Why PV testing? Overview of PV testing globally

Differences between Technologies, Efficiencies,
Performance Measurements, Uncertainties,
Influences on Performance (Low Irradiance, Spectrum, Temperature),
Energy yield

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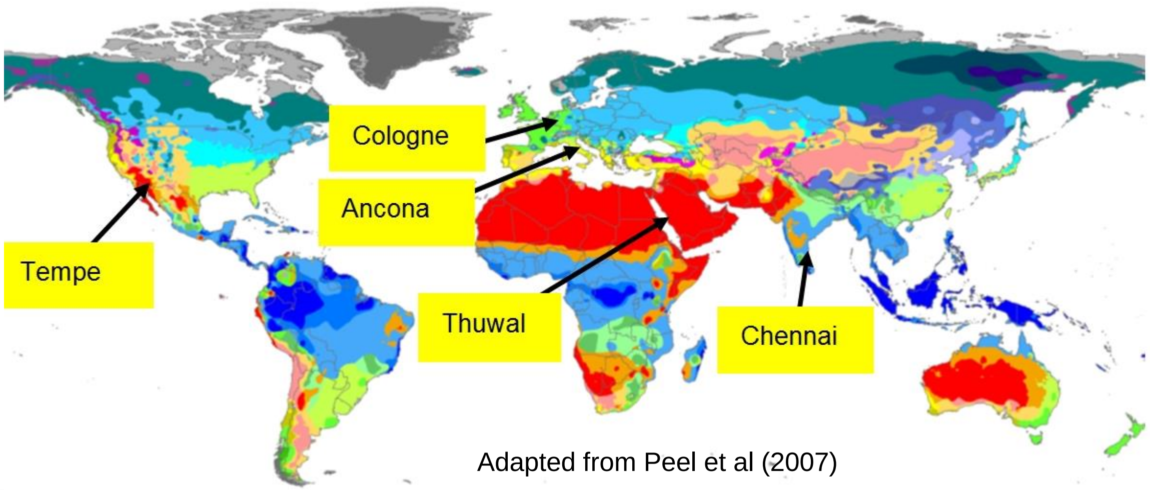
Characterization of different PV Modules (technology, type)

- **Motivation:** Enhance the profitability of PV power plants
- **Question:** Which factors influence the energy yield of PV modules, and to what extend?
- **Target:** Reduce the uncertainty of simulation by developing new models
- **Approach:** Monitoring of 15 PV module technologies at 5 test-sites worldwide

15 samples x 5 test sites

Cell-Technology	Amount (per location)
CdTe	3
CIGS	4
a-Si/a-Si	1
a-Si/µc-Si	2
poly c-Si	1
poly c-Si AR glass	1
poly c-Si textured	1
mono c-Si HJT	1
BC mono c-Si n-type	1
	15



Adapted from Peel et al (2007)

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Motivation and Approach

Cologne: temperate climate (Cfb)

Tempe: hot arid climate (BWh)

Chennai: hot humid climate (Am)

Ancona: mediterranean climate (Csb)

Motivation and Approach

NEW: Thuwal, Saudi-Arabia, dry and hot dessert climate (BWh) **Since March 2015**

Cologn ... h)

Chennai: hot humid climate (Am)

Ancona: mediterranean climate (Csb)

