BIFACIAL MODULE MEASUREMENTS WITH G_E METHOD

BIFIPV workshop, Konstanz 25-26/10/2017

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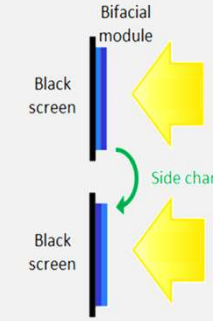
INTRODUCTION

- **Possible I-V measurement methods:**

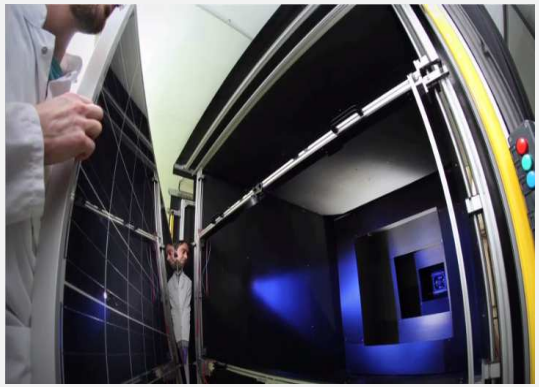
IEC 60904-1-2: Measurement of current-voltage characteristics of **bifacial** photovoltaic devices



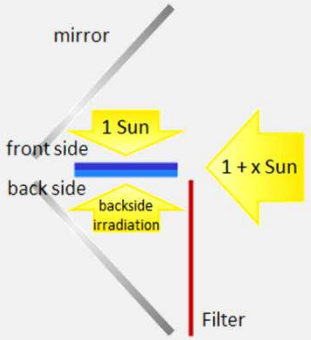
G_E method

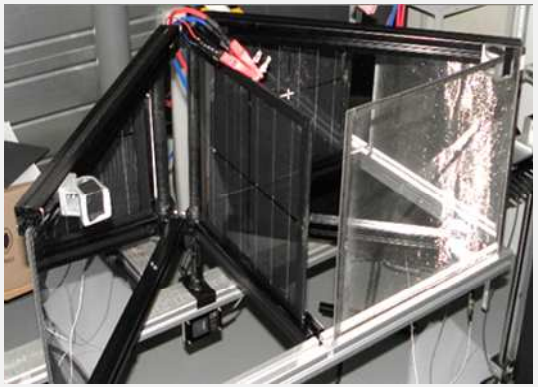
$$G_{E_i} = 1000\, W.m^{-2} + \varphi\,.G_{R_i}$$
$$\varphi = Min(\varphi_{I_{SC}}, \varphi_{P_{max}})$$

[See talk V.Fakhfouri]

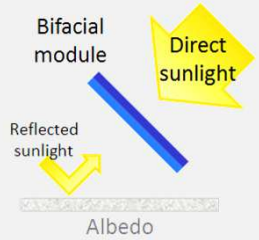


Indoor bifacial





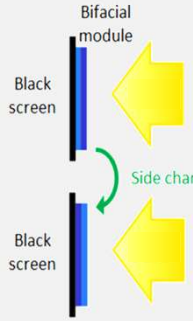
Outdoor bifacial or G_E



Goal of the study: compare G_E with bifacial indoor and outdoor methods

1) INDOOR G_E VERSUS INDOOR BIFACIAL

IEC 60904-1-2: Measurement of current-voltage characteristics of **bifacial** photovoltaic devices



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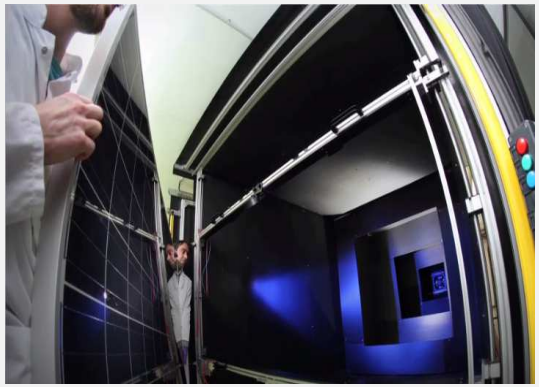

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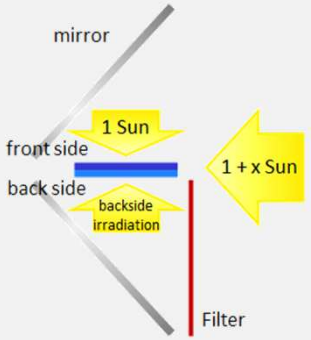
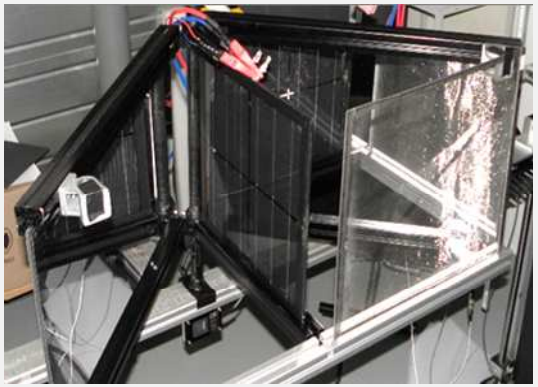




