Start Reports on Projects Funded

Public summaries of projects initiated through transnational SOLAR-ERA.NET joint calls

Status August 2018

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Authorship:

Contributions from the project coordinators, collected and edited by T. Biel, M. Gutschner, S. Nowak and B. Piller of the SOLAR-ERA.NET Joint Call and Coordination Office.

Introduction - What Is SOLAR-ERA.NET? What Is this Report about?

SOLAR-ERA.NET - the Network and its Objectives

SOLAR-ERA.NET is a network that brings together more than 20 RTD and innovation programmes in the field of solar electricity technologies in the European Research Area. The network of national and regional funding organisations has been established in order to increase transnational cooperation between RTD and innovation programmes and to contribute to achieving the objectives of the Solar Europe Industry Initiative (SEII – the mission has been taken over by the respective European Technology and Innovation Platforms (ETIP) set up in the context of the new SET Plan governance in 2015) through dedicated transnational activities (especially transnational calls). SOLAR-ERA.NET was an EU funded FP7 project running from 2012 to 2016.

SOLAR-ERA.NET - the Context

SOLAR-ERA.NET is a European network of national and regional funding organisations and RTD and innovation programmes in the field of solar electricity generation, i.e. photovoltaics (PV) and concentrating solar power (CSP) / solar thermal electricity (STE). SOLAR-ERA.NET shall carry out the coordination and support actions for the implementation of the SEII between national and regional RTD and innovation programmes. The SEII was embedded in the European Strategic Energy Technology Plan (SET-Plan) which aims to increase, coordinate and focus EU support on key low-carbon energy technologies in order to achieve Europe's 2020 energy objectives in the future. The SEII was a joint initiative of the industry sector, EC and member states. The objective of the SEII was to boost the development of the PV and CSP sector beyond "business-as-usual" in the areas of Research and Development, Demonstration and Deployment. For the concerned solar electricity technologies Implementation Plans have been developed setting out priorities for RTD in Europe.

SOLAR-ERA.NET - the Activities

SOLAR-ERA.NET's goal is to undertake joint strategic planning, programming and activities for RTD and innovation in the area of solar electricity generation. Joint activities, namely joint calls, are defined for key topics and priorities based on the Strategic Energy Technology (SET) Plan and its related Implementation Plans for PV and CSP. In order to define and support the best joint activities, strategic information exchange and use of implementation tools is be carried out among the network participants and associates from key stakeholder groups.

SOLAR-ERA.NET – Joint Calls

Joint Calls are the core mission of SOLAR-ERA.NET. Through these transnational calls, innovative industrially relevant projects shall be supported. Support and funding is provided by the national and regional agencies involved in these calls.

Organisations involved in promoting SOLAR-ERA.NET transnational calls and providing support and funding to innovative industrially relevant projects.

The general scope of the SOLAR-ERA.NET Joint Calls are to: i) seek new and complementary RTD and innovation projects in the field of solar electricity technologies; ii) to strengthen the international collaboration in the field of solar power RTD and innovation, improving the effectiveness and efficiency of regional and national programmes; and iii) to contribute both to European industry competitiveness and to its innovation capability.

The aim is to fund application oriented and industrially relevant transnational RTD and innovation projects in the field of solar electricity technologies.

The project proposals must clearly demonstrate:

- Potential commercial impact / relevance to industrial and market needs / contribution to the Solar Europe Industry Initiative and added transnational value
- Scientific and technological excellence
- Quality and efficiency of the implementation and the management

The following topics have been within scope of at least one of the four Joint Calls for PV respectively CSP. The number of projects funded can be found in brackets.

PV topics:

- Innovative processes for inorganic thin-film cells & modules (7)
- Dedicated modules for BIPV design and manufacturing (6)
- Grid integration and large-scale deployment of PV (7)
- High-efficiency PV modules based on next generation c-Si solar cells (11)
- Solar glass and encapsulation materials (4)
- Concentrator PV technology (2)
- Si feedstock, crystallization and wafering (1)
- Organic solar cells, perovskites and other emerging concepts (2)

CSP topics:

- Cost reduction and efficiency increase in components (0)
- Dispatchability through storage and hybridisation (2)
- New heat transfer media for CSP plants (3)
- Innovative thermodynamic cycles (0)

According to their RTD priorities, national and regional programmes accepted applications in all or selected topics.

In all, four sets of Joint Calls were launched. The first one was launched in early 2013, the fourth one in late 2015.

The four calls resulted in 45 projects with a total volume of 59 MEUR including public funding from 17 countries and regions (totally 39 MEUR). On average, a project involves 5 partners from 3 different countries or regions.

What is included in this report?

This document is a collection of all summaries submitted by the coordinators at the start of the project. Public summaries include a short description of the project, coordinator contact information and aggregated financial figures.

Project coordinators submit a summary at the start of the project as well as at the end of the project. The public final reports of the projects are listed under http://www.solar-era.net/publications-documents/.

The summaries are listed according to the project number which does not necessarily reflect a chronological order.

For any further information, you may contact the project coordinator.

001 SLAGSTOCK: Low-Cost Sustainable Thermal Energy Storage Systems Made of Recycled Steel Industry Waste

Project Duration: 05.2015 to 04.2018
Report submitted: 09.2015

Summary

One of the major challenges of the Concentrated Solar Power (CSP) industry is the development of cost effective high temperature thermal energy storage (TES). Currently, the most applied storage strategy in commercial CSP plants consists in a double tank configuration based on molten salt as storage material. This arrangement presents several limitations such as the reduced operation temperature range, the worldwide availability of salts and their high economic cost.

SLAGSTOCK project aims to develop an innovative thermal storage concept to overcome these drawbacks. This approach makes use of steel slags as storage material due to preliminary measurements have demonstrated that the operation temperature range of steel slags in thermal storage applications can be extended up to 1100 ºC.

Steel slags are a by-product of the steelmaking industry and currently recycled in several applications such as aggregates for construction or road materials. However, about 2,8 Mt of slags production is landfilled per year. The revalorization of steel slags as thermal storage material could represent a successful solution to obtain a low-cost storage material and hence to design an economically competitive thermal energy storage lead concept.

The versatility of the proposed solution can also be useful for different thermosolar power generation technologies such as parabolic through or power tower. In particular, the innovation proposed in SLAGSTOCK project covers the use of different heat transfer fluids such as molten salt or air in different temperature ranges. Also, in the SLAGSTOCK approach, several storage concepts are proposed which can be suitable for different CSP storage requirements.

Overall, the revalorization of this steel industry by-product into a storage material opens new possibilities within the framework of CSP and could lead to a cost-effective high temperature storage solution for both current and future thermal energy storage technologies.

Project consortium

Coordinator and contact details:

Full name of organisation:	Centro de Investigacion COOP de Energias Alternativas CIC Energigune
First and family name of coordinator:	Bruno D'Aguanno
Full address:	Parque Tecnológico de Álava C/Albert Einstein, 48 01510 Vitoria, Spain
E-mail:	bdaguanno@cicenergigune.com

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Spain	3	919'677	259'190
Switzerland	1	160'085	120'571
Germany	1	96'888	80'740
France	1	96'636	50'707
Total	*6*	*1'273'286*	*511'208*

PSI contract is in CHF, exchange rate applied 1 EUR = 1,05 CHF

005 LIMES:
Light Innovative Materials for Enhanced Solar Efficiency

Project Duration: 04.2014 to 03.2017
Report submitted: 05.2014

Summary

There is a global drive to lower the cost of solar generated electricity. The cost per watt peak (€/Wp) can be reduced by increasing PV efficiency, reducing cost of the Balance of System (BOS) and minimizing the module costs. Module assembly is material extensive and constitutes a significant part of the price. Currently, 3mm glass is the predominant cover of solar modules and it implies 30% of the price. Reduction of encapsulant materials can help to minimize the foot print of the solar panel by minimized cost over the whole chain from raw materials to installation. The aim of the project is to exploit the development of 1mm toughened glass as encapsulant to produce a light weight, low cost PV module with enhanced efficiency. To be able to reach that goal, we have constituted a consortium including necessary expertise. In the project we will develop glasses and new coatings to improve the physical properties of the cover material of PV modules. Furthermore, novel toughening techniques of thin glass will be investigated, and prototypes will be assembled. The following slogans connected to the project acronym, LIMES, explain the aim of the project.

- “Towards ultra-thin glass-glass modules”
- “Towards eliminating the transmission limit of solar glasses"
- “Towards ultra-robust module designs with extended lifetime"

LIMES aims at promoting excellence in research and innovation in order to enhance the competitiveness of European industry and increase the energy produced by sustainable solar power in the future. Results and technological advances will be disseminated by publications, seminars, conferences and reports. The results in terms of prototypes are expected to lead to patents. The initial route to market is through demonstration of new off-grid PV modules and if successful proven case histories will be presented to the BIPV industry.

Project consortium

Coordinator and contact details:

Full name of organisation:	Glafo AB
First and family name of coordinator:	Dr Stefan Karlsson
Full address:	PG Vejdes väg 15, 351 96, Växjö, Sweden
E-mail:	Stefan.Karlsson@glafo.se

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Sweden	2	764’491	694’491
Spain	1	326’880	230’916
United Kingdom	2	840’325	461’616
Total	*5*	*1’931’696*	*1’387’023*

009 BLACK:
Black Silicon and Defect Engineering for Highly Efficient Solar Cells and Modules

Project Duration: 04.2015 to 09.2017
Report submitted: 11.2015

Summary

This project consortium includes the leading academic groups and industrial partners from different parts of the photovoltaic value chain. The goal of the project is to test the previously studied ideas in industrial scale and take a step towards commercial applications. The final goal is to implement a prototype of a full-size solar panel with black silicon (b-Si) surface with atomic layer deposited coating, and thus demonstrate the significance and impact of the previous academic results on the industrial scale.

Project consortium

Coordinator and all contact details:

Full name of organisation	Aalto University (Aalto)
First and family name of coordinator:	Hele Savin
Full address:	Tietotie 3, 02150, Espoo, Finland
E-mail:	hele.savin@aalto.fi

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Finland	6	864’618	381’000
Germany	1	304’773	152’386
Spain	1	75’000	75’000
Total	*8*	*1’244’391*	*608’386*

012 INTESEM:
Intelligent Solar Energy Management Pipeline from Cell to Grid

Project Duration: 01.2014 to 12.2016
Report submitted 05.2014

Summary

Solar energy will be a major source of electricity in the future. Cost-optimal and efficient large scale utilisation and grid integration of solar energy will require more sophisticated design, structure, control and operating model. Virtual Power Plants (VPP) are a promising solution to optimise the generation and storage assets, maximise production and facilitate efficient and balanced distribution of energy to end users.

The objectives for "Intelligent Solar Energy Management Pipeline from Cell to Grid (INTESEM)" project are to optimise a distributed solar energy system (holistic from cell to grid) in a Virtual Power Plant model to enable high PV penetration levels and at the same time minimize costs. The project team is to design, demonstrate and optimise an intelligent VPP model with energy storages, which can be expanded also to the new growing energy markets in the future. The aim is also to develop and utilise new intelligent module, inverter and storage technology to enable the efficient design and operation of the VPP model. The project partners are a Nordic energy company Fortum, a back contact module and manufacturing equipment provider Cencorp, and a solar inverter and energy storage provider Ferroamp.

The objective is to build a pilot VPP system with four commercial-scale PV plants to be located in Finland and Sweden. The plants will be selected based on characteristic variation, e.g. different load profile, size of the storage and/or capabilities for demand response. The most obvious, expected benefits can be achieved with the help of local energy storage in combination with PV modules. A further objective is to demonstrate how four-quadrant inverter technology can be used in PV installations to make them part of the VPP concept and provide grid supporting functions.

The target is 15% reduction of solar energy cost per kWh and to capture a better value for energy with an intelligent system compared to a conventional one. This 15% reduction does not take into account any further reductions in module or balance of system cost but will be based on operational efficiency. A major share of the expected cost reductions can be achieved with the help of local energy storage in combination with PV systems. Local energy storage brings several benefits to VPP operators such as possibility to reduce production and consumption peaks, provide frequency support, reduce distribution losses, and within balance responsible parties to reduce balancing costs due to forecast errors. Consumers can increase their self-consumption of PV electricity, buy off-peak electricity, reduce grid fees and have access to back-up power.

As a result PV could be installed with better cost efficiency which would enable the wider penetration of solar modules also in the Nordics. The security of supply would increase with increased storage facilities and reduced peaks in the system which would also result as more stable electricity prices.

Project consortium

Coordinator and contact details:

Full name of organisation:	Fortum Oyj
First and family name of coordinator:	Riitta Ståhl
Full address:	Keilaniementie 1, 02150 Espoo, Finland
E-mail:	riitta.stahl@fortum.com

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Finland	2	1’063’800	442’530
Sweden	1	295’100	173’125
Total	*3*	*1’358’900*	*615’655*

013 NOVACOST:
Non Vacuum Based Strategies for Cost Efficient Low Weight Chalcogenide Photovoltaics

Project duration: 10.2014 to 09.2017
Report submitted: 02.2015

Summary

Chalcogenide (CuInGa(S,Se)2-CIGS, Cu2ZnSn(S,Se)4-CZTS) based technologies have a strong potential for high efficiency low cost photovoltaics (PV) solar cells and modules. Indeed, thin film technologies are well adapted for the use of alternative low weight substrates that are required for the extension of PV towards large area industrial/commercial roofs and architectural facades (BIPV) where less than 4 kg/m2 modules are expected. Among thin film technologies, CIGS prepared by vacuum based methods is the one showing the higher efficiency (with a 20,4% world record on low weigh substrate (EMPA, 2013)). This explains the significant growth in the CIGS worldwide industrial production from about 150 MW/y in 2009 up to over 2 GW/y in 2011, even if the struggling market situation is forcing many CIGS based companies to bankrupt. The struggling and competitive future is driven by the fact that electricity generated by PV is becoming increasingly competitive, with an average levelized cost of energy (LCOE) estimated to be between 0,12-0,17 €/kWh in 2011, depending on regional climate conditions. This constant reduction is struggling the European industry towards i) strong reduction of the production and investment costs, that today are at ~ 1,0 €/Wp in Europe versus ~ 0,6 €/Wp in emerging countries like China and Taiwan; and ii) investment in novel “advanced” industrial processes allowing high efficiencies and low-cost device production.

NOVACOST project aims at developing a non-vacuum low cost and up-scalable roll-to-roll manufacturing method with innovative precursors and crystallisation process for the fabrication of cost-efficient low weight CIGS and CZTS-based solar cells and modules. For this purpose, two industrials partners (‘Advanced Coatings & Construction Solutions scrl’ in Belgium-Wallonia, ‘Francisco Ramos S.A’ in Spain) and two research institutions (‘Instituto de Recerca en Energia de Catalunya’ in Spain, and ‘Uppsala University’ in Sweden) will employ their knowledge and know-how on materials, processes and characterization through 8 workpackages:

- The use of innovative chalcogenide inks formulation and the improved control of coating processes to enhance the film homogeneity will be addressed for CIGS and CZTS respectively in WP1 and WP2,
- The breakthrough introduction of Intense Pulse Lighting technique for crystallization of the CIGS / CZTS layers will be investigated in WP3,
- The set-up of a methodology for quality control of these PV thin films will be addressed in WP4.

