SOPHIA Research Infrastructure

SUMMARY OF PROJECT ACTIVITIES AND FINDINGS

SOPHIA European Research Infrastructure

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A. INTRODUCTION

SOPHIA RESEARCH INFRASTRUCTURE

Successfully promoting EU R&D infrastructure in photovoltaic technology

This document outlines the outcomes of the European project "Photovoltaic European Research Infrastructure", carried out from February 2011 to January 2015. Further information is available on www.sophia-ri.eu

Introduction

Many different Photovoltaic (PV) research facilities exist all over Europe. Some of them are considered unique (i.e. BESSY3 in HZB, Berlin or the Super Computer in FZ Jülich), while others are replicated in different places across the continent.

The SOPHIA RI project was the first European initiative to promote large-scale coordination in order to:

- avoid unintended duplication and unnecessary investment.
- get more value out of the same budgets. "Working together to progress faster or to learn more":
  - Benchmarking of characterisation methods,
  - Validation with a larger number of data to increase the confidence level

Main Goals

- Strengthen and optimise PV research capabilities, mainly by coordinating efforts on important but precompetitive topics.
- Address the issues of fragmentation and costly duplication of research at the European scale. Large research infrastructures working together will avoid the useless replication of a large number of small efforts.
- Bring together the main European Photovoltaic Research Infrastructures in order to provide the scientific community with common referential to conduct efficient and coordinated research work in the field of PV technologies.

Research topics

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

Acknowledgements

PhotoVoltaic European Research Infrastructure has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No 262533

- Total cost: EUR 11.579.421
- EU contribution: EUR 9.000.000
- Launched in Feb 2011 - End in Jan 2015
- 4-year duration

Coordinator

Partners

B. NETWORKING ACTIVITIES (NAS)

Several Networking Activities (NAs) were held under the scope of the SOPHIA project.

With the aim to create the conditions to guarantee the reliability of the activities performed in each facility and their traceability, the partners performed interoperability benchmarking and defined test procedures as well as common databases.

The SOPHIA project also offered various opportunities for staff working in one organisation member of the consortium as well as non-SOPHIA partners to receive training related to the use of equipment and test procedures in PV research infrastructure.

Training courses focused on the exchange experiences and best practices, aiming to harmonise approaches and assuring that participants could physically participate in the work, for example in making measurements independently interpreting data of selected results.

SOPHIA courses also offered opportunities to experienced researchers and senior scientists to deep in research and technical themes different from their own to improve collaboration and take profit from the cross –fertilisation of different field of science and technology as subsidiary instrument to do better and more efficiently their own work.

The Following courses were offered during the four years of the project:

- Sophia workshop on PV-Module Reliability "Interactive training course on EL & DLIT characterization of PV modules" held by ECN in June 2013
- four Sophia international workshops on PV-Module Reliability organized by FHG-ISE, FHG-IWES, JRC, CEA-INES,
- four Spectroradiometer and Broadband Intercomparison held from 2011 to 2014
- two workshops on analytical tools for PV organized by HZB;
- three summer schools ISU Energy on Solar energy, wind energy, economics of renewable energy held in Falera, Switzerland;
- two workshops on PV Modelling infrastructure: The modelling chain (2011) and PV performance modelling (2013) organized respectively by FZ- Jülich and CEA-INES

- two BIPV Workshops – the requirements and peculiarities of PV in buildings organized by CEA-INEs in 2013 and 2014
- "Best practices for power measurement of PV modules" held by JRC in July 2014.
- SOPHIA workshop on"Materials and processes for encapsulation of Organic PV devices" (Session at ISOS-6) organized by CEA-INES in December 2013
- A huge amount of guest lectures by researchers addressing a topic of relevance to PV research infrastructure offered in different Universities and organziations

Researchers involved with different technologies covered by SOPHIA had also the opportunity to visit different facilities in order to share experiences and improve research activities. Exchanges happened over a timescale ranging from 1 day to 6 weeks with a targeted population ranging from technicians, junior researchers to senior researchers.

Extra details on courses can be directly found on SOPHIA web site News&Events >past events> at http://www.sophia-ri.eu/news-events/past-events/

SOPHIA WEBINARS:

The full potential of the wide research areas of common interest of SOPHIA consortium partners and the availability of top-class scientists ready to transfer knowledge with the combination of technological capabilities offered by the utilization of SOPHIA 48 PV research infrastructures has been further exploited by SOPHi@ webinar, the e-learning platform of the SOPHIA project.

SOPHi@webinar, has been designed and powered by ENEA in collaboration with all SOPHIA project partners.

The lectures offered by Sophi@webinar covered all the 8 topics focused by the project.

Sophi@webinar also proposed online short courses organised through several webinars focused on a common theme:

- Characterisation of Thin Film Solar Cell Layers By X-Ray Based Spectroscopy (HZB, may 2014)
- Short on line course on "crystallisation of silicon" (SINTEF, Nov. 2014)
- OPV testing and Existing Standards (JRC, DTU May 2014)
- Uncertainty Estimations of PV Outdoor Measurements (DERlab, JRC, FH-ISE, FH-IWES, CREST, June 2013)

The on-line approach to knowledge exchange is very successful because time saving and reducing travel costs and it is widely diffusing for that. It creates a wider audience for training individuals in academies, research organization companies. This is a great advantage also for those who, perhaps due to lack of time, would be unable to attend physical events.

Summary of offered webinars:

- 27 webinars organised since March 2013
  - around 2-4 events/month organised
  - 20+ expected till the end of the project (on Si crystallisation, CPV, OPV, modelling, BIPV, Solar radiation characterisation, etc.)
- 570 participants (+ >60 in live streaming)
  - Majority of non-SOPHIA members. Extra non registered access (>100)
  - Several webinars (pdf, slides, videos) are available on-line on SOPHIA Events page and Sophi@webinar portal.

> *© AIT*

C. TRANSNATIONAL ACCESS (TNA)

Transnational Access (TNA) achievements

The objective of the Transnational Access Activities (TNA) within SOPHIA is to offer to the industry, research centers, and universities a free of charge access to the research infrastructures (RI) of the SOPHIA partners.

Access to research infrastructures

A large panel of testing platforms were proposed, covering most aspects of solar photovoltaics.

In total, 48 research infrastructures (test platforms) from 17 European SOPHIA partners were proposed, covering 8 PV topics: BIPV, thin films, module lifetime, system performance, OPV, Modelling, Silicon and CPV.

These European PV platforms offered various types of services, typically:

- Prototyping
- Better characterisation of materials and innovative technologies,
- Performance characterisation and lifetime prediction of PV modules
- Modelling

LIST OF RESEARCH INFRASTRUCTURES OFFERED BY SOPHIA PARTNERS

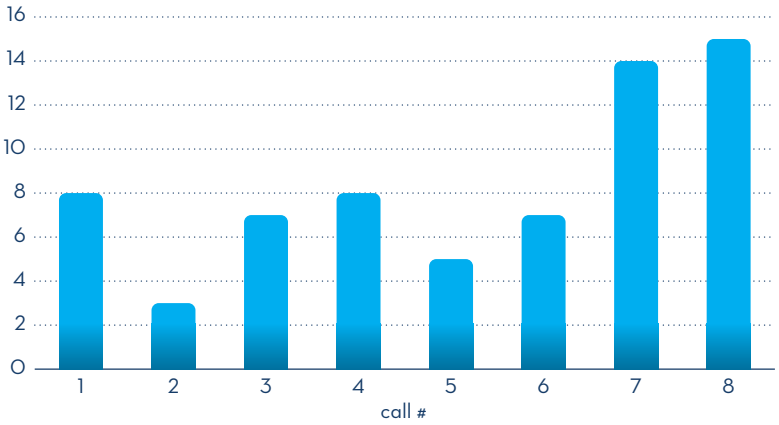
> *List of research infrastructures offered by SOPHIA partners*

Proposals

From January 2012 to December 2014, **8 calls** for research proposals were organized:

67 proposals submitted in total

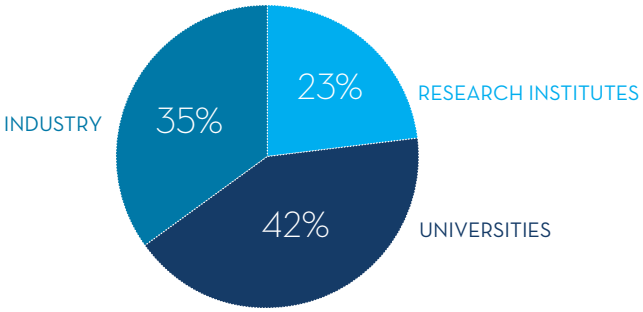
NUMBER OF APPLICATIONS PER CALL



Applicants

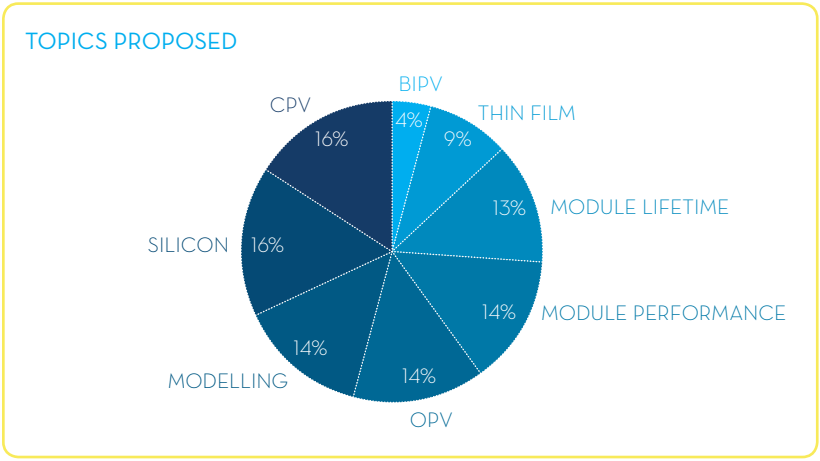
The respondents of these calls for proposals can be categorized into 3 types of users, which are quite well balanced in terms of request proportion (majority of universities):

TYPES OF APPLICANTS



Topics addressed

The 8 topic areas are covered by the proposals, but not uniformly, as visible on the following diagram:



The most popular topics addressed were Silicon and CPV, followed by Modelling, OPV and module performance.

RI hosts:

Through a selection process to assess the degree of innovation (evaluation by independent topic experts), 50 TNA access were eventually granted. Research infrastructures of 15 partners were used:

Host infrastructure	# projects hosted
Fraunhofer-ISE	7
CEA-INES	7
HZB	5
IES-UPM	4
CREST	4
Jülich	3
DTU	3
Tecnalia	3
ENEA	2
SINTEF	2
IMEC	1
AIT	1
ECN	1
RSE	1
EC JRC	1

Experiments Reports

Summary reports of experimentations performed in the framework of these SOPHIA TNA proposals are available. The list of accessible reports with their download link are given in the annex.

D. STRATEGIC VISION ON PV RESEARCH INFRASTRUCTURE

The "Strategic Vision on PV Research Infrastructure" is an important outcome of the SOPHIA project, integrating the lessons learned from the project and proposing a new PV research infrastructure strategy for the coming years. It will serve as a proposal to ESFRI, the European Strategy Forum for Research Infrastructures, which is a platform of experts with a mandate to look into Europe's research infrastructure (RI) needs.

Within the SOPHIA project and, we expect, the wider PV community, there is increasing consensus on the need to overcome fragmentation and to cooperate on the development and use of research infrastructures because:

- Funds for investing in RI are limited
- Continuous investment is needed to keep the RI at the highest level
- Sharing helps resources to be used optimally.
- It can assure faster and efficient achievement of critical mass, i.e. sufficient research activity on a topic for new ideas to be generated readily and the topic to attract interest and talent

These key points represent the practical translation of the objectives of EERA-PV, namely to ensure the implementation of the strategic research agenda beyond the SOPHIA project. There is also an increasing need to address the various means of supporting technology transfer to, and innovation within the industry. Although not initially part of the SOPHIA project, throughout the project, **pilot lines** were found to be one of the key components in supporting these required developments.

The Strategic Vision represents the consensual view of the 20 partners of SOPHIA (European research centres, EPIA and EUREC) on RI for photovoltaic energy. The proposal is detailed in the following chapters:

- Chapter 1 describes in short the context and the scope of the document
- Chapter 2 discusses current trends in the access and use of photovoltaic RI from the entire PV field: silicon materials, organic PV, thin films, concentrator PV, module lifetime, module and system performance, modelling and building integrated PV

- Chapter 3 identifies the future needs by setting up a whole range of multi-purpose RI addressing all the PV value chain from lab to fab and the market
- Chapter 4 provides concluding remarks and recommendations

The evidence base for the Strategic Vision is written input from the members of the SOPHIA consortium with expertise in certain specific fields of PV technologies, who have been consulted in a structured manner. Drafts of the Strategic Vision were presented to the whole consortium at project General Assemblies taking place in April 2013, November 2013 and March 2014. Suggestions for improvements were taken up. The document can therefore be taken to represent the view of the consortium.

The document was published in January 2015 and presented at the Symposium on European PV Research Infrastructure, which was held on 22 January 2015 in Le Bourget du Lac, France.

E. JOINT RESEARCH ACTIVITIES (JRAS)

The SOPHIA Joint Research Activities were organised with the aim to improve and optimise the services provided by the research infrastructures. In order to do so, the project partners divided their focus into four topics of interest:

- JRA 1: Quicker lifetime prediction through accelerated aging tests and improved failure analysis procedures of PV modules
- JRA 2: Greater accuracy of rated power and energy output prediction of PV modules & systems
- JRA 3: Improved photovoltaic material characterisation procedures: silicon material, thin-films and TCOs, and organic solar cells
- JRA 4: Improvement and validation of software infrastructure for photovoltaic materials, cell, module and system modelling

E. 1. JRA 1: Quicker lifetime prediction through accelerated aging tests and improved failure analysis procedures of PV modules

Initial objectives

The lifetime of a PV module is critical for PV manufactures, developers and end-users as it directly affects the energy yield and so cost of a PV system. The standards IEC61215, 61646 and 61730 are considered excellent for identification of major design issues, but they do not include sufficient testing to be able to predict outdoor performance and lifetime.

The objective of the PV Module Lifetime Prediction work-package in the FP7 project SOPHIA was to investigate and establish the research infrastructure needed to develop a standard for lifetime prediction based on a number of combined stress tests of commercially available PV modules.

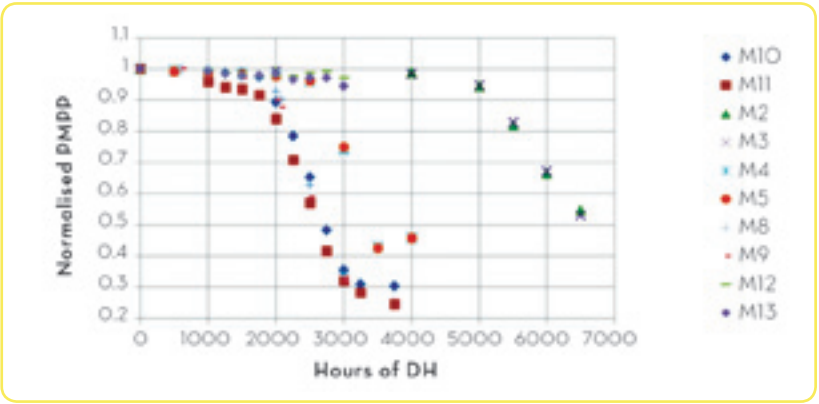
The goal of this sequence is to provide a tool to identify failure mechanisms and predict lifetimes for different climatic conditions for different module types.

Results

A test-plan was designed with 14 different test conditions including damp-heat at different temperatures and relative humidity, thermal cycling at different temperatures, combined damp-heat and UV-testing and mechanical testing with preconditioning. The tests were performed on sets of three different types of wafer based Si modules including a module with heterojunction cells, a module with a thermoplastic encapsulant and a conventional module. Degradation of the modules was followed by characterisation at intermediate steps during testing. The results of the test plan were used to identify and model the degradation mechanisms and relate the degradation rate in testing to an expected lifetime in the field. The methods used will be put forward as a proposal for a quality assurance standard for PV modules.