Outdoor bifacial or G_E

1) INDOOR G_E VERSUS INDOOR BIFACIAL

- **Mini-module tested:**

3 bus bars	3 bus bars - ½ cell	5 bus bars	5 bus bars - ½ cell
full cell 3 BB	half cell 3 BB	full cell 5 BB	half cell 5 BB

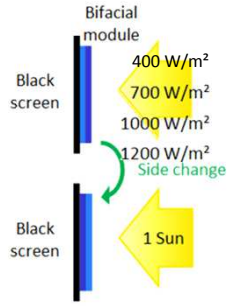



- n-type bifacial cells 156 mm pseudo square (INES PERT technology, 93% bifacial)
- encapsulant EVA UV clear
- glass-transparent backsheet structure 36 cm x 36 cm x 3 mm
- **2 modules of each architecture manufactured and measured**

1) INDOOR G_E VERSUS INDOOR BIFACIAL

- **Measurements:**

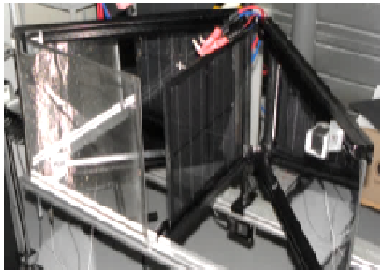
1. Front side measurement at 400, 700, 1000 and 1200 W/m²

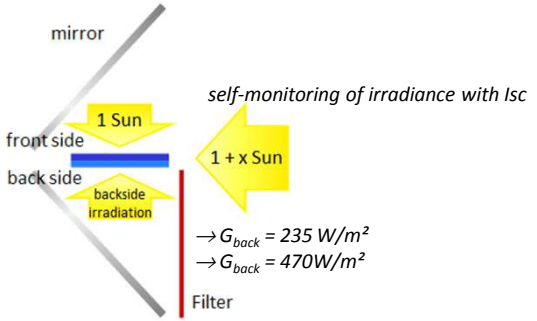


2. Back side measurement

3. G_E method — IEC 60904-1-2: Measurement of current-voltage characteristics of **bifacial** photovoltaic devices [See talk V.Fakhfouri]

