SOPHIA European Research Infrastructure

Outcomes of the Sophia Project

Philippe Malbranche,
Research Programme Manager
philippe.malbranche@cea.fr

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Outline

1. Description
    - Context and motivation
    - Scope
    - Consortium
    - Objectives
2. Main outcomes
    - Transnational access activities
    - Joint research activities
    - Networking activities

Context and Motivation

Context :

Many PV research infrastructures exist all over Europe:

- Some are unique
- Some are similar

This project was the first to promote on a large-scale an increased coordination in order to:

1. avoid unintended duplication
2. avoid unnecessary investment. Why to invest into additional research infrastructures when some of them can be made available ?
3. get more value out of the same budgets. « Working together to progress faster or to learn more » :
   - Comparison of characterisation methods, modelling software
   - Validation with an increased number of data, to increase the confidence level

⇨ Joining forces to offer better services for researchers from academia and industry

Scope of activities

- The project focuses on **8 topics** covering the whole value chain:
  - Silicon material
  - Thin films and TCOs
  - Organic PV
  - Modelling
  - CPV
  - BIPV
  - PV Module lifetime
  - PV module and system performance

- A link to the EERA PV Joint Programme is organised through:
  - Many common partners
  - Four topics are also addressed within EERA

Funding scheme : Integrating Activities	EU financial contribution : 9 M€
Duration : 48 months	Starting date : February 2011

The consortium: 20 Partners

- 17 research organisations, 3 associations for information exchange

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AIT Austrian Institute of Technology – Tomorrow Today

cea tech – From research to industry

ines – Institut National de l'Energie Solaire – COORD

DERlab

ECN – Energy research Centre of the Netherlands – WPL

ENEA – WPL

Enel

EPIA – European Photovoltaic Industry Association

EUREC Agency – European Renewable Energy Research Centres Agency

Fraunhofer – WPL

Helmholtz Zentrum Berlin für Materialien und Energie – WPL

imec

Jülich Forschungszentrum – WPL

JRC European Commission

Loughborough University

DTU

RSE Ricerca Sistema Energetico

SINTEF

tecnalia Inspiring Business

Universidad Politécnica de Madrid

VTT

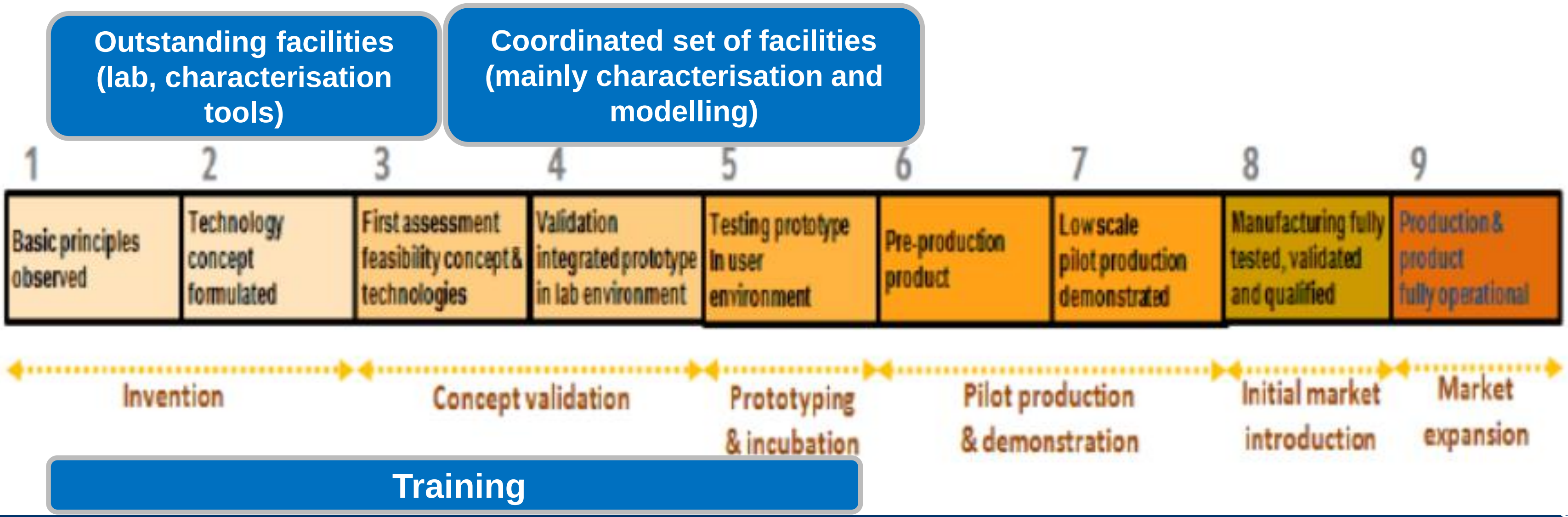
A dedicated website : www.sophia-ri.eu

Objectives

- The Sophia objectives are:

1. to give access to European researchers to a unique portfolio of laboratories and test facilities in the field of photovoltaics. This will ensure that a large number of scientists from the EU and the Associated States can benefit from expensive equipment.

2. to join forces of partners from academia and research institutes in order to address some specific challenges of solar photovoltaic energy.

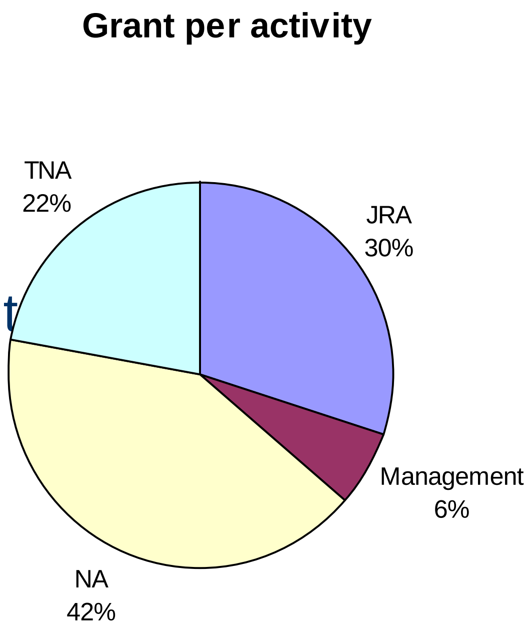


Three types of activities

- **Transnational Access Activities**:
  Free-of-charge transnational access for researchers, through a single entry point to the partner RIs.

- **Joint Research Activities**: Upgrade and improvement of the services of PV RIs

- **Networking Activites** for coordination and joint development of the RIs



Overall, this project is a driver towards an increased coordination :

1. Listing existing Ris
Equipment, procedures

2. Increasing coordination
Benchmarking, RR, improved procedures

3. Developing joint strategy

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   - Joint research activities
   - Networking activities

Trans-national Access Activities results (TNA)

- Objective: provide free of charge and open access to 48 research infrastructures, dealing with:
  - Better characterisation of materials and innovative technologies,
  - Performance characterisation and lifetime prediction of PV modules
  - Modelling

European researchers can then benefit from partners' platforms and associated technical support.