Conclusions and recommendations

The work in this WP has demonstrated the value of a large project with several partner institutes, because the results received in this work-sharing manner fit together very well. The number of tests and logistics would have made an experiment of this size impossible to be performed by a single institute within such a short time. Spreading the tests between several institutes makes this feasible. It also allows the institutes to learn from each other's approach to testing and characterisation and highlights the need for more standardisation of this type of tests. It should ultimately lead to dedicated quality assurance plans for PV modules with aim to give a more accurate lifetime prediction in different climate zones. In order to achieve this goal, further development of improved module characterization tools and climate chambers with ability to combine environmental stresses is strongly required.



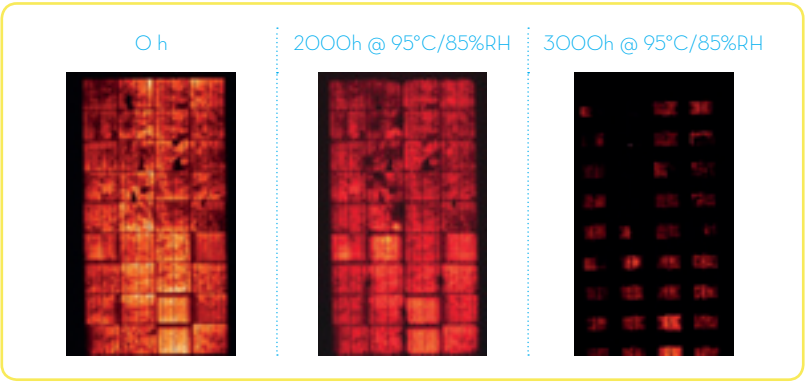


Figure 1. Plot of degradation in damp-heat for a tested commercial module and corresponding EL images of module A following degradation during damp-heat testing.

E. 2. JRA 2: Greater accuracy of rated power and energy output prediction of PV modules & systems

Module & System Performance

Initial objectives

A performance model round robin has been performed with the aim to evaluate the uncertainty of the various module energy output models and to split the uncertainty coming from the thermal module temperature models and the electrical models of the module power. Several partners of the European project SOPHIA predicted the module energy production and back side temperature.

Several types of modeling approaches for the electrical models are used during this round robin: neural networks, equivalent circuits, and empirical energy yield models. Furthermore, several thermal models are assessed which determine the module back temperature: the NOCT model, and a thermal model based thermal analog equivalent circuits which has been developed for the temperature modeling of PV modules integrated into buildings.

Experiments/Results

Outdoor monitoring data of different module technologies and locations have been provided by the project partners and uploaded to a centralized database. After a careful check, finally only five datasets with excellent data quality have been selected. Three months of data have been used to train and parameterize the models. Then, each model predicts the module power for each data point of the following twelve months. The assessment of the models' output is done by one single SOPHIA partner for all models.

The electrical models tested were the Energy Yield Model, the MotherPV method and Neural Network. Temperature models tested were NOCT-Model, Analogical electrical equivalent circuits based on TRNSYS, Linear temperature function.

One of the main results is the excellent precision of modelled energy yield, which can be only achieved when the module is characterised individually and the data quality is excellent. The power output errors (POE) where less than 1% for wafer based modules and less than 3% for thin film silicon modules. Regarding spectral effects, the use of short circuit current data for the measurement of the solar irradiation instead of a pyranometer does not improve quality of the model. Regarding the temperature effect, the use of modeled module temperature instead of measured temperature only slightly increases the error in output prediction. The errors from simplified linear temperature models cannot reduced using more sophisticated models.

Recommendations for the future joint research activities

Further joint research activities should establish methods for precise modeling the productivity of complete PV systems which are assembled by PV modules which cannot be characterised individually. This requires a statistical characterization of sample batches of PV modules and a validation with test data from real size systems. On module level, a simplified performance evaluation parameter, for example a "module performance ratio" should be established, which will be only acceptable when it can be determined from cheap and simple lab measurements. The active participation by relevant stakeholders on technical and financial level would underline the interest of this topic to increase the degree of maturity of the PV industry.

CPV

Initial objectives

Concentrator Photovoltaics (CPV) is a technology that has just started to enter the market. Although under development CPV still suffers of a lack of international standards. The International Electrotechnical Commission technical committee 82 working group 7 (IEC TC82 WG7) is responsible for the development of standards for CPV. The main goal of the joint research activities related to CPV within the SOPHIA project was to support these activities also with valid input and also real data.

Experiments/Results

The CPV JRA activities within SOPHIA were related to three topics:

- specification and influence of tracking accuracy (CPV uses trackers to assure optimum alignment of the modules to the sun)
- setting up of a spectral recording network and intercomparison of spectrally sensitive irradiance measurement devices (high concentration CPV uses multi-junction cells which show a higher dependence of their performance on changes in spectrum)
- definition of power rating procedures and testing of these procedures through a CPV module round robin (there is not yet an IEC standard related to power rating of CPV)

The focus of the SOPHIA CPV activities was on the latter point, which is related to the power rating of CPV. In this context a CPV module round robin has been established. At all stages of the round robin the IEC TC82 WG7 has been involved, including e.g. the formulation of the round robin guidelines. Initial results show very promising agreement between measurements at different partners' sites with a maximum deviation of 4 %. The work within SOPHIA has helped to allow the IEC TC82 WG7 to officially submit the current draft for power rating of CPV modules and systems as new work item proposal (NWIP) to the IEC.

Recommendations for future JRAs

The work within SOPHIA has clearly demonstrated that joint research activities of different partners can serve as a strong instrument to accelerate standardisation work. The CPV module round robin set up and performed within SOPHIA helped to **define**

and test procedures that now are implemented in the current draft standard for power rating of CPV. The main recommendation for future JRAs related to CPV is to give further support to intercomparison campaigns as started within SOPHIA. This includes a continuation of the efforts related to comparison of spectral measurements as this is still one of the impact factors on the power rating of CPV which's potential influence on measurement uncertainty is not fully quantified. Additionally the CPV module round robin performed within SOPHIA can only be seen as a good starting point: It involved only modules from one manufacturer and it strongly recommended that such efforts should be performed on a regular base with different module technologies.

Further publications related to CPV out of SOPHIA:

Siefer, G.; Steiner, M.; Baudrit, M.; Dominguez, C.; Antón, I.; Nuñez, R.; Roca, F.; Pugliatti, P.M.; Di Stefano, A; Kenny, R. and Morabito, P.; (2014, September). SOPHIA CPV module round robin: Power rating at CSOC. In 10TH INTERNATIONAL CONFERENCE ON CONCENTRATOR PHOTOVOLTAIC SYSTEMS: CPV-10 (Vol. 1616, pp. 167-172). AIP Publishing.

BIPV

Initial objectives

The main objective of the activities on BIPV topic in the SOPHIA project was to determine the impact of the installation method of BIPV modules on their energy output. More precisely, they aimed to realize:

- A benchmark of BIPV system testing and modelling methods.
- A white paper on BIPV requirements considering: energy output prediction, regulations, related building functions, cost compensation…

> *Test benches and experimental houses at CEA site, Fraunhofer IWES site and TECNALIA site*

Experiments/Results

In order to achieve these results, various actions were led by the experts through the joint research activities and the networking activities.

- Modelling guidelines were proposed based on a state of art of suitable modelling methods considering thermal, optical and electrical behaviours of BIPV systems.
- Characterization guidelines and specific requirements of BIPV products were also defined based on outcomes of the first and second INES workshop on BIPV.
- A benchmark of modelling methods was performed and presented during a plenary session at 29th EUPVSEC (Plenary session, 6DP2.3, 09/25, 9.50 - 12.10). This comparison showed that all models examined results in satisfying prediction of module temperatures. A ranking of the models was presented according to their impact on the accuracy of energy output prediction. It was noticed that a higher accuracy of the thermal model doesn't lead to a higher accuracy of the prediction of the energy output. Finally, the linear model is a satisfactory method for preliminary performance determination.
- Moreover, a common database was developed in order to share BIPV systems tests results and for numerical models validation.

E. 3. JRA 3: Improved photovoltaic material characterisation procedures: silicon material, thin-films and TCOs, and organic solar cells

Thin films and TCOs

Initial objectives

- Quicker characterisation of transparent TCOs for thin film devices by defining a figure of merit (FOM) including transmission, conductivity and scattering properties.
- Characterisation of tandem cells in a round robin to determine the uncertainty of efficiency measurements.
- The use of x-ray based surface analysis (XPS) for the characterization of compound semiconductor thin films.