4. Indoor bifacial measurement

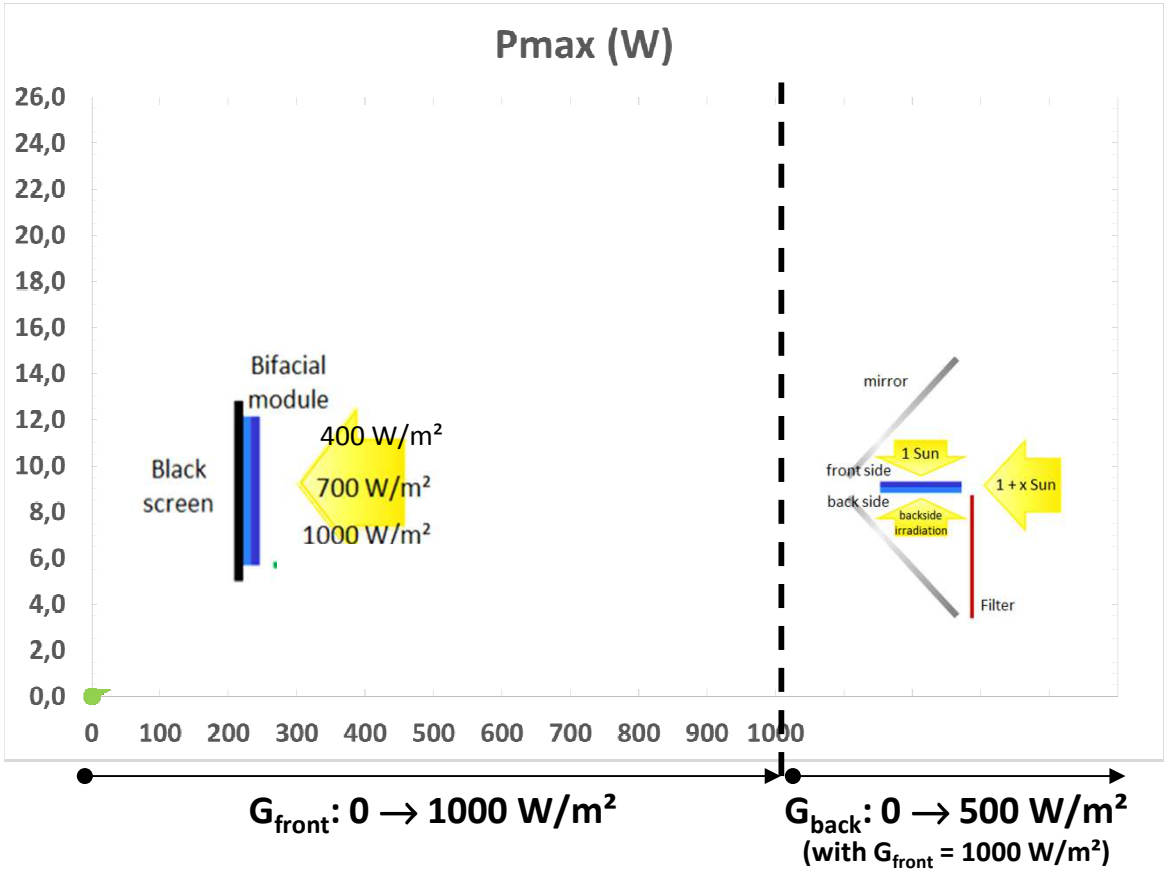




1) INDOOR G_E VERSUS INDOOR BIFACIAL

- **Results:**

[M. Joanny et al, BifiPV Wokshop 2016 (September 2016, Miyazaki, Japan)]



1 Front side measurement

4 Bifacial measurement

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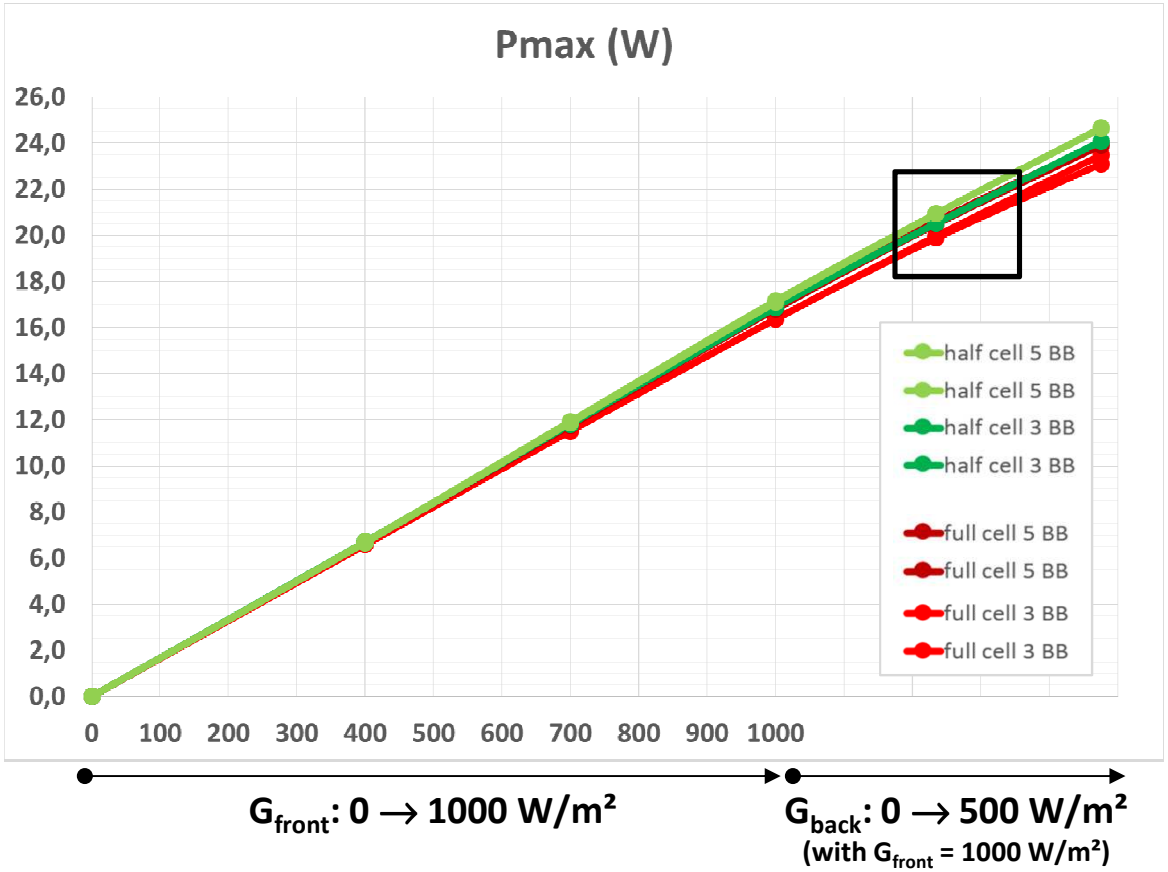