All these innovations will be assessed by solar cells and mini-module prototyping (WP5). The project includes lab scale to pre-industrial pilot development of roll-to-roll (R2R) compatible technologies and assessment of economic and environmental benefits (WP6). The global objective

is to demonstrate that the developed innovative technologies forecast a 15-50 % cost reduction in the equipment with respect to the state-of-the-art vacuum based CIGS manufacturing processes, paving the way to achieve 0,6 €/Wp system cost for the production of solar cells. Dissemination and plans for commercialization of the developed eco-friendly products and technology will be finally addressed (WP7), aiming to reinforce the industrial competitiveness of PV European actors.

Project consortium

Coordinator and contact details:

Full name of organisation:	Advanced Coatings & Construction Solutions scrl
First and family name of coordinator:	Lionel Fourdrinier
Full address:	Boulevard de Colonster B57, 4000 Liège, Belgium
E-mail:	lionel.fourdrinier@crmgroup.be

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Belgium-Wallonia	1	357'501	143'000
Spain	2	550'633	164'000
Sweden	1	213'000	213'000
Total	*4*	*1'121'134*	*520'000*

036 NovaZOlar: All-non-Vacuum Processed ZnO-based Buffer and Window Layers for CIGS Solar Cell Technology

Project duration: 09.2014 to 08.2016
Report submitted: 12.2014

Summary

The Cu(In,Ga)Se_2 (CIGS) thin film solar cell technology has made a steady progress within the last decade by raising the conversion efficiency to 21,7% on laboratory scale, thus exceeding the highest efficiency for polycrystalline silicon cells, whereas standard-size CIGS modules achieve efficiencies of up to 15,9%. High efficiency CIGS cells employ the so-called buffer layer of CdS deposited by chemical bath deposition (CBD), and its presence and, importantly, treatment and utilization of Cd-containing waste present a serious environmental concern. A second potential bottleneck of the CIGS technology is the transparent conductive oxide (TCO) layer of i-ZnO/Al:ZnO, which is deposited by sputtering requiring expensive vacuum equipment. A non-vacuum deposition of TCO relying on simpler equipment with lower investment costs will be more economically attractive and could increase competitiveness of CIGS modules with the mainstream silicon-based technologies.

The aim of NovaZOlar is to develop an innovative, low-cost process of in-situ monitored aqueous solution deposition of the ZnO-based buffer-window combination for high-efficiency CIGS solar cells. The novelty is to use a single deposition technique – CBD – for deposing the Cd-free window-buffer combination that should ultimately replace the present CdS/i-ZnO/Al:ZnO stack. A solar efficiency of > 20% is targeted, which is comparable to that for best cells with CdS buffer and should translate into CIGS module efficiency of 14-16%.

Besides the scientific and technological impact for developing the innovative low-temperature solution deposition and testing a new CIGS solar cell architecture, the main commercial impact will be on i) cost reductions by avoiding expensive vacuum sputtering of ZnO and toxic Cd waste disposal, and ii) simplified equipment making turn-key CIGS production lines more cost competitive. Reliable techniques for process monitoring and quality control at both in-situ and on-line levels will improve fabrication yield, and hence also contribute to reduction of manufacturing costs. Cost analysis and technical assessment of transferability of the developed solution techniques will be done by CIGS-manufacturing companies from Switzerland, France and Germany in this industry-driven project.

Project consortium

Coordinator and contact details:

Full name of organisation:	Empa - Swiss Federal Laboratories for Materials Science and Technology
First and family name of coordinator:	Yaroslav Romanyuk
Full address:	Empa Laboratory for Thin Films and Photovoltaics (207) Überlandstrasse 129 8600 Dübendorf, Switzerland
E-mail:	yaroslav.romanyuk@empa.ch

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Switzerland	2	533'338	400'000
France	3	327'642	293'642
Germany	2	547'181	411'091
Spain	1	181'527	114'000
Total	*8*	*1'589'688*	*1'218'733*

037 HyLighT:
Design, Development and Application of a Technologically Advanced System of Natural Daylight and Artificial PV Lighting - Hybrid Light Tube

Project duration: 09.2014 to 08.2016
Report submitted: 12.2014

Summary

In order to meet the lighting needs, the consumption of energy exceeds on average 10% of the total in a residential building and 30% in a commercial. It is therefore easily understood the importance of saving energy in the building's lighting sector. Appropriately controlled natural lighting in buildings offers many advantages over using artificial lighting; energy savings probably being the most important. Ideally energy savings should be combined with onsite energy production from renewable sources. Especially in the case of the building shell, the renewable energy technologies that seem likely to meet on-site energy needs are mainly those associated with the sun, as solar technologies for onsite energy production currently dominate the building sector. Acknowledging these facts, a research team consisting of a research centre in Cyprus (Frederick Research Centre), an industry in Poland (AG Metal Poland), and a consultants' team in Cyprus (Solar Century) proposes a novel BIPV concept, which combines the following features:

- The use of natural lighting, using a well-established concept, the light tube
- The utilization of renewable energy technologies to meet the needs of artificial lighting

The combination of the above resulted in a hybrid light tube (HyLighT). HyLighT project aims at the design and manufacturing of a novel concept, namely the integration of a CIGS thin-film photovoltaic membrane to a light tube. The main idea behind the proposed concept is that the energy produced by the photovoltaic membrane will be stored and used by demand to cover the needs for artificial lighting. For this purpose, LED light bulbs will be incorporated into HyLighT's body, activated either manually or by a motion detector. HyLighT aspires to be an innovative, energy efficient quality product, having a clear added value over standard light tubes. The proposed concept also aims at low cost and increased efficiency. The benefits of HyLighT are manifold; the integration and promotion of environmental-green solutions of natural lighting for new and existing buildings, the display of the European renewable energy technologies products in the international market, and the stakeholder's competitiveness boosting within the European and international markets. HyLighT project will focus on the design and functionality of the proposed solution as well as on the excellent aesthetics combined with high performance. Ease of installation and replacement as well as the reliability and the robustness of the proposed concept will also be investigated. The HyLighT project will be concluded with the testing and demonstration of the new product to the interested stakeholders and potential end-users.

Project consortium

Coordinator and contact details:

Full name of organisation:	Frederick Research Center
First and family name of coordinator:	Paris Fokaides
Full address:	7, Filokyprou Str., 1036, Cyprus
E-mail:	p.fokaides@frederick.ac.cy

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Cyprus	2	101’464	96’318
Poland	1	137‘685	102‘755
Total	*3*	*239’149*	*199’073*

Polish data with exchange rate of 1 Euro = 4,2 Zloty

039 InnoModu: Leadfree Modules with Low Silver Content and Innovative Busless Cell Grid

Project duration: 10.2014 to 03.2016
Report submitted: 11.2014

Summary

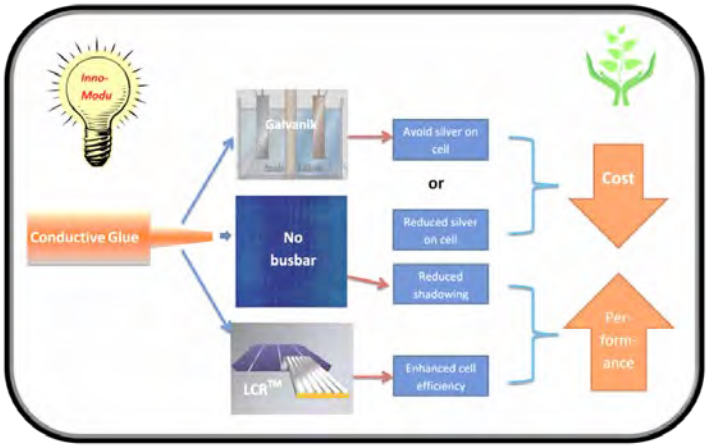
InnoModu is an industry-driven research project striving to develop the next generation of photovoltaic (PV) cells and modules. Up to now, standard crystalline PV modules consist of solar cells whose current collection system (metal grid), fingers and busbars, needs much silver (~350mg). Additionally, the stringing of the solar cells is carried out by a lead containing soldering process. However, the silver price is expected to rise in the next years showing an impact on the PV-prices, and furthermore, lead is being banned from nearly all other electronic devices for environmental reasons. Another challenge in the PV cell production is the reduction of the shadowing of the active cell material by minimizing the contacting grid on the front side of the cells. On the one side, the grid should have a low ohmic resistance in order to reduce the energy loss. On the other side, it should enable a maximum of sun light falling on the cell with decreased shadowing. These are two contradicting demands, which need to be analyzed and improved. Additionally, the ribbons which are used for the stringing process are wider than necessary in order to compensate an inexact alignment. This leads to a further shading and power reduction of the modules.

The targets of InnoModu are threefold: (1) drastically minimize the silver content (by ~50%) in solar cells, (2) reduce the share of lead used in a module due to soldering to nearly zero, and (3) reduce the shadowing of active cell material. These three main targets will allow for considerable cost and material savings as well as environmental improvements. In addition, the novel technology will bring more cell efficiency with clear market benefits for the industrial partners. In order to reach the aims, the metal grid on the solar cell surface has to be optimized and new technologies to apply high efficient connection wires (ribbons) have to be implemented, as seen in the figure below.

The main innovative step of InnoModu in relation to state of the art technologies is the combination of a galvanic process with copper and a following gluing process (application of LCR) to replace the standard screen-printing process of silver paste as well as the standard soldering process (lead-containing). This offers completely new opportunities to increase the overall cell performance, reduce costs, and increase environmental compatibility. The use of electrically conductive glue will allow to fix the metal ribbons directly to the cell and thus to avoid busbars and soldering processes, which would require soldering pastes containing lead as well as overlapping ribbons and would lead to a considerable reduction of silver paste.

Additionally, it will enable the use of innovative LCR ribbons, which can dramatically reduce the ribbon-caused shadowing and thus increase cell efficiency. Furthermore, the use of galvanic metallization techniques make a completely silver free solar cell production process possible

and the risk of breakage, when using thinner solar cells, is significantly reduced during module manufacturing.



InnoModu project idea

Project consortium

Coordinator and contact details:

Full name of organisation:	AIT Austrian Institute of Technology GmbH
First and family name of coordinator:	Michael Schwark
Full address:	Donau-City Strasse 1, 1220 Vienna, Austria
E-mail:	Michael.Schwark@ait.ac.at

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Austria	5	538’058	389’551
Germany	2	271’287	135’644
Total	*7*	*809’345*	*525’195*

047 AER II:
Industrialization and System Integration of the Aesthetic Energy Roof Concept

Project duration: 05.2014 to 04.2016
Report submitted: 01.2015

Summary

The future of the European photovoltaic industry depends heavily on breakthroughs in 'mass customization' of photovoltaic roofs, that require the European local execution of engineering, on-demand manufacturing and on-site delivery, and that need a high level of aesthetics to appeal to a broad public.

In this project the project partners Soltech, Heijmans, SEAC and AERspire join forces to research, develop, industrialize and bring to the market the Aesthetic Energy Roof (AER) concept. The AER concept is based on a patented frameless glass-glass laminate with integrated mounting functionality. AER is a full roof solution, which replaces the functionality of the conventional roofing. The building integrated energy roof concept has a unique set of properties like full roof filling, unsurpassed high-end aesthetic appearance, minimized bill-of-materials, optionally included integrated window and integrated solar thermal panel. The AER concept will result in a full range of products that can be build up modular on any type of roof at customer energy and heat demand.

The cross-border AER II project follows-up the Dutch nationally funded AER I project, in which the proof of principle for the water tightness, the mounting principle and the electricity generation of the concept has been demonstrated. The objective of the AER II project is to further develop the AER concept into more product lines, industrialize the production and bring these products to the market. A market study will deliver an overview of the various BIPV market segments and the best fit for the various AER product lines. Secondly, the base product and its manufacturing processes will be industrialized and optimized to reach the optimal price for the roof functionality and the price per Wp. A prototype roof must demonstrate the novelty of the new ventilation shaft that ensures maximum heat transfer from the module to the air in the shaft by the design of an aerodynamic profile and mounting concept.

All results and suggested improvements will be integrated in a demo-roof which roof solution will also include functional and finishing parts and all necessary components such as: PV modules, interconnections, inverter, switches and grid connection. Monitoring equipment will be installed and data will be saved for further evaluation and optimization.

Project consortium

Coordinator and contact details:

Full name of organisation:	AERspire B.V.
First and family name of coordinator:	Esther Philipse
Full address:	Jan Campertstraat 5, building 7, Heerlen, The Netherlands
E-mail:	estherphilipse@aerspire.com

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
The Netherlands	3	506'782	299'403
Belgium-Flanders	1	80'459	44'252
Total	*4*	*587'241*	*343'655*

049 SNOOPI:
Smart Network Control with Coordinated PV Infeed

Project duration: 10.2015 to 09.2018
Report submitted: 11.2015

Summary

High penetration of PV in the distribution grid will significantly impact voltage control in the distribution network. It will cause high voltage rises and fast voltage changes over a very short time period when for example clouds are passing areas with large amounts of solar power. The objective of this study is to develop and test a voltage regulation tool that is scalable and portable so that it can be used for any distribution system with high PV penetration.

The project “Snoopi” consists of 4 partners: two in Germany, namely Energynautics GmbH, EWR Netz GmbH, one institution – KTH – in Sweden and one in Austria (Fronius International GmbH). It will last in total for three years.

The project will develop and test new control methods to maintain the voltage within set limits, even if the situation in the distribution network is changing very dynamically (e.g. if electric cars are frequently connected to the distribution network together with a high share of PV).

The main challenge is to coordinate the inverter control of many battery systems and at the same time minimize the communication and measuring requirements in the distribution network. As regulating the voltage in one node indirectly regulates the voltage in the adjacent node due to the inherited interactions in the voltage, a robust control scheme must be developed. Regulating the voltage in one node should not cause problems in another, and in addition the transformer tap changer control or other controllable devices need to be taken into account in the regulation, to ensure all node voltages are within the limits.

It is the intention of the project to test the newly developed control methods in a real distribution system with considerable amounts of PV. It is planned to implement and test the voltage control tool in field tests on the EWR Grid in Germany. The EWR Grid encompasses a large amount of PV. To measure the voltage in these networks, various measurement systems will be used, e.g. phasor measurement units.

The project will be executed in six phases. In the first phase field test areas in Germany will be identified and reconstructed in network models. The voltage control tool will be developed in phase two and tested by simulations on the network models in phase three. Phase four focuses on testing the tool in the laboratory. In phase five demonstration projects will be prepared. The main goal is the execution of demonstration projects in phase six, where the tool will be tested in field tests on the real distribution grids of EWR. During these field tests, several questions will be answered such as:

- What measurement quality is required from “Battery Inverter” and “Smart Meters”, e.g. what time delays are acceptable and what data sampling rates are needed?
- How much solar power can be installed in the distribution grid and what are the limiting factors?

- What is required to make the tool scalable and portable to other network areas?

