PROJECT FINAL REPORT

EC Grant Agreement n°609788

CHEETAH

Cost-reduction through material optimisation and Higher EnErgy outpuT of solAr pHotovoltaic modules - joining Europe's Research and Development efforts in support of its PV industry

Funding Scheme: Combination of CP & CSA

Period covered: **from 01/01/2014** **to 31/12/2017**

Name, title and organisation of the scientific representative of the project's coordinator:
Jan Kroon, ECN
Tel: +31 88 515 4734
Fax: +32 2 219 41 51
E-mail: j.kroon@ecn.nl

Project website address: http://www.cheetah-project.eu/

Document information

Deliverable name	CHEETAH_D1.10_Final Report
Lead beneficiary	ECN
Due delivery date from Annex I	M48
Actual / forecast delivery date	M50
Dissemination level	Public | ~~Restricted~~ | ~~Confidential~~

Document validation

Name	Organisation	Date	Visa
Jan Kroon - WP1 leader	ECN	01/03/2018	OK
Jan Kroon - Coordinator	ECN	01/03/2018	OK

Document history

Version	Date	Modifications	Name
00	10/11/2017	Creation	M. Bossard
01	07/02/2018	Integration of WPs inputs and executive summary	E. Richet
02	15/02/2018	Updated version	F. Brutin
03	20/02/2018	Updated version (glossary, WP2), tables	F. Brutin / E. Richet
04	23/02/2018	Version revised by Jan Kroon	J.Kroon
05	27/02/2018	WP7 data included	E.Richet
06	28/02/2018	Updated version	J.Kroon / E.Richet
07	01/03/2018	With Tables	J.Kroon / E.Richet
VF	01/03/2018	Final version validated by Coordinator	J.Kroon

Section 1 - Table of content

Glossary

APCVD	Atmospheric Pressure Chemical Vapor Deposition	MWT	Metal Wrap Through
BC	Back Contact	O-IDTBR	Organic Non-fullerene molecule acceptor
BIPV	Building-integrated photovoltaics	OPEN	Unprotected devices
CAPEX	Capital Expenditure Or Capital Expense	OPEX	Operational Expenditure
CIGS	Copper Indium Gallium Selenide	OPV	Organic Photovoltaic
CIS	Copper Indium Selenide	P3HT	Poly(3-hexylthiophène)
ConCVD / ProConCVD	Continuous CVD/ Production Continuous CVD	PBHT	
CPV	Concentrated PV	PCE12	Also called PBDB- T. Donor polymers for OPVs
CTM	Cell To Module	PEDOT:PSS	Poly(3,4-ethylenedioxythiophene) polystyrene sulfonate
CVD	Chemical Vapor Deposition	PERC	
Cz	Copper-Zinc	PET	Polyethylene Terephthalate
CZTS	Copper Zinc Tin Sulfide	PL	Photo luminescence
EERA PV	European Energy Research Alliance On Photovoltaic	PMMA	Poly(methyl methacrylate)
EL	Electroluminiscence Image	Psi	Porous Silicon
EPD	Etch Pit Density	PV	Photovoltaic
EQE	External Quantum Efficiency	R&D	Research & Development
EROI	Energy Return On Energy Invested	RI	Research Infrastructure
ETIP-PV	European Technology & Innovation Platform PV	RTD	Research And Technical (Or Technological) Development
HF	Hydrofluoric Acid,	SAM	Scanning Acoustic Microscope
HJ	Heterojunction Technology	SEM	Scanning Electron Microscope
HNO3	Nitric Acid	SET	Strategic Energy Technology Plan
IBC	Interidigitated Back Contact	SF	Stacking Fault
IRP	Integrated Research Project	SHJ	Standard Heterojunction Technology
ITIC	Indacenodithiophene-based small molecule	Si_2N_2O	Silicon oxynitride
IV	Section OPV	SPUTT	Devices tested under light with full spectrum
JP	Joint Program	SPUTT+UVF	Devices tested under UV filtered light
Jsc	Short-circuit current density	SSLPE	Steady-State Liquid Phase Epitaxy
KEP	Knowledge Exchange Platform	TiOx	Titanium Oxyde
LBIC	Light Beam Induced Current	TRL	Technology Readiness Level
LCA	Life Cycle Assessment	UB	Ultrabarrier
LCOE	Levelised Cost Of Electricity	UBUV	UB + UV filter
LPC-Si	Liquid Phase Crystallized Silicon	Voc	Voltage at Open Circuit
LPE	Liquid Phase Epitaxy	Wp	Watt-Peak (Wp), the nominal power of a solar cell or panel
MDP	Microwave-detected Photoconductance		

Section 2 - Final Publishable summary

2.1. Executive summary

CHEETAH is an integrated research project on photovoltaics funded by the European Commission, under Framework Programme 7 (https://ec.europa.eu/research/fp7/index_en.cfm). CHEETAH was initiated by EERA PV (https://www.eera-set.eu/eera-joint-programmes-jps/photovoltaic-solar-energy/), which aims to increase the effectiveness and efficiency of PV R&D through alignment and joint programming of R&D of its member institutes, and to contribute to the R&D-needs as were defined in the Solar Europe Industry Initiative (SEII) in support of the Strategic Energy Technology (SET) plan.

CHEETAH was funded by European Commission to solve specific R&D issues in coherence with the EERA-PV Joint Program and SET plan, European policy and roadmap documents, to overcome fragmentation of European PV R&D and intensify the collaboration between R&D providers and industry to accelerate the industrialization of innovations. CHEETAH thus aimed at tackling the following challenges:

- Provide more PV power using less materials ("more with less");
- Accelerate the implementation of innovative technologies in the PV industry;
- Foster long-term European cooperation in the PV R&D sector.

CHEETAH project was then organised into two types of activities:

- Networking and coordination: focusing on the creation of a long-term collaborative platform by developing tools for knowledge sharing, e-learning platforms for training and education, mobility between researchers, efficient use of infrastructures and promoting best practices and standards.
- Research: focusing on developing new concepts and technologies for wafer-based crystalline silicon PV (modules with thin cells < 100 micron), thin-film PV (advanced light management) and organic PV (very low-cost barriers), resulting in reduced cost of environmentally benign/abundant/non-toxic materials and increased module performance.

The CHEETAH project consortium was constituted of 34 partners spread around Europe, consisting of 31 research centers (universities and research institutes) of excellence in PV R&D, complemented by Solar Power Europe (formerly known as EPIA) and Innoenergy (formerly known as KIC Innoenergy) as the associations, and consultancy company Ayming for project management support.

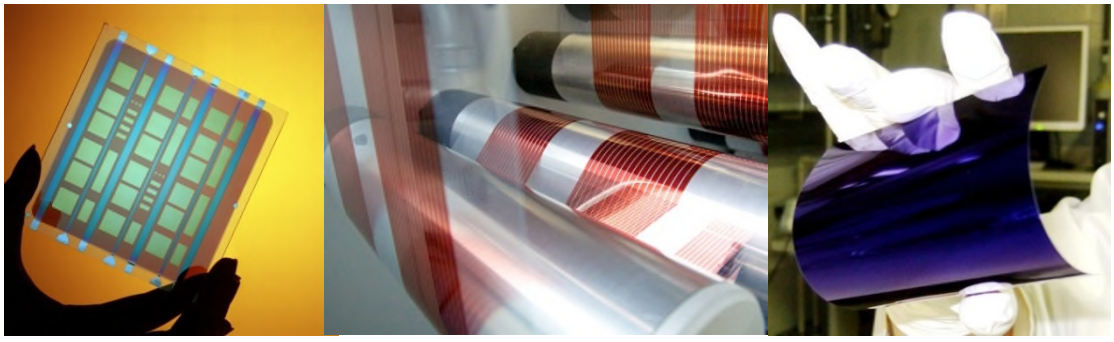
The combined efforts of the consortium have led to a number of important achievements listed below that will form an essential basis for creating a long term collaborative platform and a technology basis for Europe that should regain and build up own manufacturing capacity in all parts of the value chain:

- CHEETAH created a framework for cooperation and exchange through the establishment of a Knowledge Exchange Platform (KEP) which is an online information source to promote knowledge exchange among experts and trainees on photovoltaic (PV) solar energy research in Europe (www.cheetahexchange.eu);

- Within CHEETAH, very thin kerfless silicon foils and wafers were fabricated using the epitaxial growth method with high electrical and crystalline quality. Heterojunction cells as thin as 40 mm were demonstrated on 125 x 125 mm^2 free standing epi foils (17 % efficiency);
- Full industrial processing in automatic mode was validated for thin wafers down to 80 micron using Heterojunction technology with record cells having >22 % efficiency;
- Thin IBC and Heterojunction cells were successfully integrated in modules using different interconnection technologies, with low Cell to Modules losses (<1%) and minor crack formation. A Maximum Power outputs up to 313 Wp was achieved for a full size HJ module;
- Proof of concepts have been demonstrated for advanced thin film PV device concepts using light management strategies, i.e. microconcentrator CIGS solar cells with low and medium concentration enhancement and nanopatterned thin film Silicon produced by Liquid phase crystallisation;
- An extensive collaborative effort was done in the project to identify solutions for alternative and low cost packaging solutions and improve the intrinsic stability of OPV devices. The establishment of a E-infrastructure and an advanced chamber to test unprotected in a very systematic way are among the key exploitable results of this activity.

As a conclusion, CHEETAH succeeded in its main challenges namely:

- “More with less”: CHEETAH demonstrated that thinner materials can reach high-level efficiency thus opening the door to material, economic and environmental savings;
- Innovative technologies: as proof of concepts were demonstrated, next steps will be the up-scaling of those new technologies in industrial conditions;
- Foster long-term European cooperation in the PV R&D sector: the created cooperation both in terms of knowledge & education and research activities will be continued after CHEETAH.



2.2. Context and project objectives

2.2.1 Context

CHEETAH (Acronym for *Cost-reduction through material optimisation and Higher EnErgy outpuT of solAr pHotovoltaic modules - joining Europe's Research and Development efforts in support of its PV industry*) was a 4 year combined collaborative project and coordination and support action funded under the European Commission's 7th Framework programme and ran from January 2014 to December 2017. The project consortium consisted of 34 partners from research institutes and universities.

CHEETAH's aim was to solve specific R&D issues in coherence with the EERA-PV Joint Program and SET plan, to overcome fragmentation of European PV R&D in Europe and intensify the collaboration between R&D providers and industry to accelerate the industrialization of innovations.

2.2.2 Objectives

The CHEETAH objectives were threefold:

- **Developing new concepts and technologies for wafer-based crystalline silicon PV (modules with ultrathin cells), thin-film PV (advanced light management) and organic PV (very low-cost barriers)**, resulting in (strongly) reduced cost of environmentally benign/abundant/non-toxic materials and increased module performance.
- **Fostering long-term European cooperation in the PV R&D sector**, by sharing knowledge, organizing workshops, exchanging and training researchers inside and outside Europe, providing efficient use of infrastructures, promoting best practices and standards.
- **Accelerating the implementation of innovative technologies in the PV industry**, by a strong involvement of EPIA and EIT-KIC InnoEnergy in this program.

CHEETAH rationale and organisation are reminded in Figure 1 - CHEETAH Rationale.

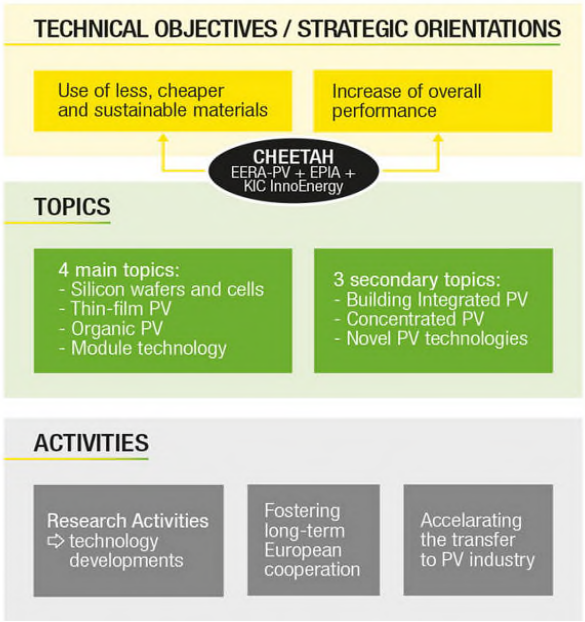


Figure 1: CHEETAH rationale

2.2.3 Description of the consortium

The CHEETAH project brought together a consortium of 34 partners spread around Europe, consisting of 31 research centers (universities and research institutes) of excellence in PV R&D, complemented by Solar Power Europe (formely known as EPIA) and Innoenergy (formerly known as KIC Innoenergy) as the associations with the aim to shape the regulatory environment and enhance business opportunities for solar power in Europe and consultancy company Ayming for project management support (see Figure CHEETAH consortium).

Figure 2: Geographical spreading of the 34 CHEETAH consortium members

2.3. Main S&T results / foreground

CHEETAH results and foreground, detailed below, are related to the two types of activities performed within CHEETAH, which are Networking and cooperation, on one side, and Research on another side. Sections 2.3.1 to 2.3.4 are related to the first category, while the section 2.3.5 to 2.3.8 correspond to the second one.

2.3.1 Knowledge Exchange by fostering the use of existing facilities and expertise

Knowledge exchange was a CHEETAH keystone to connect research organizations and companies together with wider groups and communities in the PV field. The principal benefit of knowledge exchange is to speed up achievements and boost research impacts. In this relevant area, CHEETAH project operated the following steps:

- *Knowledge Exchange needs inventory:* the consortium consolidated the background among project partners in terms of availability of expertise and infrastructures so to evaluate the needs in term of knowledge exchange;
- *Knowledge Exchange platforms:* specific tools and procedures were developed to improve knowledge exchange, among which knowledge exchange and e-learning platforms (https://www.cheetah-exchange.eu/);
- *Knowledge Exchange Actions*: a dedicated team was in charge of promoting large use of platforms and evaluating the impacts of actions.
- *Follow-up strategy and Research Infrastructure (RI) Research Agenda:* based on its exciting results, CHEETAH project provided a sustainable strategy for the medium-long term especially regarding knowledge exchange in the field of PV in Europe. In this frame a CHEETAH Strategic Research Agenda for RI was proposed.