- Electron Paramagnetic Resonance (EPR) characterization of thin films: Identification and quantification of defects in thin film silicon.
- Development of a pre-treatment procedure for thin film modules to increase the comparability of efficiency measurements

Experiments/Results

The definition of a figure of merit for TCOs was described in a report which will be used as starting point for future discussion.

XPS was used for the correlation of surface, interface and bulk properties of chalcopyrite thin film solar cells with device parameters. Especially the presence of sodium ions on the absorber surface was found to be correlated with surface oxidation, which has an impact on solar cell performance.

EPR was used for the identification of defects and the correlation of defect density with thin film silicon solar cell efficiencies. Visitors from various universities used the possibility of trans-national access to examine their samples in EPR@HZB lab.

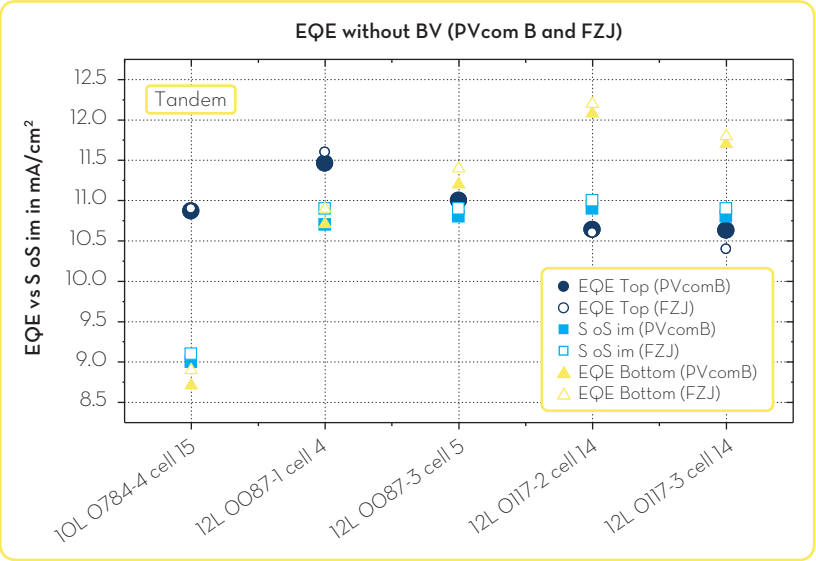
The tandem round robin showed good agreement of the results of wavelength dependent current measurements and efficiency measurements at the different partner laboratories.

Recommendations for the future joint research activities

One outcome of SOPHIA regarding thin film PV was the importance of common standards for the characterisation of devices, especially thin film tandem solar cells. This work should be continued in the future. The same is true for the pre-treatment (light soaking or forward biasing) of thin film modules, which can have a large impact on the measured efficiency of devices and which is far from being understood. In order to improve the comparability of characterisation by flasher solar simulators of thin film modules, flashers should offer the possibility of altering the pulse length in order to account for metastabilities.

Other joint research activities for the future are the development of TCOs (with higher transmission, better conductivity, and certain scattering properties) based on current and new materials, the improvement of light management in thin film devices and the improvement of encapsulation materials, especially for flexible devices.

Comparison of tandem cell short circuit current densities using different solar simulators and measurement techniques



Silicon Materials

Initial objectives

The activity on Si materials is centered to the qualification of new emerging material and cell types by improved techniques and procedures. The two main objectives for this activity were:

1) The quality enhancement of R&D available to supporting industry. For that round robins should assure comparability of results on European level and the provision of data for new parameters.

2) The generation of data bases for silicon material R&D on metrology, materials and specifications.

Experiments/Results

In measurement round robins an extensive comparison for a wide range of Si-material related variables was done. Results for IV-characteristics, quantum efficiencies and reflectivities on industrial solar cells and precursors were published (see P. Manshanden et al., EU-PVSEC 2013). Intercomparisons of impurity detection (Inductively Coupled Plasma Mass Spectroscopy ICP-MS), carrier mobilities in compensated silicon, the demanding measurement of bifacial cells and of carrier lifetime complement this activity. Detailed overviews on (i) imaging techniques for material parameters, (ii) different available silicon materials and (iii) solar grade silicon specifications were elaborated. Results were disseminated and discussion stimulated in the frame of a large workshop on "Challenges for Photovoltaic Silicon Materials" (Rome, Oct. 2013) as a worldwide platform for industry and research groups to discuss programs and future targets. A survey about scenarios for strongest cost reduction was conducted among experts during preparation of workshop and reported in "Solar Energy Materials & Solar Cells" 130 (2014) 629.

Recommendations for the future joint research activities

The development and production of silicon material suitable for high efficiency solar cell technologies is at present seen as an important target by the majority of market contributors. A strategy to bring the leadership in cost effectiveness back to Europe is needed. Europe has already a wealth of individual centres of excellence, where material development work towards this aim can be done.

In silicon materials research, networks of people are needed more than new hardware. It is by linking scientists that the challenge of finding a low-cost material for 23% efficient cells can be met and procedures for reliably and quickly evaluating silicon materials can be established. Industry has to be kept close to the network. Ownership models for newly generated intellectual property have to be developed which are suited to attract companies to entering into a contract with the network and providing co-funding. Preferably, several companies may jointly share this relationship to the network.

Important topics of the network could be n-type silicon and directionally solidified material of quality and/or crystal structure as close as possible to single crystalline silicon. Thus information flow between the two approaches to high efficiency should be facilitated.

Leading international experts formed a consortium for carrier lifetime metrology:

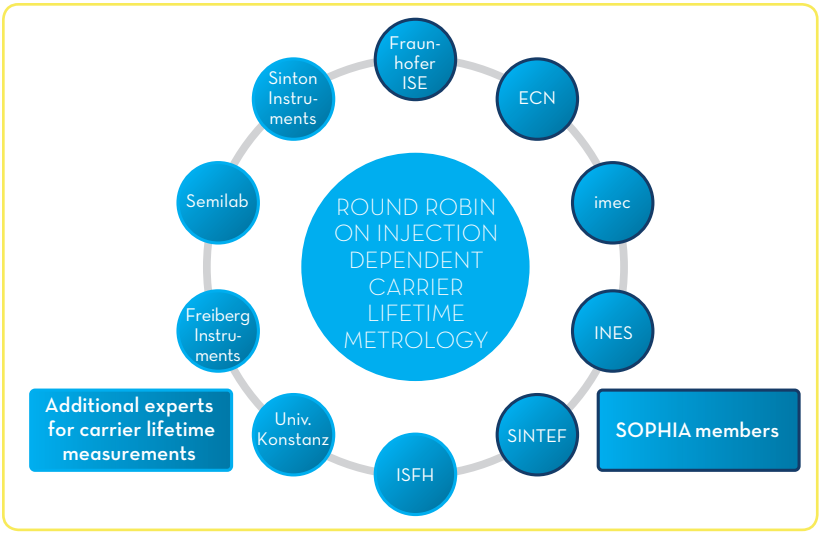


Figure 2. Consortium for comprehensive round robin on carrier lifetime metrology. In addition to the SOPHIA-partners international experts were included in this activity which complemented the expertise on lifetime measurements of the SOPHIA partners.

OPV

As a technology on a verge of industrialization, organic photovoltaics (OPV) are in a critical need for fast screening tools, harmonized characterization procedures and product design/performance qualification protocols. Thus, in the framework of SOPHIA the OPV team has set objectives to aid the process of establishing standards and protocols for device designs, characterization and stability testing.