The evaluation of the measured data as well as the delivery of the final report will also take place in phase six. The overall aim is to develop, test and validate the performance of the voltage control tool, so that it can be used as a network operating tool by distribution companies around the world.

Project consortium

Coordinator and all contact details:

Full name of organisation	Energynautics GmbH
First and family name of coordinator:	Thomas Ackermann
Full address:	Robert-Bosch-Str. 7, 64293 Darmstadt, Germany
E-mail:	t.ackermann@energynautics.com

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Germany	2	769’962	428’469
Austria	1	0	0
Sweden*	1	259’921	259’921
Total	*4*	*1’029’883*	*688’390*

071 PV4FACADES: Photovoltaics for High-Performance Building-Integrated Electricity Production Using High-Efficiency Back-Contact Silicon Modules

Project duration: 09.2014 to 08.2016
Report submitted: 01.2015

Summary

The PV4FACADES project aims at the development of low-cost and high-efficiency back-contact cell and module technology and building-integrated PV (BIPV) products based on back contact technology. This will result in higher efficiency PV modules which are perfectly suited for BIPV: much more appealing aesthetics and more suitable electrical, thermal and mechanical characteristics.

Back contact module technology is the accepted route to higher efficiency PV modules (see e.g. the SEMI PV roadmap). At the same time, back-contact module technology is also perfectly suited for BIPV in which PV elements are integrated into buildings and often have dual functions (serving as electricity generator and construction element) which reduces the balance-of-system costs. For residential rooftop and building integration, the current typical modules are aesthetically unattractive. The much more appealing aesthetics of back-contact modules make them much better suited for BIPV and for residential rooftops. In addition, the PV industry has seen little product diversification to date, and there are commercial opportunities for PV systems other than the current typical flat plate modules mounted on frames or supports.

The PV4FACADES project will run for two years and has the following main objectives:

- The development of low-cost, high-efficiency back-contact cell technologies for industrial take-up.
- The development of back-contact interconnection and lamination technologies, for 156mm x 156mm MWT (metal wrap through) and IBC (interdigitated back contact) cells, with improved integrated cell and module architecture and resulting in a lower cell-to-module loss and a lower cost than current industrial back-contact technology.
- The development of back-contact PV technology specifically designed for building integration, with improved aesthetics and resulting in a higher yearly energy yield.
- The development of module technology with thinner glass, improved reliability and lifetime.

The project includes partners from the complete manufacturing chain: from research institutes and producers of cell and module manufacturing equipment, via module producers, to producers of building integrated PV elements.

In WP1, Tempress, imec, ECN and Soltech work on development of low-cost MWT and IBC cells with efficiency over 22%, suitable and optimised for the module technologies of the later WP's.

In WP2, two innovative interconnection techniques will be tested and optimised, leading to a cell to module power loss of 0%, suitable for a module efficiency over 20,5% at lower cost. Soltech,

Eurotron and Sunlego will provide the interconnection techniques and pilot scale manufacturing equipment.

In WP3, lamination materials and technologies will be developed and optimised, leading to thinner glass, new encapsulants, shorter process time, and lower cost. Sisecam will develop and demonstrate thinner glass with thickness of 2 – 2,2mm for glass-glass and glass-foil modules. Sunlego, Eurotron, and Soltech will test and optimise lamination technology and materials.

In WP4, product integration into high-performance building elements is performed by end users Wienerberger and Eternit (roof elements) in collaboration with Soltech. Also, integration of microinverters, for better shadow performance, is developed and tested by Sunlego and Soltech. Market studies and market feedback will be collected, and impact on life cycle analysis will be included.

In WP5, analysis and reliability testing is performed by Eliosys, GUNAM, imec, and ECN. Performance variations depending on different climates and the built environment, and a test method for partial shading, will be key.

Project consortium

Coordinator and contact details:

Full name of organisation:	ECN
First and family name of coordinator:	Bart Geerligs
Full address:	Westerduinweg 3, 1755 LE Petten, The Netherlands
E-mail:	geerligs@ecn.nl

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
The Netherlands	3	1’188’875	712’167
Belgium-Flanders	4	686’186	531’902
Belgium-Wallonia	1	229’410	160’587
Turkey	2	502’836	334’884
Total	*10*	*2’607’307*	*1’739’540*

077 ACCESS-CIGS:
Atmospheric Cost Competitive Elemental Sulpho-Selenisation for CIGS

Project Duration: 03.2016 to 02.2018
Report submitted: 05.2016

Summary

Thin film Cu(In,Ga)(Se,S)$_2$ (CIGSSe) solar cells exhibit conversion efficiencies that are at the same level as those based on multi-crystalline silicon wafers. Therefore, the CIGSSe technology has potential to significantly contribute on a larger scale to the production of photovoltaic energy. However, several of fabrication steps leading to CIGSSe solar modules rely on relatively slow vacuum processes and/or involve material inefficient toxic gases. This increases considerably the costs of module fabrication reducing the competitiveness of this technology. The introduction of high through-put in-line processes using non-toxic gases will lead to a significant cost reduction. Provided that the respective power conversion efficiencies can be maintained or increased, the cost of PV-generated electricity produced with this technology can be significantly reduced.

The objectives of this project are the combined reduction of CIGSSe processing cost and the improvement of the conversion efficiency. Since the CIGSSe absorber layer has the highest cost and the highest efficiency impact on the finished CIGSSe module, this project will focus on improving sequential CIGSSe absorber formation by rapid thermal processing, the commercially and industrially most attractive process for the fabrication of CIGSSe absorbers. In this sequential process, stacks of Cu-In-Ga metallic films are transformed into the active absorber CIGSSe layer in a high-throughput in-line reactive thermal process by gaseous S and Se compounds. To reduce the costs involved in handling and safety measures related to toxic H_2S and H_2Se gas, elemental selenium (Se) and sulphur (S) vapours are used for the reaction. Furthermore, the thermal process occurs at atmospheric pressures eliminating the cost of vacuum equipment. Within the project, two measures are tested with respect to their influence on the chalcogen consumption as well as the quality of the absorber layer: First, excess selenium that is not incorporated into the deposited CIGSSe thin film is recirculated and reused. Second, selenium in the vapour is cracked into smaller Se molecules before it is provided for the thermally activated reaction.

Project consortium

Coordinator and all contact details:

Full name of organisation	Helmholtz-Zentrum Berlin für Materialien und Energie
First and family name of coordinator:	Sebastian Simon Schmidt
Full address:	Schwarzschildstr. 3, 12489 Berlin, Germany
E-mail:	sebastian.schmidt@helmholtz-berlin.de

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Germany	2	1'101'866	981'397
The Netherlands	2	844'973	506'973
Total	*4*	*1'946'839*	*1'488'370*

078 PV me: Organic PhotoVoltaic Systems Integrated in Manufactured Building Elements

Project Duration: 01.2016 to 06.2018
Report submitted: 08.2016

Summary

Heliatek's organic photovoltaic (OPV) cells currently yield record lab efficiencies of 13.2%. First modules produced on a recently installed roll-to-roll production line yield module efficiencies of 7.7%. This cell-to-module efficiency gap will be minimized by application of advanced processing methods. The objective is to increase module efficiencies to >9% within the next two years[1]. Preliminary cost calculations indicate economic viability of OPV based building integrated photovoltaic (BIPV) applications once modules efficiencies reach 8%. Extrapolated light soak lifetimes (T80) on cell level already yield values in excess of 20 years. The main challenge for OPV is now to prove the technology in real life applications exploiting the unique selling points of this emerging PV-technology.

The *PV me* project will deliver two types of power producing building elements. For the first building element (BE), based on steel substrates, Hoesch Bausysteme will integrate the OPV modules into their steel façade elements (curtain walls) by Hoesch Bausysteme. These elements will be completed with a protective coating of Akzo Nobel. The second type of BE is glass based, on which AGC will laminate flexible Heliatek OPV modules. Further integration into a glass based BE will be done by SAPA. The organic solar film of the building elements emphasizes the aesthetics of the product without compromising other functions of the construction elements such as thermal insulation and water barrier. Power converters of Heliox and all other electronic components will be integrated in the BE frame to facilitate quick installation and to ensure robust electrical contacts. These BIPV products will comply to the relevant building codes and safety norms. The BE's will be installed on a public location for demonstration purposes as well as at a test facility to be monitored by Laborelec. Within the consortium the three knowledge institutes and Solliance partners, Holst Centre, imec, and ECN, contribute to process development, system design, correlation of indoor and outdoor data and determination of annual yields of the developed building elements.

The estimated suitable area for BIPV façade elements is over 600 km^2 in the participating countries of this proposal.[2] However, today the global market for BIPV is still small: growing from 200 MW in 2009 to an estimated 2.5 GW in 2016.[3] This latter study estimates the growth rate to be 31 % for the EU region. OPV may take a significant share of the BIPV market, as this technology is particularly suitable for integration because of tunable transparency, freedom of dimension,

[1] The 9% module efficiency is beyond the state-of-the-art, and not an objective of this project. Heliatek provides *PV me* with state-of-the art modules. *PV me* benefits from progress obtained by Heliatek during the course of the project.
[2] Gutschner, Lund, Snow, *Earthscan* (2005).
[3] Cavanaugh, *Building Integrated Photovoltaics*, Navigant Research (2010).

conformal shapes and a large variety of colors against acceptable cost in €/m^2. '*PV me*' aims to demonstrate the potential of these BE's to unlock this market.

The project will run for 30 months, including 6 months of monitoring, with the following main objectives:

- A building with both glass and steel based building elements, containing fully integrated, aesthetically pleasing, state-of-the-art, opaque OPV modules, including micro-converters on building element level, to assure optimal power output on system (building) level.
- Determine annual yield and stability of grid connected organic BIPV under real life conditions.
- Correlate outdoor measurements with accelerated lifetime tests under indoor conditions.
- Determine a detailed economic perspective for the developed technology (incl. LCOE).

Project consortium

Coordinator and all contact details:

Full name of organisation	ECN
First and family name of coordinator:	Sjoerd Veenstra
Full address:	High Tech Campus 21, 5656 AE, Eindhoven, The Netherlands
E-mail:	veenstra@ecn.nl

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
The Netherlands	4	981'654	574'830
Germany	2	815'232	422'324
Belgium - Wallonia	1	345'526	138'210
Belgium - Flanders	3	337'978	118'292
Total	*10*	*2'480'390*	*1'253'656*

082 PV2GRID:
A Next Generation Grid Side Converter with Advanced Control and Power Quality Capabilities

Project Duration: 04.2015 to 03.2018
Report submitted: 11.2015

Summary

Several goals have been set at international and European levels regarding the energy and climate change of the planet. According to the European Union, these objectives are well known as the “20-20-20” targets by 2020, which require that 20% of energy consumption is produced from Renewable Energy Sources (RES), a 20% reduction in greenhouse gas emissions and a 20% improvement of energy efficiency. Higher goals are being set for 2030 (27%, 40%, and 30% respectively). This project focuses on the large scale deployment of photovoltaic (PV) systems through improving their grid integration. The driving forces of this ambitious project focus on three issues of critical significance that inhibit the massive deployment of PVs: (a) the variable/insolation-dependent nature of PV generation, (b) the problems associated with massive distributed generation (e.g. grid unbalance, harmonics), and (c) the need to develop appropriate fault ride through (FRT) solutions to allow them to support the grid during faults. It is expected that the project results and products developed will address the challenges and achieve the objectives with regards to the grid interconnection and the large-scale deployment of PV systems as set by the implementation plan of the Solar Europe Industry Initiative (SEII).

The most crucial point with regards to the grid integration of PV systems is the grid side converter (GSC) which is based on power electronic technology. GSCs are still not capable of advanced control features that enable the full control of RES with FRT capabilities, reactive power support and generation control. The major objective of this project is to develop a next-generation GSC (one for single- and one for three-phase systems) with advanced control and novel operational mode capabilities, which will benefit all stakeholders of PV systems in terms of:

a) A seamless integration of PV systems in the power grid

b) A further larger scale deployment of PV systems due to the several advantages of the new converters

c) Possibilities to extend the GSC technology to other green technologies

d) Maximization of the utilization of PV systems in order to improve the power system operation

e) Increase of the incomes/returns from a solar energy investment for a self-sustainable market of PV systems.

The GSCs designed and developed in this project will achieve an improved performance ensuring the proper grid integration of PV systems under any grid conditions. Additionally, the new GSCs will be enhanced with novel operational functionalities that will allow new operating approaches. The new operating modes will contribute to the development of multifunctional industrial products that can be used for the grid integration of several new technologies with emphasis on PV

systems. The novel operational functionalities of the GSC will pave the way for a higher penetration of solar energy and will maximize the utilization of PV systems in order to:

- Enhance the value and increase the competiveness of PV systems
- Maximize the income of a solar project for a self-sustainable market of PV systems
- Enhance the stability and reliability of power systems
- Improve the power quality and minimize the power losses of Distribution Networks (DN)

The project will clearly benefit the PV industry, the power system operator at distribution and transmission level, the investors on PV systems, the electricity consumer, and the environment. A cost-effective and smooth integration of considerably more PV systems will be achieved.

The successful completion of the project is guaranteed due to world-class/pioneer partners of a balanced and complementary consortium. The partners combine great expertise on the following areas: development of advanced methodologies for GSC, design and reliability of power electronics, and power system operation/power quality/stability and investment on energy market. The result of the project can be used to enable partners to enter into the PV industry by commercializing the results on novel single- and three-phase inverters for PV systems.

Project consortium

Coordinator and all contact details:

Full name of organisation	University of Cyprus
First and family name of coordinator:	Elias Kyriakides
Full address:	75 Kallipoleos Street P.O. Box 20537, 1678 Nicosia, Cyprus
E-mail:	elias@ucy.ac.cy

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Cyprus	2	90’624	84’700
Denmark	1	108432	97’589
Total	*3*	*199’056*	*182’289*

084 THESEUS:
Tandem High Efficiency Solar Cells Utilizing III-V Semiconductors on Silicon

Project Duration: 06.2015 to 11.2017
Report submitted: 12.2015

Summary

This proposal seeks to develop novel, very high efficiency tandem flat plate solar cells utilising III-V semiconductors grown onto Silicon substrates, using advanced epitaxial techniques to grow SiGe and SiGeSn structures, and to integrate them into high efficiency modules and test them on sun. As such, this work meets the scope as set out in the SOLAR-ERA.NET Transnational Call PV2.4 'High-efficiency PV modules based on next generation c-Si solar cells'. By utilising tandem solar cell architectures that better match the device bandgaps to the solar spectrum it is possible to significantly enhance the efficiencies compared with conventional c-Si devices. The intention is to develop these high efficiency cells to demonstrate cell conversion efficiencies well in excess of 25%. This aim will be achieved by the combination of the extensive expertise of IQE in the field of SiGe and III-V epitaxy and the solid background of UPM in the areas of multijunction solar cell design and manufacturing. In this respect, novel epitaxial wafers of InGaAsP/SiGe(Sn) on Si solar cells grown by IQE, will be processed into solar cells at UPM facilities to be eventually incorporated into prototype modules, assembled by DHV, which will be tested on-sun by UPM in Madrid. It is anticipated that the module efficiencies utilising these novel cell architectures will be well in excess of 22%, making them significantly ahead of the current state of the art. Finally, acceleration ageing test by using climatic chambers will be carried out on these novel solar cells.

