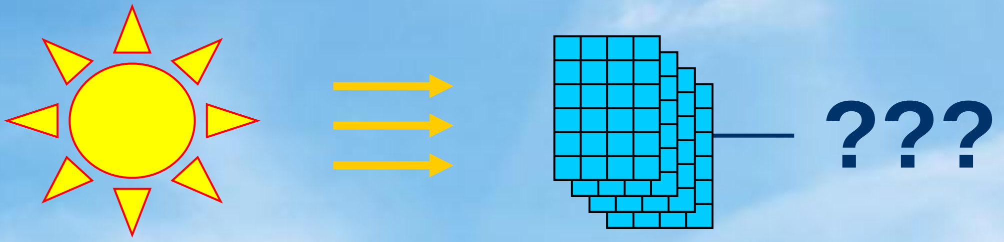
Energy prediction of PV modules & systems

J.Merten, CEA

Symposium on European PV Research Infrastructures
Chambery, France, 22 January 2015

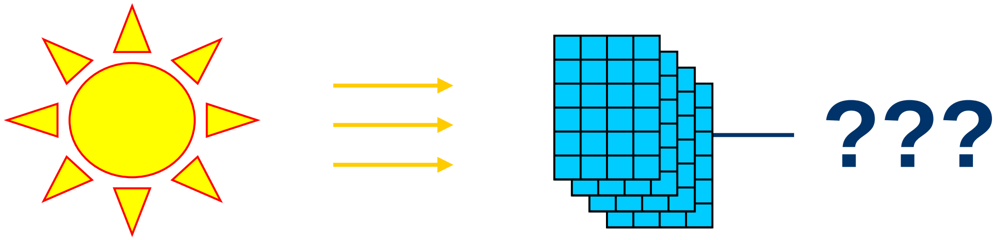


Objective: Precise prediction of PV module output

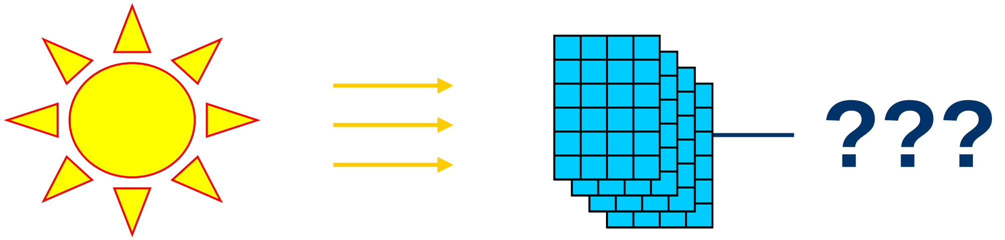
•Precise module characterisation, especially the **nominal module power**

•Precise modeling of the **module performance under real operation**

•Module aging

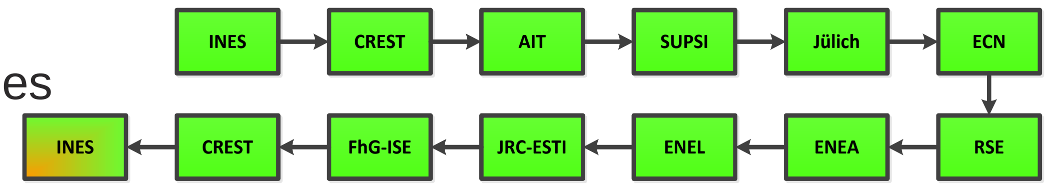


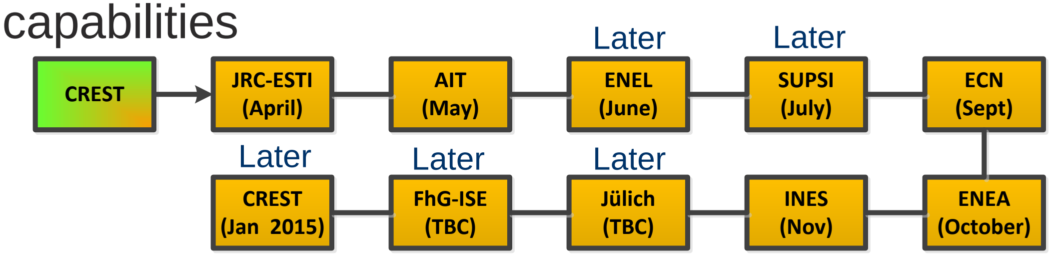
A large number of participants



Round Robin on PV modules
Work performed

- Work performed
  - Round robin 1: wafer based modules
  - Round robin 2: thin film modules
  - Preconditioning method proposed by HZB, tested @ CREST
  - Each partner depending on their capabilities measured :
    -Standard Test Conditions,
    -Low Irradiance Conditions,
    -Temperature Coefficients,
    -Electroluminescence,
    -Spectral Response,
    -Before and after pre-conditioning
  - Uncertainty estimation for all measurements