Knowledge exchange need inventory:

A wide counting of technical and scientific needs in knowledge exchange in the Photovoltaic field was launched and - for the first time in PV - numerically characterized, for PV Technologies, PV RTD topics and PV RTD Equipment. All CHEETAH contact points participated by collecting information coming from stakeholders, e.g. Ph.D. students, experienced researchers, group leaders for instance. This permitted to detect technical & scientific areas where trained scientists could transfer knowledge to trainees. This evaluation confirmed the relevant interest for emerging technologies like perovskite, specific laboratory equipment for solar cells processing and characterization, and test benches for PV modules energy rating and lifetime characterization. This activity was the basis for prospects and perspectives, reported in the CHEETAH Research Infrastructure Agenda.

Knowledge exchange platforms:

An impressive delivery of CHEETAH was the KEP (Knowledge Exchange Platform, formerly named KEAP). CHEETAH KEP https://www.cheetah-exchange.eu/ registers expertise and infrastructures (supply site), and demonstrates potential benefits and impacts. Information is classified and organized according to PV technologies/PV RTD topics and CHEETAH involved organizations.

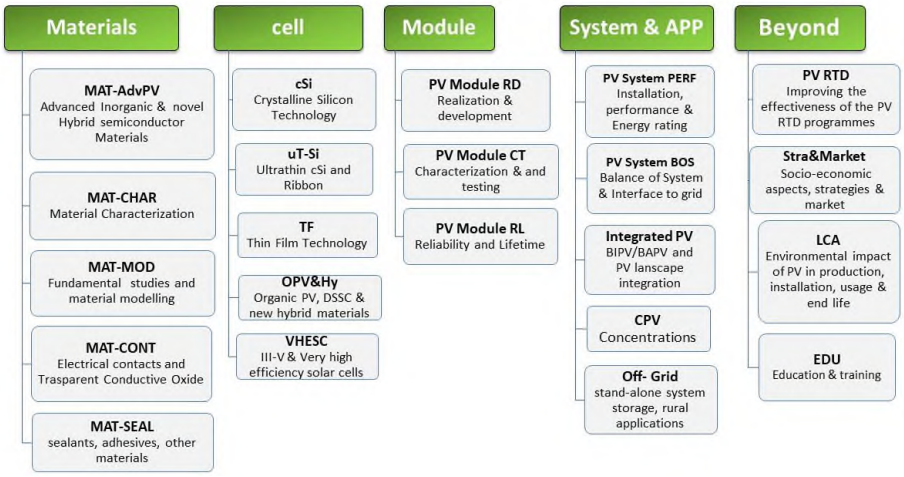


Figure 3: CHEETAH knowledge exchange cataloguing criteria

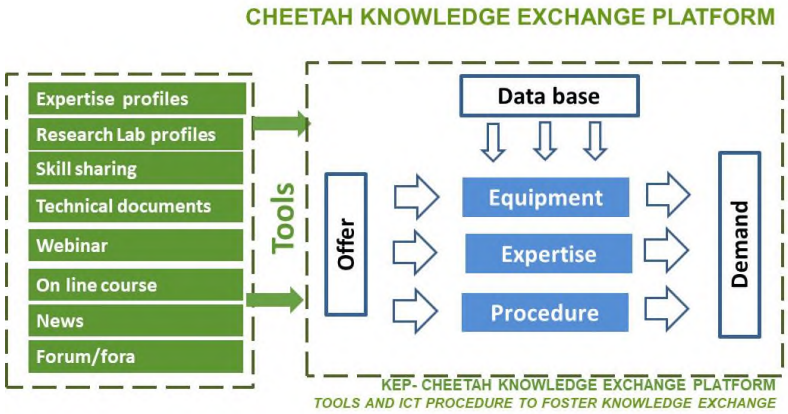


Figure 4: CHEETAH Knowledge exchange rationale

Around 900 users distributed in 60 countries worldwide are registered in CHEETAH KEP as of December 2017, about 85% are from Europe, some from India (3-4%), USA and Australia (2% each). Most of the population using the KEP are research scientist and academics at different stage of career and education.

As of December 2017 the platform counts 47 organizations, 220 experts' profiles, 60 Research Infrastructures, 23 PV Technologies, 200 PV RTD topics, 160 PV RTD Equipment. The platform recorded 19220 access to organization web pages, 90600 access to Expert web pages, 21960 accesses to Research Infrastructures web pages, 12820 accesses to PV technologies web pages and thousands and thousands of accesses to PV RTD Topic and Equipment pages.

CHEETAH e-learning platform

The internal e-learning platform, CHEETAH webinar, is available at https://www.cheetah-exchange.eu/webinars.asp. The platform offers:

- Comprehensive information and transfer of knowledge on different R&D topic in Photovoltaics;
- Presentations on several outstanding technical-scientific results highlighting the positive impact of sharing expertise.

Since January 2015, the platform offered 73 lectures, in 36 separate events, with a total of > 2000 registered users (about 1 200 live-participants).

Knowledge Exchange Actions plans and access to Research Infrastructures **:**

The idea was to assess existing access protocols, and implement a unified access protocol. Two procedures were selected: a standard "access by project", based on a project presentation including its evaluation and corresponding payment of an access cost, and an innovative "measurable & credit/debts based approach", allowing a hosting Institute to collect time to be used in accessing to another Infrastructure.

Follow up strategy and RI Research Agenda**:**

A Research Infrastructure (RI) Research Agenda was designed with public and private funding agencies as targeted audiences. Benefiting from the broad experience of the 34 organizations taking part in the CHEETAH project, experts were able to formulate recommendation for Missing RI to support future needs, and to strengthen pan-European collaboration and facilitate Infrastructures accesses. This unique document is available on www.cheetah-project.eu.

CHEETAH KEP platform represents a significant step forward in the knowledge exchange in the PV RTD sector. It will remain active in the frame of EERA-PV and other upcoming projects. The "measurable & credit/debts" approach to access to RI will also be experimented in the frame of EERA-PV.

2.3.2 Mobility, education and International Cooperation Activities

The purpose of the project activity *"*Mobility, education and *i*nternational *c*ooperation" was to intensify the collaboration between project partners through exchange visits, to increase interactions between research and industry, to foster education and training of researchers and finally to interact with experts outside of Europe.

Researcher Exchange

Exchanges between partners were considered as a key factor to intensify the collaboration, especially for the research activities of the project. Therefore, a strong emphasis was put on advertising and reporting researcher exchanges within the CHEETAH project. About 60% of the

project partners were regularly involved in researchers exchanges. In total, more than 60 exchange visits with a total of 441 days for short-term visits and involving around 50 researchers were reported during the project duration. Of these, more than 90% were for laboratory training and 10% dedicated to delivery of talks and seminars. As a remarkable point, we noticed that some visits were long-term visits (> one week). In total, 47 months of long-term visits were reported.

Some of these visits led to fruitful collaboration that resulted in publications, like e.g. the paper "T. Frijnts, N. Preissler, S. Gall, S. Neubert, B. Rech, and R. Schlatmann, Sol. RRL 2017, 1, 1700100, DOI: 10.1002/solr.201700100"" which was published partly as result of a 2-months researcher exchange between HZB and EPFL in 2016.

Mobility towards industry

An intense part of this activity was dedicated to foster mobility towards industry, i.e. exchange of personnel and ideas with industry. Further to dedicated workshops with industries, 13 exchange visits to industry were reported, for training at specific instruments or for information exchange relating to specific technologies. Moreover, intense discussions with industry representatives were reported during the CHEETAH workshop "European Solar Technology Forum" on 30 November 2017 in Berlin, Germany. The survey organized after this major event reported that 66% of industrial organization identified potential collaborations thanks to the networking during the CHEETAH final public event.

Summer Universities and workshops

As part of the education and training activity of CHEETAH, summer universities and workshops were offered each year. These educational events targeted different audiences, starting with students up to experienced researchers. The consortium took advantage of ongoing planned activities (within CHEETAH partners) for some of these events. All of the events were very popular among the participants and in many cases strict selection rules had to be applied to the applications, as there were far more applications than places available.

Some of the summer universities were announced in social media and those were also used after the respective events to share pictures and information among the participants (e.g. https://www.facebook.com/ISUEnergy).

During the project, the following summer universities were successfully organised by CHEETAH partners:

- ISUenergy in Falera, Switzerland (2014 and 2015), main organiser HZB (http://www.helmholtz-berlin.de/events/isu-energy/), with about 65 participants each from > 10 countries word-wide;

- ISOPHOS - International School on Organic Photovoltaics (2014, 2015, 2016, and 2017), main organiser Lazio Region-University of Rome Tor Vergata (http://www.chose.uniroma2.it/scuole/204-isophos-2014.html). The number of participants is around 25 from 8-10 different countries for each year;
- IKZ summer school on crystal growth (2016) main organiser Institut für Kristallzucht (IKZ) with 62 participants;
- Quantsol summer school (2014, 2015, 2016, and 2017) main organiser HZB Technische Universität Ilmenau, Germany (https://www.helmholtz-berlin.de/events/quantsol/);
- The Autumn School on Microstructural Characterization and Modelling of Thin-Film Solar Cells (2016) in Berlin, Germany, main organiser HZB (http://www.helmholtz-berlin.de/events/autumn-school/index_en.html).

During the project, the following workshops were successfully organised by CHEETAH partners:

- Workshop on advanced analytical methods (2014), main organiser HZB with 14 participants from 8 countries

  (http://www.helmholtz-berlin.de/events/sophia/index_de.html)
- Mid-term and Final CHEETAH Workshops (2015 with around 35 participants and 2017 with 115 participants), main organizer Solar Power Europe (http://www.cheetah-project.eu/dissemination-project-results/events/final-event-european-solar-technology-forum.html). These workshops were targeted towards the PV industry to raise awareness for the results of the CHEETAH project.
- International Workshops on CIGS Solar Cell Technology (2014, 2015, 2016, and 2017), main organiser HZB and ZSW (http://iw-cigstech.org/home.html) with around 100 participants every year, mainly from the thin film PV industry.
- The Foresight Workshop on Energy Materials Research at BESSY (2016), main organizer HZB (http://www.helmholtz-berlin.de/user/workshops/energy_en.html) with about 60 participants from the energy materials community.
- The ISOS-8 and -9 conferences (2015, 2016), organizer from CHEETAH: NPL
- The Second HERCULES Workshop (2016), main organizer HZB (https://www.helmholtz-berlin.de/projects/hercules/2nd-hercules-workshop/index_en.html)

International Coordination Board

An International Coordination Board consisting of PV experts from different international countries was constituted with the objective to share and exchange on technology, standardization and harmonization in the field of PV from outside of the EU and promote CHEETAH results.

Two leading scientists from ECN and HZB, representatives of the consortium, animated this board, which was composed of highly recognized scientists:

- Sigurd Wagner, Princeton, USA;
- Tokio Nakada, Tokyo University of Science, Japan;
- Armin Aberle, Solar Energy Research Institute of Singapore (SERIS);
- Ahmed Ennaoui, QEERI, Quatar.

Thin film round robin

A tandem solar cell characterization round robin was launched in 2016 in order to compare the characterization facilities at the different partner laboratories for this specific type of solar cells. Tandem devices, consisting of two individual solar cells stacked on top of each other, require special equipment and know-how in order to accurately measure their efficiency. This activity was a continuation of an action undertaken in a previous European project (SOPHIA). Preliminary evaluation of the data showed some remarkable differences between the participating labs.

Conclusion

In Brief, the mobility, education and International Cooperation Activities represented an intense effort all along the 4 years project duration with – according to the consortium – significant results in terms of knowledge / best practices sharing and highly contributed to the overall CHEETAH success. While the results are difficult to quantify, the intense exchange of ideas and knowledge between the participants has strengthened the entire European PV community, which is an important basis for future research projects.

Figure 5: Group picture from the ISUenergy 2015 in Falera, Switzerland. ©HZB

2.3.3 Dissemination, internal and external communication

The dissemination of project results to a wide audience was promoted by more than 200 different actions in the four years of the project. Much public information is available at the project's website www.cheetah-project.eu, providing periodic reports, news, public documents, etc.

The consortium published more than 40 project-related, peer-reviewed papers and contributed to more than 130 oral or poster presentations at scientific conferences. Furthermore, 18 workshops and 8 conferences were organized by project partners, which were related to the work of CHEETAH and used to promote the project and to disseminate technical results to the target audience. In total, 14 PhD or Master Theses were completed within the frame of the project, some further Theses are ongoing.

Some results of the project were published in a Chapter "Environmental Stability of Organic Semiconductors for Use in Optoelectronic Devices" of the book "Materials for Energy Infrastructure" published by Springer Singapore (ISBN: 978-981-287-723-9) and in the book "Future renewable energy costs: solar photovoltaics" published by KIC InnoEnergy (ISBN: 978-949-205-604-7).

A special achievement of CHEETAH was the fostering of e-tools for dissemination, in particular the dissemination via webinars and video recording of on-side events. Such events have the great opportunity to allow participation without travelling and getting access to the presentation at any time after uploading.

Workshop on "Advanced Characterization Methods for PV"

A full-day workshop was offered at the Fraunhofer ISE facility in Freiburg, Germany at January 14th, 2016. The aim of the workshop was to disseminate the scientific infrastructure for advanced characterization for photovoltaic research. With three different sessions, the methods for material, solar cell, solar module and solar system characterization were presented to the public. All presentations were recorded and streamed during the workshop. This allowed the on-site participation at the workshop venue as well as the live participation from the web. All presentations were made available as download here. In total, 52 participants attended the workshop on-site at the ISE facility and additional 63 participants followed the workshop online.

Webinar activities

During the scope of the project, more than twenty webinars and nano-MOOC (Massive Online Open Courses) were offered to general public. The focus of these events was the sharing of

knowledge for advanced analytics, the education of students and post-docs or the dissemination of technical results of the project. After the scientific presentations, the participants had the opportunity to use the live chat for discussion with the speaker and the audience. The events were announced via the project website, CHEETAP KEP, mailing lists and social media platforms. The presentations of the webinars were made available here. In total, 1182 participants attended the webinars provided by the project partners.

Key results identification and exploitation

CHEETAH consortium identified 13 Key Exploitable Results that were intensively discussed and described in order to maximize CHEETAH impacts, though appropriate exploitation. Furthermore, an extensive analysis of patent landscape in PV technologies was done to provide CHEETAH key exploitable results dedicated valorisation plan.

2.3.4 Acceleration of innovations implementation

The CHEETAH project comprised a series of activities to boost and efficiently enhance the transfer of knowledge developed by CHEETAH researchers to the industry sector and to important PV market stakeholders and decision makers. Solar Power Europe (the European PV industry association) and EIT-InnoEnergy supported the project consortium in establishing the link between research and industry by the organisation of public conferences and other events and the publication of reports demonstrating the commercial value of technologies developed in the CHEETAH project. As part of this set of activities, the Joint Research Centre (JRC) of the European Commission led the development of the Guidelines for standards for next generation PV technologies, with input from CHEETAH researchers and also the PV industry.