Project consortium

Coordinator and all contact details:

Full name of organisation	IQE plc
First and family name of coordinator:	Iwan Davies
Full address:	Pascal Close, Cardiff CF3 0LW, UK
E-mail:	idavies@iqep.com

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
United Kingdom	1	497'000	248'500
Spain	2	175'000	25'000
Total	*3*	*672'000*	*273'500*

090 U-light:
Ultra Lightweight PV Modules and their Applications in Innovative PV Systems Achieving Lowest Levelized Cost of Electricity (LCOE)

Project Duration: 11.2015 to 10.2018
Report submitted: 11.2015

Summary

In the “U-light” project new light weight, high efficiency and long life-time modules are developed with regard to lowest cost for integration into PV systems achieving lowest values of levelized cost of energy (LCOE). The new light weight modules will be generated by the use of thin, strong, low cost glass and by the use of compositions (mineral or organic) like glass-fibre reinforced plastic (GRP). Strong focus is set on the long term durability, failure probability, and energy harvest. The cell to module (CTM) losses are reduced by putting a strong accentuation on the development of novel thin glass and encapsulants with highest light transmissivity and low UV cut off as well on backsheet materials with 20% (abs.) larger reflectivity compared to state of the art products. In addition solar cells are developed which make the use of bypass diodes in modules unessential.

For the development of ultra-light weight modules the reduction of thickness for all layers is a clear objective, while keeping the required functional properties. For this the glass thickness will be reduced from to-days 2.0 mm to lower thicknesses, which will obviously lead to a reduction of raw-materials and energy consumption during manufacturing which is a key target of the European manufacturing industry. It further increases the light transmittance thus reducing cell to module losses.

The scope of the material development for the module backsheet is set on products with reflectivity >90% with 20% (abs.) larger reflectivity compared to state of the art products, while being at the same time a lightweight material. The new encapsulant materials will combine advantageous properties, e.g. a UV-cut-off below 320 nm and an outstanding transparency in the wavelength-range from 400 to 1000 nm. Additional cost saving can be achieved by the reduction of the lamination time for the respective encapsulant materials to a value below 10 minutes. For most solar module factories the lamination step is the bottle neck preventing lower cycle times therefore the project aims to set new standards with the material development.

The project will deliver certified lightweight glass/glass and glass/backsheet modules passing relevant IEC 61215 and IEC 61646 standards with a cost reduction of 30% as compared to standard modules (without cell cost) in €/Wp.

In addition the project will also evaluate alternative concepts for light weight modules like the use of GRP as an alternative to glass. Beside the cost reduction the light weight and bifaciality of the new modules will open up new applications for these modules, in example for greenhouses and parking roofs. In the frame of the project new applications will be evaluated.

The module development will be based on the latest generation of highest efficiency solar cells from ISC Konstanz, for example the bifacial BISON or the back contact IBC cell, so-called ZEBRA

cell and if available inside the project HIT solar cells (either bifacial or non-bifacial depending on the individual application).

The cell research in this project will focus on the development of IBC ZEBRA solar cells with intrinsic bypass diodes without additional costs. This will allow producing solar modules without bypass diodes and leads to a price reduction on module level but most of all increase the product lifetime since failing diodes is one of the main defects of solar modules in the field.

Project consortium

Coordinator and all contact details:

Full name of organisation	International Solar Energy Research Center Konstanz
First and family name of coordinator:	Andreas Schneider
Full address:	Rudolf-Diesel-Strasse 15, Konstanz, Germany
E-mail:	Andreas.schneider@isc-konstanz.de

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Germany	1	341’343	273’074
Austria	2	300’541	195’351
Switzerland	1	146’868	136’722
Total	*4*	*788’752*	*605’147*

092 HESiTSC:
High Efficiency Silicon Based Tandem Solar Cell PV Module

Project Duration: 06.2015 to 12.2017
Report submitted: 08.2016

Summary

Crystalline Si PV cell is the dominating technology on solar energy market. The declining of Si PV cell cost helps the solar energy to become as competitive as the conventional energy source. In order to replace the fossil fuel in electricity generation, the levelized cost of energy (LCOE) of Si PV cell technology has to be further reduced, which can be realized by aggressively increasing the conversion efficiency of Si PV cell. However, the maximum efficiency of c-Si solar cells is about 30% due to the Shockley–Queisser limit. Si PV industry is pursuing the cost effective and future proof high efficiency Si PV cell technology. In order to make c-Si solar cell more efficient and competitive than other electricity generation solutions, disruptive device architectures and innovations in process technology are required. The success of such objectives requires the transnational collaboration among European research institutes and industry. In this project, Swedish universities KTH-Royal Institute of Technology and Karlstad University, the Swedish start-up company Tandem Sun AB and Spanish research institute FUNDACIÓN CENER-CIEMAT will collaborate to develop and demonstrate the high efficiency c-Si based tandem solar cell (SiTSC) technology by exploiting the innovative direct III-V/Si heterojunction concept. A dual junction solar cell consisting of 1.8 eV GaInP top cell and Si bottom cell will be demonstrated by using the proprietary corrugated epitaxial lateral overgrowth (CELOG) method in the hydride vapour phase epitaxy (HVPE) reactor. The enhanced efficiency by the tandem solar cell structure will be verified by a third party. The complementary experience and expertise of our transnational consortium in c-Si and III-V photovoltaic technology will assure the success of the project. By the end of the project, a pilot production of SiTSC will be established. The outcome of the project will pave the way for an aggressive cost reduction of SiTSC in industrial scale production, which will lead to the cost competitive solar electricity in the near future.

Project consortium

Coordinator and all contact details:

Full name of organisation	Royal Institute of Technology-KTH
First and family name of coordinator:	Yanting Sun
Full address:	Department of Materials and Nano Physics, School of Information Communication Technology, Royal Institute of Technology-KTH, Electrum 229, Isafjordsgatan 22, SE-164 40 Kista, Sweden
E-mail:	yasun@kth.se

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Sweden	3	457'039	442'105
Spain	1	75'000	50'000
Total	*4*	*532'039*	*492'105*

093 InGrid:
High Efficiency PV Modules Based on Back-Contact Cells and Novel Interconnecting Grid

Project Duration: 01.2015 to 05.2017
Report submitted: 11.2015

Summary

The “InGrid” project aims to develop high efficiency rear contact solar cells (Zebra) interconnected on module level by conductive structures embedded or coated into the encapsulation material. The module development will be based on the latest generation of highest efficiency interdigitally back contacted cells (IBC), the so-called ZEBRA cell and focus as well on standard and bifacial solar cells.

The overall goal of the project is to develop a new module technology for high efficiency rear contact and bifacial solar cells. Inside the project strong emphasis is set on the development of a new encapsulation material with intrinsic conductive structures to replace the ribbon typically used in industry for interconnecting solar cells by soldering. For this, conductive inks are subject to development allowing for an interconnection process at low temperatures being suitable for the temperature limitations given by the encapsulant. The printing and sintering process for the conductive ink material as placed on the substrate (e.g. EVA) is a key to be reached inside the project including capabilities at low (lamination) temperatures. The high efficiency solar cell concept will be modified to suit the requirements for the conductive inks (as geometrical needs and conductivity) to allow for a reliable and low series resistance interconnection of conductive structure to cell.

The novel material combination (conductive ink on encapsulant) will be subject to climatic and outdoor testing to prove the concept and longevity of the product. Strong focus is set on the climatic testing requirements as required from IEC 61215 standards as damp heat and thermo-cycling. The typical requirements for such tests as 1000 hours and 200 cycles will be extended to exceed the specifications at least by a factor of two. The delivery of the project is a targeted loss in cell-to-module losses of max. 2% as compared to standard modules interconnected by soldering ribbon process due to the superior conduction path reached by printing conductive inks instead of soldering copper ribbon. The cost reduction at medium term will be of 5% in €/Wp with respect to conventional c-Si modules.

Regarding the processing technologies, focus is set on applying conductive inks on flexible substrates and on developing the involved materials to reach the stringent specifications of mechanical strength, electrical serial and contact resistance after a typical lamination cycle. For low series resistance interconnection of IBC cells, the metallization scheme will be adapted for encapsulation foils with integrated conductive layers.

The project “InGrid” combines product and process development and will deliver a novel module interconnection technology with superior outcome in terms of long-term stability, application and cell-to-module losses.

Project consortium

Coordinator and all contact details:

Full name of organisation	Specialized Technology Resources España, S.A.
First and family name of coordinator:	Ignacio Fidalgo
Full address:	Parque Tecnológico de Asturias; Parcela 36; 33428 Llanera, Spain
E-mail:	Ignacio.fidalgo@stresp.com

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Spain	2	299’889	149’943
Germany	1	184’994	36’999
United Kingdom	1	204’810	122’886
Total	*4*	*689’693*	*309’828*

095 Monoscribe: Roll-to-Roll Monolithic Interconnection of Customizable Thin-film Solar Modules

Project Duration: 11.2015 to 04.2018
Report submitted: 11.2015

Summary

The overall goal of the project is the development of an industrial scale Roll-to-Roll (R2R) machine prototype based on a novel solar cell interconnection technology (currently on TRL 5) that enables the production of customized **photovoltaic modules „on-the-fly“** without excessive set-up times.

The integrated and printed solar cell interconnection allows the production of photovoltaic modules with varying voltages, sizes and shapes. Combined with the pliability and the high yields of the underlying CIGS based solar cells such PV modules are ideal candidates for a multitude of applications ranging from PV-integrated products (sensors, chargers, lighting) to the use in BIPV products.

In order to achieve low production costs the whole machine set-up is based on a R2R approach wherein **laser processes** (selective ablation of thin-films, edge deletion, cutting) and **printing processes** are fully integrated (objective is TRL 7 at end of project). “Monoscribe” tackles the technical issues arising with the **low-cost R2R structuring and interconnecting of flexible thin film (CIGS) photovoltaics** leading to a groundbreaking production method with high freedom of module designs, increased efficiency and shortened production time. This innovation will be reached by the combination of cost-effective printing technology (inexpensive, digital controllable, with resolution of > 10µm) with highly precise laser structuring technology (depth resolution >50 nm, lateral resolution about 1 µm).

To solve these challenges Monoscribe´s project consortium comprises European manufacturers (PV modules, solar cells, printing inks), experts in printed electronics and micro laser processing together equipment manufacturers with a strong background in PV manufacturing. At the end of the project, the industrial feasibility will be demonstrated by producing batches of market-driven PV modules with extraordinary designs up to 300 mm width.

Project consortium

Coordinator and all contact details:

Full name of organisation	Sunplugged GmbH
First and family name of coordinator:	Andreas Zimmermann
Full address:	Mindelheimer Strasse 6, 6130 Schwaz, Austria
E-mail:	andreas.zimmermann@sunplugged.at

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Austria	4	540’552	324’332
Finland	2	678’894	388’000
Germany	2	441’404	350’371
Total	*8*	*1’660’850*	*1’062’703*

102 HighCast:
High Performance Silicon Casting and Wafering

Project Duration: 08.2015 to 03.2018
Report submitted: 11.2015

Summary

The project focuses on research and development of advanced casting and wafering techniques for producing silicon wafers suitable for higher efficiency solar cells. The technology developments aim to increase material quality and production performance at lower manufacturing costs, hence reducing the final cost-per-Watt of photovoltaic energy produced.

The new casting techniques comprise “High Performance Multicrystalline Silicon” (HPmcSi) and “Mono-Casting”. For HPmcSi, the nucleation phase at the beginning of the solidification is controlled either by using seed material or by use of specially designed crucible interfaces with e. g. adapted silicon nitride coatings. Thus, a high initial density of small grains evolving into larger grains with ingot height is achieved. As a consequence, the internal stress during crystal growth is diminished, leading to lower dislocation densities and grain boundaries, which are less recombination-active. The Mono-Casting technique uses monocrystalline seed crystals at the bottom of the crucible to produce ingots with a large share of monocrystalline silicon. Both techniques will be applied at laboratory scale at Fraunhofer ISE. Silicon casting on industrial scale will be carried out by Crystalox LTD, UK.

For cutting the ingot into wafers by steel wire sawing, the use of structured wires will be further developed. These structured wires can cut multicrystalline wafers as thin as 120 µm at less cost than the alternative diamond steel wires. PV Crystalox Germany is the first company worldwide to have successfully introduced the structured wire in mass production resulting in 40 % less direct cost per wafer within a year. This put PV Crystalox in a unique position to compete with Asian manufacturers at the spot market price level. Further research on this topic during this project is expected to reduce these costs by additional 25 %. The optimum wire structure will be identified taking into consideration slurry transport in the cutting slot to save further consumables costs, process time and energy. Wafering research will be performed by PV Crystalox, Germany.

Solar cells and samples in a precursor stage will be produced from selected wafers at Fraunhofer ISE at the laboratories in Gelsenkirchen and Freiburg. The development of defects after typical high temperature processes will be analysed on cell level by processing heterojunction solar cells including an amorphous Silicon layer. Since the processing temperature does not exceed 200°C, the influence of the cell processing on the material parameters to be studied can be neglected. The potential of the material is evaluated by processing and analysis of solar cells with the “Passivated Emitter and Rear Cell” (PERC) structure.

The project is coordinated by Karlstad University, where the specific detrimental influence of single defect types (dislocations, grain boundaries) will be studied. This is achieved by combining high resolution Light Beam Induced Current (LBIC) topography with automated optical microscope imaging to measure defect densities. These results will be correlated with synchrotron based

nanoprobe X-ray Fluorescence (XRF) maps carried out by MIT, Boston (using their own project). These measurements essentially support the understanding of the crystallization process and can lead to significantly improved processes for crystallization, wafering and solar cell fabrication in the industry. Additionally, the participating research partners will further strengthen their collaborative relationships and leading positions.

Project consortium

Coordinator and all contact details:

Full name of organisation	Karlstad University, Sweden
First and family name of coordinator:	Markus Rinio
Full address:	Karlstad University, Universitetsgatan 2, 651 88 Karlstad, Sweden
E-mail:	markus.rinio@kau.se

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Sweden	1	389’871	389’871
Germany	3	993’433	562’529
United Kingdom	1	439’113	219’557
Total	*5*	*1’822’417*	*1’171’957*

Karlstadt University-contract is in SEK, exchange rate applied 1 EUR = 9.2 SEK
Crystalox-contract is in £, exchange rate applied 1 EUR = 0.7 £

108 EDITOR: Evaluation of the Dispatchability of a Parabolic Trough Collector System with Concrete Storage

Project Duration: 01.2016 to 12.2018
Report submitted: 05.2016

Summary

The objective of EDITOR is to carry out industrial research that demonstrates and verifies the dispatchability and performance of a solar power system designed for continuous operation. The system will consist of a mid-sized parabolic trough collector loop combined with a concrete thermal energy storage and is experimentally designed for industrial applications requiring heating or cooling on a 24 hour basis. The solar power plant will be installed in Cyprus, which has excellent solar resources. The planning phase of the project includes identifying a consumer, for example, the Cyprus University of Technology or a company that uses industrial process heat.