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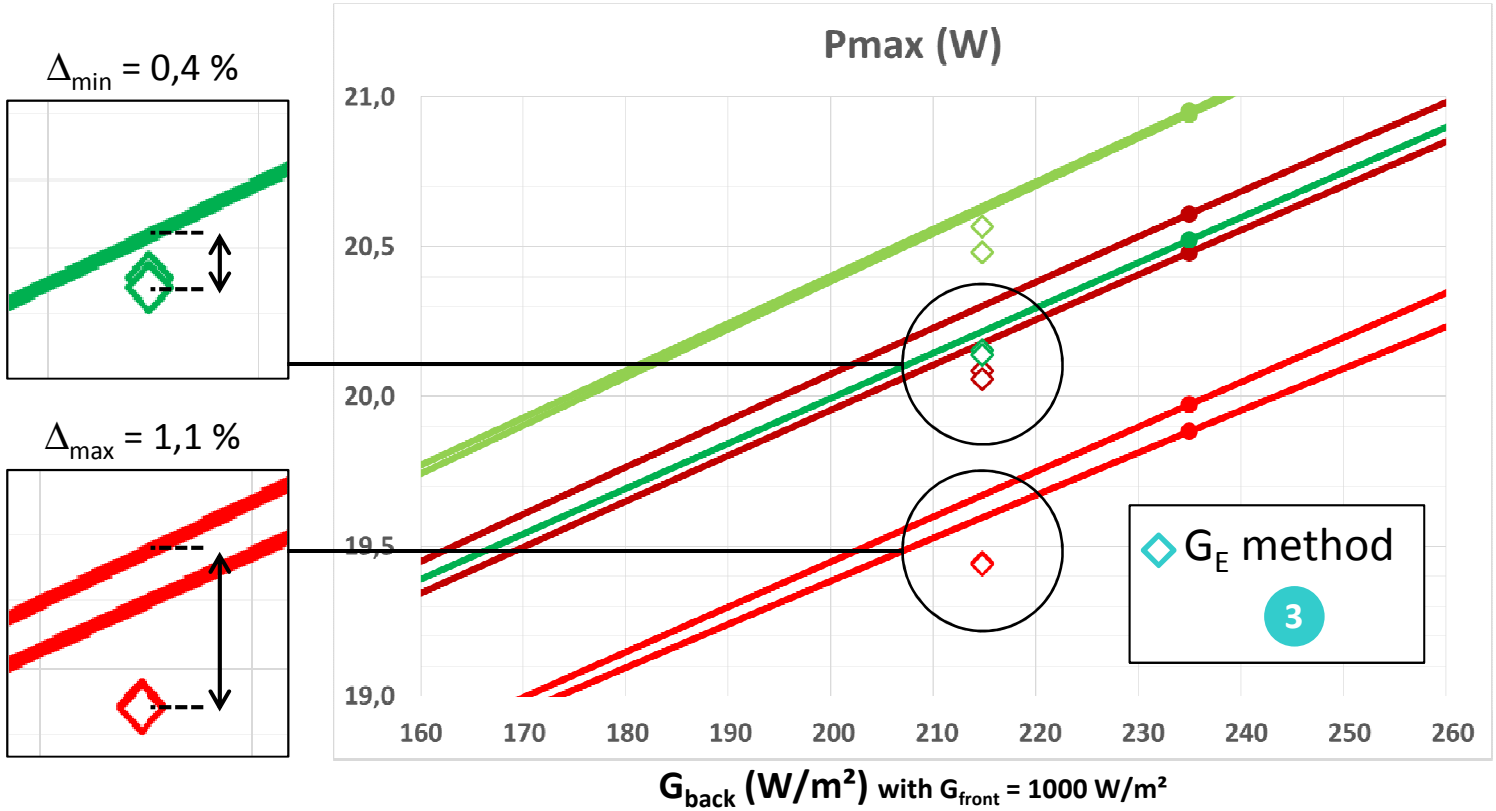
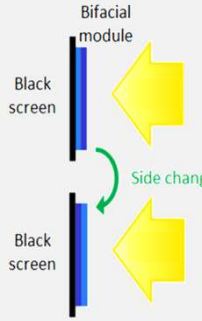


Δ Indoor G_E vs indoor bifacial = 1,1% max

2) INDOOR G_E VS OUTDOOR BIFACIAL MEASURE

IEC 60904-1-2: Measurement of current-voltage characteristics of **bifacial** photovoltaic devices



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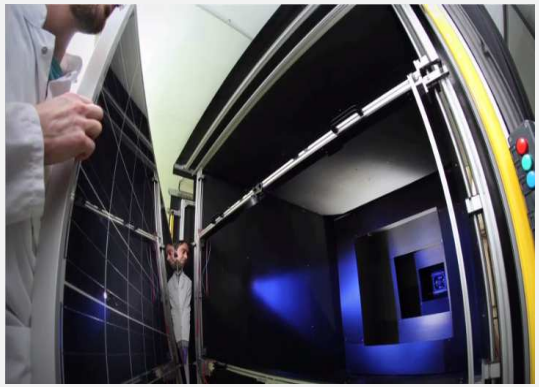

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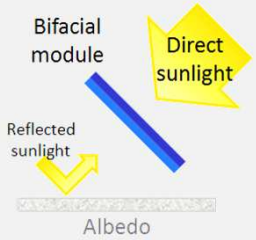