Report: Analysis of the cost reduction potential of the PV technology and the impact of technology innovation on the LCOE

This report, published in October 2015, builds on the learning curve concept in order to assess the potential for further cost reduction in modules in the coming years and in different technology families. In addition, it provides an analysis on the Levelised Cost of Electricity (LCOE) evolution and its equation components that become more critical and impactful. Finally, the deliverable provides a methodology on how to properly evaluate the impact of future innovations on the cost of the technology and the capacity to empower the market. This analysis assumes that CHEETAH innovations will impact the LCOE in two ways: 1) via costs and efficiency through decreased CAPEX, and 2) via efficiency through increased annual energy yield (kWh/kWp effect). The analysis was based on existing literature and CHEETAH researchers' knowledge as well as further in-house analysis. Download here.

Report: Mid-term and final reports on the R&D impact on cost reduction

Published in February 2016 and updated in December 2017, these reports look at CHEETAH's innovations' cost impact on ultra-thin crystalline silicon solar cells in comparison with the existing "conventional" crystalline silicon technologies that enjoy the largest share of the PV market (>90%), and also include cost estimations and competitiveness considerations related to thin film

CIGSe microconcentrator solar cells and organic PV (OPV) solar cells with improved stability, both developed in the CHEETAH project.

As for ultra-thin c-Si, there is a potential cost reduction of 22.2% when comparing benchmark wafer-based crystalline silicon photovoltaic modules (back contact, standard cell thickness, regular wire-cut wafers) to modules using epitaxially grown wafers of 100 µm thickness developed within the CHEETAH project. Regarding thin film CIGSe microconcentrator solar cells, a profitability analysis was conducted that shows that concentrating CIGSe PV systems are almost always less profitable than non-concentrating CIGSe PV systems, when both use tracking with the light conditions in Europe. As for OPV cells with improved stability, the conclusion of the energy cost analysis was due to much better stability achieved through ultrabarriers, the chances to reach Energy Return on Energy Invested (EROI) = 1 for ultrabarriers are better than for PET-based encapsulation, even though ultrabarrier based encapsulation was more expensive than PET-based encapsulation. Download here.

Report: Impact of quality and reliability on PV competitiveness

Revised and published in August 2017, this report provides an analysis of the cost components (and sub-components) of a standard PV system in order to identify which technology improvements will provide the best returns in terms of PV competitiveness, expressed as LCOE in this analysis. In that respect, this document goes in depth in the CAPEX and OPEX structure, looking at the sensitivity of each element. When speaking about 'technology improvements' or 'innovations', this report distinguishes between two theoretical mechanisms both contributing to progress but very different in nature: (1) progress via cost reduction and (2) progress via quality enhancement. This document researches which are the drivers of both aspects of 'technological improvement' by analysing the effect they have on cost on the one hand and output/performance degradation on the other hand, and thus on PV competitiveness. For this purpose, CAPEX-related technological competiveness improvements have been subdivided into three categories: (1) innovations in the manufacturing process, (2) innovations in material quality and (3) innovations in other CAPEX components such as project development and transport, installation. The results of the analysis show that technology innovations aimed at increasing yield, such as module level power electronics, better heat dissipation and smart monitoring have the largest potential. The second most significant effect on competitiveness is achieved by manufacturing process innovations such as vertical integration and increased manufacturing plants (economies of scale). The third largest effect on competitiveness is achieved via increased module lifetime, a material quality improvement. Download here.

Guidelines for standards for next generation PV technologies

R&D and industrial organisations have an important role to play in the development of standards for new technologies, both at a pre-normative stage and working in the technical committees of national, European and international standards organisations. In this context, the CHEETAH project has a double interest: a) some of the results from the research programme and from coordination activities may be relevant to improving existing standards or setting the basis for new ones, and b) as a group representing many of leading European research organisations, it has special insight on possible standards issues for innovate PV technologies and the associate pre-normative research needed to address these.

This report, published in December 2017, is a comprehensive status report on standards for PV systems and priorities for development work. It brings together the innovative expertise of the R&D organisations as well as opinions of industry. As a basis for this report, two surveys were conducted, one in late 2015 and one in late 2017, covering the opinions of R&D as well as industry regarding regarding the standards and best practices, and priorities for development. A sizeable majority consider the current status of standards for PV to be "satisfactory, but with scope for improvement and/or new initiatives", whereas only 9% replied "unsatisfactory, important issues need to be addressed". The respondents see "reliability degradation and lifetime" as key priority for all components and indeed for systems. Beyond the results of the two surveys, this report also covers an overview of the currently active standards bodies; an analysis of CHEETAH project research results relevant or potentially relevant to standards; and a discussion on areas for coordinated action. Download here.

Two public conferences for disseminating the CHEETAH results to the PV industry and the research community

To disseminate and discuss the innovations generated as part of the CHEETAH project, the consortium organised two public conferences open to the wider research community and the PV industry. The first conference, which was attended by 80 participants, took place half-way through the project, on September 16th 2015 in Hamburg, Germany during the 31st European PV Solar Energy Conference and Exhibition (EU PVSEC). The event was titled: “Europe’s Research and Development efforts in support of its PV industry”. Download the conference documentation here.

The second conference took place towards the end of the CHEETAH project on 30 November 2017 in the premises of the Helmholtz-Zentrum Berlin für Materialien und Energie in Berlin, Germany. The event was named the first “European Solar Technology Forum” and was attended by over 100 experts with approximately 25% being industry representatives. After the conference there was a networking reception. Coffee breaks and the lunch break also offered good networking opportunities between research and industry. The breaks and the networking reception took place in the foyer of the conference building where 12 CHEETAH result posters were placed to present CHEETAH innovations otherwise not covered in detail in the conference. Download the conference documentation here.

Figure 6: Picture taken during the European Solar Technology Forum

2.3.5 Ultrathin wafer development.

CHEETAH aimed at producing thin wafers (approx. 80 µm) and ultrathin wafers(below ≤ 40 µm) thickness, featuring electronic and mechanical properties, to allow for > 20% solar cells, which can be implemented into advanced modules. Results are described below.

Fabrication of epitaxial foils by high temperature CVD.

To obtain a cost-effective way of manufacturing substrates with a thickness below 80µm, several institutes and companies started the fabrication of foils by lifting off thin layers of high quality silicon substrates, as a substituting technique for wafer sawing. The porous silicon-based layer transfer process, is a well-known method to obtain high quality epitaxial foils. At imec and Fraunhofer ISE, the foils are created by a MWT (PSi) based layer transfer process. The most important steps of this fabrication process are depicted in Figure 7.

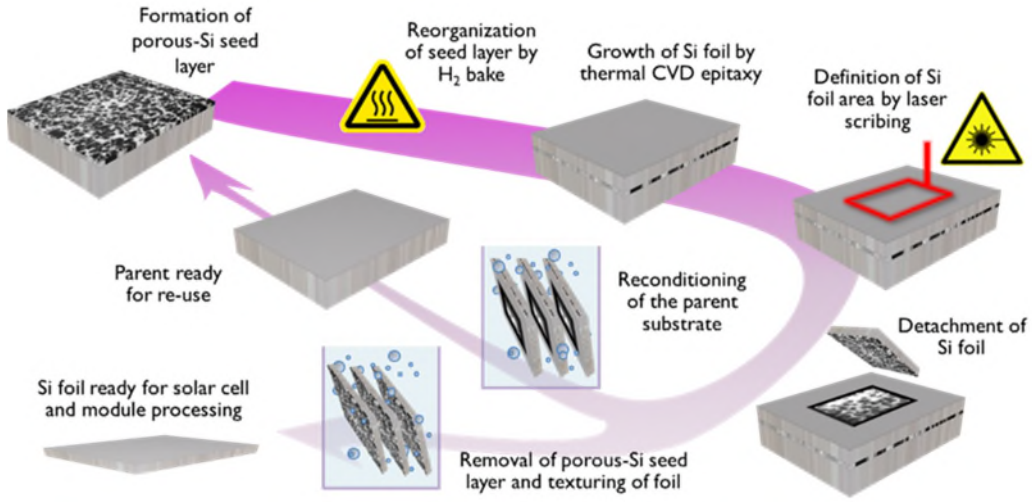


Figure 7 Schematic overview of the most important steps of the fabrication of foils using a porous silicon seed layer.

In this process, a PSi stack consisting of a low- and high-porosity layer is etched on a highly doped silicon wafer. During a high temperature bake just before epitaxial growth, this PSi stack is reorganized such that the low porosity layer has small voids and the high porosity layer becomes a long lateral void, supported by some tiny Si pillars (see Figure 8). This is called the separation layer. On top of this, the absorber of the solar cell is grown epitaxially by atmospheric pressure chemical vapor deposition (APCVD).

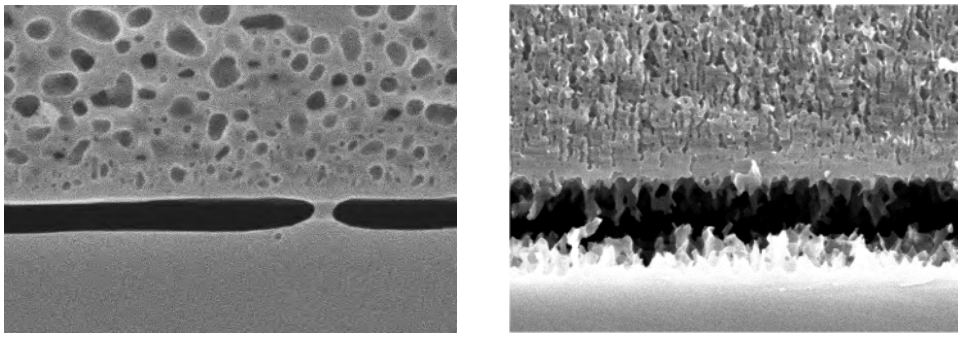


Figure 8: Cross SEM pictures of the separation layers of epitaxial foils fabricated at IMEC (left) and ISE (right)

At ISE, the final foil thickness was set to be around 80 µm, while at imec, ultimate thin 40 µm foils were produced. In cross-section SEM pictures are shown of the separation layer of epitaxial foils reorganised and grown at ISE and imec. At imec, a single wafer tool was used to grow the epitaxial layer. This allowed sufficient flexibility to optimize the process and investigate different growth parameters. However, the throughput was very limited. At ISE, an inline high throughput tool was available, simulating the process conditions that could be used in industry. Because of the differences in the reorganization process (temperature, gas composition and time), the samples looked rather different, but in both cases, a weak layer was formed in which a crack can propagate during detachment. After growth, the area of the foil was defined by a dicing technique. Several dicing methods based on laser scribing and mechanical saw dicing were tested. Both at imec and ISE, it could be concluded that foils obtained from diamond sawing, have the best mechanical properties. After sawing, the foil was detached from its parent substrate at the detachment layer formed in the Psi. A free standing foil/wafer was then obtained (Figure 9). To achieve smooth surfaces, wet chemical etching was applied, removing all the Psi seed layer remaining and, at the same time, texturing the surface on both sides.

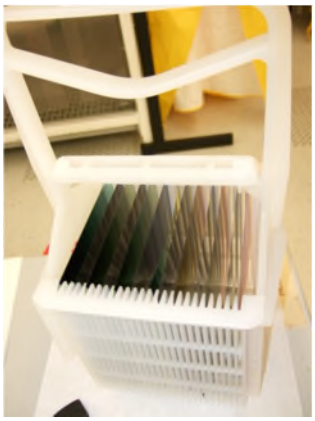


Figure 9 Batches of 12.5x12.5cm2 foils after seed removal, ready for cell integration

Figure 10 shows a large area detached foil processed in the ProConCVD tool. Thickness of the foils varied from 90 to 110 um directly after growth, measured with a bifacial microscope.

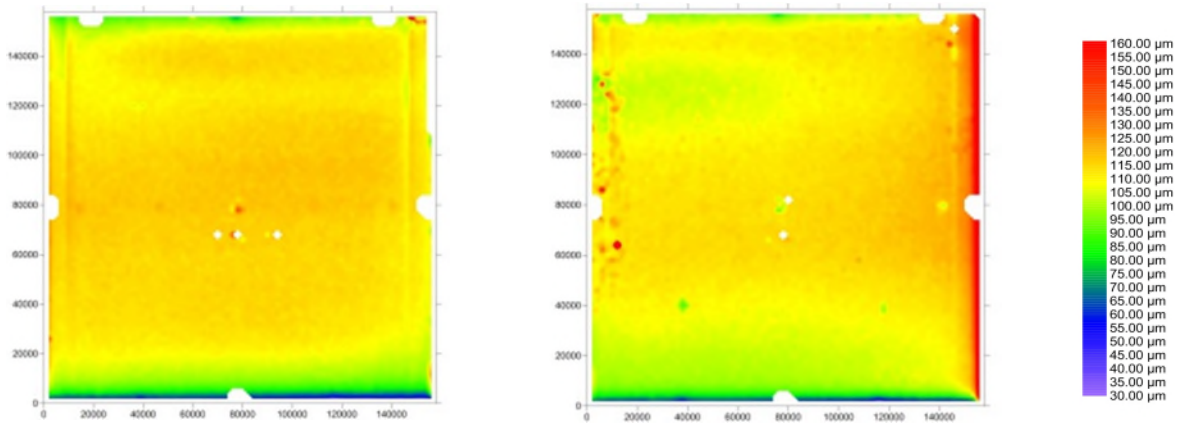


Figure 10: Thickness mapping of epitaxially grown Si foils (each with an area of 156x156 mm2) measured with a bifacial microscope before and after Si deposition.

A detachment yield above 90% was obtained in both CVD tools. All 9 samples of the carrier shown in the SAM mapping in Figure 11 could be detached successfully. A picture of one EpiFoil is also shown on the right. Effective lifetime of epitaxial foils were measured to be around 300µs.