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Free access to 48 research infrastructures

TNA01 : better experimentation and characterisation

Si Material
- FT facilities (ECN)
- Si solar cell and analysis lab (IMEC)
- SUSI Platform (CEA/INES)
- Heliosi Characterisation (SINTEF)
- Wafer/cell Imaging (ISE)
- Realization Line for high efficiency cost effective cSi Solar Cells (ENEA)

Organic PV
- Permeameter (CEA/INES)
- Polymer solar cell processing & characterisation facility (RISOE)
- Thermal deposition of molecular materials (HZB)
- Polymer solar cell processing facility (VTT)
- Polymer solar cell processing facility (TECNALIA IAE)
- O-line (IMEC)

Thin film technology
- UHV-end station(HZB)
- EPR characterization (HZB)
- European Solar test installation (JRC)
- TCO sputter-deposition and Characterization (HZB)
- Module laboratory (CEA/INES)

Modelling
- Electrical, Thermal and Mechanical Characteristics Modeling (IWES)
- Computing resources and modelling of solar cells (Jülich)
- Optical, thermal and mechanical modeling of PV and BIPV (TECNALIA IAE)
- Sentaurus 2D- and 3D-modelling (IMEC)
- ENEA GRID (ENEA)

TNA02 : harmonised vision on performance and liftetime

CPV
- Indoor simulator for concentrator modules (ISE)
- CPV test facility (ERSE)
- Outdoor monitoring station for concentrator modules (ISE)
- Indoor and outdoor characterization of concentrator modules and cells (UPM)
- CPV modules outdoor test station (ENEL)
- CPV systems long term monitoring station (ENEL)
- Indoor PV-C Solar cells and lens Characterization (ENEA)
- PV-C Outdoor cells, Modules and system Characterization (ENEA)

Module lifetime
- Performance and Degradation Modelling of Solar Modules (ECN)
- Micro-Raman Spectrometer (ISE)
- 2-D and 3-D thermo-mechanical modelling software (IMEC)
- Characterization of stress distribution in mini-modules(IMEC)
- Module Characterisation Facility (CREST)

Module & system performance
- PV test lab (IWES)
- Outdoor module test facility(ISE)
- PV Test facility (ERSE)
- Indoor and Outdoor PV Module test facility (CEA/INES)
- BIPV platform (CEA/INES)
- Outdoor test lab for PV flat modules (ENEL)
- KUBIK (TECHNALIA IAE)
- Tecnalia battery test station (TECHNALIA)
- Outdoor PV Module Test facility (ECN)
- PV Module Qualification laboratory (ENEA)
- PV module and system lab (AIT)
- indoor durability test facility (ISE)

Research Infrastructures listed by topics

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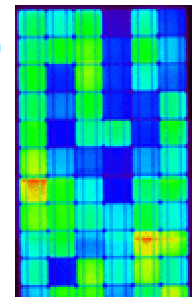
LOGIN | Search...

HOME ABOUT USER ACCESS TECHNOLOGIES NETWORKING ACTIVITIES RESEARCH ACTIVITIES NEWS & EVENTS

- Si Material
- Organic PV
- Thin Films
- Modelling
- CPV
- BIPV
- Module lifetime
- Module and system performance

YOU ARE HERE : TECHNOLOGIES > MODULE LIFETIME



PV module lifetime prediction is a very important issue for industrial companies, developers and especially end-users. The well-known IEC qualification tests set minimum design criteria, but do not provide comparative information about the durability of PV modules. No scale exists so far to sort out between modules lasting 20 years or 40 years within specific climates.

In order to improve the accuracy of PV module lifetime predictions, several research infrastructures work together on the following issues :

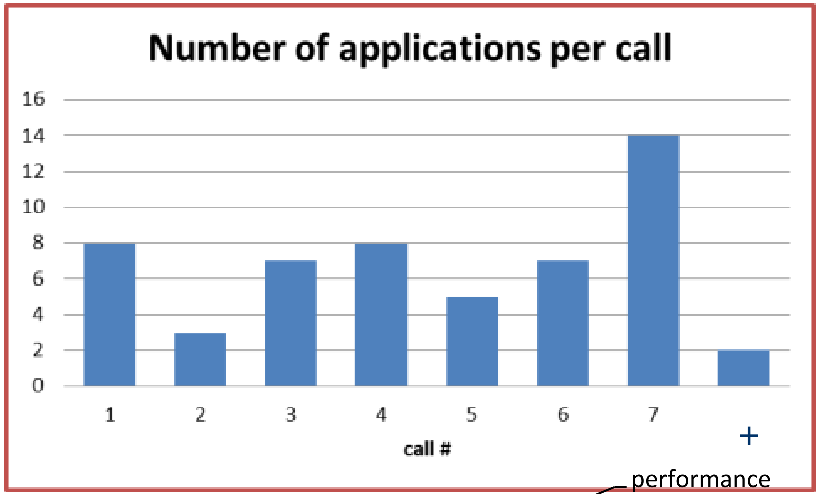
- failure analysis : characterisation methods
- definition and benchmarking of accelerated ageing tests

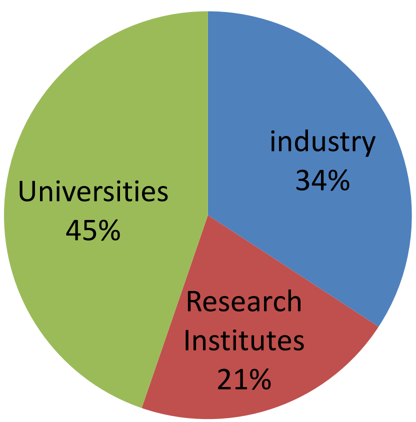
Several research infrastructures are available for research work on this topic:

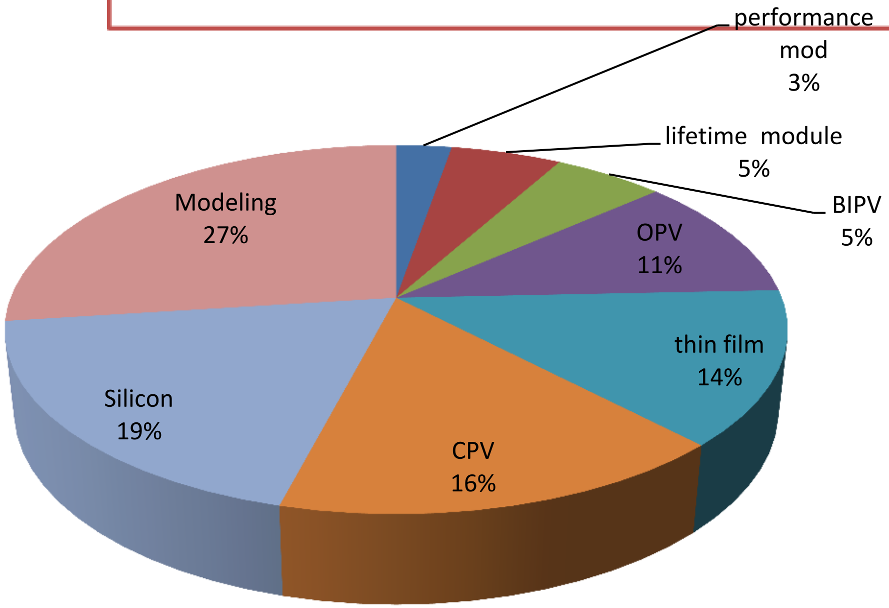
Partner	Research Infrastructures	Main Characteristics
CEA-INES	PV module laboratory	PV module lamination (1,3x1,7m), IV curves, EL characterisation, climatic chambers, failure analysis
ECN	Performance and degradation modeling of PV modules	Software platform based on multiphysics simulation, in conjunction with experimental work
ENEA	PV module laboratory	Climatic chambers, including DH, UV and salt spray corrosion test
Fraunhofer ISE	Outdoor PV module test facility	5 locations in various extreme climates (temperate, mountain, desert, marine, tropical)