The current market for solar collectors designed for process heat applications is dominated by systems with maximum operating temperatures of around 250 °C. Whilst these collectors are able to generate process steam effectively, few of these have been equipped with any form of storage. Larger solar collectors designed for supplying energy to electrical generation plants have been equipped with complex molten salt storage systems and can operate at higher temperatures, but to do so often use thermal oils as heat transfer media that are classified as toxic and harmful.

EDITOR will not only test an innovative new concrete storage system, but will operate at temperatures of over 400 °C, which is made possible by the use of a new evacuated receiver tube and a new environmentally friendly silicone based thermal oil.

The three year project not only involves the technical activities of building, commissioning and running the solar power system but will also cover commercial considerations such as the feasibility of scale-up, the identification of future customers and communication regarding this important development with the potential market.

The EDITOR team is made up of 5 partners from three countries, all of whom bring the specific experience of the solar industry required to ensure that the project will be successful.

Project consortium

Coordinator and all contact details:

Full name of organisation	protarget AG
First and family name of coordinator:	John Mitchell
Full address:	Zeissstrasse 5, 50859, Cologne, Germany
E-mail:	mitchell@protarget-ag.com

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Germany	3	722’041	578’310
Cyprus	1	100’000	100’000
Spain	1	124’761	62’380
Total	*5*	*946’802*	*740’690*

112 APPI:
Atmospheric Pressure Processing for Industrial Solar Cells

Project Duration: 09.2015 to 08.2018
Report submitted: 11.2015

Summary

European PV manufacturers are suffering from higher production and capital cost compared to their Asian competitors. The PV industry needs to compensate these costs by higher efficiency and higher quality, while keeping production costs as low as possible. Therefore, the retention of a PV industry in Europe depends on Europe's capacity to lead global PV innovation. This proposed project brings together large European PV industries, small to medium enterprise (SME) and research institutes, to develop solar cells exceeding 21.5% in efficiency, manufactured using low-cost atmospheric pressure (AP) processing.

Three key atmospheric pressure processes (advanced texture, high-efficiency emitter, AP passivation) will be developed for low-cost high-efficiency solar cells. Each of these processes can be individually retrofitted into an existing solar cell production line. This scenario would yield an increase of solar cell efficiency with a production cost reduction of up to 40% while keeping investment costs low. By applying these three key processes together, the production of high-efficiency solar cells without any high-vacuum processes can be realised.

The very limited investment capacity of the PV industry does not allow major modification of the production lines. Therefore the next generation of high-efficiency solar cell needs to fit current, existing equipment. The most feasible cell structure for modification is the high-efficiency passivated emitter and rear solar cell (PERC). The proposed project work plan would allow the increase of p-type PERC efficiency while reducing the production cost. It is a fundamental evolution for the competitiveness of the industry. The high-efficiency solar cells will be interconnected and encapsulated in innovative modules reducing the cell-to-module losses. This technology exploits the advantages of low processing cost and high power output.

As we are approaching the limit of the gain from reducing recombination and series resistance, the cell efficiency remains limited by optical losses. The ultimate efficiency limit for the silicon material will be obtained when all the light (in the relevant part of the spectrum) is absorbed. This is especially true for multi-crystalline silicon, which represents about 70% of the market share. In this project, a strong focus will be put on the development of advanced texturing processes based on wet and dry etching. The development of these new textures will allow obtaining high efficiency on >80% of the world market (mono- and multi-crystalline silicon). Our solar module will be specially adapted for this new texture in order to optimise light trapping.

The quality assurance of our high-efficiency modules fabricated in the project will be realised through reliability testing in an environmental chamber. Life-cycle analysis (LCA) will also be performed.

This project will directly benefit four European companies, representing a large part of the PV value chain:

- Module manufacturer with Solar Capture Technologies Limited in the UK (SME).
- Equipment manufacturer with Schmid GmbH in Germany and Nines Photovoltaics (SME) in Ireland, as associated partner.
- Gas manufacturer with Solvay Fluor GmbH in Germany as associated partner.

The collaboration between research institutes and industrial companies at different parts of the value chain will contribute greatly to reduce the time between research, development and industrial application.

Project consortium

Coordinator and all contact details:

Full name of organisation	Fraunhofer Institut für Solare Energiesysteme
First and family name of coordinator:	Pierre Saint-Cast
Full address:	Heidenhofstrasse 2, D-79110 Freiburg, Germany
E-mail:	Pierre.saint-cast@ise.fraunhofer.de

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Germany	3	1’669’197	1’418’506
France	1	550’044	199’814
Spain	1	75’000	75’000
United Kingdom	1	440’516	264’474
Ireland	1	n.a.	0
Total	*7*	*2’734’757*	*1’957’794*

120 FunGlass:
FunGlass – Multi-Functional Glass for PV Application

Project Duration: 03.2016 to 02.2018
Report submitted: 09.2016

Summary

The main objective of this project is to develop chemically functionalized surfaces for glass sheets of PV modules, with the main targets of reducing the electricity generation cost by increasing the module power, providing increased long-term reliability and improving energy yield. To achieve these goals an existing glass technology developed by D.A.Glass will be transferred to PV application. A highly controlled, low cost chemical process at the glass surface enables optimizing glass properties without deposition of additional coatings. By texturing the surface on different length scales from the nanometre to the micrometre range, anti-reflective, light trapping and light diffusion properties can be tailored. Structures at the micrometre scale can reduce bonding of dirt and dust particles to the surface, improving anti-soiling properties. Furthermore the modification of the surface has a mechanical toughening effect on the glass (50-60% increased mechanical strength, improved rigidity and resistance against a hailstorm). In this project the individual effects and their combination will be investigated, optimized and applied to PV modules to improve module power, energy yield and lifetime without increasing material cost.

Project consortium

Coordinator and all contact details:

Full name of organisation	J. v. G. Thoma GmbH
First and family name of coordinator:	Patrick Thoma
Full address:	Möningerberg 1a, 92342 Freystadt, Germany
E-mail:	p.thoma@jvgthoma.de

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Germany	2	677’769	503’703
Poland	1	449’705	244’197
Total	*3*	*1’127’474*	*747’900*

123 SITEF:
Silicon Fluid Test Facility

Project Duration: 01.2016 to 12.2017
Report submitted: 09.2016

Summary

The SITEF (Silicone fluid Test Facility) project demonstrates the loop scale functionality and applicability of a new Wacker Chemie AG silicone heat transfer fluid (SHTF) named HELISOL® and associated parabolic trough collector (PTC) components at temperatures up to 450°C. Such operation temperatures are beyond state of the art in PTC power plants and increase the overall power plant efficiency. This innovative project will be achieved in a German-Spanish cooperation making use of the so called PROMETEO test facility at Plataforma solar de Almería (PSA).

Silicone fluids have been used in the past as heat transfer fluids (HTF) in medium scale installations such as PTC test loops e.g. at PSA, NREL (National Renewable Energy Laboratory) and elsewhere (DOW, SYLTHERM 800®). SHTFs are pumpable at temperatures below 0°C, environmental friendly (new fluid), low in hydrogen formation, almost odourless and very low in acute toxicity. Until now, such fluids are not used in large-scale commercial CSP power plants because currently available SHTFs are far more expensive than the widely used eutectic mixture of diphenyl oxide and biphenyl (DPO/BP). According to laboratory test results HELISOL® may tolerate operation temperatures up to 450°C and will be available at a price similar to DPO/BP fluids (current price level).

During the preceding project called “Si-HTF”, HELISOL® has been investigated experimentally and economically in comparison to DPO/BP revealing promising results such as a considerably higher operating temperature and a low tendency to hydrogen formation. Based on and motivated by these results the “development” of HELISOL® shall be completed within SITEF by demonstrating its utilizability under actual power plant operation conditions on a loop-scale.

In addition to the heat transfer fluid demonstration, this project comprises the development and demonstration of adapted/appropriate receiver tubes from SCHOTT / RIOGLASS and rotation and expansion performing assemblies (REPAs) from Senior Flexonics to be used with HELISOL® at 450°C. These components are integrated into the PROMETEO test facility; an existing test loop consisting of two east- west aligned parabolic trough collectors with 8 trough modules each. Further technical modifications to its piping system implementing the necessary temperature upgrade enable the said loop outlet temperature of 450°C.

Intensive solar operation of the PROMETEO test loop, representing relevant power plant conditions, forms the core activity of SITEF. Its operational loop outlet temperature is increased in reasonable steps according to the results of accompanying thermos-physical and chemical laboratory analyses. These examinations are performed to monitor the degradation of the HTF and also to determine its long-term behaviour heading for a 25 year lifetime.

The economic benefit of the tested HELISOL® incorporating technical investments derived from the higher HTF temperature / different HTF and the greater energy output is studied at full power

plant scale. This task combines practical test experience, facility requirements and detailed component costs with theoretical analysis carried out during Si-HTF preceding project. A safety review identifies potential Si-HTF specific operation risks and points out technical measures.

Silicone fluid technology can contribute largely to the next step towards highly efficient and environmental-friendly parabolic trough plants. Unlike other alternative heat transfer fluids, HELISOL® may be used without major modifications to the solar field design and with components already in use in many other existing CSP plants.

Project consortium

Coordinator and all contact details:

Full name of organisation	DLR, Deutsches Zentrum für Luft- und Raumfahrt
First and family name of coordinator:	Christoph Hilgert
Full address:	Institut für Solarforschung Linder Höhe 51147 Köln, Germany
E-mail:	christoph.hilgert@dlr.de

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Germany	5	1’222’144	946’574
Spain	1	172’901	74’999
Total	*6*	*1’395’045*	*1’021’573*

128 PROOF:
Competitive Industrialized Photovoltaic Roofing

Project Duration: 12.2015 to 11.2018
Report submitted: 05.2016

Summary

The concept of building integrated PV solutions has great potential to become both cost effective and aesthetically appealing but despite the fast growth of the PV market in general, the concept of BIPV has not yet been realized in any significant numbers. There is a lack of cost effective standardized solutions which could be easily integrated in the building process. The standard PV-program has its limitation regarding aesthetics, and this aspect is anticipated to be of great importance for a breakthrough for PV on buildings. Furthermore there are several other potential benefits with PV integration such as more efficient installation, reduced material quantities etc. The overall target for this project is to develop an industrialized concept for BIPV/BAPV roofs that visualizes a number of added values, minimizes additional costs and thus paves the way for a wide use of PV in the built environment. The concept will be developed and demonstrated as a roof integrated PV system aimed for a multifamily house; however the potential for further innovation based on the core of it is huge. SIPS elements or “PLUS roof” combining insulation and roof in the same module is a cost effective module giving fast and simple installations, and these techniques will be used as the basis for the development of new PV solutions in new building construction as well as in refurbishment. Good aesthetics as well as high performance and competitive costs are believed to be attained in this way. The product must of course fulfil all applicable regulations and directives regarding energy efficiency.

The time plan for the project is 3 years and within this time an actual demonstration will take place on Skanska’s project Lindholmshamnen in Gothenburg. Partners of the project are, beside Skanska, SP Technical Research Institute of Sweden, Glafo, Solkompaniet, SEML, a Danish partner Gaia Solar and, as a sub-consultant to SP, the internationally well renowned architect Ingo Hagemann from Germany.

Project consortium

Coordinator and all contact details:

Full name of organisation	SP Technical Research Institute of Sweden
First and family name of coordinator:	Olleper Hemlin
Full address:	Box 857, SE-501 15 Borås, Sweden
E-mail:	Olleper.hemlin@sp.se

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR (1€ = 9,5Sek)**	**Public funding in EUR**
Sweden	5	329’219	240’856
Denmark	1	88’500	50’700
Total	*6*	*417’719*	*291’556*

138 SolFieOpt:
Optimal Heliostat Fields for Solar Tower Power Plants

Project Duration: 07.2016 to 09.2019
Report submitted: 04.2017

Summary

A solar tower power plant (also known as central receiver system (CRS)) consists of a receiver on top of a tower and a field of hundreds or thousands of heliostats. The heliostat field reflects and concentrates direct solar radiation onto a receiver placed at the top of the tower. At the receiver the light is absorbed and the resulting high-temperature thermal energy is transferred to the heat transfer fluid in order to either directly produce electricity through a conventional thermodynamic cycle or to be stored. Today four large tower plants are already operating in the US (Ivanpah 1-3 and Crescent Dunes), three in Spain (PS10, PS20 and Gemasolar) and one is under construction in South Africa (Khi Solar One). Numerous small-scale plants exist around the world for demonstration and research purposes (e.g. the Solarturm Jülich in Germany, and the facilities CESA-1 and SSTS-CRS in Spain).

Solar tower power plants technology is very well suited for converting sunlight into dispatchable electricity. Dispatchability is important as the electricity demand hardly ever matches the production of renewable energies, such as wind and photovoltaics. While for small amounts of renewable energies the effect on the electric grid is negligible, countries with high shares of solar energy (such as Italy and Germany) face a challenge. Solar tower systems operate at high temperatures, making thermal storage systems very cost-efficient. Their storage capabilities help to even out fluctuations of other renewable plants and thus help to further increase the capacity of the non-dispatchable renewable energy technologies.

The design of the heliostat field layout is a challenging task of exceptional importance. It is the sub-system with the highest cost and its optimal design highly depends on the specifications for each project. Within this project the partners will create a tool to optimize the field layout including new features and constraints as for instance tripod foundations for heliostats or multi-tower layouts. A hybrid software will be created based on preliminary works of the two university research groups (University of Seville and RWTH Aachen University). A storage system will be modelled to consider the dynamic energy charges during day and night, and it will be optimized for meeting the electricity demand. The optimizer will have the possibility to consider pattern-based and pattern-free fields. An optimized cleaning strategy will be studied and applied for any kind of field layouts, aiming to reduce the path length of the cleaning trucks or robots. The developed simulation and optimization tools will be cross-validated against commercial and in-house tools of TSK Flagsol. Real data for the cost model and a reference field will be used.

The methods developed within this project will yield more efficient and thus more competitive heliostat fields, which lead to higher market penetration of this technology, benefitting the entire industry.

Project consortium

Coordinator and contact details:

Full name of organisation:	TSK Flagsol Engineering GmbH (TSK Flagsol)
First and family name of coordinator:	Dr. Mark Schmitz
Full address:	Anna-Schneider-Steig 10, 50678 Köln, Germany
E-mail:	mark.schmitz@flagsol.de

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Germany	2	436’872	345’456
Spain	1	120‘000	120‘000
Total	*3*	*556’872*	*465’456*

139 BIPVpod: Building Integrated Photovoltaics Panels on Demand

Project Duration: 01.2016 to 05.200
Report submitted: 03.2018

Summary

The BIPVpod consortium will focus on the further processing of semi-finished PV panels using one each of the two available groups of thin film technologies: superstrate and substrate modules. Substrate will be represented by CIGS, and superstrate by thin-film silicon. The involvement of an additional refinement manufacturer in the value chain will give European industry the opportunity to add value to mass-produced products, even if the semi-finished modules are produced elsewhere. The refinement of BIPV products will enable the customization of the product aesthetics, electrical capabilities, and other functional properties of the panel for each specific building, at a reasonable price. The refinements will include size and shape adaption by laser cutting of the PV panels, color tuning by post-deposited series connection, and integration of the panels into construction materials such as e.g. double glass windows or insulation plates. The final products will be fully aligned with the demand of the building industry.