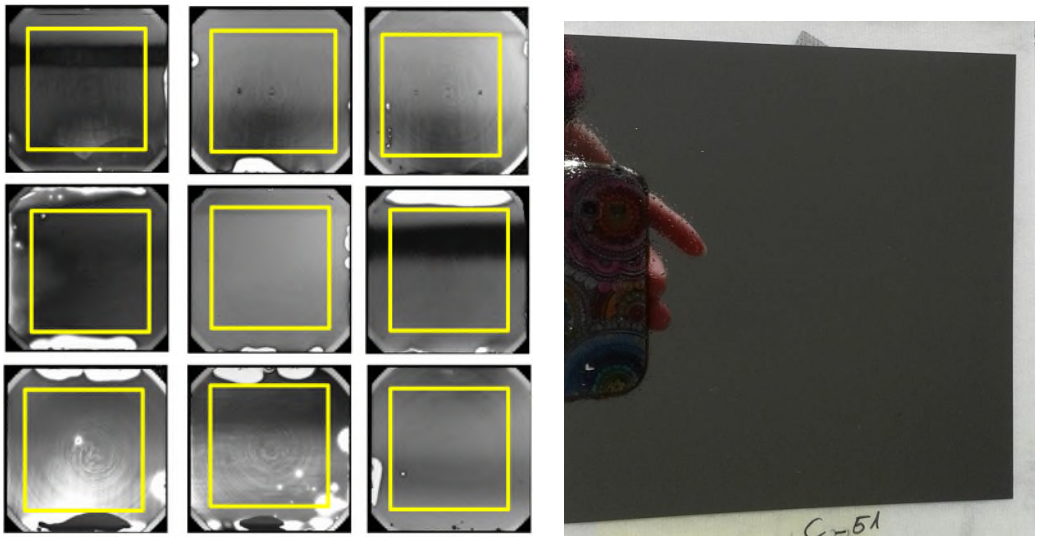


Figure 11: Scanning Acoustic Microscope (SAM) mapping of all wafers of one carrier. Areas marked in yellow have been defined with dicing and successfully detached afterwards (left). Photograph of detached 125x125 mm2 foil (right).

Recycling the parent substrate

To make this foil fabrication process cost effective, the silicon parent substrate used as a template for epitaxial growth should be reused several times. This recycling process consists of wet chemical etching of the wafer surface by a chemical polishing solution (HF and HNO_3). The

recycling process was demonstrated for 5 subsequent cycles. No significant losses in detachment yield could be observed for higher cycles when sufficient etching is applied between each cycle. To evaluate the electronic and crystalline quality of the foils, lifetime measurements and defect etching were applied. For higher generations, the stacking fault density increased, but stabilized around $2x10^4$ defects/cm^2, which indicates still high quality foils after 5 generations. The effective lifetimes of foils from different generations showed no trend. (Figure 12).

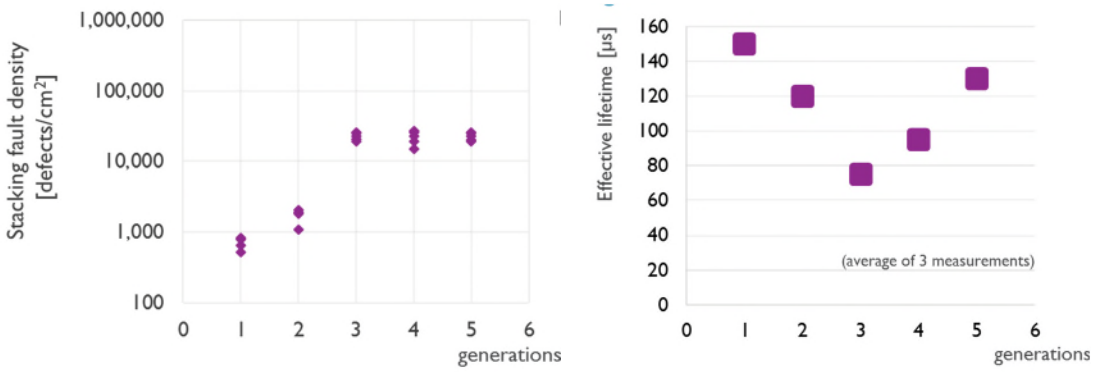


Figure 12: SF density and effective lifetime results for 5 subsequent generations

Growth by LPE

Besides the concept of high temperature CVD, a second growth process was investigated to create kerfless silicon foils using steady-state liquid phase epitaxy (SSLPE) method from a tin solution. Hereby, the crystalline substrate is placed upside down on the solution. A constant temperature difference between the substrate at the top and a Si source at the bottom of the crucible causes the Si from the source to be transported through the solution, eventually being recrystallized on the foil (see Figure 13).

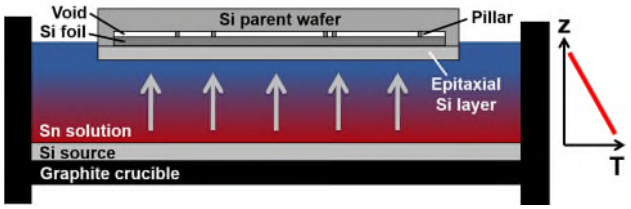


Figure 13: Cross-sectional sketch of the SSLPE crucible

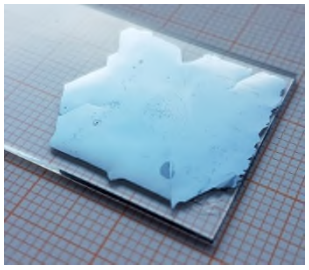


Figure 14: Detached SSLPE-grown of 1x1cm2 epilayer on glass carrier

Flat, even and homogeneous layers with adjustable thickness were grown on the reorganised seeds. The detachment of the layers was done with a thermowax, which is applied on the epilayers after growth and glued to a glass carrier, from where it can be removed in acetone after detachment (see Figure 14).

Microwave-detected Photoconductance (MDP) measurements on an unpassivated 40 µm detached, free-standing epilayer produced efficient lifetimes of 8 to 106 µs. The transient showed a significant change during illumination with bias light and exhibited a high

lifetime under low injection conditions, which is an indication of traps induced by the detachment process. The diffusion length was estimated to exceed 100 µm. The determined Etch Pit Density (EPD) varies from 1.8×10^5 cm^{-2} to 3.6×10^7 cm^{-2}.

At the final stage of the project, we clearly achieved the following results vs targets:

- Porous Si template suitable for high-yield detachment (>90%) of 125x125 mm2 wafers after epitaxy: though based on very limited statistics, very high yield values were obtained (**for some batches: up to 100%**).
- Processes running on ConCVD/ProConCVD reactors on areas as large as 156x156 mm^2, delivering 125x125 mm2 silicon layers **over 80% homogeneity** on porous Si template with high minority carrier lifetime: growth conditions were optimized (speed of the carriers in ProConCVD) and thus the homogenity was improved significantly with thickness varying between 100 and 110 um (**90% homogeneity**).
- Based on theroretical calculation, cost reduction of epitaxial wafer compared to cut wafer of today by >30% at a production scale of 1 GWp/year is achievable.

2.3.6 Cell processing of ultra-thin wafers

In this part of the project, the research activities focused on processing of cells starting from thin (70-100 µm) 156x156 mm^2 wafers to ultra-thin (40 – 70µm) 156x156 mm^2 wafers and to 125x125 mm^2 epitaxial foils. The goal was twofold: firstly to reduce cell production costs using less crystalline Si (cSi) material while keeping high PV conversion efficiency (CHEETAH major objective one can summarize with the creed **"Less is more"**) and secondly to enable innovative module designs, like lightweight modules, either flexible or rigid.

The need for cost reduction was driven by the fact that mono-cSi wafers costs still represent as much as 35% of the total costs of current industrial PV-modules. The second goal, innovative module architectures, was motivated by potential new PV applications in areas such as aerospace, vehicles, boats or building integration where non-planar shapes and weight reduction can be a key requirement.

To target >22% conversion efficiency with <100µm substrates, the cell technology of choice in the CHEETAH project was the Si Heterojunction (SHJ) cell, since a good maturity of this technology was reached for several partners in the project (imec, EPFL, CEA) and because of its potential to be thinned. Indeed, SHJ cell design is symmetrical in both front- and backside, and all steps of the cell and module process run at moderate temperatures, i.e below 250°C (compared to about 800°C for most other cell designs). This makes the cell much less sensitive to bowing/warpage during cell metallization, a phenomenon even worse for thin wafers. Most importantly, surface recombination mechanisms generally increases upon reducing the wafer thickness. Thus

the SHJ cell offers a competitive advantage over other cell designs as the hydrogenated amorphous Si thin layers (aSi:H) gives an outstanding surface passivation of the c-Si. Aside from thin and high-efficiency cells, ECN worked on thin homojunction cells to investigate the benefit of a back contact design for module manufacturing.

Dealing with thin wafers in a heterojunction cell production environment

The first and main focus was to properly setup thin wafer handling and processing in a free-standing mode, down to 40µm, in order to achieve acceptable breakage rate. Regarding semi-industrial operation in full automatic mode, the CEA SHJ pilot line has a standard capability to produce 130 to 160 µm SHJ cells at 2400 wafers/hour, and the global breakage rate on the line is below 1.5% for this standard thickness. As shown in Figure 15, the breakage rate was monitored during the whole process chain as a function of the wafer thickness. Integration of thinner wafer in standard line settings enabled to identify the main issues for their production. Remarkably, despite the fact that wafer flexion tests demonstrated that thin wafers were not more fragile than the reference, a strong increase of breakage rate was observed for thickness below 100 µm. It was mostly related to handling wafers between deposition chambers and cassettes, wafer stiction during wet processing, misplacement during PVD (performed on trays with open pockets) and metallization screen printing. Thus, to reduce breakage rate and global cell defectivity, several line adjustments were initiated. The reduction of the total line breakage rate obtained in the course of last year following these changes is shown in Figure 15. Although line throughput is usually impacted for wafers <100µm (slower wafer robotics, less wafers per carrier), processing of wafers down to 80 µm could be maintained at nominal throughput with simple modifications on cassettes or pickers. On the other hand, cells from 70 to 40 µm were processed in semi-automated / manual mode to prevent high breakage rate.

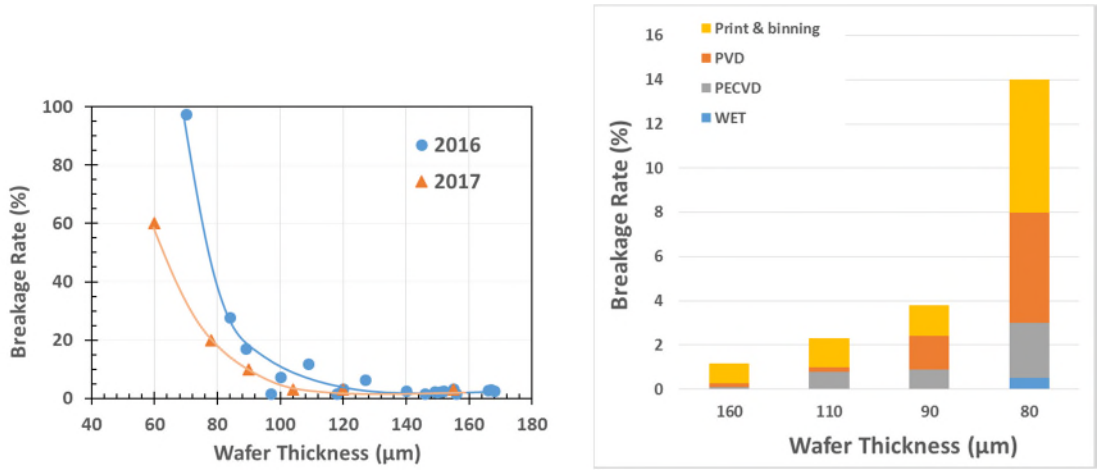


Figure 15: Progress in breakage rate on SHJ pilot-line operated in automatic mode (left) and typical best step by step achieved end 2017 (right).

SHJ cells on ultra-thin epitaxial foils

Epifoils processed by imec and ISE, presented in the previous section, were used for SHJ cell integration. As shown in Figure 16, imec demonstrated the feasibility of free standing processing of full size 125x125 mm^2 40µm foils with a four 4x4 cm^2 cell pattern.

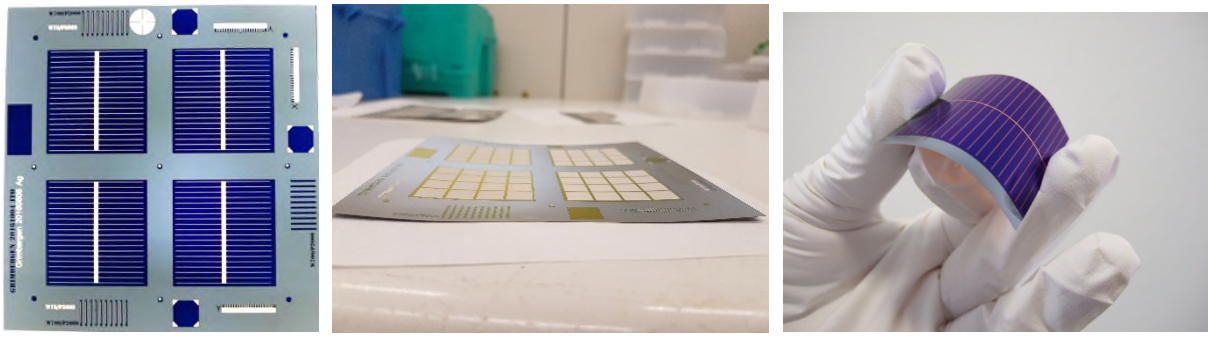


Figure 16: Left, picture of a solar cell after screen printing on a 125x125 mm^2 foil with 4 cells. Middle, rear side of a wafer after processing. Because of the thermal stress, the thin wafers and foils are slightly bended. Right, picture of a free standing SHJ cell on a 50µm epitaxial foil after cell separation.

Standard SHJ flow chart and recipes were used along with adapted process and handling schemes to insure a low breakage rate. The only specific process made to the ultrathin substrate, was a new texturization for small size random pyramids which led to a substrate etch limited to less than 5µm/side. It ensured surface damage and contamination removal while keeping the integrity of the 50µm foils. The best cell efficiency achieved was 17% with a mono-facial design.

In a subsequent experiment and based on previous learnings from imec, CEA, used their pilot line equipment to produce bifacial SHJ cells on 40 microm epifoils with standard processing total area and integrated these cells into single cell module laminates. As shown in Figure 17, best cells were produced with 14.4% efficiency and a cell to module power ratio of 97% (standard glass back sheet design), allowing 1.5Wp/g Si. This collaborative work was an outstanding demonstration of the “less is more” creed.