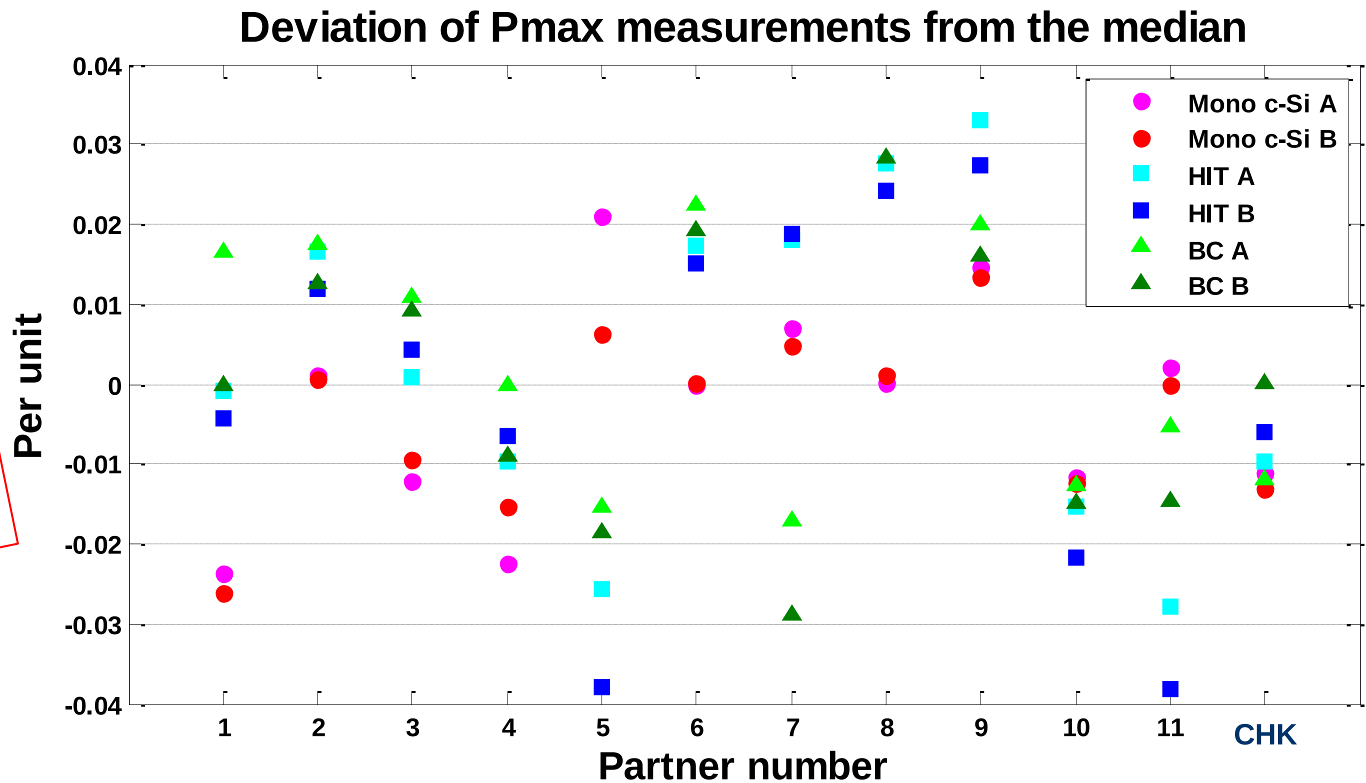
2x Mono c-Si Suntech
2x Back contact c-Si Sunpower
2x HIT c-Si Sanyo

2x (CIGS) Solar Frontier
2x (CIGS) Avancis
2x (CdTe) GE Solar
2x (ua-Si tandem) Sharp Solar
2x (c-Si control) Suntech from RR1