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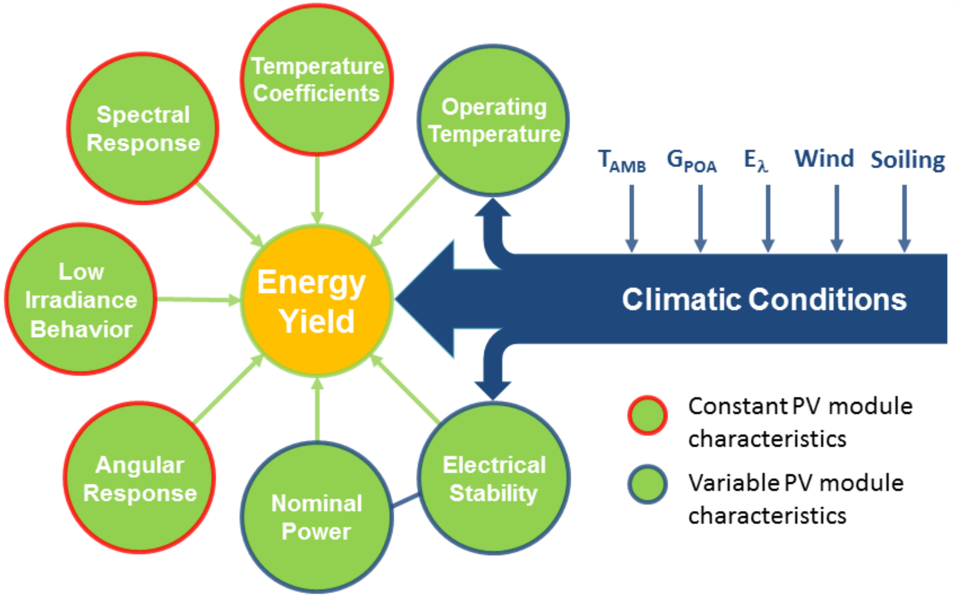
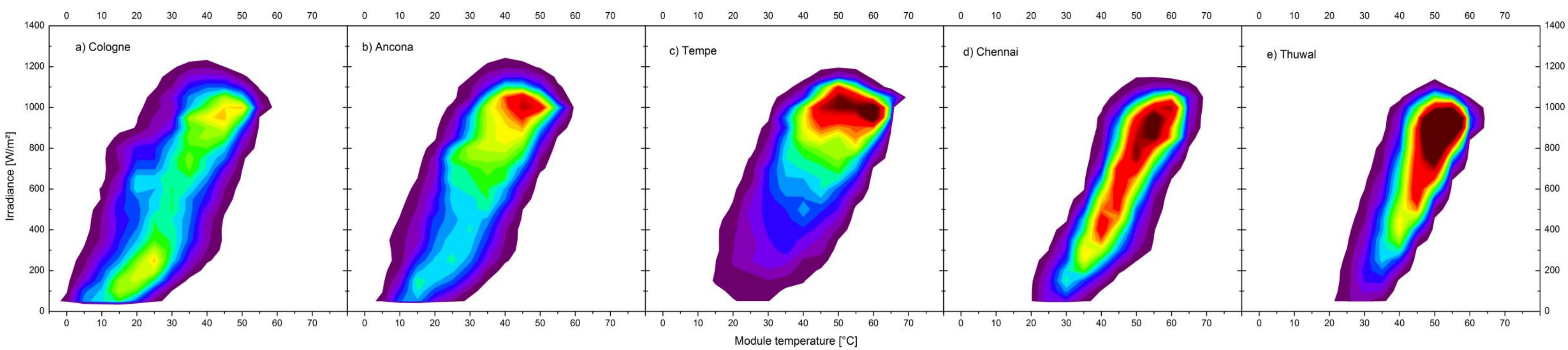
Factors Affecting the Energy Yield Performance of PV Modules

The return on investment is determined by the energy yield of the PV modules at physical outdoor conditions which depend on the location of the PV system and are in general substantially different from STC conditions:





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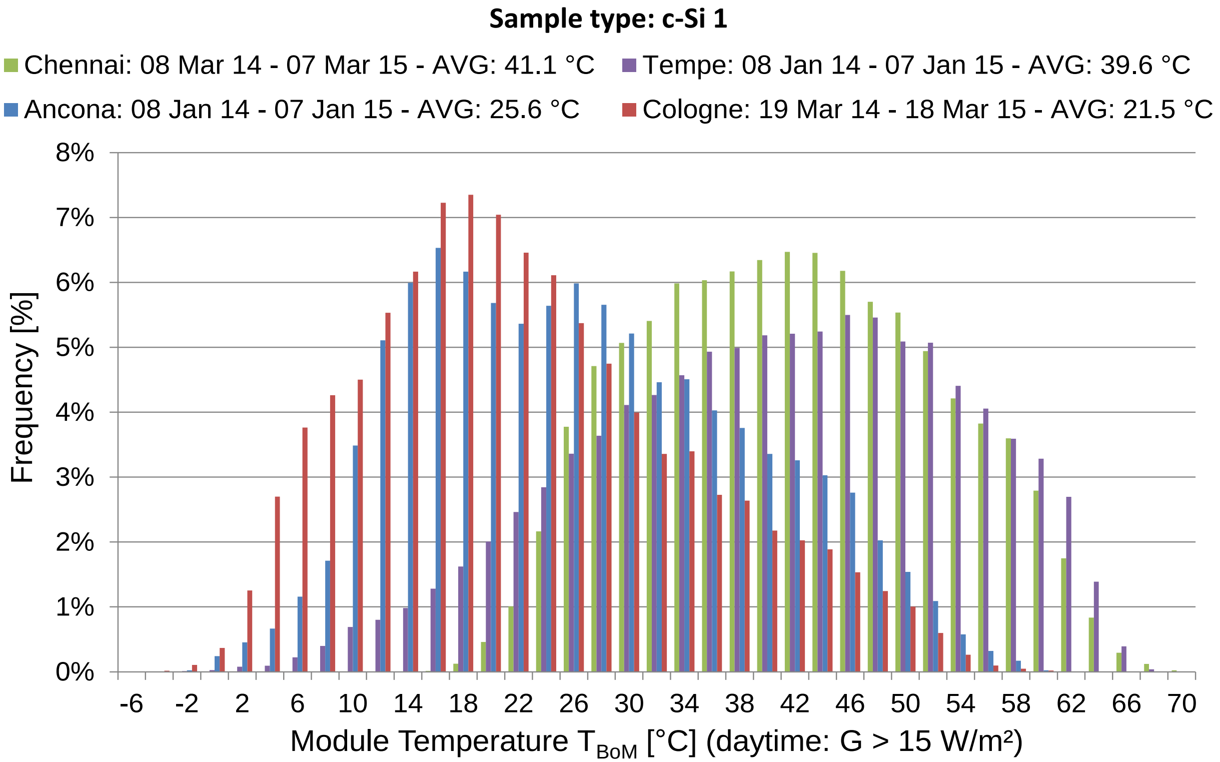
Temperature Effects (sample type : c-Si1)