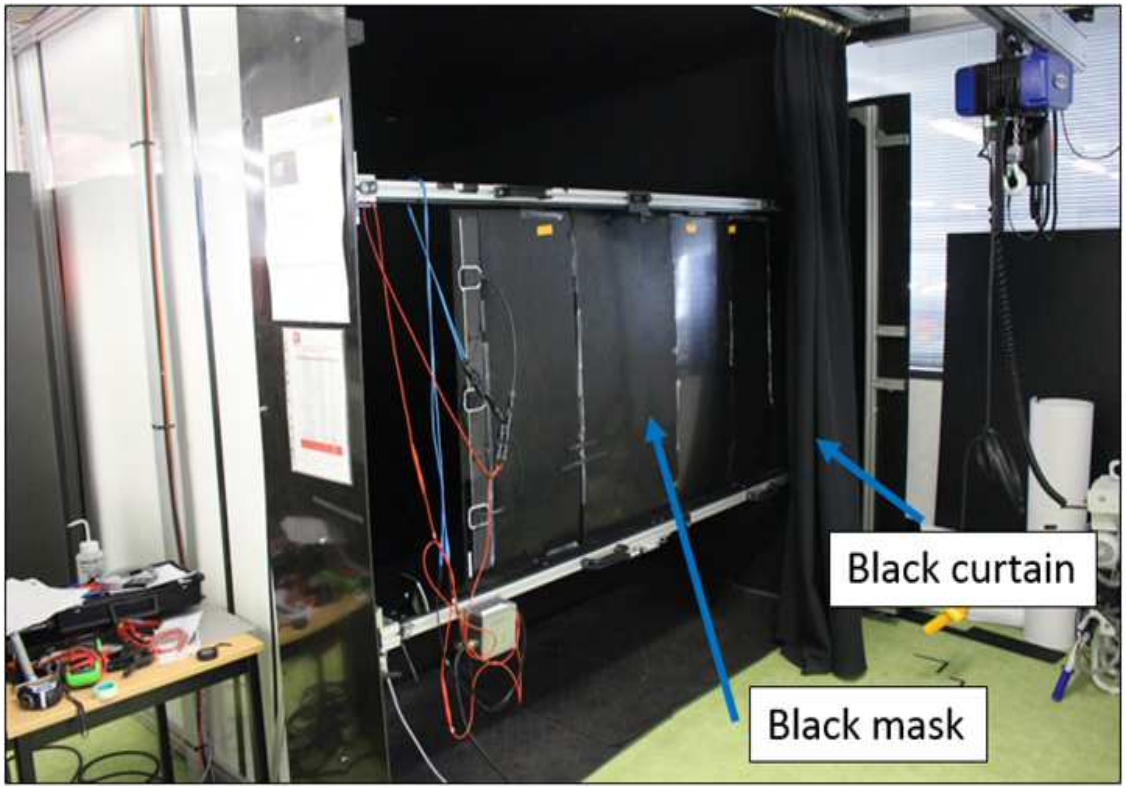
2) INDOOR G_E VS OUTDOOR BIFACIAL MEASURE

- **Measurements: indoor G_E**

  - HET-type bifacial SWCT modules (Meyer-Burger) :

  - glass-glass structure
  - 60 cells module

  - **2 modules (A and B) measured**



2) INDOOR G_E VS OUTDOOR BIFACIAL MEASURE

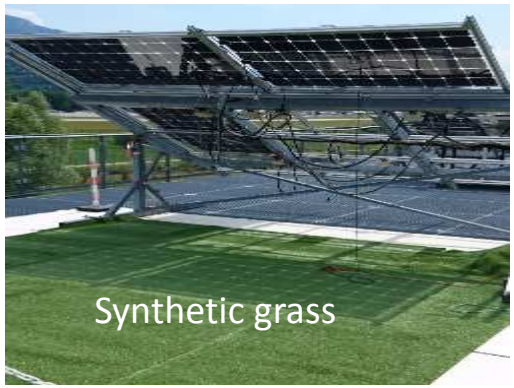
- ## Measurements: bifacial outdoor

a. 1 kW/m² or corrected to 1 kW/m² on the exposed side
   i. Set up of the 2 modules, measurement of Isc_r for first module (back side on top) and Isc_f for second module (front side on top)
   ii. Flip over of both modules, measurement of Isc_f for the first module and Isc_r for the second module

b. Determination of φ_{min} (Isc, Pmax) among φ Isc = Isc_r / Isc_f and φ Pmax = $Pmax_r$ / $Pmax_f$.

c. Flip over of the second module (both modules with front side on top), then:
   i. Pmax = f (G_R) plot
   ii. measurement of backside irradiance