Transnational access activities outcomes

- **8 calls** for research proposals organised
  - Since January 2012
  - Last call still open
- **52 proposals** submitted in total







Proposals: Fields of interest

TNA: Evaluation / selection / hosting

- 35 TNA access granted:
  - 3 cancelled by applicant
  - 20 under discussion with RI host
  - 7 tests currently running
  - 5 tests finalised

Host infrastructure	# projects hosted
HZB	6
Fraunhofer-ISE	4
IES-UPM	3
Tecnalia	3
Jülich	3
ENEA	3
CEA-INES	3
DTU	3
CREST	3
SINTEF	2
ECN	1
RSE	1
IMEC	1
AIT	1
EC JRC	0
Enel	0
VTT	0

TNA: example 1

- "BECAR" proposal
  = "Best prototype Efficiency Concentration and Acceptance angle chaRacterization"
  - Topic: CPV
  - Call 3
  - Proposed by: Becar S.R.L., Bologna (I)
  - Host: IES-UPM
- Result
  - An extensive set of indoor and outdoor experiments was carried out to characterize CPV modules manufactured by BECAR. Their optics is based on a parabolid square mirror and a refractive pyramid as secondary optical element and it has been designed to attain a geometrical concentration of 1344X.
  - Two module prototypes were measured indoors using the Helios 3198 Solar Simulator

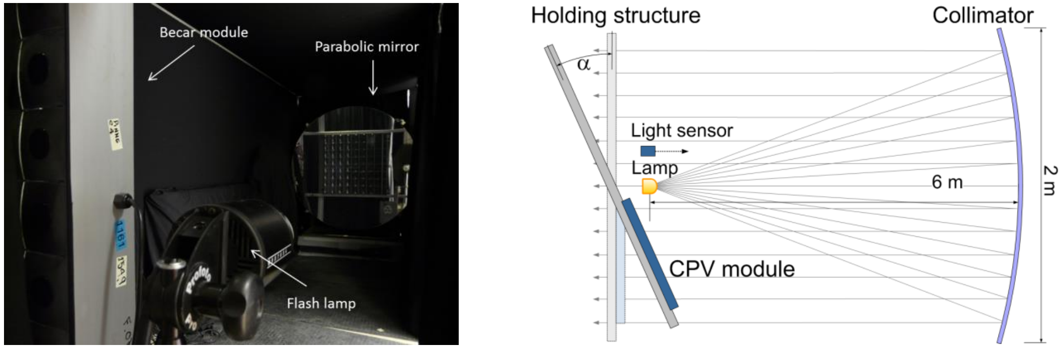


Fig. 1. Left: Experimental set up, the photograph has been taken from the the focus of the parabolic mirror, that is the position of the flash lamp. Right: Scheme of the solar simulator that allows the acurate roration of the module to measure its angular transmission curve.

TNA: example 1

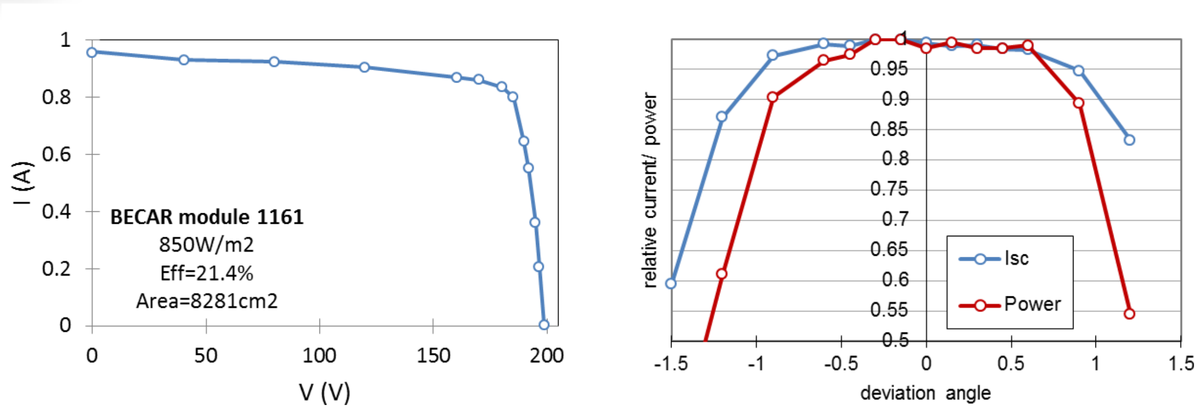


Fig. 2. Left: IV curve of the best-performing module on-axis measured indoors using the Helios 3198 Solar Simulator. Right: Angular transmission curve for the best performing module measured indoors.

- Most remarkable results
  - Optimisation of the optics
  - Characterisation of the thermal drops (cell to dissipative fin and dissipative fin to ambient), which were higher than expected, leading to a cell temperature higher than 100ºC. Consequently, it was recommended to redesign the configuration of the thermal stack

Microsoft Word Document

TNA: example 2

- “DEF-HYDFT”
  = “Defects in ZnO using hybrid density functional theory”
  - Topic: Modeling
  - Accepted as part of the 4th call
  - Proposed by: Solar Energy Institute (Universidad Politécnica de Madrid, Spain)
  - Hosting RI: Jülich Supercomputing Centre
- Testing period
  - [January 2014 – December 2014] in “open access”
- Status
  - Ongoing.
- Experimentation
  - simulation at supercomputer

TNA: example 2

- Results
  1. Explanation of the differences in electrical and spectral properties of thin films obtained with both dopants.
  - Ga-ZnO behaves as a metal, with low resistivity (10-4 Ωcm) that increases with temperature,
  - Al-ZnO and intrinsic ZnO behave as semiconductors, with larger resistivity that decreases with temperature: the origin of the peaks observed in the HAXPES spectrum at the Fermi level, can be assigned to defect combinations of interstitial oxygen with substitutional cations (Al or Ga), and to interstitial Al.