Round Robin on PV modules
Results RR1 - wafer based

RR1:
- Wafer based

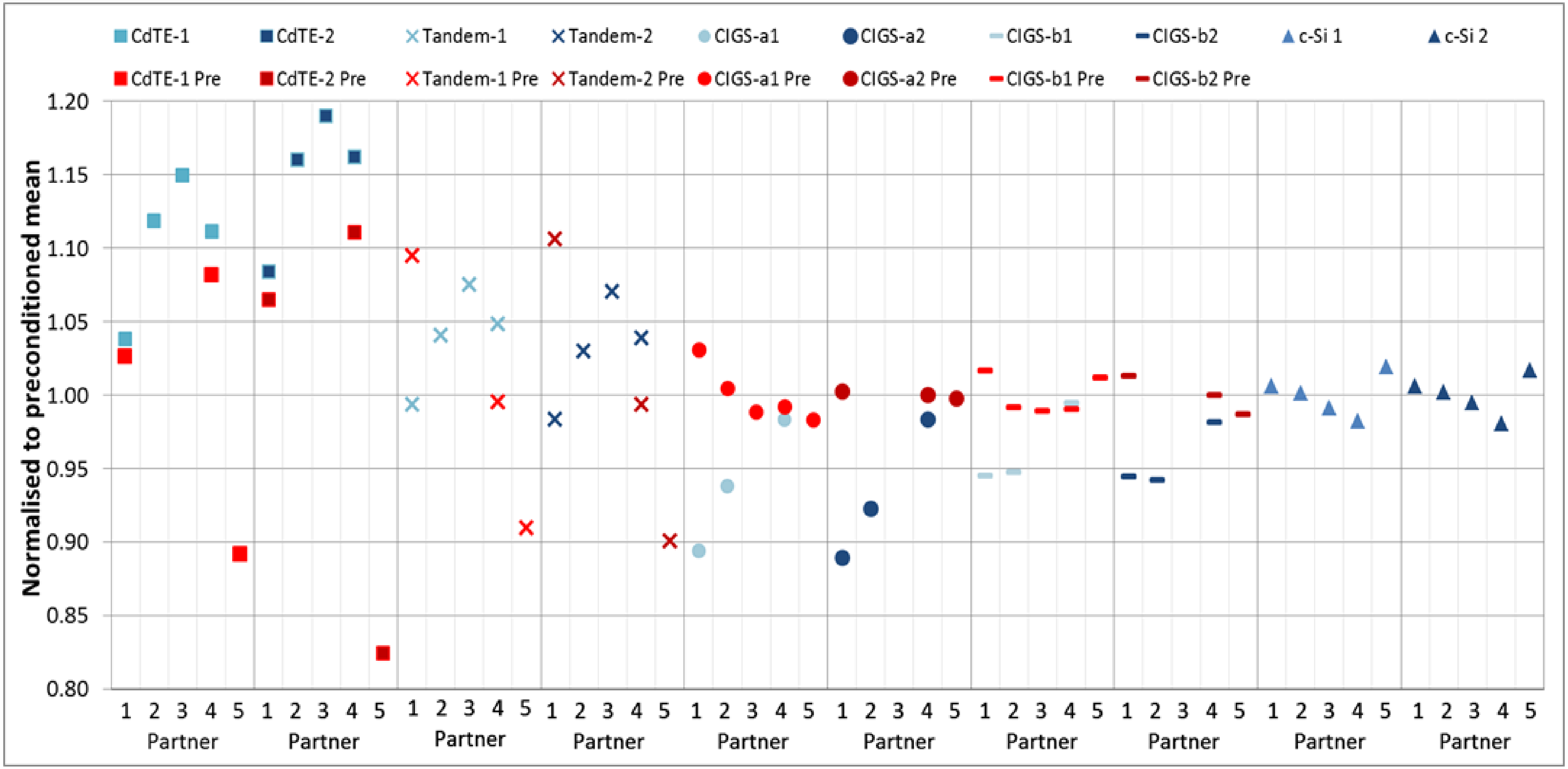
11 Partners
3 Technologies



Technology	Deviation from the median	
Standard c-Si	-2.4%	+2.1%
Back contact c-Si	-2.9%	+2.8%
Heterojunction c-Si	-3.8%	+2.7%

Round Robin on PV modules

Results RR2 - thin film



RR2: 6 partners, waiting on the last set of measurements
4 TF technologies and 1 c-Si.

Round Robin on PV modules
Conclusions/Recommendations

A wide spectrum of lessons learned

Preconditioning:

- Short term metastability effects need to be evaluated per module type and addressed.
- Electrical pre-conditioning useful for CIGS, but not for tandem and CdTe.