The BIPVpod consortium is a Dutch-German expert team representing all different segments along the supply chain – from module manufactures and experts of the electrical interconnection methods, to architects, insulating glass experts and finally the distributers and installers.

The outcome of this project should be a set of processing methods that will allow production of customer tailored ‘panels on demand’ with specified PV panel dimensions and colour for small production batches and low added costs. The ‘panel on demand’ technology will be developed, implemented and demonstrated in building elements. This opens up a huge variety of possibilities and niche applications for BIPV. In order to demonstrate the potential, a small number of demo-projects will be realized with these customized panels.

Project consortium

Coordinator and contact details:

Full name of organisation:	DLR-Institut für Vernetzte Energiesysteme e. V.
First and family name of coordinator:	Kai Gehrke
Full address:	Carl-von-Ossietzky-Str. 15, 26129 Oldenburg, Germany
E-mail:	kai.gehrke@dlr.de

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Germany	3	1'653'863	1'327'141
The Netherlands	4	941'450	738'160
Total	*7*	*2'595'313*	*2'065'301*

142 SPRINTCELL: Sulfide-based Ink for Printable Earth-Abundant Solar Cell

Project Duration: 04.2016 to 03.2019
Report submitted: 05.2016

Summary

The thin film photovoltaic (TFPV) industry is currently facing two critical challenges for its long-term expansion. One of the challenges is to increase the production capacity and the other concerns the use of abundant raw materials for sustainable TFPV production. TFPV production still operates far below the silicon photovoltaics production capacity level of 2.5-3.5 GWp/year, which gives rise to more expensive TFPV modules. One of the causes is that the production rate and scale of state-of-the-art, vacuum-processed thin films remain limited. Efforts to expand the vacuum-based TFPV fabrication facilities to larger area deposition systems require huge capital investment and maintenance costs. Another critical issue for the TFPV industry concerns the sustainable raw material supply when a terawatt-scale TFPV deployment is projected. Both established TFPV technology of CIGS and CdTe are believed will meet their yearly production limits due to the scarcity of critical In, Ga and Te elements.

In order to reduce investment and maintenance costs, non-vacuum, solution-based processing has attracted particular attention as a new thin film deposition technology for TFPV. It is an industrially relevant technology that is capable of high throughput film deposition over large areas, and is compatible with roll-to-roll (R2R) TFPV production. Meanwhile, photovoltaic materials containing more earth abundant elements have been regarded as the solution for sustainable, terawatt-scale TFPV production. One of the emerging abundant photovoltaic materials is the Cu_2ZnSnS_4 (CZTS) compound absorber (mineral name: kesterite) which contains abundant elements of Cu, Zn, Sn and S, both in terms of natural reserve and annual ore production. The use of CZTS as a photovoltaic material for envisioned large-scale TFPV deployment secures the long term production, being a perfect alternative for currently used CIGS and CdTe photovoltaic materials.

SPRINTCELL proposes an innovative TFPV fabrication route, which offers lower manufacturing costs as well as the use of earth abundant photovoltaic materials, through a combination of selected technologies for large-scale commercial powder synthesis, advanced powder milling, novel solar ink formulation as well as solution-based and non-vacuum film processing. SPRINTCELL has the primary objective to demonstrate an industry-oriented TFPV fabrication route, based on the development of the sulfide-based ink, containing earth abundant CZTS material and the high throughput production capacity of the non-vacuum solution-based processing technology. This newly proposed route takes advantage of the ample supply of CZTS that can be synthesized in large quantities on an industrial scale by the solid-state synthesis process from abundant elements or compounds and the capability of the solution-based film technologies to fabricate large area thin films.

Project consortium

Coordinator and all contact details:

Full name of organisation	AIT Austrian Institute of Technology GmbH
First and family name of coordinator:	Rachmat Adhi WIBOWO
Full address:	GIefinggasse 2, 1210 Vienna, Austria
E-mail:	rachmat.wibowo@ait.ac.at

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Austria	3	345'000	265'900
United Kingdom	1	108'759	65'254
Total	*4*	*453'759*	*331'154*

143 DINAMIC: Dilute Nitride Based Concentrator Multijunction Solar Cells, with Efficiencies over 47%

Project Duration: 12.2015 to 06.2019
Report submitted: 02.2017

Summary

This proposal will significantly advance the state of the art in multi-junction cell technology for High Concentration Photovoltaics (HCPV) through the implementation of a novel lattice-matched 4 junction (4J) device architecture utilising ~1eV bandgap dilute nitride technology as the 4th sub-cell, and at the same time operating at high concentrations. To this end it is expected that >47% multi-sun efficiency 4J solar cells will be developed during the lifetime of the project. The development of extremely high efficiency cells is a key requirement for the deployment of HCPV as it will significantly reduce the cost of this technology (€/kWh and €/Wp), thereby addressing one of the major obstacles to the widespread adoption of this technology. If the goals of the project are achieved, the impact of these solar cells on the overall CPV system cost would be to bring it below €c15/Wp (for operation at 1000 suns) instead of the current levels of around €c35/Wp (for operation at 500 suns). A special emphasis will be devoted to dilute nitride material characterization since there are scarce data available for these alloys which will be used in the HCPV cells. In this case, they will be produced, initially, by Molecular Beam Epitaxy (MBE) to provide the highest efficiency cells in the shortest time, and then these materials will be compared directly with those grown by Metal Organic Vapour Phase Epitaxy (MOVPE), which provide the lowest cost manufacturing solution. Finally, accelerated ageing tests will be accomplished on the resulting cells in order to quantify their long term reliability, and initial estimates of manufacturing yields will be obtained.

Project consortium

Coordinator and contact details:

Full name of organisation:	IQE plc
First and family name of coordinator:	Iwan Davies
Full address:	Pascal Close, Cardiff CF3 0LW, UK
E-mail:	idavies@iqep.com

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
United Kingdom	1	500’000	250’000
Spain	2	315’000	315’000
Total	*3*	*815'000*	*565'000*

144 ALCHEMI: A Low Cost, High Efficiency, Optoelectronic HCPV Module for 1000 Sun Operation

Project Duration: 02.2017 – 07.2019
Report submitted: 07.2018

Summary

Project ALCHEMI will demonstrate a new type of low cost, high concentration photovoltaic (HCPV) module which has a DC module efficiency (η) >37% (at Concentrator Standard Test Conditions (CSTC) of 25°C cell temperature and a DNI of 1000W/m2), which operates at a concentration factor of ~1000x. This module efficiency value will be achievable in manufacturing volumes, and not just as a hero result. The module will use small III-V multijunction solar cells (~1mm x 1mm), no external heat-sinking, and refractive optics – Fresnel Primary Optical Element (POE) and a Silicone Secondary Optical Element (SOE). The receiver element of the module will be a surface mount device (SMD), and the module will take full advantage of cost reductions associated to the LED industry by only using surface mount devices and components, using pick and place assembly. In this respect, this project will demonstrate a low cost route to high concentration photovoltaics, by exploiting existing assembly equipment and processes of the well-established optoelectronic industry. Modules will be extensively tested, both on-sun for around six months to establish performance and reliability, and using environmental testing in-line with the CPV module standard IEC62108. In testing, the performance of these modules will be compared with conventional flat plate c-Si modules and other lower concentration HCPV modules geographically situated at the same location, to demonstrate the performance and energy yield advantage of the modules that will be developed.

Project consortium

Coordinator and contact details:

Full name of organisation:	IQE plc
First and family name of coordinator:	Iwan Davies
Full address:	Pascal Close, St Mellons, Cardiff CF3 0LW, United Kingdom
E-mail:	idavies@iqep.com

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
UK	1	567’183	283’592
Spain	1	192’000	192’000
Germany	1	250’000	250’000
Cyprus	1	100’000	0
Total	*4*	*1’109’183*	*725’592*

147 IPERMON: Innovative Performance Monitoring System for Improved Reliability and Optimized Levelized Cost of Electricity

Project Duration: 04.2016 to 03.2019
Report submitted: 09.2016

Summary

Photovoltaics (PV) continues to be a fast growing market, with an expected growth in global installations of up to 60 GW in 2015, according to the European Photovoltaic Industry Association (EPIA), and is on track to achieve the goal of 12 % of European electricity demand to be provided by PV by 2020. A key factor that will enable the further increase of the uptake of the technology is the reduction of PV electricity costs by increasing the lifetime output as highlighted by the Solar Europe Industry Initiative (SEII). This can be achieved by improving the reliability and service lifetime performance through constant, solid and traceable PV plant monitoring of installed systems, hence directly impacting positively investment cost, levelised cost of electricity (LCoE) and in general PV competitiveness. In this sense, a main challenge in the quest for ensuring quality of operation especially for grid-connected PV systems is to safeguard reliability and good performance by identifying and quantifying accurately the factors behind the various performance loss mechanisms, while also detecting and diagnosing potential failures at early stages or before occurrence, through robust performance monitoring, fault detection and preventive maintenance. The importance of the above is evident by the increasing number of recent international initiatives devoted to advanced condition monitoring and reliability such as the International Energy Agency (IEA) Photovoltaic Power Systems Programme (PVPS) Task 13, the PV Performance Modelling Collaborative (PVPMC) facilitated by Sandia National Laboratories, the National Renewable Energy Laboratory (NREL) workforce on reliability, degradation and performance monitoring, and the alignment with the main objectives of the SEII for quality assurance, long term reliability, active monitoring and accurate energy forecasting.

It is with this background that project the IPERMON has been initiated in order to primarily monitor and assess PV system performance, through the formulation of a procedural protocol (starting from sensor installation, data acquisition and filtering, to time series analysis) for the development of algorithms to detect performance losses, failures and degradation mechanisms at an early stage. The developed algorithms will be integrated in an end-product which will be an innovative monitoring system with improved operations and maintenance (O&M) tools. The monitoring system will act as a high level watchdog by ensuring reliability and operational quality of PV power plants and eventually yielding increased lifetime output. In this respect, it is anticipated that the project will assist in providing a robust and accurate platform to detect losses, failures and estimate degradation at early stages and in real-time using data measurements and statistical tools. This is the first time such a system will be demonstrated with functionalities well beyond the current state-of-the-art. These types of tools are well anticipated in the fast growing PV market with continuously narrowing profit margins.

In addition, the advanced monitoring system can further act as the buffer between PV installations and the grid, contributing with the control algorithms to supportive functions for grid stability especially for the important task and requirement by many distribution/transmission system operators (DSO/TSO) for forecasting the day ahead energy yield. Therefore, the proposed system is of interest to a large stakeholder target group ranging from policy makers and utilities, plant operators, engineering procurement construction (EPC) contractors, module producers and investors.

Finally, the project is based on a transnational collaboration between a leading industrial partner, Gantner Instruments (GI), that will provide the platform for the development of the end-product and a research organisation, the University of Cyprus (UCY), with significant track record and award winning research work and innovations in the field. The skills, complementarity and balance of the consortium will greatly assist in materialising its objectives, thus contributing to the solar energy ambitions of the participating countries, as well as generating a commercial product that will enhance the competitiveness of a European industrial partner.

Project consortium

Coordinator and all contact details:

Full name of organisation	Gantner Instruments Test & Measurement GmbH
First and family name of coordinator:	DI Jürgen Sutterlüti
Full address:	Montafoner Straße 4, 6780 Schruns, Austria
E-mail:	j.sutterlueti@gantner-instruments.com

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Austria	1	300’000	180’000
Cyprus	1	100’000	100’000
Total	*2*	*400’000*	*280’000*

150 HVolt-PV: High Voltage IBC Photovoltaic i-Cells and Modules

Project Duration: 06.2016 to 05.2018
Report submitted: 09.2016

Summary

The actual photovoltaic module efficiencies in the market are around 16-17 % with price of about 50 ¢€/W. The modules efficiencies higher than 17% staconstitute still a relatively small part of the total market. For efficiencies higher than 17% the module selling price increases significantly at a rate of about 10 ¢€/W for each additional absolute point efficiency.

The aim of this project is to develop a high efficiency n-type monocrystalline silicon IBC i-Cell module (efficiency > 21%) at lower cost. The following aspects will be investigated by means of industrial production tools:

1. Reduction of the quantity of pure monocrystalline n-type silicon: it has been demonstrated that monocrystalline foils of 40 µm thickness can give cell efficiency higher than 20%. However, present industry uses thickness of 180-200 µm. In this project, solar cells and modules will be made with wafers of 160 µm, 100 µm and 60 µm thickness using a fully standard wire sawing as a mean for silicon wafer slicing
2. Reduction of Cell to Module losses using the high voltage low current i-Cell configuration: so far around 3 % of absolute efficiency is lost after stringing and encapsulating photovoltaic cells into a module. The i-Cell concept will be used in this project reduce these Cell to Module losses. This concept consists in realising quarter monocrystalline sub-cells (39x156 mm^2) connected in series by the mean of a low cost substrate that serves as mechanical support and electrical connection. This allows for a Voc increase by a factor of 4 (from which the acronym HVolt-PV is derived), electrical current reduction by a factor of 4, and therefore resistive losses reduction by a factor of 16. The only resistive losses reduction into the ribbon will be responsible for reducing Cell To Module losses by 0,7% absolute efficiency. Unused area into the module will be reduced using i-Cell interconnections and full square wafers. Targeted Cell To Module losses are 1,5% instead of 3%. The decrease of cell current will also allow for silver consumption reduction
3. Use of a low cost Interdigitated Back Contacts (IBC) cell technology: screen-printing processes will be used for IBC cell for cost reduction purposes. This project proposes to make an optimisation of this process based on thin silicon foils wafers and i-Cell configuration

Under the previous considerations, 8 standard-size x60 IBC i-Cells (156x156 mm^2) photovoltaic modules will be produced and tested under real outdoor operating conditions and indoor standard test conditions to validate each kind of module prototype. The study will be conducted iteratively, starting by a full module validation using 160 µm thick IBC cells, and pursuing the thickness reduction down to 100 µm and finally 60 µm.

In this project ISC Konstanz, a top level German research institute in the field of photovoltaic will be the partner in charge of IBC cell steps. S'Tile, a French spin off from the CNRS, will be in charge of cell cutting into quarter, assembly in series on its patented sintered substrate and module integration. The University of Cyprus that have outstanding outdoor facilities coupled with very favourable climatic conditions will be in charge of the outdoor evaluation of the modules. A certified European subcontractor will be asked to realise module certifications according to the indoor norms.