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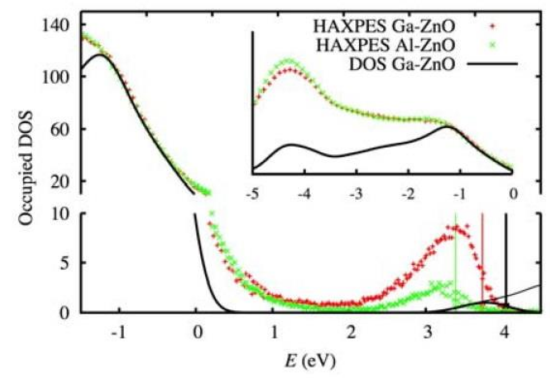


Figure 1. HAXPES spectrum compared with the theoretical density of states.

Adobe Acrobat Document

Joint Research Activities

- Objectives: to improve and optimise the services provided by the research infrastructures.

- Our work is focused on four topics:

1. Greater accuracy of rated power and energy output prediction of PV modules & systems
2. Quicker lifetime prediction of PV modules though accelerated ageing tests and improved failure analysis procedures
3. Improved Material characterisation procedures dedicated to:
    1. silicon material,
    2. thin films and TCOs,
    3. and organic solar cells
4. Improvement and validation of software infrastructure for material, cell, module and system modelling

1. Objective: Greater accuracy of PV modules rated power and energy output prediction of PV modules and systems

Activities performed:

- RR1 : Six c Si modules
- RR2 : Eight thin films and two c Si modules
- Power rating of innovative technologies (preconditioning studies)
- Energy output prediction methods (collection and management of monitoring data)
- CPV
- BIPV

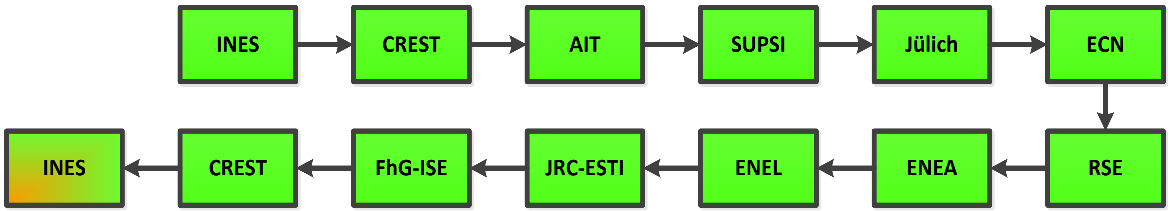
Tests

- Standard Test Condition (STC) (Pmax, Isc, Voc)
- Low Irradiance Condition (LIC) (Pmax, Isc, Voc)
- Temperature Coefficients (TC)
- Spectral Responsivity (SR)
- Electroluminescence (EL)

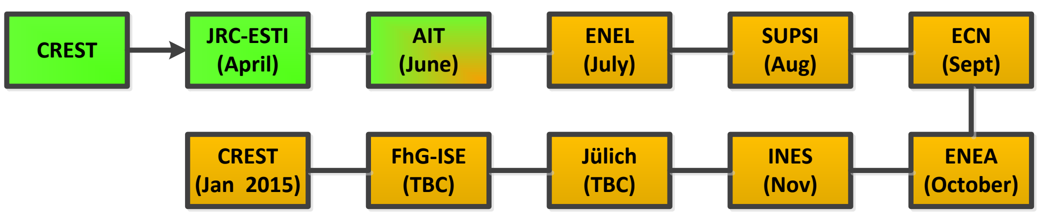
Partne	Module technolo gy	nclinatio	Installation Method Module type	Data for Info-Table in the database already supplie	Measured data available	Measured data uploade
ECN	a-Si	30	free-standing, Standard	Yes	Yes	Yes
INES	a-Si	30	free-standing, Standard	Yes	Yes	Yes
JRC	a-Si	45 deg.	free-standing, Standard	Yes	Yes	Yes
JRC	CdTe	45 deg.	free-standing, Standard	Yes	Yes	Yes
JRC	CIGS	45 deg.	free-standing, Standard	Yes	Yes	Yes
AIT	mono	35	free-standing, Standard	Yes	Yes	Yes
ECN	poly	30	free-standing, Standard	Yes	Yes	Yes
INES	poly	30	free-standing, Standard	Yes	Yes	Yes
INES	poly	15	BIPV	Yes	Yes	Yes
JRC	poly	45 deg.	free-standing, Standard	Yes	Yes	Yes
ECN	x-Si (MWT	30	free-standing, Standard	Yes	Yes	Yes

Round Robins

- Module Energy output : measurement and prediction
  - First Round Robin completed (c-Si)
    - measurements analysed: recommended practices
    - Disseminated at workshop in Freiburg (Feb 2014)
    - Oral presentation of results at EU-PVSEC 2014 (Mihaylov et al, 5DO.9.3)



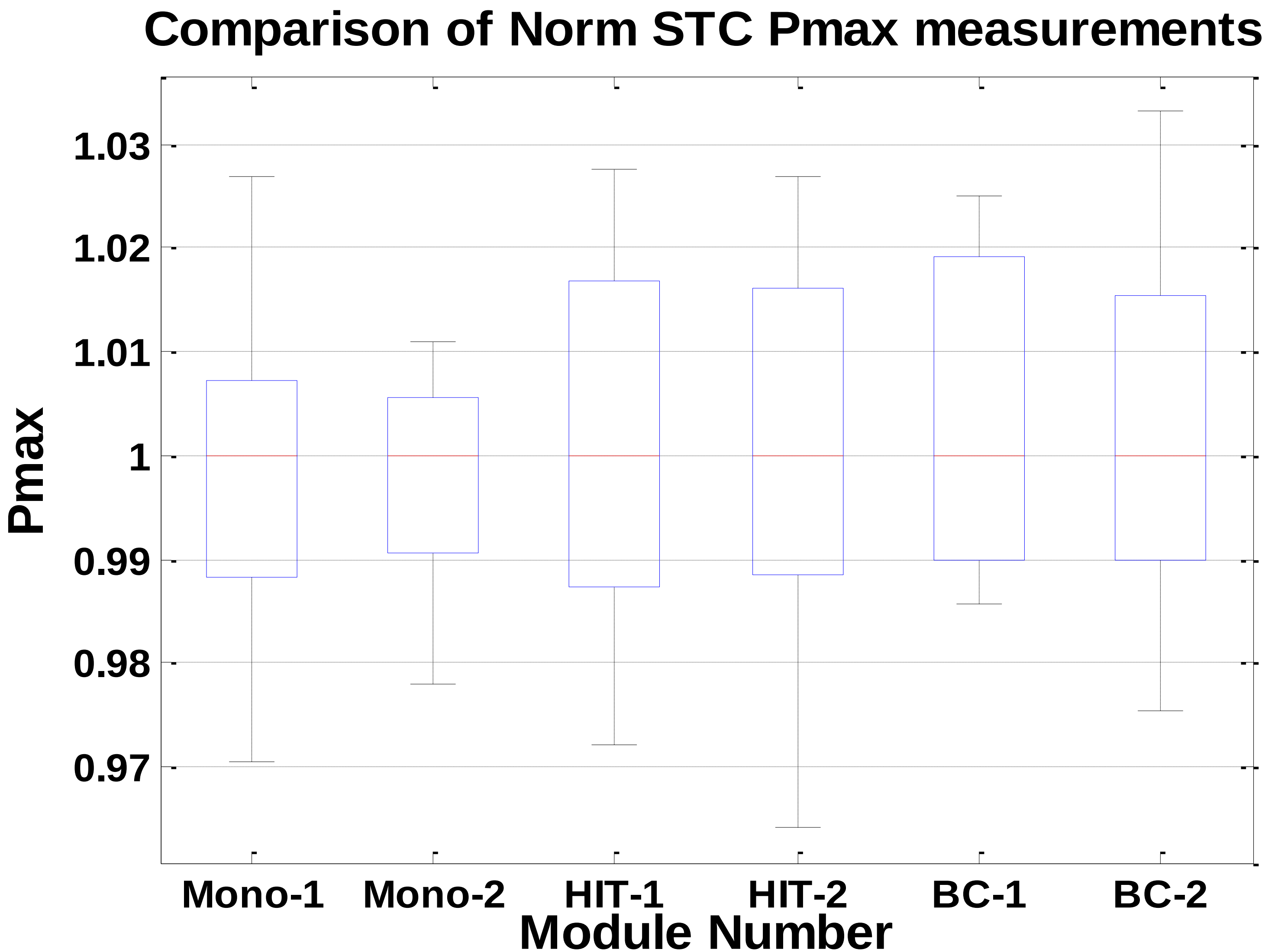
  - Second round robin started (thin film)
    - Preconditioning method proposed
    - Round-robin underway (see schematic)