Module temperatures in the range of:

-4.3 °C to 59.4 °C for Ancona, **-5.1 °C to 68.4 °C** for Tempe,

14.1 °C to 69.8 °C for Chennai and **-7.5 °C to 60.4 °C** for Cologne



Average module temperature:

21.5°C in Cologne

25.6°C in Ancona

39.6°C in Tempe

41.1°C in Chennai

Highest temperature measured:

74.9 °C for “CIGS 3” in Chennai.

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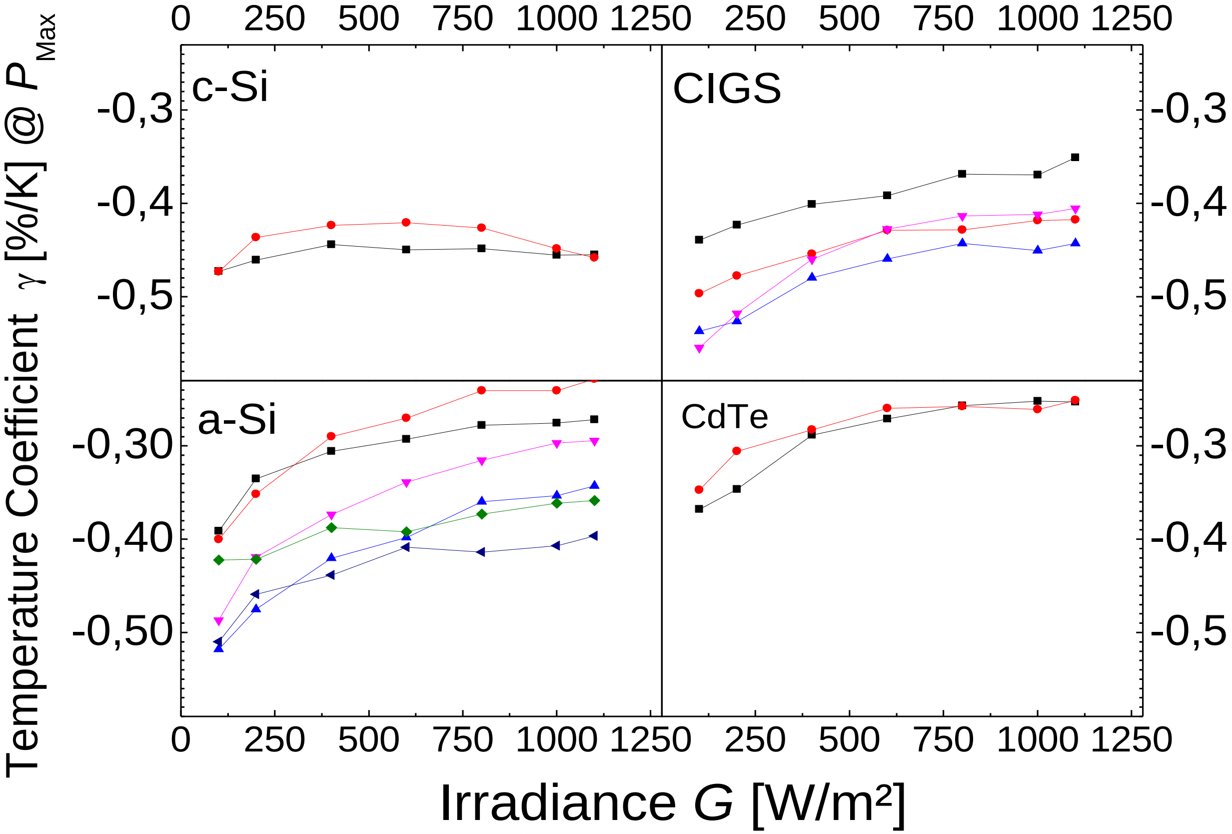
Temperature coefficient and average module temperature

Temperature coefficient of P_{Max} in dependence on the irradiance G measured with a pulsed solar simulator (no spectral shift):