Uncertainty analysis:

- Most partners had uncertainties that are either underestimated or overestimated. The methodologies and contributing source have been harmonised
- Difference in uncertainty in the state of the modules and the measurement uncertainty.
- Both contribute to the over all deviation in measurements.

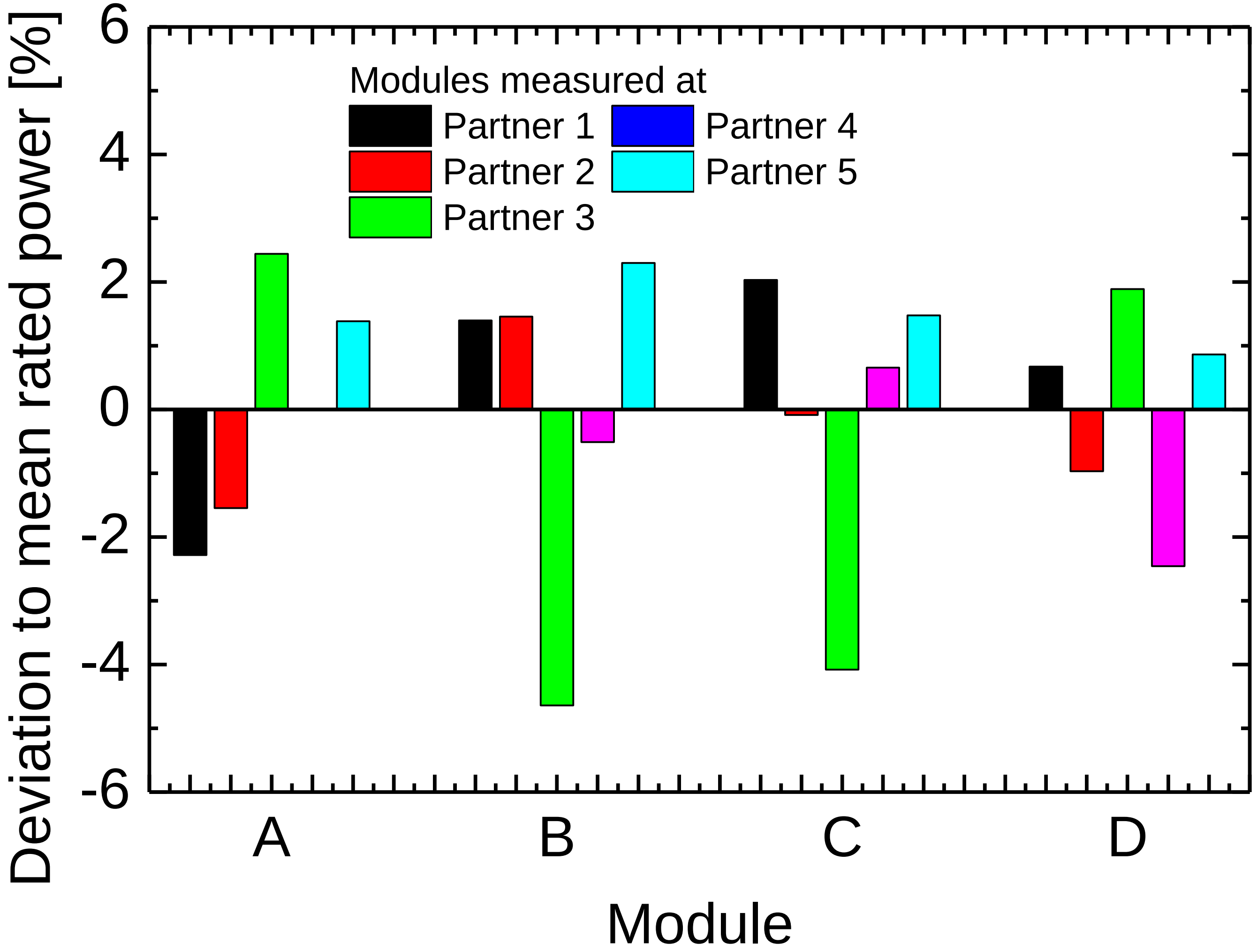
Improvements required

- Mitigating the capacitive effects
- Linearity of the reference device
- Mismatch correction
- Further efforts on harmonisation of measurement procedures and uncertainty estimation