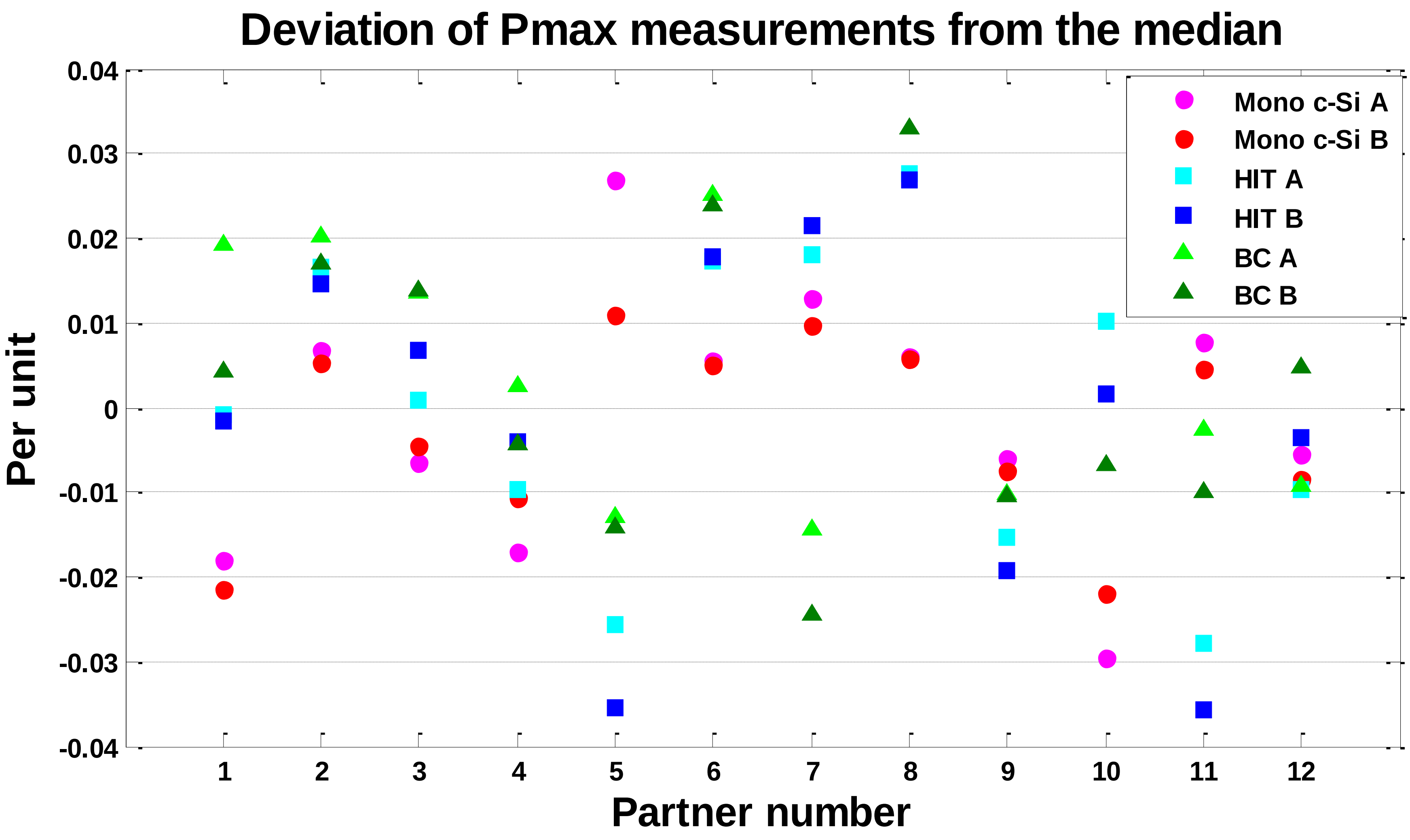
2x (CIGS) Solar Frontier
2x (CIGS) Avancis
2x (CdTe) GE Solar
2x (ua-Si tandem) Sharp Solar
2x (c-Si control) Suntech from RR1

- "Recommended practices for power measurement and measurement uncertainties" – submitted
- "Cross-calibration studies with various sun simulators and preconditioning studies" – RR2 output

Deviation per technology (RR1 results)



Deviation per partner and per technology (RR1 results)



Outcomes of this first JRA

- Round Robin 1 highlighted improvements required in most labs' uncertainty analysis and for more consistent approach to determining temperature coefficients.
  - Eg: CREST made a small change to thermal control hardware and a larger change in the procedure used for the temperature coefficient measurements.
- Impact of these changes should be noticed in the round robin 2, because of the inclusion of a pair of modules from round robin 1.
- Improvement of preconditioning and test procedures

- CPV
  - DNI spectrum measurements
  - Round robin with Monomodule ongoing
  - Guidelines for power rating of CPV systems

- for BIPV systems
  - Guidelines "Specific requirements of Solar Photovoltaics in building" , "Specific requirements for BIPV products characterization ",
  - Thermal modeling of BIPV: ongoing

Joint Research Activities results: Topic 2

- **Objective: Quicker lifetime prediction though accelerated ageing tests and improved failure analysis procedure**
  1. Test and analysis inventory
  2. Accelerated ageing tests
  3. Improved failure analysis methodologies