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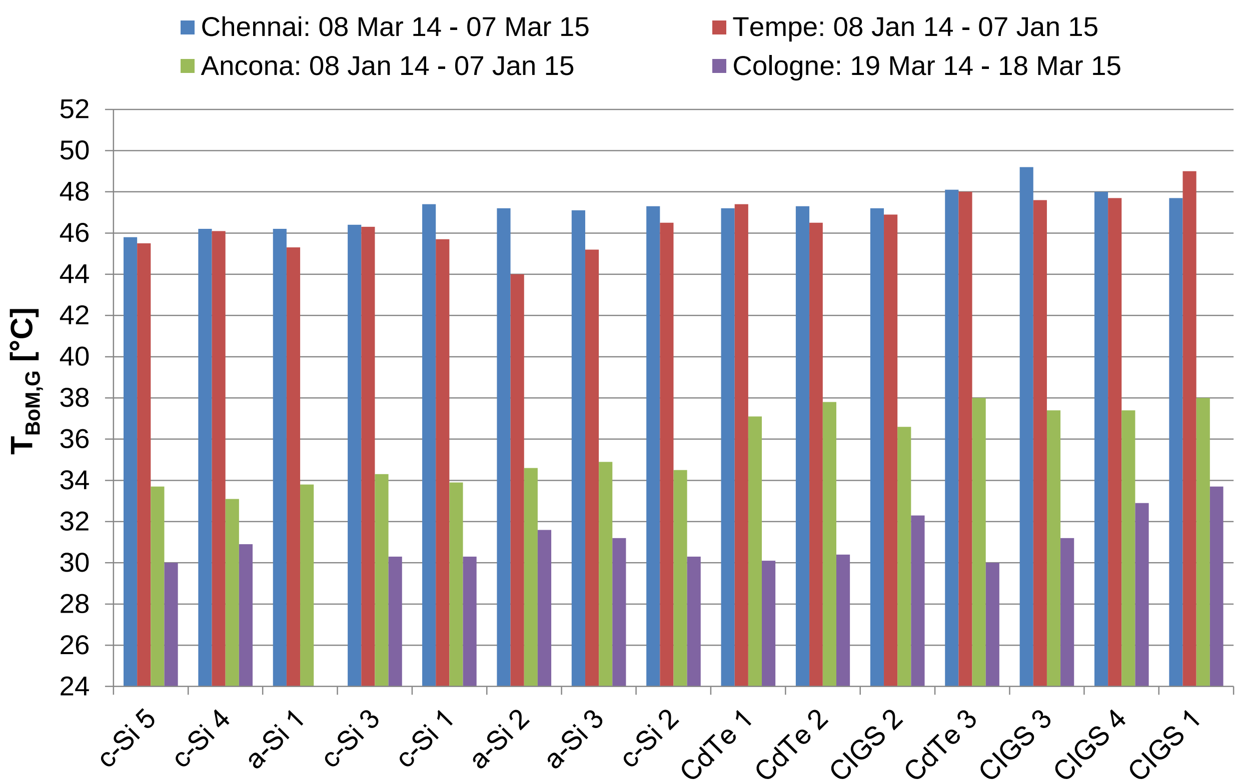
Temperature Effects

$$\overline{T}_{BoM,G} = \frac{\sum (T_{BoM} \cdot G)}{\sum G}$$

Considering the effect on energy yield the temperature is weighted with irradiance ($\Delta\overline{T}_{BoM,\,G}$).



Range of temperature coefficient of P_{max}:

-0.22 %/K and -0.44 %/K

Location	**Energy yield loss due to module temperature**
Germany	-1.2 % to -3.7 %
Italy	-2.6 % to -5.3 %
India	-5.3 % to -9.6 %
Arizona	-5.1 % to -10.6 %

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Low irradiance behaviour

Low irradiance behavior of 5 representative thin-film modules:

Yield differences:

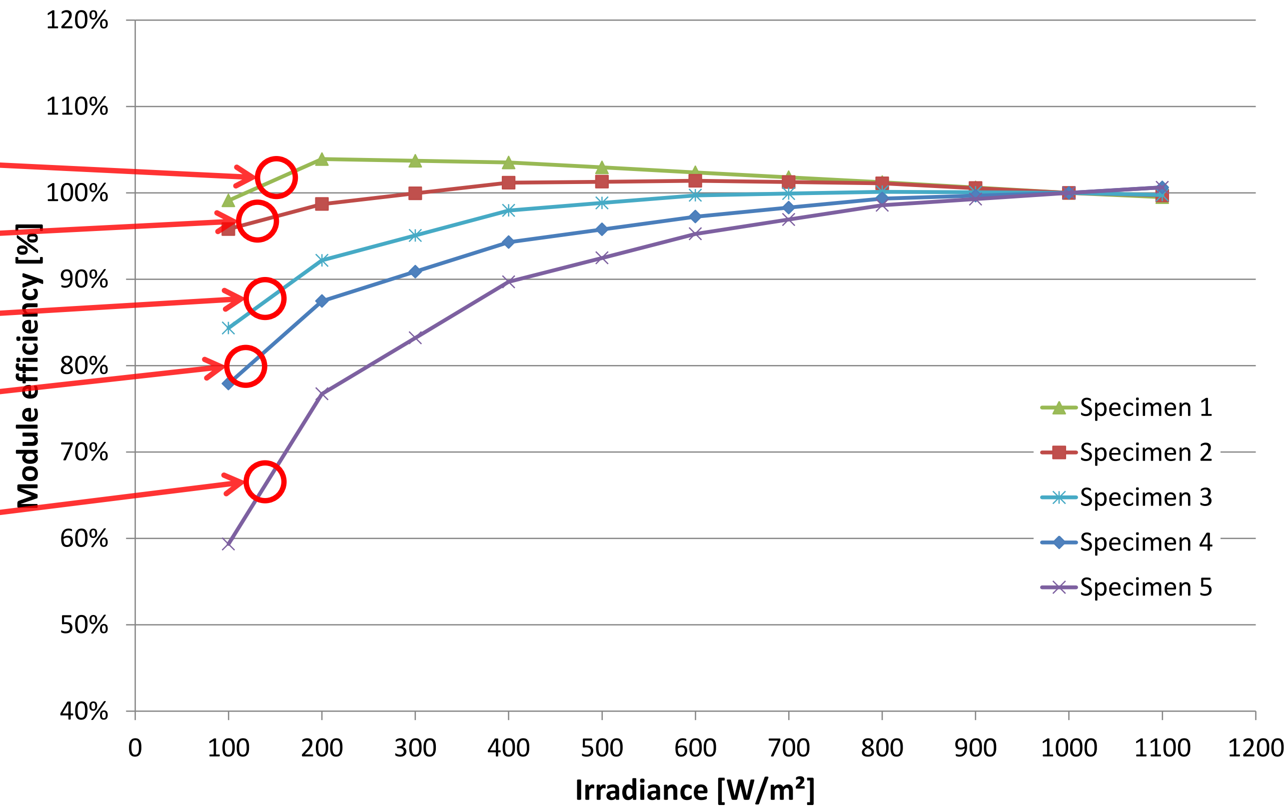
+2 %

+1 %

-3 %

-5 %

-10 %



(Losses for mounting situation differing from south even bigger)

Low Irradiance Behavior

Best low irradiance behavior achieved by:

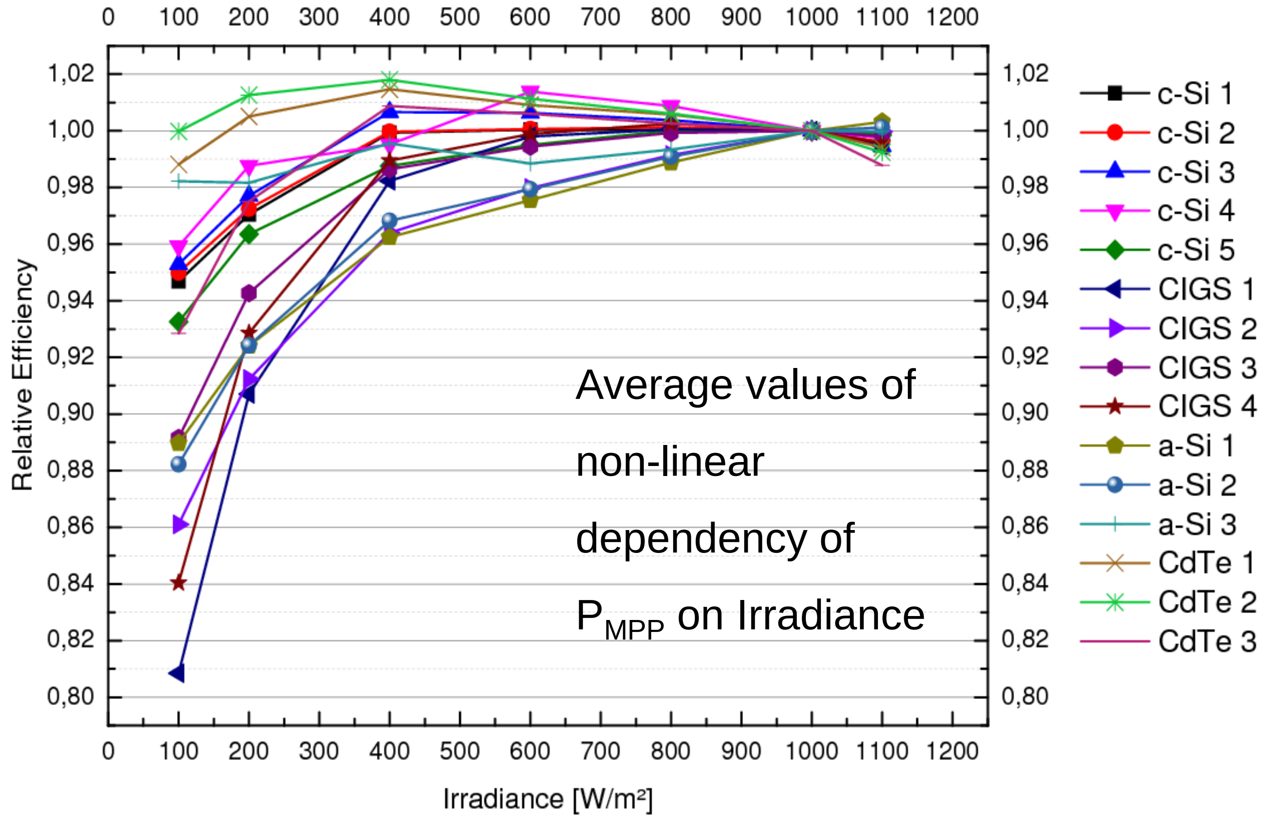
CdTe 1 + 2

Strongest dependency on irradiance show samples CIGS 1 + 2 + 4.

Crystalline samples show middle-rate results.

Indoor-Measurement of low irradiance behavior:

100 – 1100 W/m² at 25°C according to IEC 61853-1



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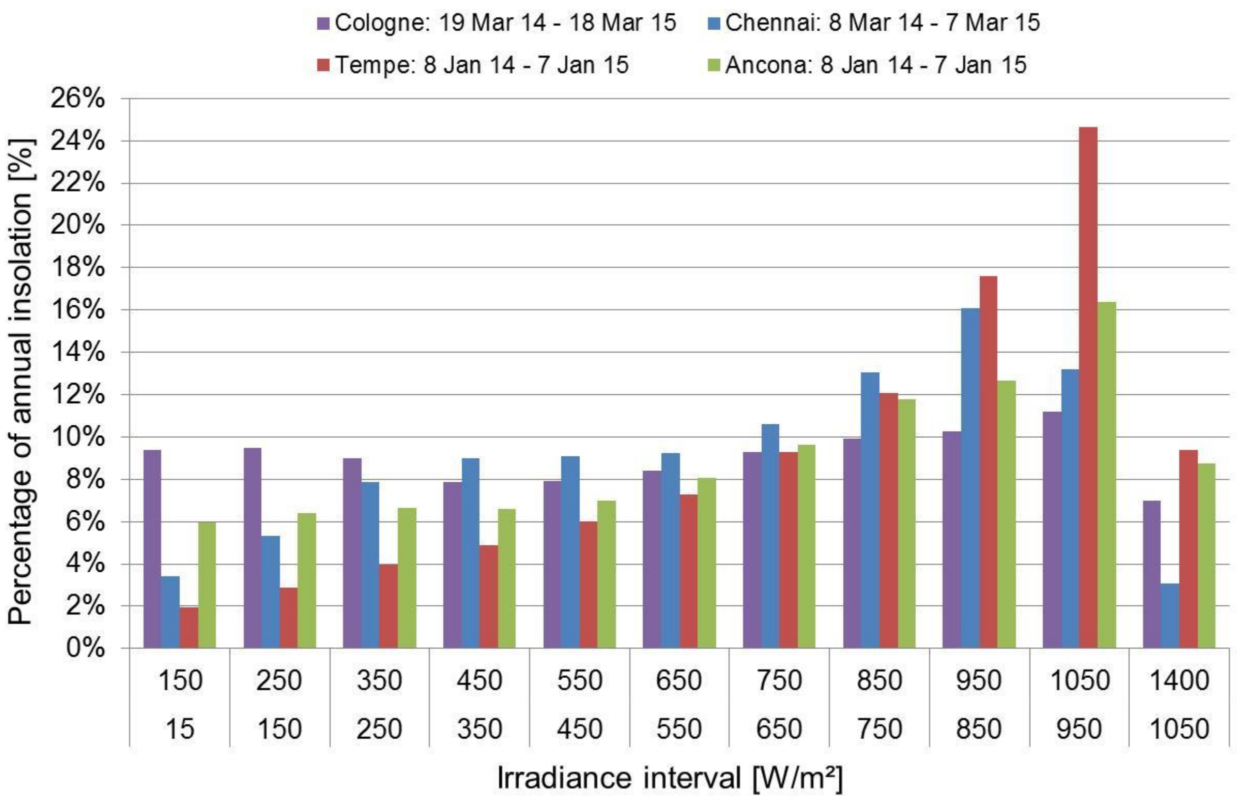
Low Irradiance Behavior

Irradiance distribution at the test sites for the first year:



- best low irradiance behavior: 99% efficiency at 100 W/m²
- Worst low irradiance behavior: 78% efficiency at 100 W/m²

Location	Energy yield loss due to low irradiance behavior
Arizona	-1.8 to +0.3 %
India	-2.9 to +0.6 %
Italy	-3.2 to +0.3 %
Germany	-3.6 to +1.1%