Project consortium

Coordinator and all contact details:

Full name of organisation	S'Tile SA
First and family name of coordinator:	Alain Straboni
Full address:	3 Rue Raoul Follereau, 86000 Poitiers, France
E-mail:	Alain.Straboni@silicontile.fr

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
France	1	353'062	208'403
Germany	1	146'221	116'977
Cyprus	1	99'996	99'996
Total	*3*	*599'279*	*425'376*

152 Bifalo:
Bifacial PV Modules for Lowest Levelized Cost of Energy

Project Duration: 10.2016 to 09.2019
Report submitted: 04.2017

Summary

After several years of dramatic reductions of PV module production cost and prices, module prices are now stabilizing and further reductions of LCOE (levelized cost of energy in €/kWh) will now be driven by reduction of the Balance Of System (BOS) cost. A main driver for reduction of the BOS cost is the enhancement of the energy yield (kWh/m2 of module area) of the PV modules. On the one hand, this can be achieved by increasing the energy conversion efficiency of the solar cells - with the risk of increased production cost for cells and modules (see e.g. back-contact module technology by Sunpower and hetero-junction technology by Sony/Panasonic). A more cost effective way for increasing the energy yield of PV modules is the implementation of bifacial cells and modules: under favorable installation conditions (e.g. high albedo of the ground at the installation site), the rear side contribution to the total energy production of a bifacial module can reach 30% or more, while 10-15 % gain can be easily achieved even with bifacial PV systems installed over grassland. Taking the example of a bifacial module with 19% front side efficiency, its total energy yield will be the same as the energy yield of a monofacial module with 24.7% (= 19.0% x 1.3) - accordingly, the bifacial module has an equivalent efficiency of 24.7%, outperforming any non-concentrating PV module based on c-Si and, first and foremost, in the same price and cost range as standard modules with less than 18% efficiency. In addition, contrary to e.g. back-contact technologies, bifacial cells are suitable to be processed in standard module manufacturing lines that are currently available for more than 40 GW/year capacities worldwide. Bifacial PV is becoming even more relevant due to the fact that many new advanced cell concepts (as e.g. n-type and p-type PERT) are inherently bifacial. Accordingly, very recently, bifacial PV is gaining more and more interest, both from manufacturers and from PV system operators. Most companies that are currently implementing high efficiency bifacial cells on industrial scale are working on n-type wafer based cell-technology. The same is valid for the research activities at the main R&D institutes worldwide.

From the technological point of view, working with n-type Si-wafers is more straightforward with respect to achieve high front side efficiencies and, in addition, bifaciality comes automatically with n-type cell production (P-diffused BSF instead of Al-alloyed BSF in p-type). However, current market prices for n-type Cz-Si wafers are around 20% higher compared to p-type Cz-Si. The reason for this is mainly the better economy of scale of the p-type wafer production that today represents around 80% of the overall monocrystalline production capacity for PV - accordingly, the situation is not expected to change in the short term. The latest achievements in fabrication technology of high efficiency p-Si based bifacial solar cells allow starting development of high efficiency bifacial modules using such cells. Cheaper starting Cz p-Si, readiness of the industry to produce material with high quality recombination parameters and existing cell fabrication technology able to retain the bulk lifetime are making this cell type very promising for production of

high efficiency bifacial modules enabling a low LCOE. The working conditions of a bifacial module are different compared to the conditions of a regular monofacial module: higher current density due to the both sides contribution to the current generation, time and weather dependence of the gain due to back side contribution, effect of the back shading on the power generation. These differences affect the test set-up, power classification, design and safety requirements. These topics were not investigated practically up to now. The achievements of the BiFaLo project in the field of cell and module design and manufacturing in terms of module efficiency and energy yield (kWh/kWp) and of manufacturing cost will contribute to the overall project goal: a reduction of the LCOE of 10% compared to the state of the art of bifacial modules at time of the project kick-off.

Project consortium

Coordinator and contact details:

Full name of organisation:	International Solar Energy Research Center (ISC) Konstanz e.V.
First and family name of coordinator:	Joris Libal
Full address:	Rudolf-Diesel-Str. 15, 78467 Konstanz, Germany
E-mail:	joris.libal@isc-konstanz.de

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Germany	3	919’729	735’775
France	1	96‘416	42‘358
Israel	2	348’000	148’000
Total	*6*	*1’364’145*	*926’133*

155 CNT-PV:
Carbon Nanotube Hole-Transporting and Collecting Layers for Semi-Transparent, Flexible and Low-Cost Solid-State Photovoltaic Cells

Project Duration: 06.2016 to 05.2018
Report submitted: 04.2017

Summary

The perovskite solar cell (PSC), quantum dot solar cell (QDSC) and dye solar cell (DSC) are interesting emerging solar cell technologies, whose manufacturing costs and energy payback times could be considerably lower than those of silicon solar cells that dominate the photovoltaics (PV) market today. Other interesting properties of the PSCs, QDSCs and DSCs are for instance semi-transparency, flexibility, color and light weight – properties that can be utilized for instance in building-integrated PV products and indoor and outdoor consumer PV products.

The commercialization of the high-efficiency (> 20 % power conversion efficiencies have been obtained) PSCs is hindered today by the use of unstable and expensive hole-transporting materials (HTM) deposited by the industrially non-viable spin-coating and silver or gold counter electrodes (CE) deposited by a vacuum technology. It was however observed by the applicants, that a press-transferred, semi-transparent, extremely flexible single-walled carbon nanotube (SWCNT) film functions as a hybrid hole-transporting and collecting layer in the PSC, meaning that the expensive HTM and silver or gold CE could be omitted completely. 15.5 % power conversion efficiency was obtained for the PSC with SWCNT CE with a small amount of drop-cast molecular HTM. The SWCNT film was also successfully used in conjunction with extremely cheap HTMs. Furthermore, an extremely transparent (70 %) SWCNT film functioned well as the front contact of a very transparent QDSC – meaning that the both metallic contacts of these solar cell types could be replaced by the SWCNT films by tuning the SWCNT films' properties. The film was used as the CE of liquid- and solid-state DSC too.

In this project, the solar cell with the SWCNT HTM-CE will developed for maximum performance and the manufacturing process of the cell will be upscaled to pre-industrial stage. The result will be a stable, flexible, semitransparent and cost-effective solar cell prototype.

Project consortium

Coordinator and contact details:

Full name of organisation:	Uppsala University
First and family name of coordinator:	Gerrit Boschloo
Full address:	Box 523, 751 20 Uppsala, Sweden
E-mail:	gerrit.boschloo@kemi.uu.se

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Sweden	2	390'000	100'000
Finland	2	330'000	119'000
Total	*4*	*720'000*	*219'000*

158 HESTPV:
High-Efficiency and Stable Tin-Based Perovskite Solar Cells

Project Duration: 01.2016 to 07.2019
Report submitted: 02.2018

Summary

The emerging solar cells based on hybrid organic-inorganic perovskites (HOIPs), specifically Pb halides as light harvesters, have stunned the photovoltaic community and captured intense attention of the academia and industry in renewable energy. The power conversion efficiency (PCE) of the best, small lab-scale perovskite solar cells exceeds now 20%, a feat never achieved for other solution-processed materials before and suggests that HOIP-based cells may become comparable to crystalline solar cells in performance. However, the present reliance on Pb as a key element in the HOIP militates against the adoption of such products in consumer or building integrated applications. A key challenge for commercialization of HOIP solar cells is to replace the Pb with a less toxic metal, such as the chemically similar tin (Sn), with which reasonably efficient cells have been reported, or germanium (Ge). Completely lead-free Sn HOIP solar cells were reported. Unfortunately the device efficiency is significantly less than that of lead-containing perovskites and the devices are very prone to oxidation, as (Sn(II) to Sn (IV) is more facile than the corresponding Pb process. Learning how to develop high performance and stable Sn-based perovskite solar cells is thus an important path forward for widespread applications of HOIP solar cells.

By introducing new material design concepts, novel deposition techniques and optimal device structures, this project aims to improve the efficiency and stability of Sn-based perovskite solar cells and thus to help push this novel photovoltaic technology into the marketplace.

Project consortium

Coordinator and contact details:

Full name of organisation:	Universitat de València Estudi General
First and family name of coordinator:	Hendrik Jan Bolink
Full address:	C/ Catedrático José Beltrán 2
E-mail:	henk.bolink@uv.es

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Spain	1	261’032	229’709
Sweden	2	605’180	402’419
Israel	1	300’000	120’000
Switzerland	1	371’000	148’400
Total		*1’537’212*	*900’528*

160 HIPPO:
High-Efficiency Poly-Si Passivated Contact Solar Cells and Modules

Project Duration: 07.2016 to 06.2019
Report submitted: 11.2016

Summary

The actual tendency of the PV market is to focus on higher cell and module efficiency, which to a large extent is currently being done with the introduction of passivated emitter and rear (PERC) p-type solar cells in production. However, to overcome limitations of the PERC structure, new technologies need to be implemented that enable both higher efficiency and stronger cost reduction, although these new technologies should utilize existing tools and processes to a large extent to reduce the time to market.

In this project, a strong consortium has formed to develop large area p-type silicon solar cells with a full area passivated rear contact and wire interconnected solar modules with bifacial properties. The passivated rear contact consists of a tunnel oxide layer, upon which a LPCVD poly-Si layer is deposited.

The implementation of passivated contacts by deposition of a poly-Si layer was shown to allow for very low recombination values and thus high open circuit voltages. In addition, the current flow at the rear side of a passivated contact structure is strictly one-dimensional, like for solar cells with a full area aluminium back surface field rear contact. Thus, the poly-Si passivated rear contact combines the advantages of PERC and Al-BSF concepts in one structure, which is highlighted by a demonstrated high efficiency of 25.3% (calibrated measurement) at lab level on an n-type wafer.

In this project, however, the partners will fabricate high-efficiency bifacial p-type solar cells with a conversion efficiency of over 22%. Finally, we aim to fabricate bifacial modules with over 20% efficiency (STC conditions, front illumination) to prove the efficiency and reliability of our concept.

The implementation of a passivated rear contact will allow the production of bifacial solar cells while decreasing the specific cost.

For module fabrication, combining the novel cell technology with the wire interconnection concept will additionally lower the fabrication costs by reduced silver consumption due to less required conductivity for the front and back fingers and will improve the reliability due to a reduced risk of power loss by micro cracks. Furthermore, for a bifacial module the power output will be increased significantly by harvesting irradiation from the rear side as well.

Project consortium

Coordinator and contact details:

Full name of organisation:	Fraunhofer Institute for Solar Energy Systems ISE
First and family name of coordinator:	Sebastian Mack
Full address:	Heidenhofstrasse 2, 79110 Freiburg
E-mail:	sebastian.mack@ise.fraunhofer.de

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Germany	2	1'402'051	802'051
The Netherlands	1	800'000	0
Finland	1	100'000	50'000
Spain	1	N/A	0
Total	*5*	*2'302'051*	*852'051*

417 INFORPV: Innovative Forecasting PV Energy Yield Solution for Sustainable Large Scale Deployment

Project Duration: 08.2017 to 07.2019
Report submitted: 04.2018

Summary

A main challenge in the scope of ensuring large scale deployment and sustainability of photovoltaic (PV) systems is to improve the accuracy of production forecasting for both large and small systems in high concentrations on the distribution grid. Accurate point and aggregated PV production forecasts are major themes of the research roadmap of many international taskforces and are also in line with the objectives of the Solar Europe Industry Initiative (SEII) for accurate energy yield forecasting, increased flexibility of the power system and deployment.

It is with this background that the INFORPV project has been initiated to enable large scale deployment of PV systems through accurate production forecasting and active grid management, in countries with a high solar resource and a potentially significant PV share of small capacity systems.

In particular, the project aims to develop a forecasting solution with improved accuracy for point and aggregated forecasts. The solution will be benchmarked and validated in Israel and Cyprus through a network of ground meteorological stations and monitored PV systems. The end-product will be an innovative PV production forecasting system that will provide to distribution system operators (DSO) an accurate forecast for PV systems connected at any grid location with a target root mean square error (RMSE) accuracy of less than 5 % for single plants and less than 4.5 % at a regional level for both day-ahead and hour-ahead forecasts. The accurate forecasts will be incorporated into a developed distributed grid management system that will also act as the buffer between PV systems and the grid, contributing supportive grid stability functions and enabling large scale deployment.

Finally, the project is based on a collaboration of five (5) experienced partners that will greatly assist in materialising its objectives and generating a commercial product that will enhance the competitiveness of their research institutions and industries.

Project consortium

Coordinator and contact details:

Full name of organisation:	M.G.Lightning Electrical Engineering (MGL)
First and family name of coordinator:	Mike Green
Full address:	8 HaPalmah street Raanana 43414, Israel
E-mail:	info@lightning.co.il

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Israel	2	346’484	173’242
Cyprus	3	190’830	175’000
Total	*5*	*537’314*	*348’242*

419 Liquid Si 2.0: Liquid Phase Deposition of Functional Silicon Layers for Cost-Effective High Efficiency Solar Cells

Project Duration: 10.2017 to 09.2020
Report submitted: 11.2017

Summary

Primary target of this project is the manufacture of low-cost highly efficient PV cells employing p-/n-doped thin silicon layers prepared by liquid phase processing of hydrogenated polysilanes. Key-important to all high efficiency solar cell concepts is the targeted deposition of highly doped layers or structures of multi-crystalline silicon (mc-Si). Typically, these layers are generated by vacuum based deposition techniques e.g. CVD (chemical vapour deposition). In many cases necessary subsequent patterning steps result in laborious, multi-step procedures with a high demand of consumable materials and cell manufacturing lines featuring a multitude of costly tools. Solution-based silicon deposition and processing starting from hydrogenated polysilanes is an appealing and cost efficient alternative. Precursors currently used in this context such as Si_5H_{10} (CPS), Si_6H_{12} (CHS) or Si_5H_{12} (NPS), however, suffer from the lack of proper synthetic approaches suitable for their preparation on a larger scale, their unsuitable volatility and their undesirable pyrophoric character. The aim of this project is the development of commercially viable synthetic pathways suitable for the large-scale production of alternative perhydridopolysilane precursor materials (Liquid Silicon 2.0) for liquid phase silicon deposition. Furthermore, mc-Si layers will be deposited from the resulting target materials, characterized with respect to their potential for PV applications and finally tested in prototype low-cost and high-efficiency solar cells. Successful realization of the project will make highly innovative liquid phase processed solar cells with high efficiency available on a broad scale to competitive costs which substantially contributes to the objectives of the Solar Europe Industry Initiative (SEII).

Project consortium

Coordinator and contact details:

Full name of organisation:	Evonik Creavis GmbH
First and family name of coordinator:	Michael Holthausen
Full address:	Evonik Creavis GmbH, Paul-Baumann-Straße 1, 45772 Marl, Germany
E-mail:	Michael.holthausen@evonik.com

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Germany	1	504’489	327’918
Austria	1	373’633	317’588
Total	*2*	*878’122*	*645’506*

428 FrontCIGS: Re-Designing Front Window in Flexible CIGS Modules for Cost-Effective Moisture Protection

Project Duration: 01.2017 to 10.2019
Report submitted: 01.2018

Summary

Flexible PV modules are attractive for installation on buildings (BIPV and BAPV), transport and portable applications because of their light weight, low energy input for manufacturing, as well as reduced installation costs thanks to easy integration with other construction elements. Whereas the previous generation of a-Si thin film modules could not reach large market success mainly because of their low conversion efficiency, the flexible modules based on Cu(InGa)Se2 absorbers have much better commercialization potential as they are twice more efficient, with up to 16.9% for mini-modules.