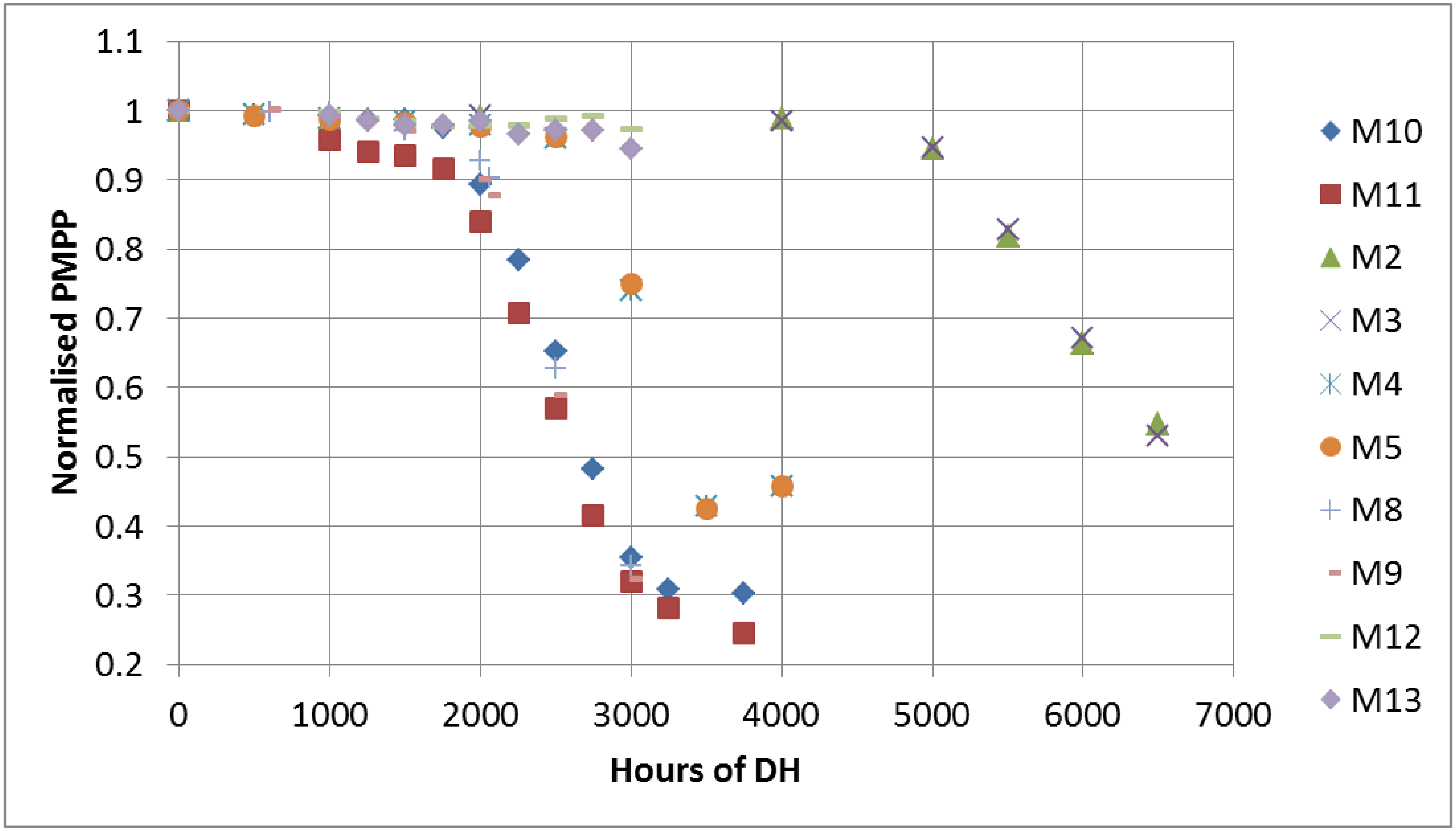
- Development of accelerated test procedures: New tests methodology assessed
- Aging testing on test samples completed
- Modelling performed using data from test-plan, additional data from assessment of new test methodology are analysed using the same models
- Initial model for modelling and verification of new test methodologies
- Evaluation of the improvement of the ageing tests (after modelling)

A coordinated test plan between 7 institutes

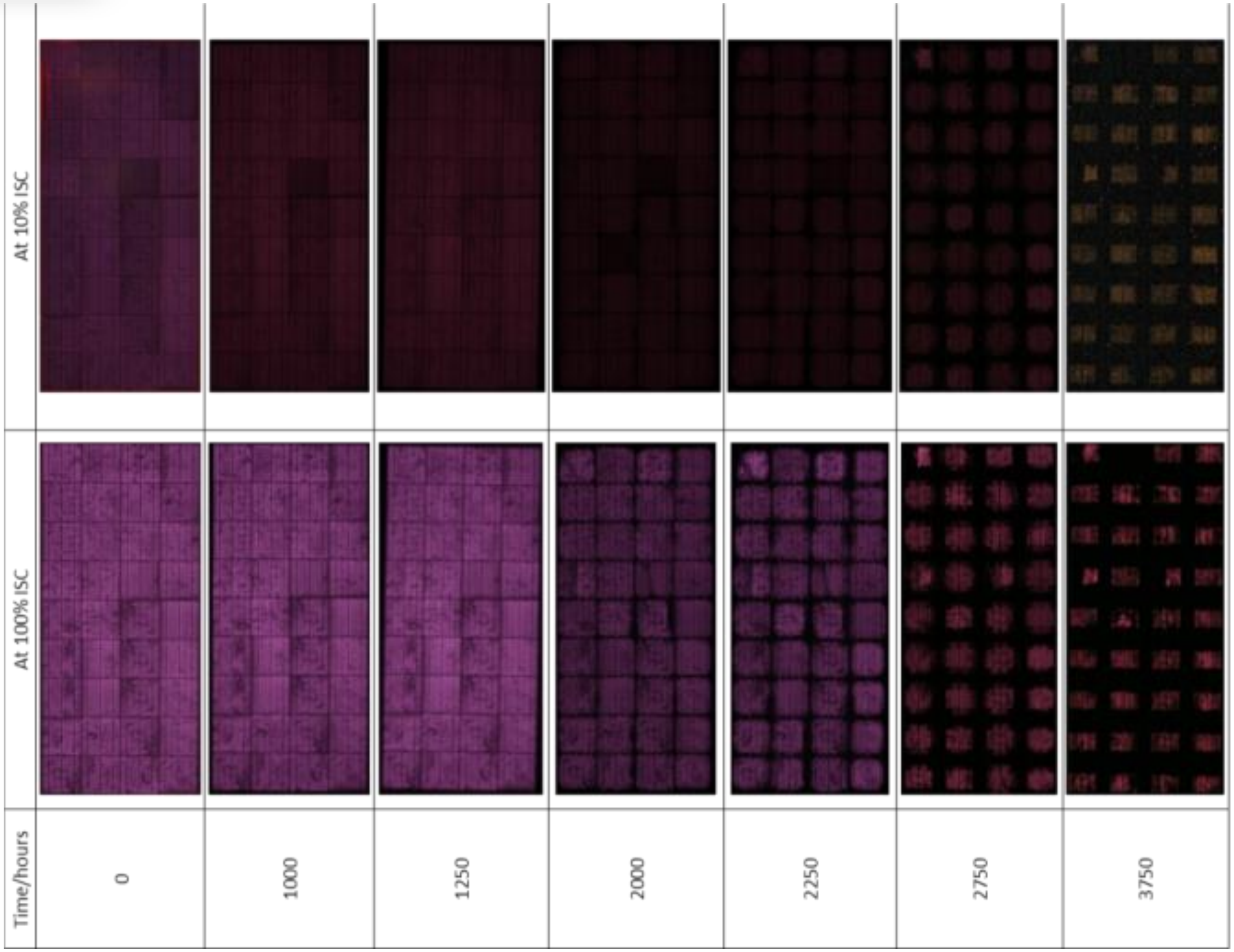
- Total of 15 tests designed
  - Tests performed until 20% reduction on power output measured