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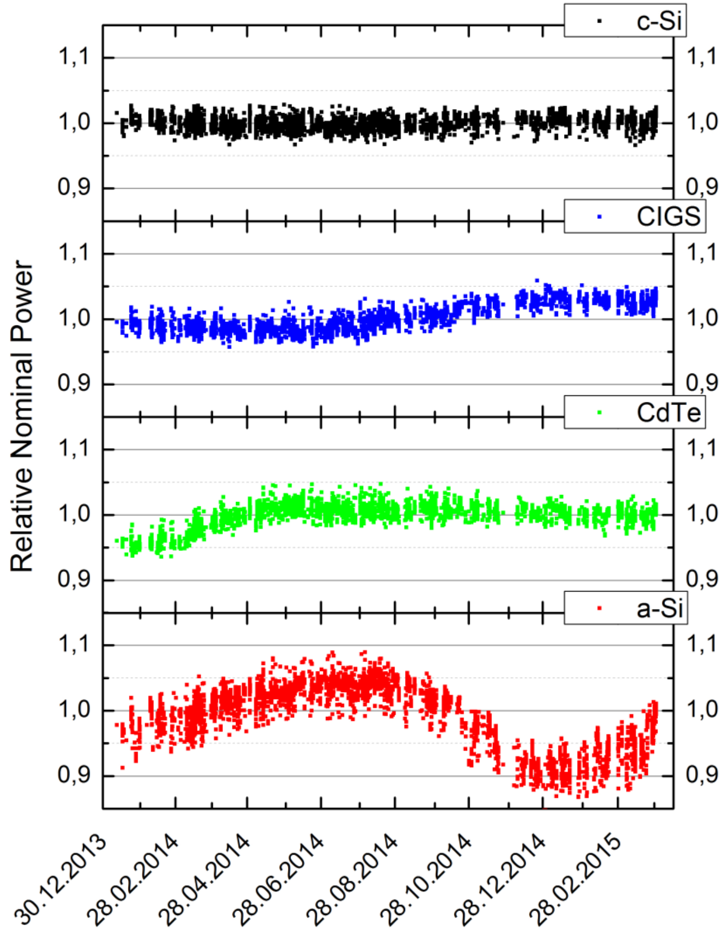
Influence of Metastability