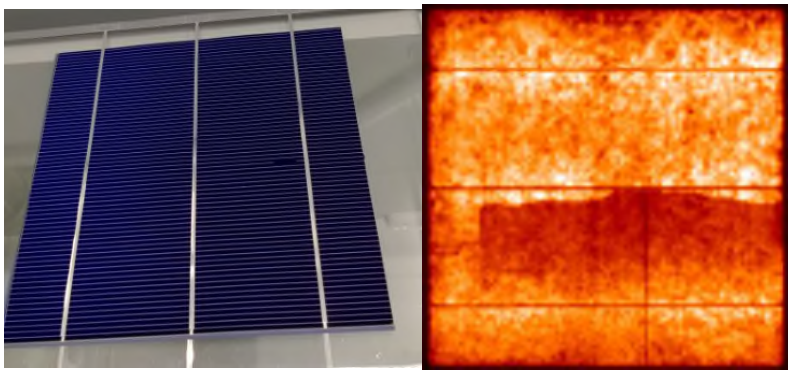


Figure 17: Single cell mini-module (left) and Electro-Luminescence picture of a full size 125x125 mm^2 40µm epifoils

High efficiency SHJ cells on thin Cz wafers

To optimize thinning from an efficiency and operational point of view, commercial Cz wafers, 180µm thick as-cut and thinned down by chemical pre-etch, were used to produce large amount of 156x156 mm^2 thin cells on the CEA pilot line in the past 3 years. However, thinning wafer also leads to lower short-circuit current, attributed to reduced photon absorption in the infrared (IR) region of the solar spectrum. Nonetheless, EPFL demonstrated that the thin cells IR response can be increased by specifically optimising the electro-optical properties of the rear-TCO layer, in order to improve internal reflection and IR light trapping.

Improving the overall quality below 100µm and developing new PECVD recipes, in order to achieve effective surface passivation bellow 1 cm/s, allowed us to benefit from the Voltage at open circuit (Voc) gain expected in thin wafers, and to overcome the Short-circuit current density (Jsc) loss (see Figure 18). For cell thicknesses, ranging between 160µm and 90µm the final cell efficiency remained approximately the same. At 89µm, the record efficiency was 22.1%, very close to the 22.3% for a reference cell at 160µm, proving that thinning wafers does not alter efficiency. However, for even thinner wafers, the Jsc loss becomes too strong. Furthermore, cell-handling difficulties led to localized defectivity as illustrated in Figure 18 with Photo-Luminescence (PL) pictures. In consequence, we obtained only 20% cells at 60µm and 18% at 40µm, the ultimate standalone thin 156x156 cells processed at CEA. Our Voc records, measured by imec, were 749mV on a 50µm 16cm^2 cell and 748mV by CEA on a 90µm 244.3cm^2 total area cell, both manufactured on Cz wafer thinned down by chemical etch. This is very close to the current world record of 750mV demonstrated by Panasonic on a 97µm 100cm^2 SHJ cell.

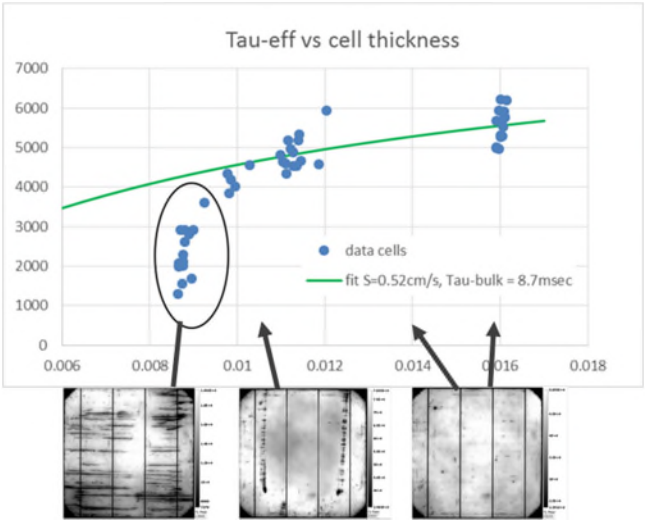


Figure 18: Effective lifetime data against thickness of SHJ cells produced on CEA pilot line fitted by an outstanding 0.5 cm/s surface recombination velocity. Highlight of localized defectivity occurring more frequently for thin cells as revealed by PL.

Despite the fact that most of process improvements are generic to any SHJ cell thickness, a specific point was demonstrated for thin cells with experimental (CEA) and simulation (IFE) data. As shown in Figure 19, the Voc gain on thin cells was larger for low quality Si bulk, offering potential added value to thin cells.

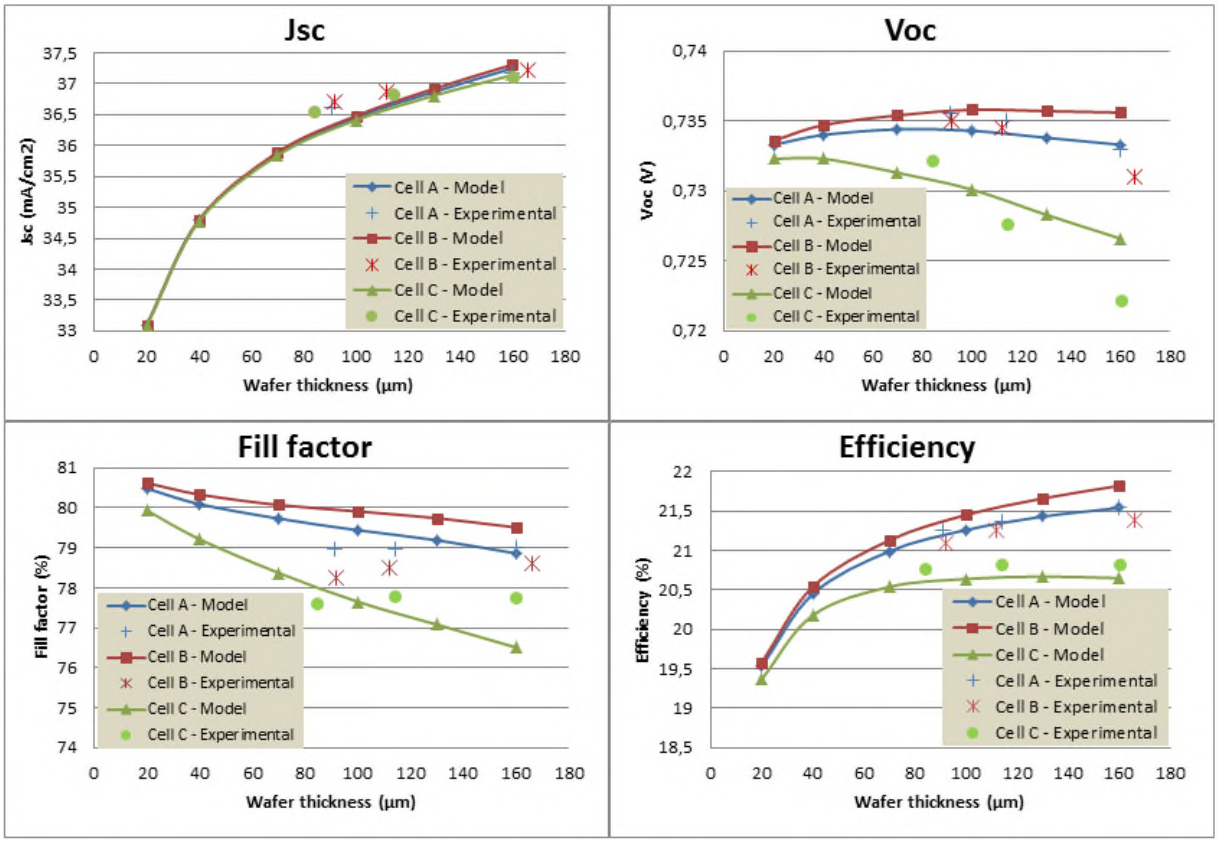


Figure 19: Experimental and model data of rear emitter SHJ cell integrated on 3 types of Cz material. A: high quality 1 Ohm.cm and 6ms ; B: high quality 5 Ohm.cm and 15ms ; C: medium quality 3 Ohm.cm and 2ms.

In conclusion, the industrial compatibility of thinner wafers for the manufacturing of heterojunction cells has been demonstrated down to 80 µm, and even further to 40 µm. The optimal thickness range, with respect to performance, production cost and compatibility with the current pilot line layout was identified around 95 µm. With these 95 µm thin cells, modules were successfully assembled, which allowed to reduce weight and increase flexibility, targeting lightweight or semi-flexible module applications. Therefore, ultra-thin heterojunction cells offer industrial cost reduction, high performance, innovative module applications and finally demonstrate that “less is more”.

2.3.7 Module development for ultrathin x-Si cells

CHEETAH project addressed development of PV panels based on thin crystalline silicon wafers as well as thin film based modules.

Although the costs for photovoltaic solar energy have decreased considerably, there is still a need for a further cost reduction. Promising (completely) new technologies (e.g. thin film) can possibly play a role in this, but so far, they lack an economy of a comparable scale to crystalline silicon (Si) wafer-based technology. For this reason, the dominant PV technology will remain wafer-based

for a long time, even though the wafer costs are relatively high and comprise a substantial part of the module costs. The CHEETAH project addressed this issue by developing technologies enabling the use of thinner wafers for cell and module manufacturing, that could lead to significant cost reduction.

The most common current design of solar modules has remained essentially unchanged since the start of commercial module production of wafer based x-Si cells. The H-patterned cells are interconnected by soldering a flat wire (called tab) to the bus bars on the cells. The front side of one cell is connected to the rear side of the adjacent cell with the tab passing between the cells. The current lower limit of cell thickness for soldering to fired silver metallization is considered to be 160 µm. A substantial part of the CHEETAH project aimed at reducing this wafer thickness in order to save costs for Si material. On the one hand, the route of incremental change in wafer thickness was followed by cutting thinner wafers, generating more useful material out of an ingot. This technology has practical limitations with respect to the thickness reduction that can be reached and also regarding the amount of kerf loss which will always be considerable and cannot be re-used. On the other hand, another (very attractive) route was based on epitaxially grown wafers, enabling wafer thicknesses of 40 µm or less, essentially without any waste of expensive material. Though very promising with respect to their cost reduction potential, epitaxial wafers are not produced on a scale comparable to the scale for cut wafers nowadays and large-scale market introduction is still very dependent on technical developments. For that reason, cut wafers (thinned down by chemical etching) have been used as a practical vehicle for most of the research carried out in the project, knowing that eventually epitaxial wafers have the potential to replace cut wafers. The ultimate developments for this part of the project were concentrated around cell and module processing based on thin wafers, keeping the efficiency at least at the same level as for standard thickness wafers.

Three technology platforms were used as a basis for the experimental work:

1. Standard heterojunction technology (SHJ) based on front to rear interconnection using tabs and conductive adhesive.

2. Foil-based back contact technology (BC), featuring a metal foil integrated in the module back sheet in combination with a number of point contacts (conductive adhesive). An essential feature was that all interconnection between cells were realized on the rear side of the cells only, resulting in a low stress interconnection. Metal wrap through (MWT, Figure 20) and interidigitated back contact (IBC) are two varieties of this technology.

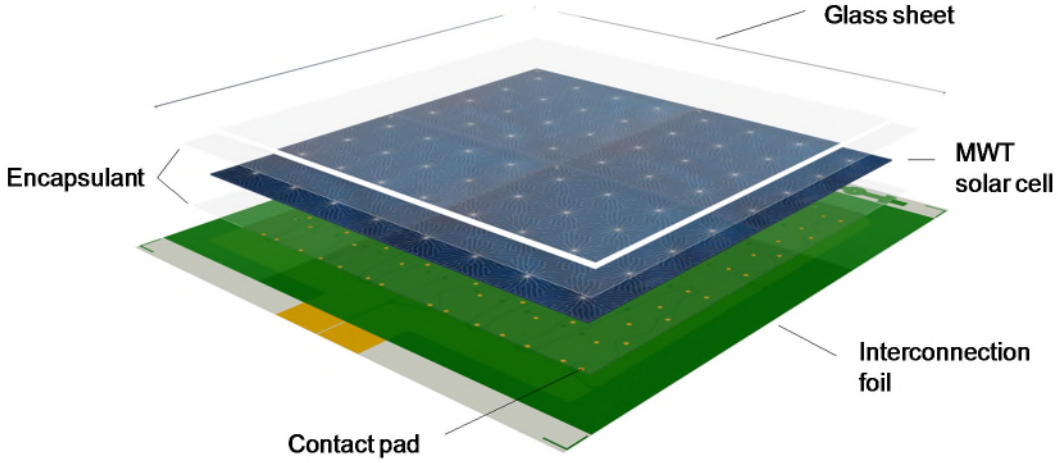


Figure 20: Buildup of a back contact module (MWT in this case)

Module manufacturing and testing

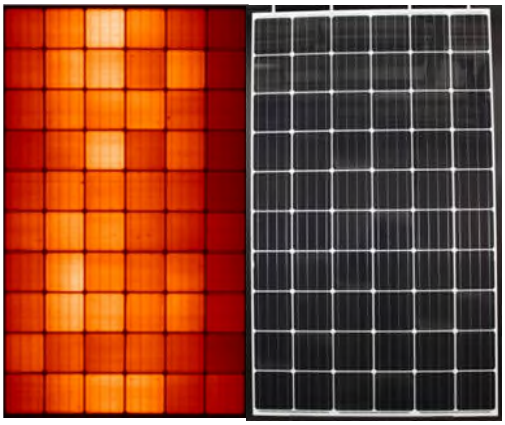


Figure 21: EL image and photo of 60-cell module by CEA-INES

At CEA-INES, the feasibility of module assembly with 90 µm SHJ cells was evaluated on the module pilot line. Full-size 60 cell modules and 4 cell mini-modules were fabricated without significant breakage rates. These included monofacial (glass-backsheet) and bifacial (glass-glass) module designs, using ribbons or SmartwireTM technology as cell inter-connection. The electro-luminescence images revealed defect-free modules after lamination as is shown in Figure 21. For the best module, 313 Wp was achieved based on 93 µm cells (average of 86 to 99 µm cells) corresponding to a net use of 1 g Si/Wp. The cell to module (CTM) coefficient of 99.1% (or 0.9 % CTM loss) is within the range for standard thickness cells: 99% to 100%.

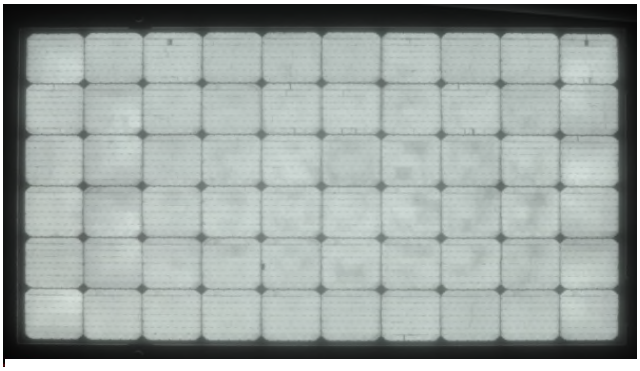


Figure 22: EL image of full size 60 cell functional IBC module based on 95 µm cells. CTM power > 99 %.