In that regard four interlaboratory experiments were conducted, where various OPV samples were produced and shared among partners and characterized with various techniques. The first two studies, which involved sharing and accurate determination of performance for various samples, addressed the architectural challenges of the samples and the availability of accurate testing equipment and reproducibility of test procedures in different laboratories. The third study focused on lifetime determination and prediction for various OPVs by comparing the sample performance under moderate and accelerated ageing conditions. The final study analyzed the links between the barrier properties of the encapsulation material, the intrinsic stability of

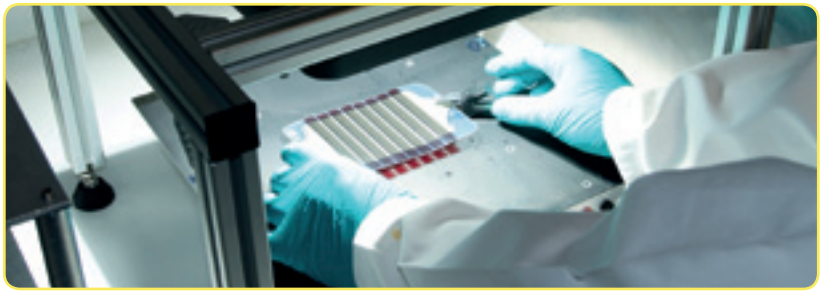
the absorbing polymer and the lifetime of the complete devices. The aim of the latter was to rate the lifetime of the final product based on the individual performance of its components. All four studies were conducted in collaboration with EERA partners. The results were also published in articles and communicated to standardization committees via the annual International Symposiums of OPV Stability (ISOS).

The studies revealed a number of important issues. Significant deviations of test results during accurate characterization of samples among different laboratories were recorded, which were caused by deficit of appropriate testing equipment and lack of experience. In addition, while the significant amount of data generated throughout the SOPHIA project initiated the process, the development of RELIABLE protocols for OPV characterization and lifetime testing required much larger set of statistical data which was not possible to obtain within the given time period and resources.

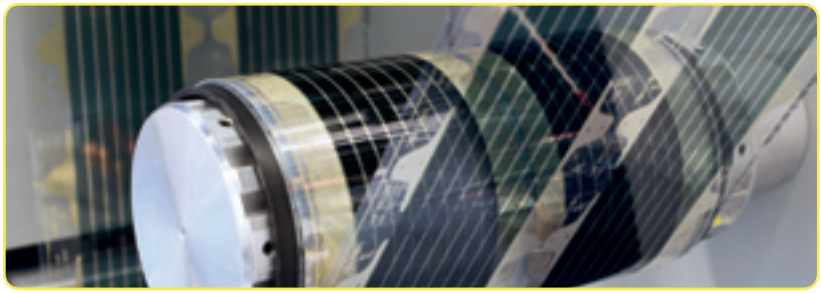
Thus, based on the experience gained within SOPHIA the following is recommended as the next logical step towards further development of the process for establishing standard characterization tools and protocols for OPV products and harmonizing the test procedures among the laboratories:

- Facilitation of interlaboratory experimental projects: Establishment and funding of (research level) committees for coordinating interlaboratory (round robin) studies
- Funding for equipment for characterization and ageing test is highly encouraged
- Facilitation of projects, which will establish online tools for OPV characterization and lifetime tests and will create centralized data collection tools (databases)
- Supporting educational webinars and workshops related to OPV characterization is recommended

> *A small part of the world's first Organic PV based solar park installed in Roskilde, Denmark: the image shows 6 rows of 100 meters long OPV rolls produced on roll-to-roll machinery. © Technical University of Denmark*



> *Testing a roll-to-roll produced Organic PV module under solar simulator in Characterization Laboratory for Organic Photovoltaics (CLOP). © Technical University of Denmark*



> *Roll-to-roll production of Organic PV: the image shows the web of an OPV solar cell roll during the processing on roll-to-roll machinery. © Technical University of Denmark*

E. 4. JRA 4: Improvement and validation of software infrastructure for photovoltaic materials, cell, module and system modelling

Overall concept: Development of the infrastructure to support a simulation chain, that allows simulations at material, cell, module and system level to communicate efficiently.

Calculation of macroscopic parameters from ab-initio simulations

Urs Aeberhard (Juelich), Philippe Czaja (Juelich), Aude Berbezier (Juelich), Massimo Celino (ENEA)

The interface between ab-initio atomic level material simulations and device level simulations is a difficult one to standardise. Macroscopic material parameters, such as the absorption, or mobility, must be calculated from the initial physical configuration of the individual atoms.

To this end, an atomic configuration for hydrogenated amorphous silicon from ab initio molecular dynamics consisting of 72 atoms was calculated using the supercomputer at ENEA. DFT calculations of this configuration were performed in Jülich, and the ab initio electronic structure, i.e. wave functions and (local) density of states, of the provided configuration was calculated using the Quantum Espresso package. Wannier states have been calculated from the wave functions using the Wannier90 program. Work on calculating the macroscopic parameter of the recombination rates from these local density of states is currently in progress.

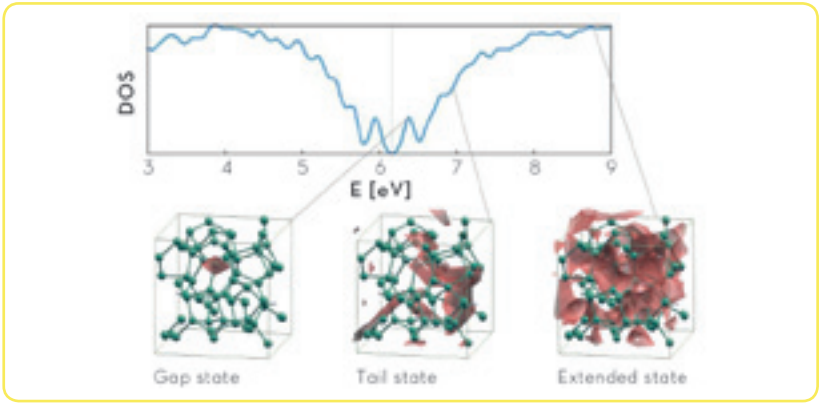


Figure 3. Graph of the density of states (DOS), with images showing the atomic configuration and local DOS of: (a) a localized trap (gap) state, a semi-localized tail state, and a delocalized bulk (extended) state.

Development and testing of a universal library to facilitate data transfer between PV simulation tools, from cell to system level.

B.E. Pieters (Juelich), B. Kubicek (AIT)

A proof of concept of this library has been written, using the Octave programming language. The library currently allows I-V curves or PV parameters obtained from IV curve fitting at any illumination intensity or temperature to be imported or exported in the appropriate format for each individual simulation program. Both experimental or modelled data can be exchanged via this library. This library has been used to obtain data for an investigation of error propagation along the modeling chain, for three different technologies.

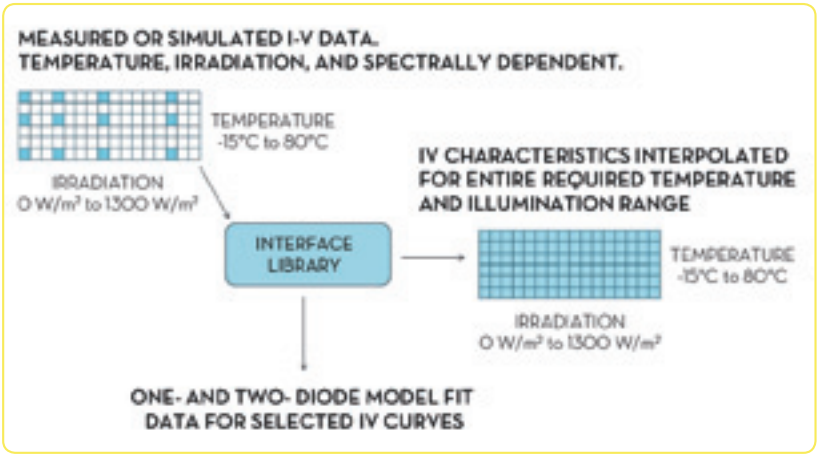


Figure 4. Schematic representation of the initial universal interface library developed in the Sophia project. The library is provides a standard format to pass IV curve data or IV parameters obtained from one- or two-diode fitting of the data for between any simulation programs within the desired temperature and illumination range.

Investigation of error propagation along the modelling chain (Publication EUPVSEC 2014)

Y. Augarten (Juelich), W. Sprenger (ISE), I.R.Cole (CREST), B. Pieters (Juelich), R. Varache (CEA-INES), O. Bakaeva (HZB), G. Janssen (ECN), F. Friedrich (HZB), C. Kaufmann (HZB), B. Kubicek (AIT), J. Hüpkes (Juelich)

The individual simulation tools have been successfully integrated into a simulation chain by use of the simplified universal library described above. The annual energy output of an installed system, has been successfully calculated for three different technologies, beginning with cell-level data.