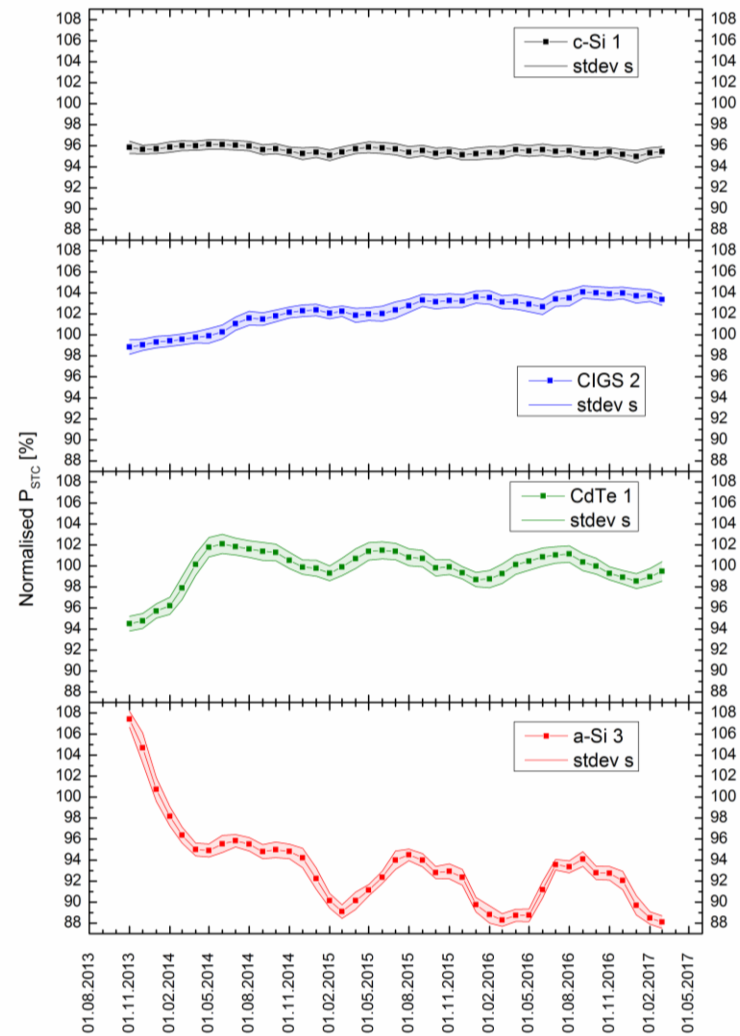
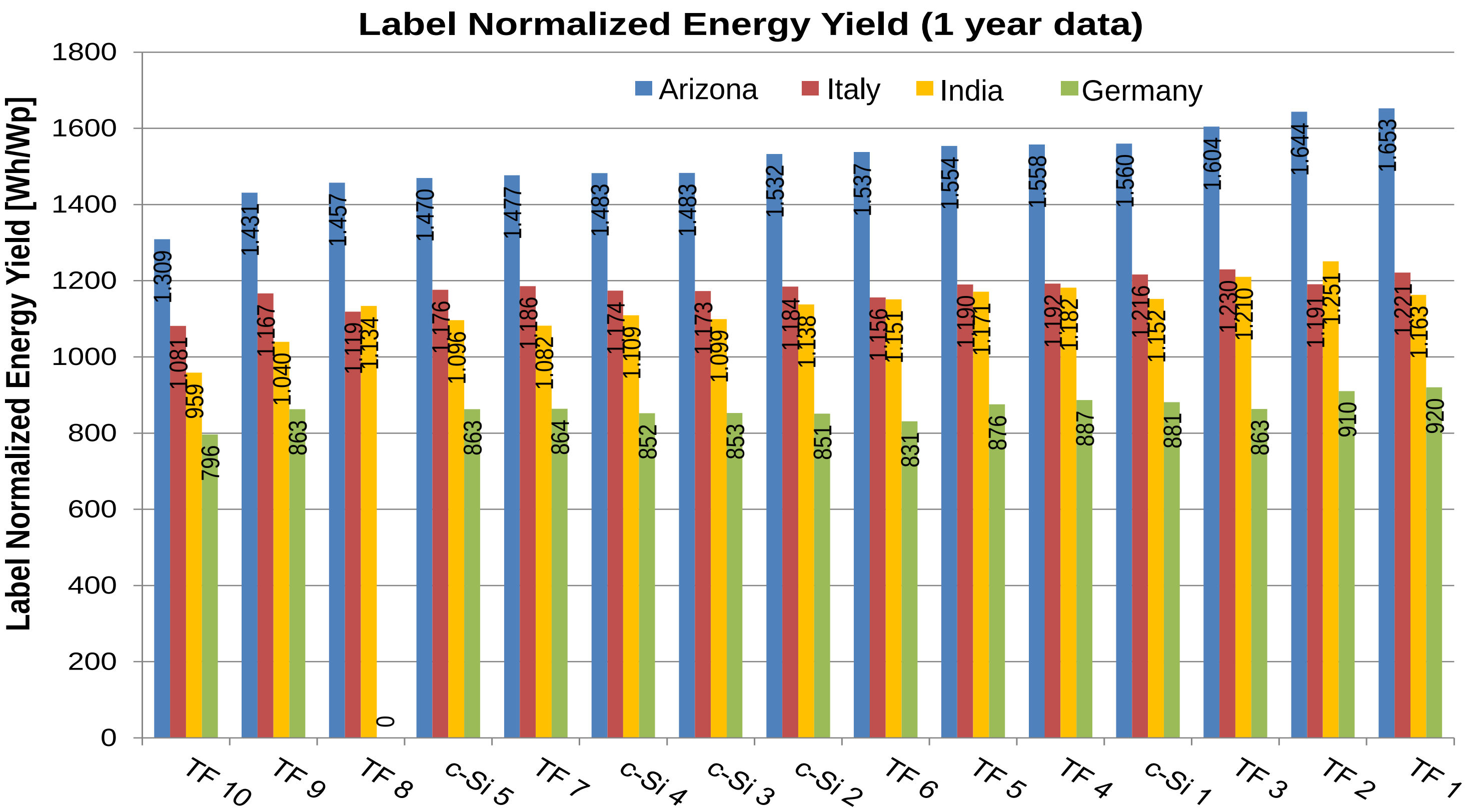


Figure shows P_{Max} stability of four representative samples in Italy

Choice of Technology
Global Energy Yield Benchmark



	Variation between technologies
Italy	**12 %**
Germany	**14 %**
India	**23 %**
Arizona	**21 %**
Saudi Arabia	Not available yet

Main Influence on Energy Yield:
- Temperature
- Angular dependency
- Low irradiance
- Spectral dependency

! Choice of technology and optimised product is crucial for high energy yield and return of investment.

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Conclusions

- Output power under standard test conditions (STC) is important for establishing the price at which photovoltaic (PV) modules are sold.
- However, significant differences of up to 23% in the energy yield of PV modules with same STC power detected.
- A combination of indoor tests and reference climate datasets is sufficient for estimating and comparing the energy yield performance of different PV module technologies.
- Special care must be taken on accurate STC values and its long-term stability.
- The ultimate owner of the PV installation should consider a well-defined module performance ratio before making an investment decision.


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danke
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Баярлалаа
спасибо
faafetai lava
mersi
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dank je
misaotra
matondo
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grazzi
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tapadh leat
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thank you
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