Sensors
ISE-Soitec Mono-Modules
Soitec CPV-Modules

Round Robin on CPV modules
Participants

Partner	Location	Altitude
CEA-INES	Le Bourget du Lac, France 45.65N, 5.87E	230
ENEA	Portici, Italy 40.81N, 14.34E	sea level
Enel I&R	Catania, Italy 37.40N, 15.00E	30
Fraunhofer ISE	Freiburg, Germany 48.01N, 7.83E	270
IES-UPM	Madrid, Spain 40.45N, 3.71W	695
JRC	Ispra, Italy 45.82N, 8.63E	220
RSE SpA	Piacenza, Italy 45.05N, 9.70E	61


Deviation to mean rated power [%]
6
4
2
0
-2
-4
-6
Modules measured at
Partner 1
Partner 2
Partner 3
Partner 4
Partner 5
A
B
C
D
Module

Round Robin on CPV modules
Conclusions

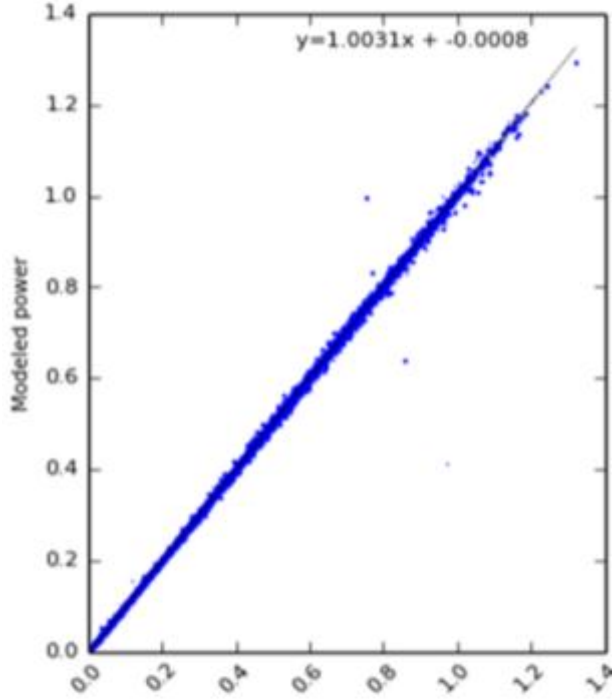
- CSOC rating with low deviation between labs possible
- All investigated power rating methods are suitable
- Tested and accepted rating procedures and standards
- Input for IEC WG7 power rating group

Energy Productivity Modeling
Work performed

Data collection:

- Outdoor I/V data collected in one single database
- 5 module technologies examined

Description	PV-Cell Technologies	Tilt angle (°)	Applications
ECN | MWT 6x10 156^2	x-Si (MWT)	30	free-standing
Heckert Solar | HS-PXL-200	poly	30	free-standing
UniSolar | PVL-68	a-Si	30	free-standing
Wuerth Solar | WSG0036E075	CIGS	45.	free-standing
First Solar | FS-270	CdTe	45.	free-standing
IBC Solar| Bacsun Ploysol 230T	poly	15	BIPV



3 different electrical models tested:

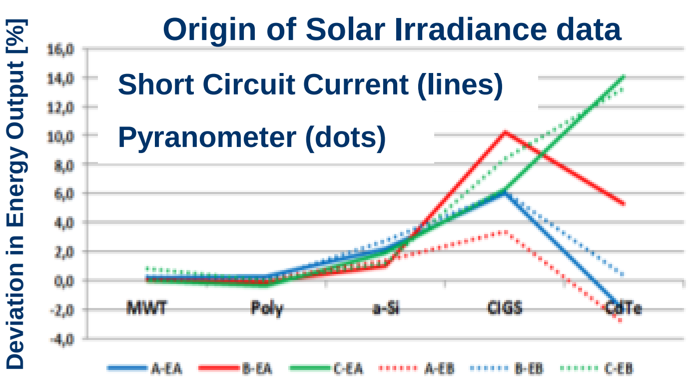
- Neural Networks
- Energy Yield Model
- MotherPV method

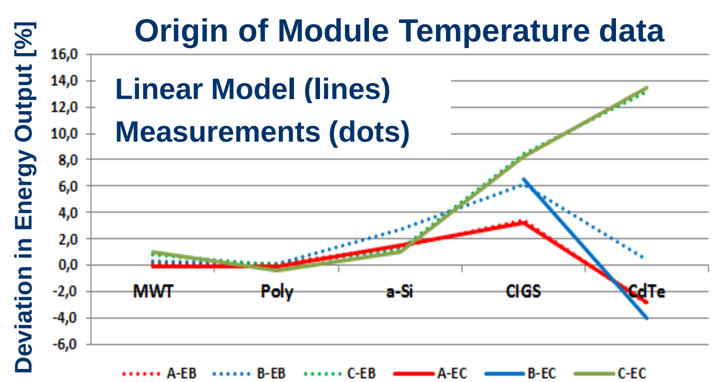
Test of different data used for modelling:

- Measured short circuit current versus pyranometer data
- Measured module temperature versus modeled module temperature

Energy Productivity Modeling
Conclusions

- Deviations of modelled productivity is **excellent** (<1% c-Si, <3% thin film) **only under following conditions:**
  - Module is characterised individually
  - Data quality is excellent ➔ Derlab Guidelines for Outdoor Measurements
- Spectral effect:
  - using pyranometer data instead of module short circuit current data does not significantly reduce quality of the model
- Temperature effect:
  - Using modeled module temperature slightly increases error in output prediction
  - NOCT model is sufficient for module temperature modeling: more sophisticated models do not reduce output prediction errors

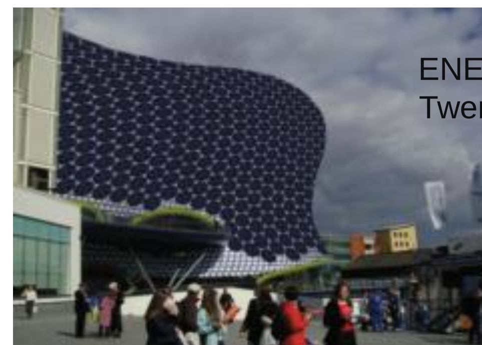




Energy Productivity Modeling BIPV
Work Performed

Objectives: Determine the **thermal** impact of the installation method of BIPV modules on their energy output.

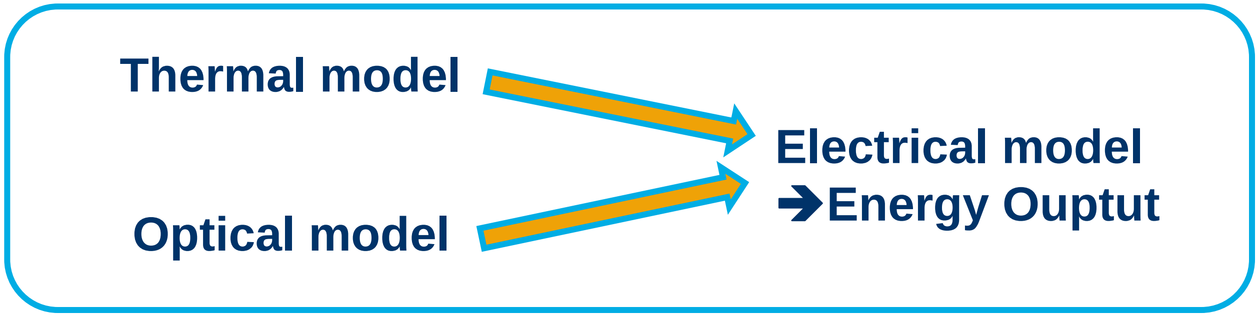
Work performed:
- Benchmark of BIPV system testing and modelling methods.
- White paper on BIPV requirements considering: energy output prediction, regulations, related building functions, cost compensation…



ENEA/ Univ Twente,NL

Energy Productivity Modeling BIPV
Results

- Modelling guidelines
  - State of art of BIPV systems modelling methods.



- Characterization guidelines
  - Specific requirements based on outcomes of 1st INES workshop on BIPV.
- Benchmark of modelling methods (29th EUPVSEC Plenary session, 6DP2.3).
  - All models examined results in satisfying prediction of module temperatures.
  - Ranking of the models according to their impact on the accuracy of energy output prediction. (less than 1% error in energy output).
  - Higher accuracy of the thermal model doesn’t lead to higher accuracy of the prediction of the energy output.
  - For practical purposes, the standard linear model is fully satisfactory

Conclusions/ Recomendations

- Development of a BIM (Building Information Modelling) for BIPV (association of Building software, a BIPV model and a database of BIPV products) adressing architects and designers.
- Accuracy of thermal models is sufficient.
- Definition of Guidelines for BIPV systems characterization: tests methods and choice of sensors, definion of standards.
- Quantification of BIPV systems additional functions other than electrical production.
- Definition of solutions to increase BIPV systems lifetime.

.

Thank you very much for your attention

Jens.Merten@CEA.FR