A comparison of experimental and simulated data at each stage of the chain, as represented in Figure 1, was performed. Again, all data was exchanged between simulation programs using the universal library.

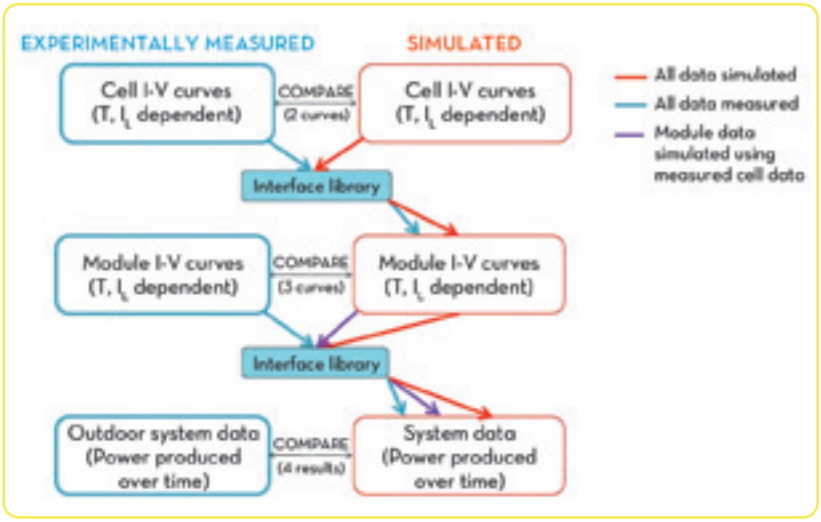


Figure 5. Data passing up the PV chain using the universal interface library, providing access to the system annual energy yield from both simulated and measured cell level data.

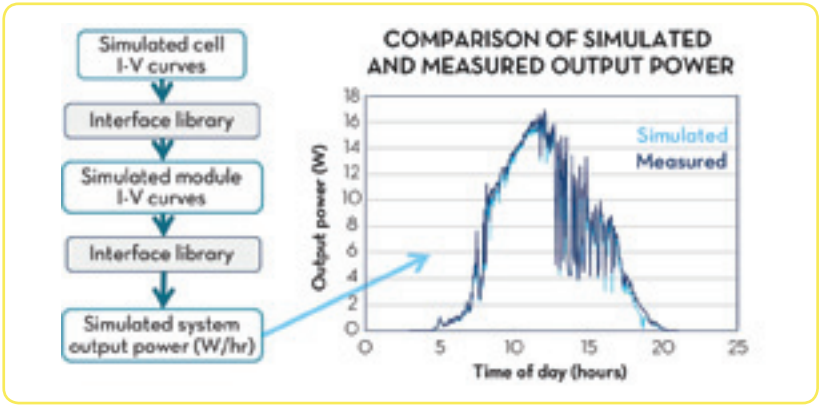


Figure 6. Final system output, simulated from the output of cell level simulations as shown in the flow chart to the left, compared with measured outdoor system data.

F. ANNEXES

List of performed TNA projects

The following TNA proposals have completed their experimentations in one of the Research Infrastructure proposed by the SOPHIA partners.

Summary reports of the TNA experimentations are available on SOPHIA website at http://www.sophia-ri.eu/user-access/selected-projects/

DUSOP

- Description: "Thermal and Spectral Dependence of Dual Silicone Optics"
- Proposed by: Fullsun Photovoltaics Ltd (UK)
- Host: IES-UPM (ES)
- Topic: CPV

Comcell

- Description: Photoluminescence and spectral response measurements of III-V triple junction devices
- Proposed by: Cyprus University (CY)
- Host: RSE (IT)
- Topic: CPV

ComPRI

- Description: Precompensation for Performance Ratio Increase of CPV-modules
- Proposed by: Soitec Solar (FR)
- Host: IES-UPM (ES)
- Topic: CPV

BECAR

- Description: "Best prototype Efficiency Concentration and Acceptance angle chaRacterization"
- Proposed by Becar S.R.L., Bologna (IT)
- Host: IES-UPM (ES)
- Topic: CPV

HiTOp

- Description: Highly Tolerant Optics for CPV: Characterization and Optimization of CPV optics
- Proposed by: Martifer Solar S.A. (PT)
- Host: IES-UPM (ES)
- Topic: CPV

cSiPID

- Description: "Indoor and outdoor monitoring of potential-induced degradation and recovery of conventional crystalline silicon photovoltaics"
- Proposed by: Cyprus University (CY)
- Host: AIT (AT)
- Topic: PV Module lifetime

PID1500

- Description: Study of the PID effect on modules serial connected until 1500Vdc
- Proposed by: VOLTINOV (FR)
- Host: Fraunhofer ISE (DE)
- Topic: PV Module lifetime

DEF-HYDFT

- Description: "Defects in ZnO using hybrid density functional theory"
- Proposed by: IES-UPM (ES)
- Host: FZ Jülich (DE)
- Topic: Modeling

MD-Rut-DSSC

- Description: Metal Doped Rutile TiO2 as electrode in DSSC
- Proposed by: Institute for Nuclear Sciences VINCA (RS)
- Host: ENEA (IT)
- Topic: Modelling

Black Si

- Description: Modeling and Fabrication of Light-Trapping Nanostructures by Top Down Approaches
- Proposed by: Center for Solar Energy Research and Applications-Middle East Technical Univ. (TR)
- Host: IMEC (BE)
- Topic: Cell modelling

Graphocell

- Description: Graphene in organic photovoltaic cells
- Proposed by: Graphenea SA (ES)
- Host: HZB (DE)
- Topic: OPV

Proxitam

- Description: Water-based Solution Processable Oxides as Recombination Layers for Tandem OPVs
- Proposed by: Catalan Institute of Nanoscience and Nanotechnology (ICN2-CSIC) (ES)
- Host: DTU (DK)
- Topic: OPV

Artsol

- Description: Accelerated Reliability Tests on organic SOLar cell
- Proposed by: Padova University (IT)
- Host: DTU (DK)
- Topic: OPV

Standardized OPV device stability evaluation

- Description: Standardized stability evaluation of promising OPV devices from Imperial College
- Proposed by: Imperial College London (UK)
- Host: DTU (DK)
- Topic: OPV

Compenor

- Description: OPV module encapsulation with composite materials
- Proposed by: Disasolar (FR)
- Host: Tecnalia (ES)
- Topic: OPV

Polmol

- Description: Use of EPR at 263 GHz to unravel the formation of polaron states in thiazolo[5,4-d]thiazole (TzTz) – based small molecules
- Proposed by: Antwerp University (BE)
- Host: HZB (DE)
- Topic: OPV

CODE RESI

- Description: Correlation of defect luminescence and recombination in multicrystalline silicon
- Proposed by: NMBU (NO)
- Host: Fraunhofer ISE (DE)
- Topic: Silicon materials

PLCuI

- Description: Photoluminescence based imaging of copper concentration in silicon
- Proposed by: Aalto University (FI)
- Host: Fraunhofer ISE (DE)
- Topic: Silicon materials

ZSO/K

- Description: Development and characterization of sputtered Zn(S,O)/Cu2ZnSnSe4 heterojunctions
- Proposed by: University of Luxembourg (LU)
- Host: HZB (DE)
- Topic: Thin films

ANSSAL

- Description: Advanced Nanostructured Silicon-Based Films for Stable Absorber Layers
- Proposed by Delft University (NL)
- Host: HZB (DE)
- Topic: Thin films

MOHP

- Description: Modelling Organic Halide Perovskites
- Proposed by: IES-UPM (ES)
- Host: FZ Jülich (DE)
- Topic: Modelling

BRING-OUT

- Description: Blue Response Impact aNd aginG effect On modUle performance raTio
- Proposed by: VOLTINOV (FR)
- Host: Fraunhofer ISE (DE)
- Topic: PV Module lifetime

ISCAEM

- Description: Impact of Salt Corrosion on the Adhesion of Encapsulant and Module power
- Proposed by: VOLTINOV (FR)
- Host: Fraunhofer ISE (DE)
- Topic: PV Module lifetime

MUSAS-Atomistic

- Description: Multiscale atomistic simulation of amorphous Silicon Solar cell: investigation of amorphous silicon materials for solar cell by atomistic approaches
- Proposed by: University of Bremen (DE)
- Host: ENEA (IT)
- Topic: Modelling