As a nice add-on for the project, a 24 cell module was assembled with 115 µm thick SHJ cells. It was intended for a semi-flexible applications for a stratospheric airship (or

HAPS: High Altitude Pseudo Satellite) for tele-communication. The module efficiency reached 18% and the module had a very low specific weight of only 600 g/m2.

A full size 60 cell functional IBC module was successfully built at ECN, using 95 µm cells (processed at ECN). From the 108 cells produced, 60 cells were selected for module integration with an average efficiency of 19.4 %. For a given cell area of 239 cm2 this translates into 278 W for the sum of all 60 cells. The resulting module was made without any cell breakage and resulting in a power output of 277 W and (compared to the power output of the total of all cells) a CTM ratio of 99.4 % EL analysis (Figure 22) revealed only minor local contacting issues (darker area's) and a few micro cracks.

A thermomechanical model was built by Fraunhofer ISE to evaluate the expected impact of module bending regarding cell fracture, in relation to mechanical load testing. Figure 23 reveals that the highest tensile stress is to be expected at the location of the contact joints between cells and metal foil.

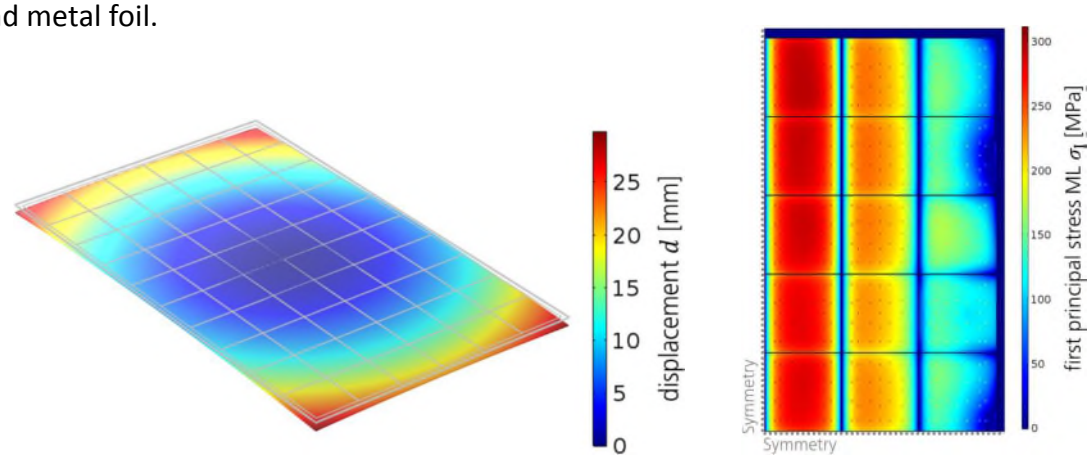


Figure 23: Bending of the laminate after lamination, the grey grid indicates the undeformed laminate (left). First principal stress σI on the rear side of the solar cells at 2400 Pa mechanical push load (right)

Impact of thin wafers on module costs

The ultimate way to create thin crystalline kerf free Si wafers is epitaxial growth of silicon on a parent substrate (also Si) and the primary technology of choice within CHEETAH . Thus, this technology was taken as a basis for cost calculations to reveal the potential for cost reduction. Figure 24 illustrates the impact of the wafer costs on total module costs, based on 120 µm thick wafers. This thickness is considered to be largely compatible with current cell and module processing (SHJ and BC), and require only minor adaptations. The cost reduction when using epitaxial wafers can amount to 21 % compared to state of the art module costs (IBC) as a selected benchmark in 2015.

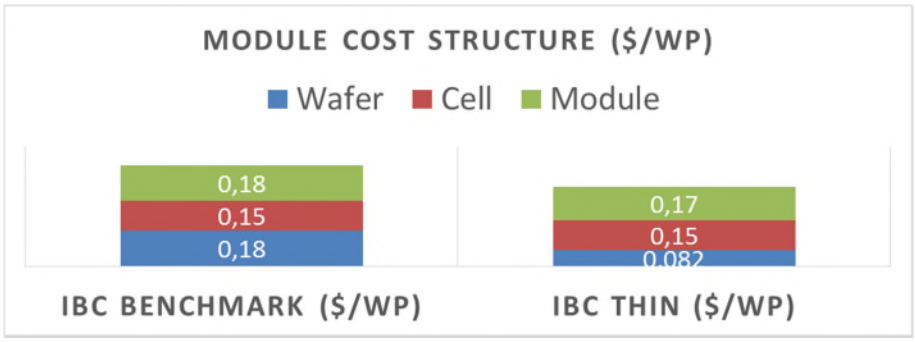


Figure 24: Cost structure of benchmark 2015 IBC module (left) and optimized with thin wafers (right), featuring costs for wafer, cell processing and module manufacturing

Also, compared to the current commercial module production costs of 0.36 $/Wp (0.16 $/Wp being the cost of the wafer), the projected cost reduction from 0.16 for cut wafers to 0.08 $/Wp for epitaxial wafers would be substantial, amounting to more than 21 % of the current module costs.

Life cycle assessment

A life cycle assessment (LCA) has revealed a substantially lower embodied energy of epitaxial wafers compared to cut wafers. This results in a potential reduction of the energy payback time (EPBT) from 0.98 year for current commercial benchmark modules (standard thickness 180 µm) to 0,56 year for the epitaxial wafer based module (assuming 100 µm wafer thickness) under Southern Europe irradiation conditions.

Conclusion

This activity has achieved the following results vs targets:

- Development of module manufacturing process suitable for ultrathin wafers target 40-80 micron), with yield of process > 90% and cell to module loss demonstrated to be less than 1%: we reached the target of **80 micron**, with **yield of process of 100%**, and cell to module loss less **than 1%.**
- Demonstration of an improved environmental profile in terms of energy payback time and carbon footprint: we successfully demonstrated the feasibility of **a reduction of 30 %** in energy payback time.
- Demonstration of a cost reduction (from cost of ownership calculation) of **~20 %** vs SoA was demonstrated to be feasible.
- Successful implementation of module interconnection schemes for thin film solar modules using 3D device design and micro-concentrators: this challenge was achieved with proven feasibility of 16% module efficiency. **The demonstrated contacting scheme should allow for simple and low-cost encapsulation**.

2.3.8 Advanced light management for thin-film PV cells and modules

Thin-film photovoltaics have brought a significant step forward in terms of reduced consumption of solar cell base material. The persistent goal of decreased fabrication cost and increased production capacity, however, still asks for "less material, higher efficiency". In this regard the two thin-film PV technologies of liquid phase crystallized silicon (LPC-Si) and chalcopyrite ($Cu(In,Ga)Se_2$ – CIGS) together with kesterite ($Cu_2ZnSn(S,Se)_4$ – CZTS) material were developed further by reducing absorber dimensions and applying advanced concepts for light management.

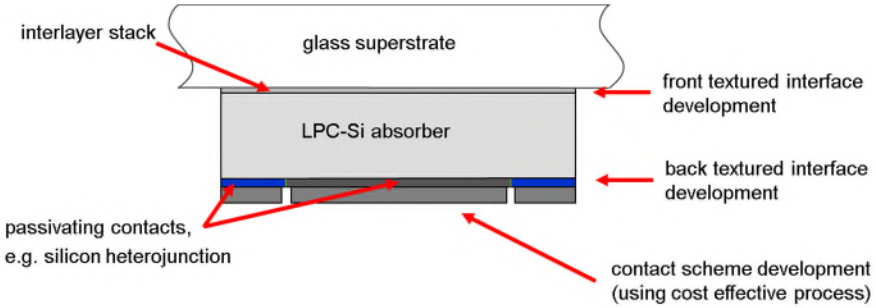


Figure 25: Overview on approaches for photonic concepts enhancing absorption in LPC-Si solar cells.

For LPC-Si, ultra-thin absorbers (thickness less than 10 µm) were used and nanophotonic concepts developed to allow for light trapping without deteriorating the electrical performance. Novel, cost-effective contacting schemes, that enable up-scalable module fabrication, were developed. In the case of CIGS, material reduction was pushed even further by restricting the absorber to micrometer size in the lateral dimension and the coverage to about 1 - 15%. To direct the incident sun light onto the small solar cells, concentrator optics were added leading to micro concentrator devices. Compared to the macroscopic concentrator PV system, this microscopic counterpart offers improved heat dissipation and a much more compact module design. For both material systems, the proof-of-concept of the novel designs was achieved, laying the basis for further development, which can lead to transfer on industrial level.

Nanophotonic concepts for absorption enhancement in LPC-Si solar cells

The very low absorber thickness (≤10 µm) of the LPC-Si solar cell requires the implementation of a light trapping scheme at front and back interface to maximize light absorption (see Figure 25). Such light trapping scheme needs to be compatible with the production process of the cell. This means, on the one hand, that the light trapping structures at the front interface have to withstand the deposition and crystallization process of the LPC-Si. Furthermore, the crystallization of the silicon on top of the light trapping structure has to lead to defect-free material properties. This is realized by either periodic, sinusoidal textures[1] with moderate texture heights or by "smooth anti-reflective three-dimensional textures" (SMART[2]), where the texture is covered by TiO_x to fill the voids between the interface structures. As the flexibility of implemented front-side textures is technologically limited, additional and independent back-side textures where developed. Such textures where implemented as "post-passivation light trapping

[1] G. Köppel et al. *Nanoscale* **8** 8722 (2016)
[2] D. Eisenhauer et al. *Scientific Reports* **7** 2658 (2017)

back contacts"[3], which where optically attached to the device but electrically decoupled to maintain the passivation and contacting scheme.

The efficiency potential of the LPC-Si technology was demonstrated by using a full emitter cell structure, which results in a power conversion efficiency of 15.9% on a cell area of 0.1 cm². As such a cell contacting scheme is not applicable for serial interconnection, it cannot be scaled up. Instead, an interdigitated back contact (IBC) scheme was also applied that can in principle be integrated into large area module devices. On such IBC structure, efficiencies of up to 13.2% were realized.

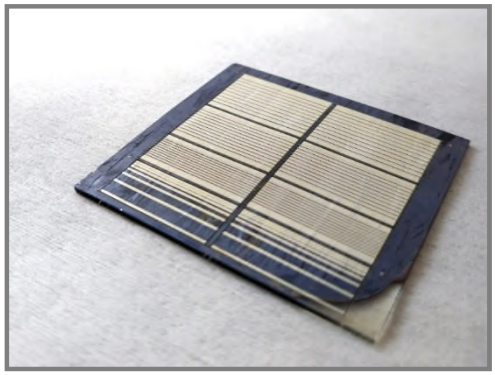


Figure 26: Picture of the fabricated LPC-Si solar cell (back side).

In order to technologically improve the back contacting scheme, tunnelling heterocontacts were developed for LPC-Si solar cells, which have the potential to reduce the costs compared to the complex process steps of common IBC technology. The tunnelling heterocontacts were already validated on mono c-Si based cells with 9 cm² cells and an efficiency of more than 22.5%[4]. The process was adapted to the LPC-Si solar cells. Different mini-modules were successfully prepared on a sample of 5x5 cm² area (Figure 26). An alternative way of a direct laser lithography process for IBC or module fabrication was developed which avoids mask lithography, is flexible on the desired design and cost effective.

Besides the development of highly-efficient LPC-Si solar cells and modules, the analysis of the electrical loss mechanism is of particular importance, as the devices still suffer from defects in the absorber layer (in particular when deposited on textured superstrates) and lack of passivation quality. Therefore, a nanoscopic optoelectronic investigation was performed by combining scanning near-field optical microscopy and photocurrent measurement. Thereby, a detailed insight into the optical as well as the electrical limitations was provided. It could be demonstrated that nano-pillar textures at the front side of LPC-Si solar cells lead to a significant reduction of photocurrent caused by local defect formation. In this way, the characterization on the nanoscale can support the choice of adequate textures.

Microconcentrator solar cells based on CIGS and CZTS

The proof-of-principle of efficiency enhancement by microconcentrator solar cells started from high quality planar CIGS material, which was restricted horizontally by mechanical scribing or etching. In the example leading to the results depicted in Figure 27 the front window layers were etched off except for a small area of 0.06 mm² defining the micro solar cell. The efficiency increased beyond 22.5% at 100 suns, corresponding to a 4% absolute efficiency rise compared to the performance of this cell under one sun[5]. The enhancement is mainly originating from the

[3] M. Smeets et al. *Nanoscale* **8** 18726 (2016)
[4] A. Tomasi et al. *Nat. Energy* **2** 17062 (2017)
[5] E. Lotter et al. *Proc. EU-PVSEC* **Munich** (2016)

logarithmic gain in open circuit voltage, which however may meet limitations at lower concentration levels already in the case of lower quality material.

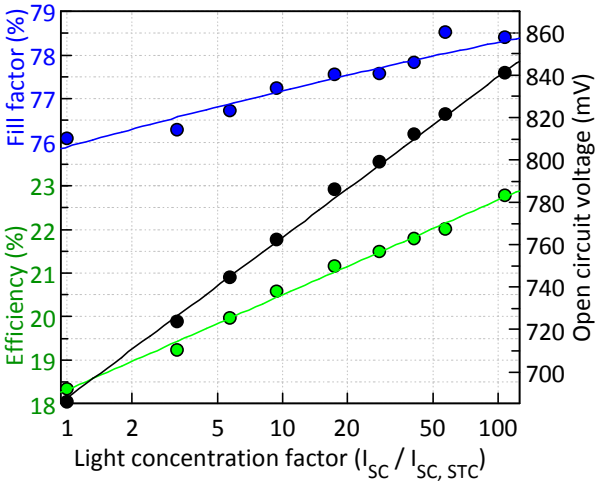


Figure 27: Performance of 0.06 mm2 micro cell obtained in top-down approach from planar CIGS absorber.

Nevertheless, also for inkjet-printed CIGSe absorbers, reaching an efficiency of 11.3% as planar films[6], an enhancement of micro cells, fabricated as described above, could be shown with light concentration[7]. In contrast to the top-down approaches of restricting planar reference material, inkjet-printing can also offer the opportunity of local material deposition and hence material reduction.