Sample No	No of samples	Test performed at	Test	Temperature/°C	Relative humidity (%)	UV		Test time intervals (hours) and number of cycles							
1	1	ISE	Dry UV	85	0	5	500	1000		1500	UV preconditioning followed by DH 85/85	add 1000 @85/85			
2.3	2	ISE	DH	75	85							2000		4000	4500
4.5	2	AIT	DH	85	85		500	1000				2000	and +250	until P < 0,5 P0	
6.7	2	ECN	DH	95	95		500	1000	1250	1500	1750	and +125	until P < 0,5 P0		
8.9	2	INES	DH	95	85		500	1000	1250	1500	1750	and +125	until P < 0,5 P0		
10.11	2	CREST	DH	95	70		500	1000	1250	1500	1750	and +125	until P < 0,5 P0		
12.13	2	ENEL	DH	90	50		500	1000	1250	1500	1750	2000	*2250*	*2500*	
14	1	ISE	Preconditioning 2000 hours DH 85/85	85	50	4	500	1000		1500					
15	1	ISE	Preconditioning 2000 hours DH 85/85	65	85	4	500	1000		1500					
16	1	AIT	TC	(-40 / 85)				200		400		600	Cycles		
17	1	RSE	TC	(-40 / 20)											
18	1	ISE	Freeze-thaw	(-40 /40)	85			50		100		200	Cycles		
19	1	ISE	Freeze-thaw	(-40 /40)	85	Preconditioning 2000 hours DH 85/85		50		100		200	Cycles		
20	1	AIT	Mechanical loading	25				followed by TC200							
21	1	AIT	Mechanical loading	-40				followed by TC200							

Module 1: conventional cSi – DH test results



Module 1: cSi – EL images during DH



Proposed test sequence and (N)DT of modules

- 1st proposed test sequence

	1st test	2nd test	3rd test
2 modules	120 kW UV + 70°C	500 hours DH 95/85	DML 2000 Pa 1000 cycles 50°C
2 modules	120 kW UV + 60°C	500 hours DH 95/85	DML 2000 Pa 1000 cycles 40°C

  - Performing tests at two temperatures allows calculation of activation energy
  - DML = Dynamic mechanical loading
  - Test performed to compare modules
  - Depending on the results, a second proposal may be made

- Characterisation of degraded modules
  - NDT
    - DLIT (dark lock-in thermography), LBIC for complete module (laser beam induced current), analysis EL images, SAM (scanning acoustic microscopy), pulse thermography
  - DT
    - Raman spectroscopy

Main results so far

- Collaboration between several institutes necessary to be able to perform such an extensive test
  - Focus needed on standardisation of characterisation methods e.g. EL

- Development and evaluation of alternative certification sequence
  - Tests designed to allow determination of activation energy for specific degradation mechanisms

- Modelling to determine activation energies
  - Activation energy related to climate and expected life-time and energy yield in the field

- Improved Material characterisation procedures
  - **Example of Silicon**
    - Higher performance methodologies

Advanced analysis techniques**:** Efficiency Limiting Bulk Recombination Analysis (ELBA)

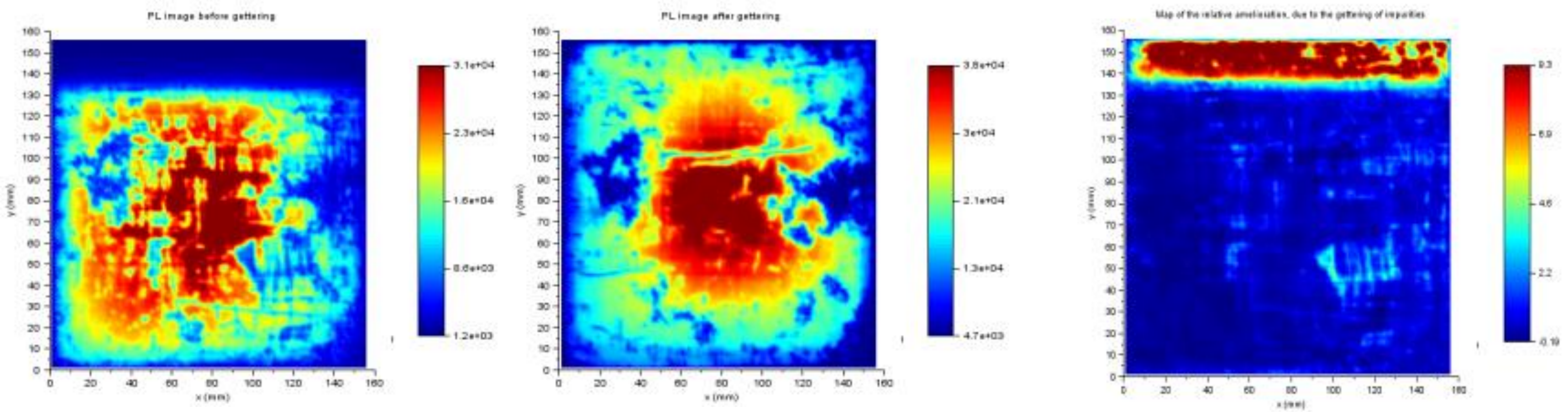
- Access to new parameters

Charge carrier mobilities: of special interest for compensated materials;

- Database of different available alternative silicon materials available

Development of common formats for imaging results

- Photoluminescence images before and after gettering
- Image processing to enable comparison



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2. Main outcomes
   - Transnational access activities
   - Joint research activities
   - **Networking activities**

Networking activities results (NA)

- They aim at :

- Defining and sharing common objectives over the future of PV research (training, research and innovation, technology, market, standards),
- Organising expert committees to propose common procedures for testing and characterising PV materials, modules and systems,
- Performing training and exchange activities for all European scientists (summer universities, exchanges between different research organisation).