MUSAS-Device

- Description: Multiscale/Multiphysics device simulation of amorphous Silicon Solar cell. Simulation of amorphous silicon solar cell by using multiscale approaches in a multipartner collaboration
- Proposed by: University of Rome Tor Vergata (IT)
- Host: FZ Jülich
- Topic: Modelling

List of deliverables of public interest from the SOPHIA project

The deliverables are available on http://www.sophia-ri.eu/user-access/deliverables/

Deliverable title	Deliverable Nr	Status
Infrastructure Database	1.1	Available
Transnational access procedure	1.2	Available
Recommendations for NA02 "Strategic vision"	1.4	Available
Consolidated public yearly progress report on PV Infrastructure Networking Activities	2.2	Available
Contribution of SOPHIA to EERA Work Programme	2.3	Available
Strategic vision document on PV Research Infrastructure	2.4	Available
Organisation of networking events on at least three selected topics	3.1	Available
Report on "Task 3.2: General criteria for laboratory work and equipment management"	3.2	Available
Common reference database	3.3	Available
Development of inter-comparison protocols and harmonised test procedures	3.4	Available
Yearly report on contribution to standardization committees	3.5	Available
Human mobility and learning plan	4.1	Available
Report on exchange of personnel and internal training courses	4.2	Available
Report on summer Schools	4.3	Available
Proceeding of the Interim Workshop	5.8	Available
Proceeding of the Final Forum	5.9	Available
Listing of required and available testing at the various partners	9.1	Available
Round-robin: definition of test samples and test procedure	9.2	Available
Reviewing the test criteria for interconnect and encapsulation quality	9.3	Available
Aging testing on test samples completed	9.4	Available
Establishment of indoor measurement protocols and organisation of the Round Robin tests	10.5	Available
Recommended practices for power measurement and measurement uncertaintie	10.6	Available
Cross-calibration studies with various sun simulators and preconditioning studies	10.7	Available

List of project publications (peer reviewed publications), starting with the most important ones

#	DOI	Title	Main Author
1	10.1039/c3cp54635g	Electronic structure of positive and negative polarons in functionalized dithienylthiazolo-[5,4-d]thiazoles: a combined EPR and DFT study	Y.Ling, S.Van Mierloo, A.Schnegg, M.Fehr, P.Adriaensens, L.Lutsen, D.Vanderzande, W.Maes, E.Goovaerts, Sabine Van Doorslaer,
2	10.1016/j.renene.2013.09.034	Round Robin Performance Testing of Organic Photovoltaic Devices	S.A. Gevorgyan, O.Zubillaga, J.M. Vega de Seoane, M.Machado, E.A. Parlak, N.Tore, E.Voroshazi, T.Aernouts, H.Müllejans, G.Bardizza, N.Taylor, W.Verhees, J.M. Kroon, P.Morvillo, C.Minarini, F.Roca, F.A. Castro, S.Cros, B.Lechêne, J.F. Trigo, C.Guillén, J.Herrero, B.Zimmermann, S.B. Sapkota, C.Veit, U.Würfel, P.S. Tuladhar, J.R. Durrant, S.Winter
3	http://dx.doi.org/10.1016/j.polymdegradstab.2014.07.013	Interlaboratory indoor ageing of roll-to-roll and spin coated organic photovoltaic devices: Testing the ISOS tests	S.A. Gevorgyan, M.Corazza, M.V. Madsen, G.Bardizza, A.Pozza, H.Müllejans, J.C. Blakesley, G.F. Dibb, F.A. Castro, J.F.Trigo, C.M. Guillén, J.R. Herrero, P.Morvillo, M.G. Maglione, C.Minarini, F.Roca, S.Cros, C.Seraine, C.H. Law, Pabitra S. Tuladhar, J. R. Durrant, F.C. Krebs
4	10.1016/j.solener.2014.02.021	Genetic programming for photovoltaic plant output forecasting Solar Energy	M. Russoa, G. Leottab, P.M. Pugliattib, G. Gigliuccic
5	X	RESULTS OF THE SOPHIA MODULE INTERCOMPARISON PART-1: STC, LOW IRRADIANCE CONDITIONS AND TEMPERATURE COEFFICIENTS MEASUREMENTS OF C-SI TECHNOLOGIES	B. Mihaylov1, J.W.Bowers1, T.R. Betts1, R. Gottschalg1, T. Krametz2, R. Leidl2, K.A. Berger2, S. Zamini2, N.Dekker3, G.Graditi4, F. Roca4, M. Pellegrino4, G.Flaminio4, P. M. Pugliatti 5, A. Di Stefano5, F. Aleo5, G. Gigliucci5, W. Ferrara5, G.Razongles6, J. Merten6, A. Pozza7, A.A. Santamaría Lancia7, S. Hoffmann8, M. Koehl8, A.Gerber9, J. Noll9, F. Paletta10, G. Friesen11, S. Dittmann11
6	10.1002/pip.2436	A new 2D model for the electrical potential in a cell stripe in thin-film solar modules including local defects	B.E. Pieters, U.Rau

	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Date of publication	Relevant pages	Is/Will open access provided to this publication
	Physical Chemistry Chemical Physics	Vol 16, Issue 21	Royal Society of Chemistry	United Kingdom	1/1/2014	10032 - 10040	No
	Renewable Energy	Vol 63	Elsevier BV	The Netherlands	3/1/2014	376-387	No
	Polymer Degradation and Stability	Vol 109	Elsevier BV	X	7/18/2014	162-170	No
	Solar Energy	Vol 105	Elsevier	X	7/1/2014	264-273	No
	Accepted for publication	Accepted for publication	Accepted for publication	Accepted for publication	Accepted for publication	Accepted for publication	Accepted for publication
	PROGRESS IN PHOTOVOLTAICS: RESEARCH AND APPLICATIONS	X	Wiley Online Library	Online	26-Oct-13	2436	No

#	DOI	Title	Main Author
7	Under preparation	Stability of Organic PV devices vs the barrier properties of the encapsulant	S.A. Gevorgyan, M.Corazza, M.V. Madsen, G.Bardizza, A.Pozza, H.Müllejans, J.C. Blakesley, G.F. Dibb, F.A.Castro, J.F.Trigo, C.M. Guillén, J.R. Herrero, P.Morvillo, M. G. Maglione, C.Minarini, F.Roca, S. Cros, C.Seraine, C.H.Law, P.S. Tuladhar, J.R. Durrant, F.C. Krebs
8	http://dx.doi.org/10.1016/j.solmat.2014.07.021	Worldwide outdoor round robin study of organic photovoltaic devices and modules and modules	M.V. Madsen, S.A. Gevorgyan, R. Pacios, J. Ajuria, I. Etxebarria, J.Kettle, N.D. Bristow, M.Neophytou, S.A. Choulis, L.Stolz Roman, T.Yohannes, A.Cester, P.Cheng, X.Zhan, J.Wu, Z.Xie, W.C. Tu, J.H.He, C.J. Fell, K.Anderson, M.Hermenau, D.Bartesaghi, L.Koster, F.Machui, I.González-Valls, M.Lira-Cantu, P.P. Khlyabich, B.C. Thompson, R.Gupta, K.Shanmugam, G.U. Kulkarni, Y.Galagan, A.Urbina, J. Abad, R.Roesch, H.Hoppe, P. Morvillo, E. Bobeico, E. Panaitescu, L.Menon, Q.Luo, Z. Wu, C.Ma, A.Hambarian, V.Melikyan, M. Hambsch, P.L. Burn, P.Meredith, T.Ratha, S.Dunsta, G.Trimmela, G.Bardizza, H.Müllejans, A. E. Goryachev, R.K. Misra, E.A. Katz, K.Takagi, S.Magaino, H.Saito, D.Aoki, P. M. Sommeling, J.M. Kroon, T.Vangerven, J.Manca, J.Kesters, W.Maes, O.D. Bobkova, V.A.Trukhanov, D.Yu. Paraschuk, F.A. Castro, J.Blakesley, S.M. Tuladhar, J.A.Röhr, J.Nelson, J.Xia, E.A.Parlak, T.A. Tumay, H.J. Egelhaaf, D. M. Tanenbaum, G.M. Ferguson, R. Carpenter, H.Chen, B. Zimmermann, L.Hirsch, G.Wantz, Z. Sun, P.Singh, C.Bapat, T.Offermans, F.C. Krebs