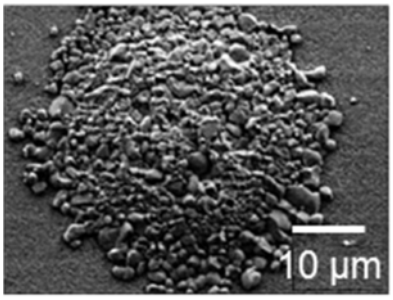


Figure 28: CIS micro absorber fabricated by local growth from In island in bottom-up approach.

For true material saving, bottom-up concepts were followed, e.g. the local CIS growth from indium droplets. Figure 28 depicts such an absorber which was obtained from an indium island self-assembled on a laser-patterned site on the molybdenum substrate. Upon addition of a planar copper layer and selenization, $CuInSe_2$ formed as well as excess copperselenides, which could be removed by etching. Micro absorbers fabricated in this way revealed structural and opto-electronic properties similar to planar reference material[8]. Furthermore, in a parallel interconnection scheme they showed a clear diode characteristic and efficiency enhancement under light concentration.

An integrated micro concentrator device requires the addition of concentrator lenses for focusing the incident sun light onto the small solar cells. With the idea of proposing a single technology to fabricate the integrated device, a printing process for concentrator optics was developed. By drop-casting of PMMA solution millimeter-sized lenses could be obtained[9] and an optical efficiency exceeding 90% observed. The dimensions of few mm diameter that could be reached make these optical elements suitable for combination with micrometer-sized solar cells to obtain low and medium concentration levels.

Even though the concentration of sun light allows efficiency enhancement, this is restricted to the direct part of the incident radiation. In order to make use of all light components, a concept was developed that enables the joint exploitation of direct and diffused irradiation. For this purpose CIGS micro cells were aligned in the focal positions of the concentrator lenses, whereas the areas in between were filled with cheap, e.g. CZTS material[7]. CZTS has the benefit of

[6] X. Lin et al. *Energy & Environmental Science* **9** 2037 (2016)
[7] M. Schmid et al. *Proc. EU-PVSEC* **Amsterdam** (2017)
[8] B. Heidmann et al. *Materials Today Energy* **6** 238 (2017)
[9] F. Loffredo et al. *Proc. EU-PVSEC* **Amsterdam** (2017)

enhanced fill factor with reduced illumination and is thus performing better under weak light making it predestined for integration as a spacer layer for diffuse light absorption. Figure 30 shows the prototype of such a combined device.

Figure 30 Prototype of combined direct-diffuse microconcentrator device with CIGS in the focal spots of the concentrator lenses and CZTS in the spacings.

In order to achieve controlled alignment of the concentrator lens array on the micro solar cells, a sun simulator equipped with a hexapod has been developed optimizing the relative position with respect to maximum current and thus power.

For the integrated interconnection of micro-cells on a micro-concentrator module an isolation barrier between front and back contact is required in areas where no absorber layer is present. For this purpose Al2O3 layers have been deposited and laser-patterned adequately, see Figure 29. Micro-cell modules have been fabricated in geometries designed for one- and two-dimensional concentration. The performance of the interconnected cells was estimated to exceed 17% at 60 suns.

Figure 29: Array of 67 rows made up of 21 interconnected cells each. Each cell has a total size of 1x1 mm² and an active area of ≈ 100 x 100 µm², designed for 100x 2D-concentration.

Thin film module developments

Helmholtz Zentrum Berlin (HZB) in collaboration with the project partners provided functional, interconnected CIGSe micro-concentrator modules, demonstrating the benefits of concentrating light on chalcopyrite solar cells. Concentrating light enables a device efficiency increase but also substantial material savings, reducing the ecological footprint.

The most promising scheme to achieve the required monolithic interconnection has been selected. By employing laser technology and mechanical approaches, the various material layers composing CIGSe solar cells were structured for light concentrating photovoltaic devices, without drastically changing state-of-the-art CIGSe module manufacturing. Commercially available lenses were used to concentrate the incident light onto each interconnected cell in the device. In Figure 31 a schematic overview of the interconnection and a completed 4 cells module are shown.

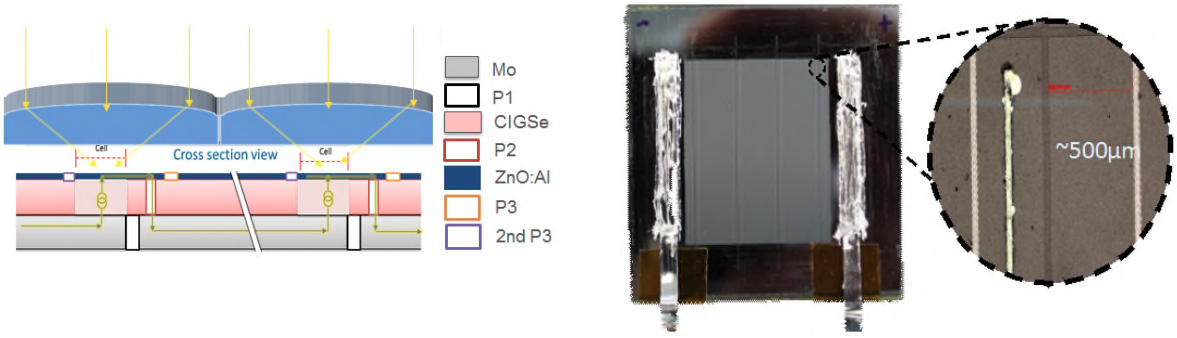


Figure 31: Interconnection scheme and device model (left), interconnected module (right).

The main results obtained from the produced modules show a concentration of 5.8 for the incident light. This increased the efficiency of the module from 14.4 to 17.2 %, which represents a relative performance increase of nearly 19%.

The activity successfully achieved the following results vs targets:

- Efficiency reached for c-Si thin-film solar cell with new photonic light enhancement ("flat grating" or "nano-patterning" as percentage of efficiency goal (15% in 12/2017)): 15.9% were nicely obtained by HZB;
- Efficiency increase of CIGS micro concentrator solar modules by implementation of a bifunctional spacer based on a semi-transparent CZTS mono grain PV module: two prototypes of combined CIGSe (direct) – CZTS (diffuse) device were successfully achieved, the second one showing improved contacting and alignment.
- Efficiency reached for CIGS micro solar cell under concentration as percentage of efficiency goal: starting from 22%, we finally succeeded 105% (efficiency: 23% @ 100 suns, etched window) by ZSW, and 83% (efficiency: 18.25% @ 50 suns, shaded absorber 110 nm diameter) by HZB.

2.3.9 Very low-cost OPV

Packaging of emerging photovoltaics (PVs), such as organic or perovskite PV constitutes a significant portion in the total cost of the technology.[10] Thus, an efficient way to reduce further the cost of such PVs is to develop cheaper alternatives to the current expensive packaging. To be able to do so, it is important to improve both the intrinsic stability of the device itself and the weak links in the packaging geometry. This will allow easing the requirements for the barrier and hence substituting the expensive ultrabarriers with cheaper alternatives.

This was addressed through three main activities in the project:

- Advanced characterisation of device to identify pitfalls limiting stability
- Improving intrinsic stability
- Optimising packaging procedure

[10] Sol. Energ. Mat. Sol. Cells 120 (2014) 692

Advanced characterisation

A characterisation metrics was developed for assessing the intrinsic stability of the devices by monitoring and benchmarking a large set of parameters, while ageing the samples under controlled atmosphere. For this purpose, a chamber with multiple individually controlled compartments was utilised and five environmental stresses/conditions were applied: dark, light, oxygen, water, mix. Characterisation of the samples was conducted via combined IV (Current Voltage) tracing, EQE (External Quantum Efficiency) measurements and LBIC (Light Beam Induced Current) analyses. The approach allowed categorising the intrinsic ageing mechanisms for devices with various configurations and identifying the most stable materials/devices. One of the main observations was that the difference in stability for various polymer-based samples was significantly less compared to the difference between stresses, suggesting that active materials may not be the main limiting factor in the device stability (Figure 32).

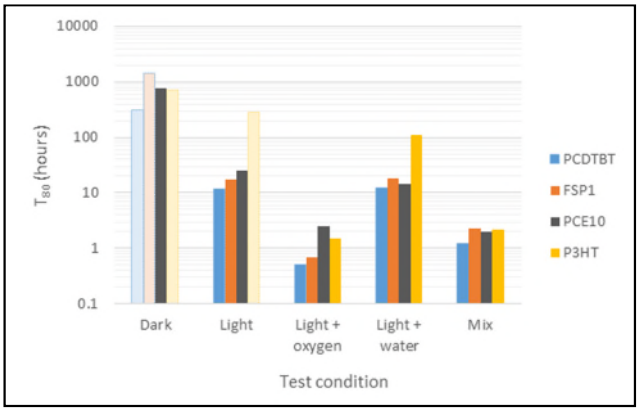


Figure 32 Degradation metrics of each polymer under each test condition. T_{80}, time taken for device maximum power to drop by 20 %.

With the very dynamic ageing behaviour of emerging PV it is also challenging to identify the lifetime T_{80} (time taken for device performance to drop by 20%) based on ageing curves of varying nature. An algorithm was developed that applied a set of filtering and fitting steps to the curves to accurately determine the ageing rate of the device both at the initial fast ageing stage and at the more stabilised second stage.[11] Based on this, the algorithm then determined a starting point for each stage and calculated lifetime values T_{80} and T_{S80} for the two stages of the curve, respectively (in accordance with pre-normative ISOS,testing guidelines, an International Organization for Standardization).[12] In particular, for the second stage the starting point was chosen such that the produced energy by the device over the T_{S80} lifetime span was maximal. This enabled reproducible determination of lifetime value for any devices with varying ageing curves, fair comparison of lifetime among large set of samples and benchmarking against literature database developed during the project.[13]

Intrinsic stability

To determine the weakest links in the intrinsic device stability and their effect on overall stability, several device components were investigated. In particular, devices with nine donor materials were manufactured, optimised and subjected to lifetime studies (indoor ISOS-L-2 soaking, a standardized solar cell) to determine the effect of these on device stability. The samples were laminated in either polyethylene terephthalate (PET) or commercial ultrabarrier with UV filter (UB). When comparing the devices with different donors against the well-established P3HT

[11] Small Methods 2017, 1700285
[12] Sol. Energ. Mat. Sol. Cells 95 (2011) 1253
[13] Adv. Energy Mater. 6 (2016) 1600910

polymer in terms of device stability, two materials outperformed P3HT by a factor of 2-3 in the case when devices were packaged in PET (Figure 33). However, when UB was utilised for packaging, the performance of all donors virtually evened out. The reason was ascribed to the fact that because PET does not filter UV component in the light, the donors that are less sensitive to UV, outperformed P3HT, while in the case of UB with UV filter UV stability of the outperforming donors was no longer advantageous. Overall, in line with results presented in previous paragraph donor materials proved not to play the biggest role in limiting device stability.

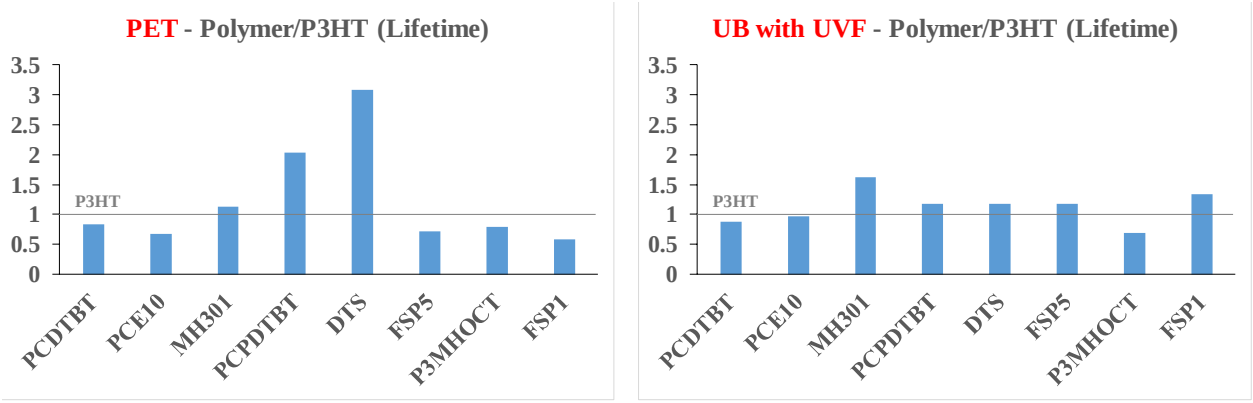


Figure 33 Lifetime ratio between devices with polymer or reference P3HT for devices packaged in PET (left) and in ultrabarrier with UV filter (right) measured according to ISOS-L-2 conditions.

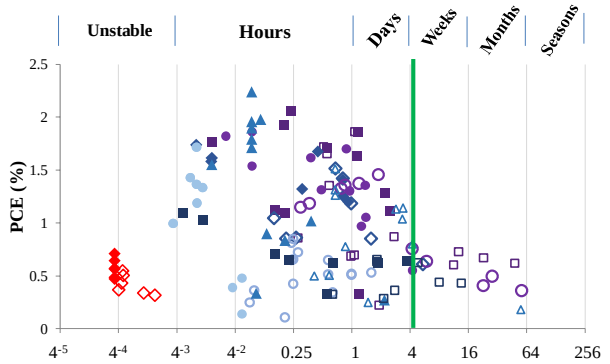


Figure 34 Starting efficiency versus device lifetime distributed along the time blocks. Solid and open labels represent the lifetime at the initial fast ageing stage and at the stabilised stage, respectively

PEDOT:PSS polymer is traditionally being used in OPV as a hole transporting layer due to its easy processability and high conductivity. Nevertheless, *PEDOT:PSS* is known to be very hydrophilic leading to reduction of device lifetime when exposed to environment.[14] Since, alternative materials with comparable properties have not been found yet, reduction in *PEDOT:PSS* layer thickness was carried out instead. This was done without sacrificing the electrical properties of the layer and the function of protecting the active layer from the printed top electrode. The resulting stability of devices encapsulated in UB was improved by a factor of five when thinner hole transport layer was used.