Networking activities results (1/5)

- 18 networking seminars and workshops

- 11 common databases
  - Sets of measurement data and test results:
  - Listing of test- and analysis capabilities:TNA infrastructures, TCO test facilities, PV systems and smartgrid test facilities, PV module test equipment, accelerated ageing test procedures, silicon imaging techniques
  - Overviews of modelling tools

- Proposals of common testing procedures, and recommended best practices, proposals of amendment to IEC TC82 WG2 & WG7

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Networking activities results (2/5)

- Exchange of personnel, spreading of good practices, and training courses to new users, summer schools
  - E-learning platform: “SOPHi@Webinar”

- ❑ 21 webinars organised since March 2013
  - Around 2-4 events/month organized
  - 30+ expected in 2014
- ❑ 570 participants in total (+ 60 in streaming)
  - Majority of non-SOPHIA members
- ❑ Information on all courses available on the Sophia “events” web page
  - http://www.sophia-ri.eu/news-events/news/
  - http://uttp.enea.it/sophiawebinar
- ❑ Several pdf presentation of workshop and webinar (pdf, video) are available on-line on Sophia Events pages.

- Examples

OPV Testing and Existing Standards

Dr. Suren Suren GEVORGYAN (DTU) Dr. Giorgio BARDIZZA ; Dr. Tony SAMPLE (JRC)

Participants: 34 SOPHIA 63 NON-SOPHIA — May 6th 2014

Wet-chemistry deposition of semiconductor nanostructures for IR photovoltaics

Iris VISOLY-FISHER BGU University, Israel

Participants: 7 SOPHIA 30 NON-SOPHIA — May 9th 2014

Extraction of refractive index data from optical measurements of flat, rough and inhomogeneous thin films

Martina SCHMID Phillip MANLEY (HZB)

Participants: 35 SOPHIA 47 NON-SOPHIA — May 22nd 2014

Characterization of thin film solar cell components by x-ray based Photo Electron Spectroscopy

Iver LAUERMANN, Britta HOPFNER, Wolfram CALVET (HZB)

Participants: 22 SOPHIA 28 NON-SOPHIA — May 23rd 2014

- Next foreseen events:
  - Online course on uncertainty in PV outdoor measurements (DerLab, FH-IWES): 5 webinars
  - Online course on CPV (ENEA,UPM,FH-ISE, CEA-INES): 5 webinars
  - Online course on PV material modelling (ENEA,JUELICH, HZB): 3 webinars
  - Short course on Elipsometry (ENEA. CNRS): 3 webinars
  - BIPV training workshop: 6 webinars
  - PV module reliability characterization (ECN, FH.ISE, LLORO,JRC) : 4 webinars
  - OPV Barrier and realibility (DTU,ENEA,ECN,CEA): 5 webinars

Networking activities results (4/5)

- Training courses and summer schools
  - Next sessions
    - 25-27 June 2014 Berlin, DE (HZB)

      Workshop on analytical tools for PV

      (Surface sensitive Synchrotron based materials analysis and Multi resonance EPR/EDMR. External)
    - 3-4 July 2014, Ispra, Italy

      Short course on Best Practices for Power Measurement of Photovoltaic Devices
    - 4th August to 5th September 2014 in Falera, Switzerland

      International Summer University on Energy ISU-ENERGY

- Personal exchange:
- “Expression of Interest” proposed to younger researchers/students & to organizations interested in hosting scientist/expert

	2012-2013		2013-2014	
	Students	Experts	Students	Experts
cSi				1
Thin film	2			2
CPV			1	1
OPV				3
PV module performance			1	
PV module reliability		2		
lab intercomparison		6		6
BIPV				1
TOTAL	2	8	2	14

Networking activities results (5/5): Writing of a Strategic Research Infrastructure Agenda

It will serve as an input to the ESFRI roadmap:

- Mapping of existing Ris
- Trends
- Needs: Several types of research infrastructures, all along the TRL scale

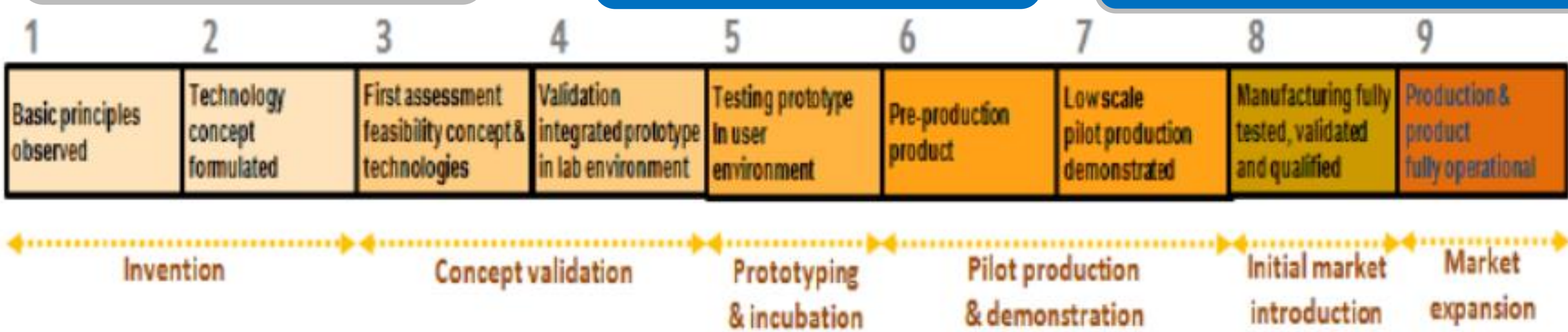
2. Coordinated set of facilities (mainly modelling and characterisation)

4. A network of various pilot lines for pilot production demonstration

1. Outstanding facilities (lab, characterisation tools)

3. A global quality and reliability PV infrastructure

5. E-infrastructure for large-scale management of PV systems



6. Training for all the PV value chain

…. Coming up soon:

Within the framework of :

- EUPVSEC : a 3 hour side-event is currently being organised (date to be communicated later by EPIA)

- SOPHIA final meeting: January 22nd 2015, at CEA-INES, Chambéry, France

January 22nd @INES in Chambéry (France)

First European Conference on PV Research Infrastructures

Photovoltaic Research Infrastructures as a support to solar PV R&D, industry and market development

- Objectives:

This conference will:

- highlight the main outcomes of the SOPHIA project and make proposals based on the lessons learned
- provide a forum for discussion on the type of PV research infrastructures and e-infrastructures required in Europe for the next decade covering several aspects:
  1. R&D needs (upgrade, access, coordination, etc.)
  2. Support innovation in the PV industry (pilot lines in particular, reliability and quality issues)
  3. Training needs
  4. Support to market integration (monitoring and management of millions of PV systems)

Overall conclusions

- a Research Infrastructure project has to include activities such as networking, exchange, and common vision

- It clearly supports a three step approach :
  1. Listing RIs, by identifying current facilities and equipment and surveying characterisation procedures
  2. Increasing the coordination, by organising Round Robin tests and validating characterisation methods
  3. Developing joint strategies through elaboration of roadmaps and knowledge transfer

10 databases

5 Round Robins + 1 large test plan

18 Workshops + webinars

- This first-of-its-kind project has gradually been gaining momentum (webinars, TNAs, ..), and it sets the basis for more in-depth collaboration

- This impetus has to be extended to a larger understanding of the “Research Infrastructures” concept

Thank you for your attention

Philippe Malbranche

philippe.malbranche@cea.fr