	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Date of publication	Relevant pages	Is/Will open access provided to this publication
	Under preparation	Under preparation	Under preparation	Under preparation	Under preparation	Under preparation	Under preparation
	Solar Energy Materials & Solar Cells	Vol 130	Elsevier	-	7/14/2014	281-290	No

List of publications (project paper in proceedings of a conference/ workshop)

#	DOI	Title	Author(s)
1	10.4229/ 27thEUPVSEC2012-5AV.2.42	Numerical analysis of the impact of environmental conditions on the BIPV systems, an Overview of BIPV Modelling in Sophia Project	B.Ya-Assoa, S. Zamini, W. Sprenger, S. Misara, M. Pellegrino, A, Astigarraga Erleaga
2	10.4229/ 27thEUPVSEC2012-3CV.1.56	2D - Finite element model of a cigs module	G. J.M. Janssen, L. H. Slooff, E.E. Bende
3	10.4229/ 28thEUPVSEC2013-2BO.4.2	Round Robins Of Solar Cells To Evaluate Measurement Systems Of Different European Research Institutes	P. Manshanden, N.J.C.M van der Borg, M. Bliss, B. Mihaylov, R. Gottschlag, M.Izzi, M. Tucci, F. Roca, M. Pellegrino, A. Romano4, G. Graditi, J. Hohl-Ebinger, W. Warta, M. Debucquoy, O. El Daif, I. Gordon, J. Champliaud, A. Jouini, J. Glatz-Reichenbach, K. Bothe and A. Herguth
4	X	Thermal and electrical analysis of BIPV systems in the Sophia Project.	B.Ya-Assoa,
5	10.4229/ 27thEUPVSEC2012-4CO.12.5	Harmonised Procedures on Photovoltaic Modules Long-Term Energy Yield Measurements and Performance Evaluation under Outdoor Conditions	D. Craciun, V. Helmbrecht, S. Tselepis, A. Kyritsis, N. Hatziargyriou, K. Latoufis, S. Misara, P. Funtan, P. Strauß, A. Ellis, R. Bründlinger
6	10.4229/ 28thEUPVSEC2013-4AV.6.27	PV Roof Integrated Systems vs. Best- and Worst-Cases: Novel Measurement for Long-Term- Outdoor Measurement of PV Roof-Top Integrated Systems (Electrical, Thermal and MEchanical Behaviors)	J. Firges, P.Funtan, N.Henze, M.Roos, S.Misara
7	X	Changes of solar cell parameters during damp-heat exposure	J. Zhu, R. Gottschalg, M. Koehl, S. Hoffmann, K.A. Berger, S. Zamini, I.J. Bennett, E. Gerritsen, P. Malbranche, P. Pugliatti, A. Di Stefano, F. Aleo, D. Bertani, F. Paletta, F. Roca, G. Graditi, M. Pellegrino, O. Zubillaga, P. Cano, A. Pozza, and T. Sample

	Proceedings	Date of publication	Start date of Conference / Workshop	End date of Conference / Workshop	Publisher	Publisher location	ISBN
	27th European Photovoltaic Solar Energy Conference and Exhibition	9/28/2012	9/24/2012	9/28/2012	WIP	Munich, Germany	3-936338-28-0
	27th European Photovoltaic Solar Energy Conference and Exhibition	9/28/2012	9/24/2012	9/28/2012	WIP	Munich, Germany	3-936338-28-0
	28th European Photovoltaic Solar Energy Conference and Exhibition	9/30/2013	9/30/2013	10/4/2013	WIP	Munich, Germany	3-936338-33-7
	29th European Photovoltaic Solar Energy Conference and Exhibition	9/26/2014	9/22/2014	9/26/2014	WIP	Munich, Germany	X
	27th European Photovoltaic Solar Energy Conference and Exhibition	9/28/2012	9/24/2012	9/28/2012	WIP	Munich, Germany	3-936338-28-0
	28th European PV Solar energy Conference an dexhibiton, Sept. 2013, Paris	10/4/2013	9/30/2013	10/4/2013	WIP	Munich, Germany	3-936338-33-7
	WCPEC	X	X	X	X	X	X

#	DOI	Title	Author(s)
8	X	Uncertainties in Energy Yield Estimation due to Module Characterisation Uncertainty As Borne Out By the Sophia c-Si Module Inter-Comparison	B. Mihaylov, J.W.Bowers, T.R. Betts, R. Gottschalg, T. Krametz, R. Leidl, K.A. Berger, S. Zamini, N.Dekker, G.Graditi, F. Roca, M. Pellegrino, G.Flaminio, P. M. Pugliatti, A. Di Stefano, F. Aleo, G. Gigliucci, W. Ferrara, G.Razongles, J. Merten, A. Pozza, A.A. Santamaría Lancia, S. Hoffmann, M. Koehl, A.Gerber, J. Noll, F. Paletta, G. Friesen, S. Dittmann
9	X	Towards PV module lifetime prediction	J.Zhu, R.Gottschalg, L.Kropp, M.Koehl, S.Hoffmann, K.Weiss, K. Berger, S.Zamini, I.Bennett, E.Gerritsen, P.Malbranche, L.Sicot, P.Pugliatti, F.Aleo, F.Paletta, F.Roca, G.Fraditi, M.Pellegrino, O.Zubilaga Alcorta, P.Cano, S.Tselepis, A.Pozza, T.Sample
10	10.4229/ EUPVSEC20142014-7AV.6.42	Strategic Vision on PV Research Infrastructure in Europe	J.M. Kroon*, M.de Bruijne, I.Bennett G.Arrowsmith, P. Malbranche, J.Merten, B.Ya-Assoa, N.Taylor, S.Georgyvan, I.Lauermann, J.Huepkes, Y.Augarten, G.Siefer, M.Köhl, W.Warta, F.Roca, I.T.Theologitis
11	10.4229/ EUPVSEC20142014-5DO.11.4	PV Module Lifetime Prediction and Quality Assurance as addressed by SOPHIA	I.J. Bennett (ECN), J. Zhu, R. Gottschalg (CREST), M. Koehl, S. Hoffmann (ISE), K. A. Berger, S. Zamini (AIT), E. Gerritsen, P. Malbranche (CEA INES), P. Pugliatti, A. Di Stefano, F. Aleo (ENEL), D. Bertani, F. Paletta (RSE), F. Roca (ENEA), G. Graditi7, M. Pellegrino7, O. Zubillaga, P. Cano (Tecnalia), A. Pozza, T. Sample (JRC)
12	10.4229/ EUPVSEC20142014-7AV.6.61	SOPHIaWebinar the advanced e-learning platform of the Photovoltaic European Research Infrastructure 7FP-SOPHIA Project	F.Roca*,L.Pavia,D.Casaburi, G.Cipolletta, S.Pirozzi, A.Vita, F.Beone, M.Steffé, Y. Augarten J.Hüpkes, I.Lauermann, I.Bennett, M.de Bruijne, J.M. Kroon, S.Gevorgyan, S.Misara, T. Pettersen, N.Taylor, M.Koehl, M.Schubert, G.Siefer, B. Ya-Assoa, F.Bergeron, J.Merten,P.Malbranche
13	X	Temperature effects on two stage optics made of silicone	M. Victoria, S. Askins, I. Antón, G. Sala, G. Duggan

	Proceedings	Date of publication	Start date of Conference / Workshop	End date of Conference / Workshop	Publisher	Publisher location	ISBN
	WCPEC	X	X	X	X	X	X
	NREL reliability workshop	X	25/02/2014	26/02/2014		Golden, USA	X
	29th European Photovoltaic Solar Energy Conference and Exhibition	9/26/2014	9/22/2014	9/26/2014	WIP	Munich, Germany	3-936338-34-5
	29th European Photovoltaic Solar Energy Conference and Exhibition	9/26/2014	9/22/2014	9/26/2014	WIP	Munich, Germany	3-936338-34-5
	29th European Photovoltaic Solar Energy Conference and Exhibition	9/26/2014	9/22/2014	9/26/2014	WIP	Munich, Germany	3-936338-34-5
	CPV-10 Conference	11/1/2014	4/7/2014	4/9/2014	AIP	Melville, USA	X

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