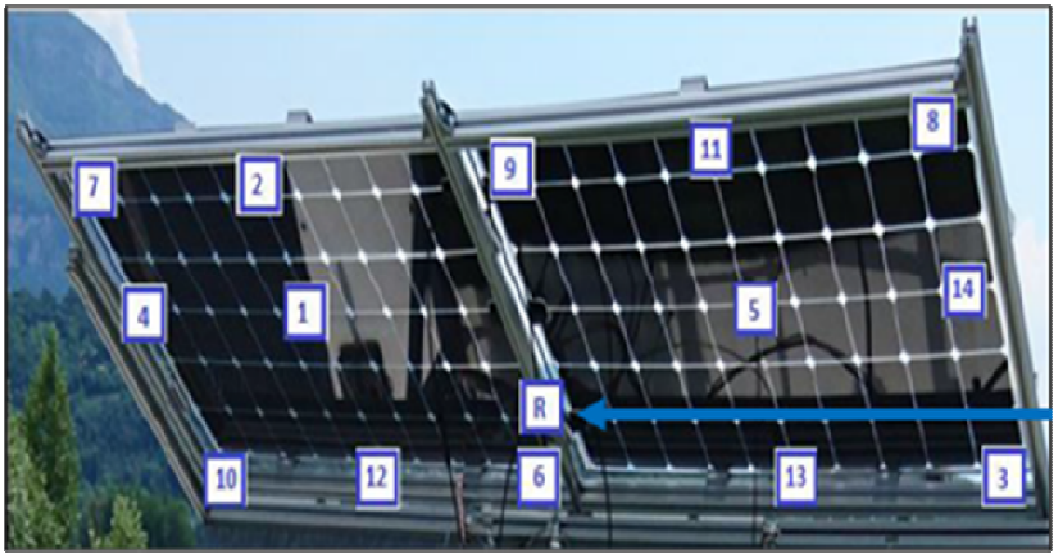
d. $Pmax_{BiFi10}$ and $Pmax_{BiFi20}$ reporting (either measured values at step c. or interpolated).

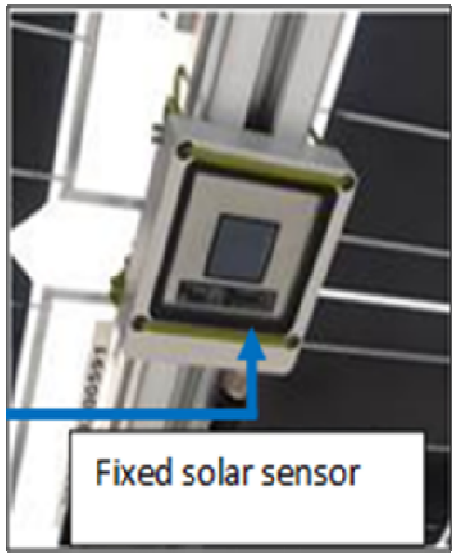


2) INDOOR G_E VS OUTDOOR BIFACIAL MEASURE

- **Measurements: bifacial outdoor**

  Positions of the fixed reference cell (R) and of the 14 points measured by a mobile irradiance sensor for back side irradiance inhomogeneity analysis:





Covering floor color	White	Brown	Green
Inhomogeneity min [1-((average-σ)/average)]	7,3%	13,2%	18,0%
Inhomogeneity max [(max-min)/(max+min)]	11,2%	21,8%	29,7%

Inhomogeneity values are > 5%. Choice of the white floor (lowest inhomogeneity) for the study.

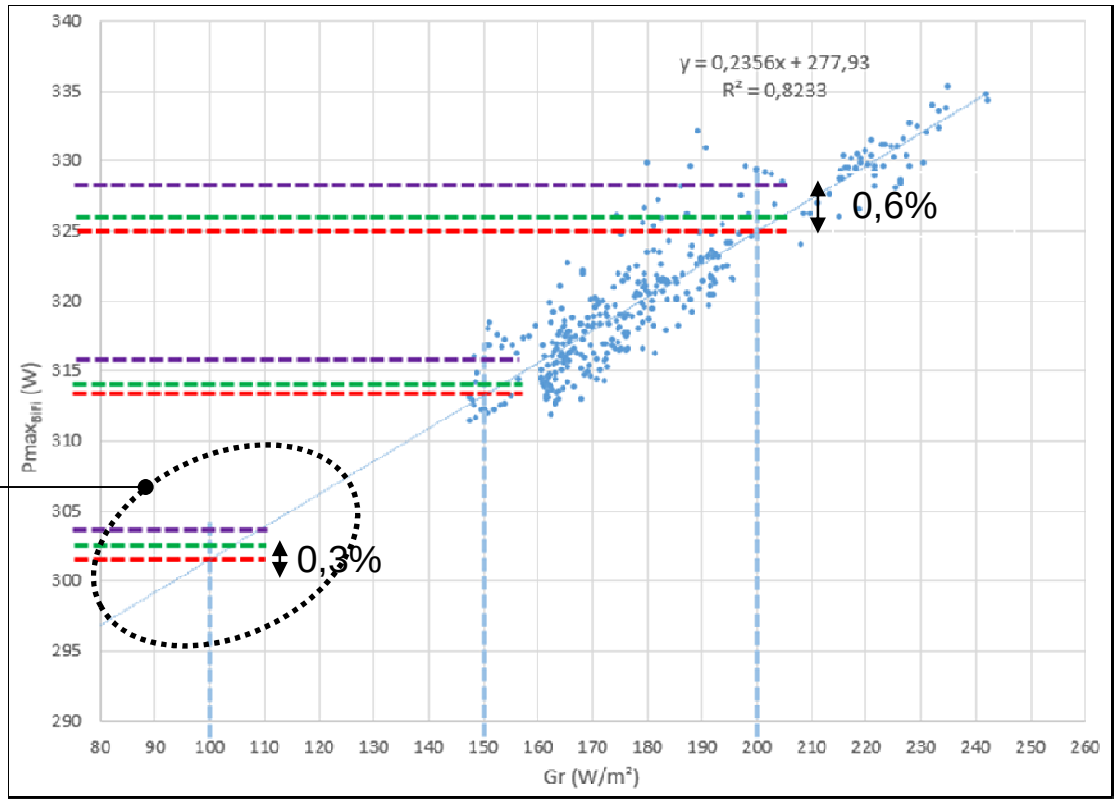
2) INDOOR G_E VS OUTDOOR BIFACIAL MEASURE

