation of scientists from all around the world. As last time, we will connect it to the Silicon PV conference allowing the visitors to combine both events. The nPV workshop will take place from

**April 5-6, 2017 in Freiburg, Germany.**

The first day is dedicated to scientific n-type presentations and is a combined day with Silicon PV conference. The second day is the "industry day" with invited talks dealing with well known n-type wafer, solar cells and module technologies from e.g. Panasonic and Sunpower as well as with emerging technologies from e.g. LG Electronics, Solar City, Hyundai and Sunpreme.

Arthur Weeber (ECN) | Stefan Glunz (FH ISE) | Radovan Kopecek (ISC) | Delfina Munoz (INES) | Joachim John (IMEC) | Jan Schmidt (ISFH) | Matthieu Despesse (csem)

[www.nPV-workshop.com](http://www.nPV-workshop.com)

hosted and organized by: Fraunhofer ISE | ECN | projects in solar energy | PSE

linked to: SiliconPV 2017