The project will make flexible CIGS modules more cost-competitive while maintaining extended lifetime and efficiency levels. This will be possible by employing a corrosion-stable electrical contact allowing a less expensive frontsheet, which can also feature the “easy-to-clean” property desirable for BIPV and portable applications.

In the project consortium three R&D institutes will develop innovative front window concepts which will address the need of two SMEs and one equipment manufacturer to reduce the module manufacturing costs. The immediate project outcome will be a new design of the flexible module, with anticipated 20% module cost reduction.

Project consortium

Coordinator and contact details:

Full name of organisation:	Empa – Swiss Federal Laboratories for Materials Science and Technology
First and family name of coordinator:	Yaroslav Romanyuk
Full address:	Überlandstrasse 129, 8600 Dübendorf, Switzerland
E-mail:	yaroslav.romanyuk@empa.ch

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Switzerland	2	761’764	340’589
The Netherlands	2	711’250	482’000
Austria	1	43’000	0
Total	*5*	*1’516’014*	*822’589*

431 SIMON:
Silicone Fluid Maintenance and Operation

Project Duration: 11.2017 to 10.2019
Report submitted: 01.2018

Summary

The SIMON project is closely linked to a successful demonstration of the loop scale functionality and applicability of the Wacker Chemie AG silicone heat transfer fluid named HELISOL® 5A and associated parabolic trough collector (PTC) components – REPAs and receiver tubes at continuous operation temperatures of 425°C during the SITEF project. While the SITEF project's aim was to demonstrate the feasibility of silicone oils for CSP plants, the aim of the SIMON project is to accelerate the market introduction by lowering all identified obstacles.

SIMON demonstrates the applicability of two advanced HELISOL® products: a) The HELISOL® 5A based HELISOL® XA with improved viscosity properties. b) HELISOL® LP, this HTF should not generate cyclic products during long term operation thus this HTF is free of classification even after long term operation. This has a significant impact on the improvement of the environmental situation as well as on the health issue of operating personnel.

The enhanced HELISOL® LP recently introduced by Wacker is an entirely new developed silicone heat transfer fluid (SiHTF). Like HELISOL® 5A it comes with a major cost reductions potential compared to currently available SiHTFs and hence, combined with the known SiHTF advantages plus an operation temperature of 430°C, it plays a major role for the next generation of highly efficient parabolic trough plants. SIMON demonstrates moreover an associated reconditioning / recycling procedure for a 25 year endurance of the viscosity of HELISOL® 5A and HELISOL® XA in CSP applications at 425°C. As the low boiler separation with a typical "ullage"-system is not applicable for silicone based heat transfer fluids, a suitable separation process for gases and low boiling degradation products is designed and tested

Project consortium

Coordinator and contact details:

Full name of organisation:	Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR)
First and family name of coordinator:	Christoph Hilgert
Full address:	Linder Höhe, 51147 Köln, Germany
E-mail:	christoph.hilgert@dlr.de

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Germany	7	2'319'864	1'611'577
Spain	2	180'450	171'404
Total	*9*	*2'500'314*	*1'782'981*

436 DURACIS: Advanced Global Encapsulation Solutions for Long Term Stability in Industrial Flexible Cu(In,Ga)Se_2 Photovoltaic Technology

Project Duration: 09.2017 to 09.2020
Report submitted: 09.2017

Summary

For a cost-competitive full market entry, flexible CIGS PV technologies require the availability of innovative encapsulation solutions with both very low costs and excellent barrier properties guaranteeing a long operating time of the devices. Even if there are already existing solutions with acceptable performance levels, costs remain a relevant issue that needs to be solved in order to keep the stringent cost reduction targets established for these technologies. To solve these problems, DURACIS will explore new alternative encapsulation and optical glue materials and concepts, compatible with their implementation into already existing industrial CIGS pilot lines and allowing a significant extension of the lifetime while substantially reducing costs. To achieve this goal, transfer of concepts previously developed for organic technologies (with very stringent encapsulation requirements) will be investigated.

The final goal of DURACIS is the development of a novel encapsulation technology with costs below 15 €/m2 and ensuring a durability higher than 25 years for flexible CIGS devices. The project will adopt a global strategy including solutions for the main industrial substrate technologies that have been developed for flexible CIGS (polyimide, steel substrates) and will also include the analysis of their transfer into industrial pilot lines available in the consortium. The implications of the different kinds of substrates on these new encapsulation concepts will be specifically addressed aiming at the development of optimized cost efficient solutions compatible with very long term stability.

The project will also include the development of advanced methodologies for the non-destructive monitoring of the encapsulation processes and layers. This involves both monitoring of the deposition processes as well as the definition of fast methodologies for detection of potential degradation effects affecting the encapsulation and device lifetime.

Project consortium

Coordinator and contact details:

Full name of organisation:	Fundació Institut de Recerca de l'Energia de Catalunya
First and family name of coordinator:	Alejandro Pérez-Rodríguez
Full address:	C Jardins de les Dones de Negre 1, 2a planta 08930 Sant Adria de Besòs (Barcelona), Spain
E-mail:	aperezr@irec.cat

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Spain	2	364'410	185'750
France	2	346'342	178'982
Belgium-Wallonia	2	410'221	269'423
Germany	1	455'433	455'433
Austria	3	316'747	212'128
Total	*10*	*1'893'153*	*1'301'716*

438 Refined PV: Reduction of Losses by Ultra Fine Metallization and Interconnection of Photovoltaic Solar Cells

Project Duration: 07.2017 to 06.2020
Report submitted: 01.2018

Summary

In the last decade, major improvements in crystalline solar cells have been achieved by successively increasing emitter sheet resistance and reducing finger width and finger distance on the cell, allowing for decreased recombination, absorption, shading and resistance losses. While the reduced width could partly be compensated by a better aspect ratio of screen printed fingers, the trend to narrower fingers had to be additionally supported by an increased number of bus bars, from initially two, to firstly three, and lately also four, five or six. A further prerequisite was the reduction of specific contact resistance to high ohmic emitters. While contact resistance of actual pastes would allow for a further shrinking, screen printing faces difficulties to keep pace. And for classical soldering, more than six ribbons seem not to be feasible. Recently Utilight has demonstrated an ability of printing high aspect ratio ultra-fine finger lines, see Fig. 1 and 2. Meyer Burger has developed the Smart Wire Connection Technology (SWCT), which interconnects cells with a multitude of wires, see Fig. 3. Merging both approaches in the project will allow for a notably increased efficiency and drastically reduced silver consumption for crystalline solar cells. Utilight will develop the hardware and process for high quality printing of 15-20 µm wide finger lines with high aspect ratio suitable for mass production. ISC Konstanz will optimize the solar cell in order to take maximum advantage of ultra fine line metallisation. Due to the very narrow finger width and the intent to use emitters with even higher sheet resistance, control of contact formation will be of major importance. The optimization of the metallization layout will be performed in close conjunction with Meyer Burger, providing the bus bar free connection of the cells to a module of increased efficiency and superior reliability. The module will be built tested and qualified by Meyer Burger.

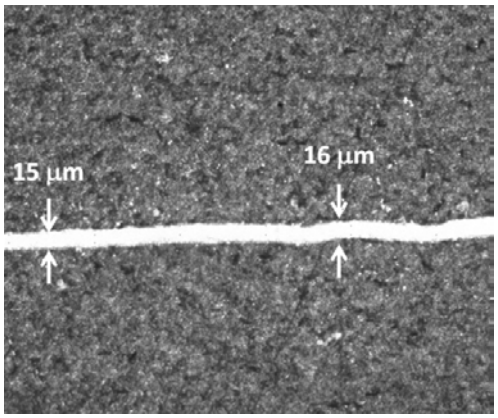


Fig. 1: Ultra-fine line of around 15-16 µm width printed by PTP.

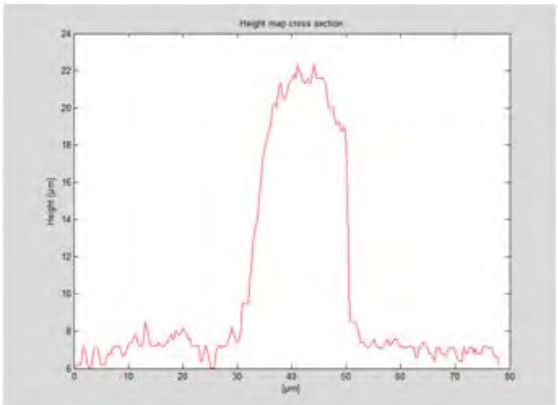


Fig. 2: Cross section of a ulta-fine line printed by PTP.

Fig. 3: Smart Wire concept developed by Meyer Burger.

Project consortium

Coordinator and contact details:

Full name of organisation:	International Solar Energy Research Center Konstanz e.V.
First and family name of coordinator:	Dominik Rudolph
Full address:	Rudolf-Diesel Str. 15 / 78467 Konstanz / Germany
E-mail:	Dominik.rudolph@isc-konstanz.de

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Germany	1	1’200’755	960’604
Israel	1	475’580	237’790
Switzerland	1	1’000’000	400’000
Total		*2’676’335*	*1’598’394*

441 ENHANCE: Enhanced Rooftop PV Integration through Kinetic Storage and Wide Area Monitoring

Project Duration: 04.2017 – 03.2020
Report submitted: 10.2017

Summary

This project aims to pave the way for a seamless and massive grid integration of small rooftop photovoltaic systems (PVs) by enriching the paradigm of conventional demand response with PV generation and storage response. Some of the obstacles against the large-scale deployment of small rooftop PVs include the variable nature of solar energy, the unavailability of accurate generation forecast, and the fact that the actual generation of rooftop PV systems cannot be monitored or controlled in near real-time. Moreover, the unavailability of local small scale storage systems, the poor Fault Ride Through techniques and the lack of demand response mechanisms that respond in accordance to the current PV generation and the battery charging state, are some of the other factors that do not allow to substantially enhancing the operational capability and flexibility of PVs and their grid-friendlier integration. Progress in these issues would alleviate the concerns of Distribution System Operators, allowing a higher PV penetration.

The ENHANCE project will tackle the above barriers in a transnational Cyprus-Israel framework. The proposed project will put the foundation stone for synergies and the development of industrially relevant transnational RTD and innovation projects in the two neighbouring countries with significant industrial impact and noteworthy contribution to the SET plan, tailored to their industrial and market needs. The project is particularly important since the two countries, apart from sharing the same vision regarding the decarbonisation of their economies; they also share one of the highest solar potentials on earth, while they are currently working on the interconnection of their power systems. A well selected consortium including one university and three industrial partners is tailored to the needs of the project, bridges the gap between industry and academia and fulfils all the requirements for a successful project implementation.

Project consortium

Coordinator and contact details:

Full name of organisation:	University of Cyprus
First and family name of coordinator:	Dr. Elias Kyriakides
Full address:	University Avenue 1, POBox 20537, 1678 Nicosia-Cyprus
E-mail:	elias@ucy.ac.cy

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Cyprus	2	211‘400	200‘000
Israel	2	1‘463‘350	731‘675
Total	*4*	*1’674’750*	*931’675*

442 HIPER:
High-Efficiency Si Perovskite Tandem Solar Cells

Project Duration: 01.2017 – 07.2019
Report submitted: 03.2018

Summary

The overall objective of the HIPER project is to combine development of novel advanced industrial crystalline silicon (cSi) cell and module processes and know-how, with state of the art perovskite solar cell and module research, aimed at hybrid perovskite/ccSi tandems. The objectives include demonstration of 28% cell efficiency and 25% module efficiency, the latter on at least 6 inch scale. The development aims to reach a TRL of 5. The project contributes to the SOLAR-ERA.NET and SEII topics in lowering the LCOE to below 0.1 Euro/kWh, increasing PV efficiency (even above the 2020 targets of the SET plan), and demonstrating proof of concept of a very high-efficiency novel PV technology.

The cSi technology, with activities by Tempress, ECN, iTechSolar, and TUE, is footed on two routes for high-performance industrial bottom cells, optimized for tandem application: Tempress and ECN will focus on novel cells specifically optimized for tandem application, in particular novel cells with polysilicon (polySi) passivating contacts on both front and rear side. iTechSolar and ECN will also supply IBC cells from their ongoing development projects. Alkylammonium lead halide perovskites (perovskites) can lead to single junction solar cells with efficiencies up to 22 %. HIPER will prepare high quality perovskites (with optimized bandgap and stability) using vacuum processing (UVEG and iTechSolar) and slot-die coating (ECN/TNO), both compatible with large scale production. Highly transparent conductors and charge recombination layers will be developed using thermal evaporation (ECN, UVEG) and atomic layer deposition (TUE) methods.

2T and 4T tandem cells and modules will be prepared and evaluated in particular on stability (indoor and outdoor). A thorough cost assessment and life cycle analysis will also be performed. This will provide key information allowing Europe to position itself on the forefront of the next generation solar cells.

Project consortium

Coordinator and contact details:

Full name of organisation:	Universitat de València Estudi General
First and family name of coordinator:	Juan Martinez Pastor
Full address:	C/ Catedrático José Beltrán 2, 46980 Paterna, Spain
E-mail:	Juan.Mtnez.Pastor@uv.es

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Spain	1	261'032	229'709
Turkey	1	254'150	183'863
The Netherlands	4	1'264'327	999'999
Total	*6*	*1'779'509*	*1'413'517*

450 PEARL TF-PV: Performance and Electroluminescence Analysis on Reliability and Lifetime of Thin-Film Photovoltaics

Project Duration: 07.2017 to 06.2020
Report submitted: 02.2018

Summary

Renewable energy assets are characterised by a high initial investment, long payback times and low operational costs. This is especially true for PV plants. PV modules represent up to 50% of the investment, and module reliability is crucial for the economic success of the plant. Each unexpected yield reduction or increase in maintenance expenses will seriously threaten the economic viability of the plant.

Pre-installation testing and field inspection can reduce investment risks and increase plant yield. For silicon wafer technologies, there exists a generally accepted set of standards for rejecting modules that are unlikely to perform to specification. However for thin film, it is not yet understood how to interpret the test results. This introduces uncertainty into investment models and maintenance reserve estimates, in turn reducing bankability of thin film PV projects.

The PEARL TF-PV project aims to reduce the cost of electricity produced by thin-film PV power plants, by improving plant reliability, yield, and prediction of overall plant lifetime using electroluminescence imaging methods.

The knowledge gain on the appearance, behaviour and progression of failure mechanisms acquired during this project will be implemented to strengthen the productivity and competitiveness of European industry within the O&M and quality assurance industry, as well as within the thin film research and manufacturing sector.

Project consortium

Coordinator and contact details:

Full name of organisation:	Forschungszentrum Jülich
First and family name of coordinator:	Vito Huhn
Full address:	Wilhelm-Johnen Strasse, Jülich, 52428, Germany
E-mail:	v.huhn@fz-juelich.de

Participating countries and financing:

Country	**Number of organisations involved**	**Project costs in EUR**	**Public funding in EUR**
Germany	3	1'517'905	1'273'137
The Netherlands	6	902'762	722'208
Austria	2	330'824	273'660
Total	*11*	*2'751'491*	*2'269'005*