- **Results:**

Real outdoor measurements (in taken into account of illumination inhomogeneities)

GE calculated from φPmax

GE calculated from φIsc



No data available because the white floor covering brings Gr > 100 W/m²

Variations of the PmaxBiFi, i as a function of the back illumination (GR, i) for the module B

Δ indoor G_E vs bifacial outdoor = 0,3% to 0,6% max (for φPmax and φIsc resp.) for module B
= 0,4% to 0,6% max (for φPmax and φIsc resp.) for module A

3) OUTDOOR G_E VERSUS BIFACIAL OUTDOOR

IEC 60904-1-2: Measurement of current-voltage characteristics of **bifacial** photovoltaic devices

G_E method

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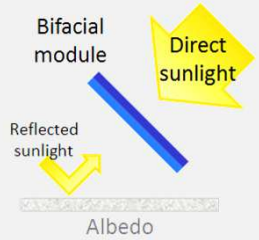
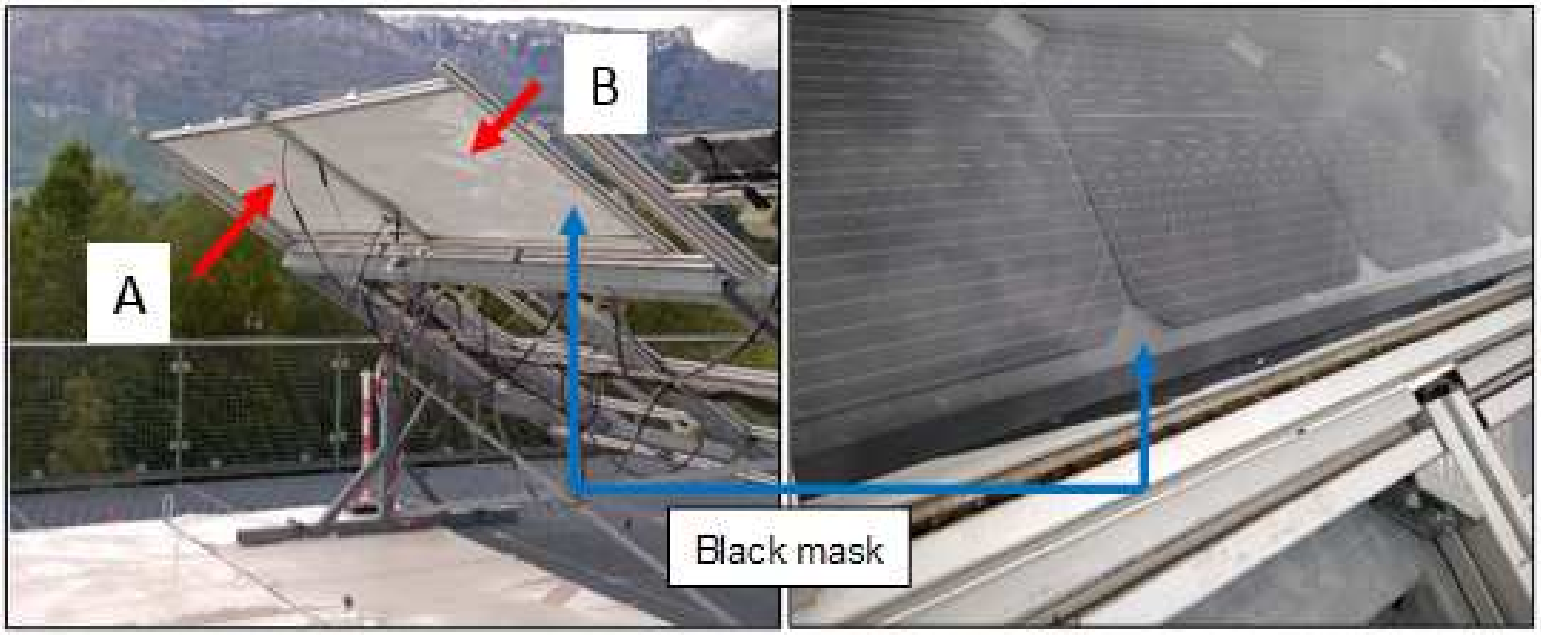


3) OUTDOOR G_E VERSUS BIFACIAL OUTDOOR

- **Measurements:**

I-V outdoor with black cover on the backside:



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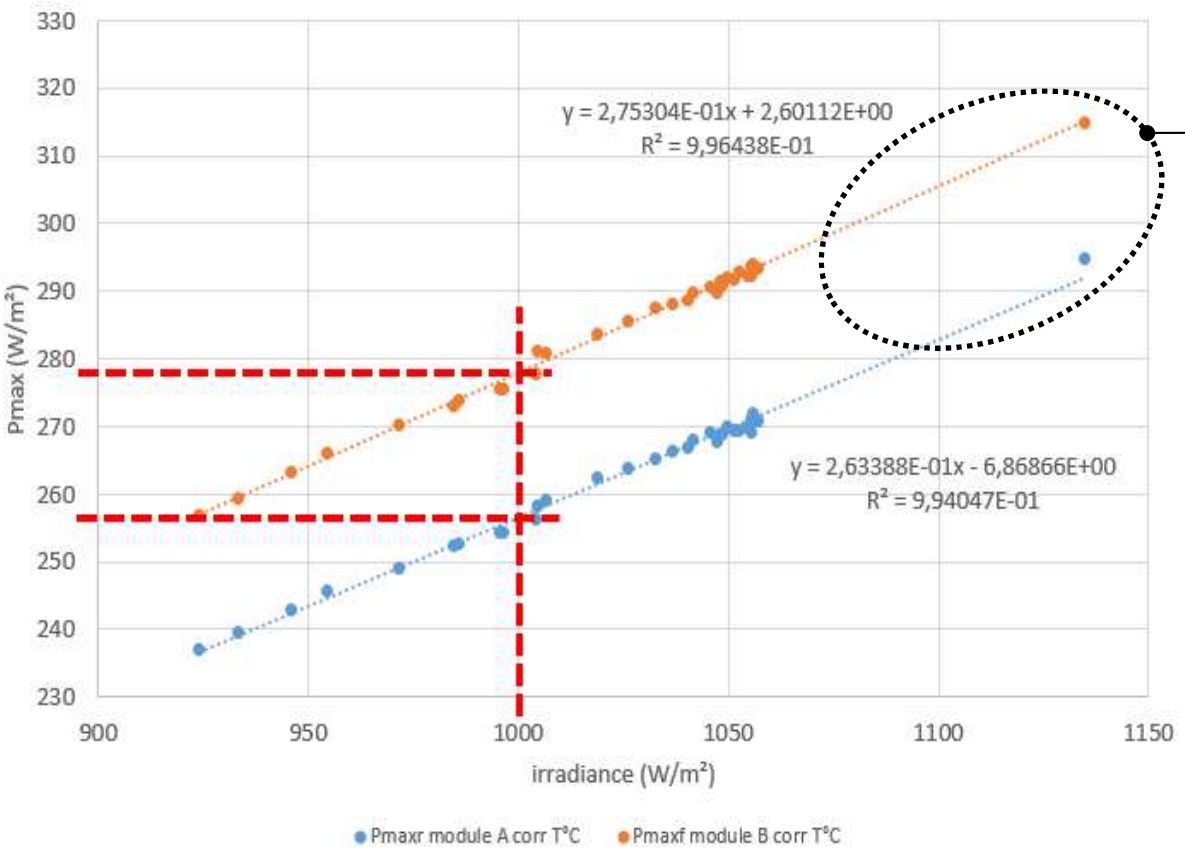
3) OUTDOOR G_E VERSUS BIFACIAL OUTDOOR

- **Results** (Front side module B and backside module A exposed to the sun)

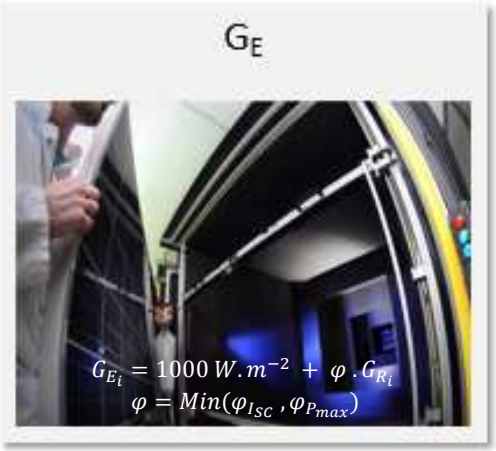


Very few data available because outdoor irradiance is usually < 1200 W/m²

Δ outdoor G_E vs bifacial outdoor = from 0,3% to 2,5%

CONCLUSION OF THIS STUDY

- Outdoor bifacial:
  - PmaxBiFi10 and PmaxBiFi20 cannot be measured with the same outdoor setup (using for instance brown floor and white floor respectively)
- Outdoor G_E:
  - natural irradiance hardly reach 1200 W/m² front side
- Indoor G_E:
  - indoor G_E method characterizes with 1% max. divergence the bifacial PV module performances versus indoor double side illumination and outdoor natural exposition conditions
  - in the proposed G_E equation, φP_{max} parameter gives closer results than φI_{sc}



THANK YOU FOR YOUR ATTENTION