Fullerene free acceptor materials have recently been identified as a promising approach for increasing OPV efficiency to more than 15% and prolonging the device lifetime. Several acceptors were investigated in this project with the target to prolong the lifetime of devices. In particular, a specific fullerene-free acceptor, *O-IDTBR,* led to device efficiencies of close to 10% and twice-

[14] Org. Electron. 13 (2012) 432

longer lifetime in inert atmosphere under elevated 85°C temperature.[15] Another set of fullerene-free acceptors ITIC, a indacenodithiophene-based small molecule, showed efficiencies beyond 10% with an organic polymer donor named *PCE12* and significantly reduced *burn in* under light tests in inert atmosphere. Nevertheless, air stability of these materials is yet to be demonstrated. An alternative approach to improving the intrinsic stability of devices is introducing barrier layers in the device structure during device processing, prior to lamination. In order to explore this, direct sputtering of protective layers on OPVs was carried out. For this purpose, Si_2N_2O was identified as the best candidate due to high transparency and good barrier properties. The protective layer was deposited with varying thicknesses directly onto organic solar cells using chemical vapour deposition technique and the samples were tested for lifetime under indoor light soaking. The resulting device stability increased from unstable for unprotected devices to several months of stability for devices with 150nm (and above) protective Si_2N_2O layer, as is demonstrated in Figure 34 where the starting efficiencies of protected devices against lifetime, distributed along the time blocks, is shown. Nevertheless, a strong *burn in* was present for all the samples and thus, the prolonged stability was achieved for samples with significantly reduced efficiencies. The reason was ascribed to strong edge diffusion and roughness of the devices. The former can be eliminated with the additional lamination of the devices with a plastic film, while the latter is related to smoothing the top electrode.

Extrinsic stability: optimising packaging

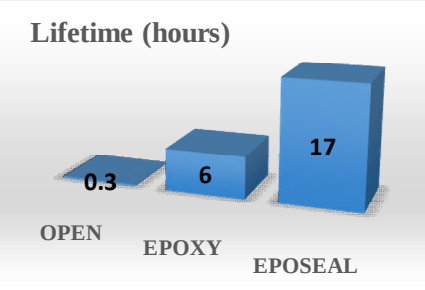


Figure 35 Comparison of lifetimes for samples with and without protective layer of adhesive

Apart from intrinsic stability, pitfalls in the lamination itself can also drastically reduce the stability of devices. Thus, the weakest links in lamination process were investigated and addressed as well. In particular, delamination and edge diffusion of environmental agents through adhesive has been identified as a major source for device degradation. Thus, to fortify the adhesive mixtures of conventional epoxies with water resistive compounds was explored. In particular, mixing silica gel with UV curable conventional epoxy (named *eposeal*) resulted in significant improvement of the resistivity of water permeation through the layer. When samples were protected by a layer of *eposeal* the lifetime was improved by more than an order of magnitude compared to unprotected devices (Figure 35). Laminating identical samples with PET foil has led to significant stability improvement compared to conventional cells without protective layer.

Outline optimisations in the device packaging proved to be another efficient method for prolonging the lifetime of the devices. In particular, the electrical contacts of the device were extended further from the active layer by using conductive tapes and packaging was performed on the entire device including the extended contacts. The contacts were accessed by making holes in the lamination on the extended electrodes. This has led to significant extension of the diffusion pass of environmental agents into the device via contacts and thus prolonged the

[15] Adv. Mater. 2017, 29, 1701156

lifetime of the devices. As a result, when the optimised samples were exposed to outdoor ageing on a stand still platform, after initial rapid *burn in* the performance stabilised and showed no further degradation after 1.5 years (Figure 36).

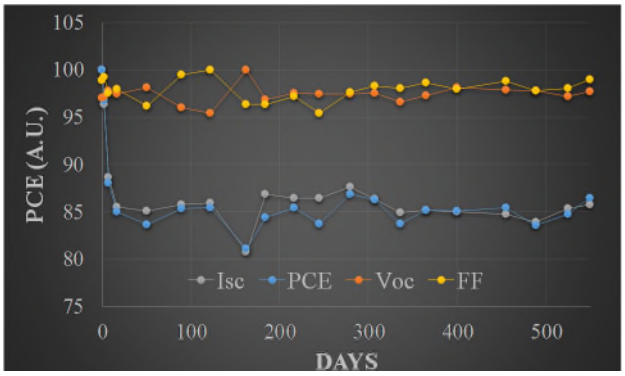


Figure 36 Performance of two cells tested in outdoor conditions, while mounted on standstill platform (Denmark)

To benchmark the stability of the samples with different packaging configurations, a large number of devices were tested under ISOS-L-2 indoor light soaking and the lifetime was calculated. In particular, the studies included unprotected devices (*OPEN*), devices protected by sputtered barrier layer (tested under light with full spectrum – *SPUTT* or tested under UV filtered light – *SPUTT+UVF*) or devices laminated with PET or with UB + UV filter (*UBUV*). The resulting lifetime distributions are plotted against the average lifetimes of literature reports database (Figure 37)[13].The upper and lower plots correspond to lifetime extracted from the initial *burn in* stage and from stabilised stage of the curves respectively. It was revealed that the initial *burn in* is not affected significantly by the packaging materials, which confirms that the initial fast ageing is associated with intrinsic ageing mechanisms in the device. Clear difference however was observed for the stabilised parts of the curves for the different packaging procedure. In particular, for UBUV the longest lifetime could be achieved reaching several months of stability under indoor continuous light soaking and outperforming the literature average. In the case of sputtering of barrier layers the achieved stability was in the range similar to PET and even outperforming it when the samples were tested under UV filtered light, which shows the promising potential of the approach.

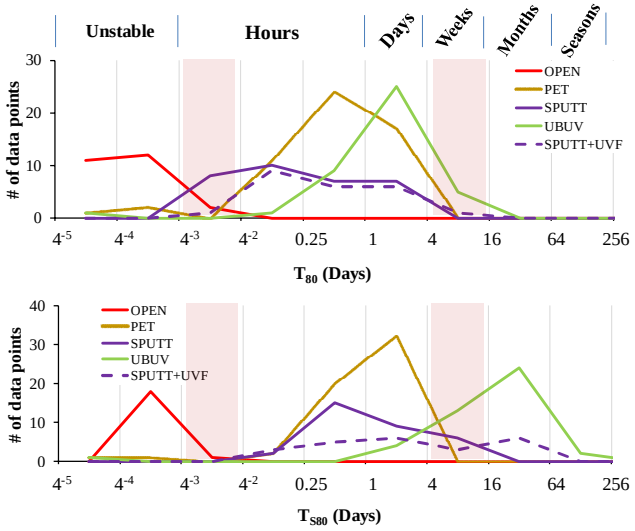


Figure 37 Distribution of lifetimes of devices with different protection configurations. The time-blocks highlighted with red correspond to the literature average for the unprotected and encapsulated samples.

At the final stage of the project, following results and ley learning were achieved, opening the doors to further research:

- CHEETAH successfully reached the challenge of 100 hours with sputtered transparent layer, 10.000 hours with optimized packaging, achieved with low efficiency (1%) devices. This anyway opens an opportunity for substituting the expensive ultrabarriers with cheaper PET alternatives thus lowering the cost of the technology even further.
- Material screening setup was developed and an online tool combined with lifetime database was established. The former allows rapidly identifying a large set of ageing mechanisms in devices and linking inherent stability to complete device lifetime, while the latter enables extrapolation and reproducibly determines lifetime values from ageing patterns.
- Directly sputtered layer and optimized packaging extended the lifetime: as lifetime studies of combination of PET and sputtered barrier layers were not completed, we cannot clearly state the question of improved cost of ownership. This will thus require future steps including, lifetime studies of PET + sputted layers, comparison of these with ultrabarriers, conducting thorough analyses of costs associated with sputtering of protective layers for large industrial scale volume production and identifying the true potential of the approach.
- Fullerene free acceptors show improved stability and thus reduced energy return of investment: unfortunately, cost reduction could only be partly estimated since the materials are not established in the market yet. A true estimation of the cost reduction may be possible if the industries providing the materials today will reveal details and estimations of the market potential.

2.4. Potential impact and dissemination and exploitation of results

2.4.1 Potential impact

European context

Europe has invoked the Strategic Energy Technology (SET)-Plan to design and implement an energy technology policy for Europe to accelerate the development and deployment of low-carbon technologies.

PV has emerged as one of the key sources of clean energy at global scale and could play a key role in realizing the SET plan goals. It stands out from other renewable technologies in terms both of the broad range of technology options and of the scope to significantly improve energy conversion efficiency in the coming years. In several European countries PV already provides more than 5% of the annual electricity demand, a level originally anticipated to occur only after 2020. It is estimated that PV has the potential to meet 8% of the EU electricity demand in 2020 and 15% in 2030. If successful, this would result in a significant contribution to the reduction of CO2 emissions, since the carbon footprint of PV systems is at least 10 times lower than that of fossil fuel-based electricity, with no CO2 emissions during operation.

Between 2005 and 2010, the PV sector was challenged by the European Commission to set ambitious targets for the PV Sector and this resulted in the Solar Europe Industry initiative (SEII) developed by SolarPower Europe (formerly EPIA) and the PV Technology platform (now ETIP). This initiative outlined the R&D efforts needed to enable ambitious market deployment and a prominent role of the European PV industry.

However, the global PV industry has dramatically changed since then, as cell and module manufacturing capacity almost completely moved to Asia. It led to stagnating prices, production overcapacities and a global crisis in PV. From an initially strong global position Europe lost its market share despite the enormous market growth.

Despite all these difficulties, the EU PV industry is still well positioned along the value chain, especially in the sectors of equipment manufacturing, inverter manufacturing, project business and installation. In addition, Europe still has a very large cluster of research institutes and academia on PV with scientific leadership roles.

As the worldwide growth projection of PV are still very high with an increasing demand for special application areas like BIPV (Building-integrated photovoltaics), Infrastructure integrated PV, Europe should be able to profit from these new opportunities and play again an active role in this sector. This was recognized by the European Commission and led to the formulation of a new strategy that build on the existing PV industrial and R&I base in Europe, with a clear view to build up the complete value chain and bringing cell and module manufacturing back to Europe with a focus un new innovative technologies and products. Ambitious targets in terms of system cost and performance, reliability have been formulated after consultancy with all the relevant stakeholders like the ETIP-PV, EERA-PV and other European platforms and are defined in the SET plan, declaration of intent.

To achieve these target goals and ensure again a strong industrial position for Europe in all parts of the value chain, Europe must continue to invest in Research and Innovation, in industrial production and other activities. This can only be realized by a coordinated approach at the complete European level. This has recently resulted in the SET-Plan implementation plan for PV, produced by the Temporary Working Group comprising representatives of the EU Member States, industry, the research sector (among which EERA-PV) and academia. This implementation plan describes in general terms the (non-) technological R&D activities needed to achieve the overall strategic targets as defined in the SET plan Declaration of Intent and should form an important basis for all the coordinative efforts and definition of future European research calls.

Impact of EERA-PV

It is within this historic context that the European Energy Research Alliance (EERA) was established. This is an alliance of European public research centres and universities and considered as one of the cornerstones of the European Strategic Energy Technology Plan (SET-Plan) mentioned above. There are several EERA's with Joint programmes for Wind Energy, smart grids, Concentrated Power and many more. The EERA on PV was established in 2010 and was formed by clustering the key research institutes active in PV.

It has the general goal to support the PV sector in support of the SET plan through strengthening the innovation power of the R&D community by:

- Developing high-level technology and foster manufacturing capabilities so that Europe can regain and build up own manufacturing capacity in all parts of the PV value chain in due time.
- Overcoming the existing fragmentation of PV R&D in Europe, and to intensify the collaboration and by aligning the national R&D programmes

Therefore, a Joint Programme was prepared for PV starting with four technology-related subprogrammes on Si materials, Si modules, thin film PV, OPV and one coordinative subprogram on training, education and access to infrastructures. Since the execution of the joint programme mainly relied on existing, national funding instrument, some joined projects were needed to fulfil important objectives of this programme. SOPHIA project (http://www.sophia-ri.eu/) was the first of its kind with a strong focus on access and sharing of research infrastructure, mobility exchange.

The CHEETAH project is the second project that was initiated by EERA-PV. It got the opportunity to subscribe for a tender for Integrated Research Projects, with the aim to overcome technology bottlenecks in PV technology that were identified in the EERA PV Joint Program (JP) and create the tools for long-term collaboration and training and education for young scientists. Together with Integrated Research Projects (IRP) on Wind, Smart Grid and concentrated solar power this project was selected for funding in 2013.

In the meantime, the EERA-PV JP restructured itself to be aligned with the changing PV landscape and additional subprograms on Concentrated PV, reliability and systems and operation were added to the Joint program. EERA – PV was consulted in the definition of the new SET plan targets as defined in the declaration of intent and was represented in the temporary working group

defining the SET implementation plan, showing its impact on the decision-making processes regarding the strategic choices Europe is presently making to rebuild their position.

Impact of CHEETAH's technology innovations

The main technological achievements of the project are extensively summarized earlier in this report. The TRL associated with these innovations ranged from 3 to 6/7. One of the aims in the project was to receive feedback from the European PV industry whether these innovations are at a level that it could be taken up or implemented by the industry. The link between the CHEETAH research and industry was provided by the organization of dedicated webinar meetings and public events as was pointed earlier in this report. The main feedback that was collected regarding the potential impact of the CHEETAH achievements per technology cluster are listed below:

Crystalline Silicon

The insights and discussions at the European Solar Technology Forum (the CHEETAH project's final public event) on 30 November, 2017 in Berlin showed that in the current market situation there is not a great drive towards thinner silicon wafers. Silicon is relatively cheap, production yield through the production chain needs to be very high, and efficiency cannot be lost due to poor light management in the cells. Yet the solutions are available already to go towards low cost 100 µm wafers. Wafers at 80-90 µm thicknesses developed in the CHEETAH project, whether they are thinned diamond sawed wafers or thick epi-wafers, still represent a revolutionary jump in technology development for the cell producers. High CAPEX cost and high investments for Epi-wafer lines, technology that has not proven itself yet in volume production and a constantly and aggressively moving wafer cost target makes for a high barrier for the commercial introduction of this technology. Already the cost of Chinese modules is at or near the 30 USCent/W level, which was the goal of the CHEETAH project. The benefits of thin wafer technologies are, however, still very interesting. Thin wafers will reduce the environmental footprint of solar cell use by reducing the amount of material, energy and waste, which is an argument that will only become more important in the future. These reductions will also enable cost reductions when production is at scale. Thin wafers may enable lightweight modules and flexible modules and should therefore lend themselves especially well to BIPV products. These possible niche products may currently be the only way to introduce Epi-wafers to market. These markets may give Epi-wafers a chance to grow in volume so that they become increasingly competitive. Moreover, one may envision parallels with the introduction of other technologies in PV, e.g. p type Passivated Emitter Rear Contact (PERC) cells.

Thin film PV

The insights and discussions at the European Solar Technology Forum (the CHEETAH project's final public event) on 30 November, 2017, in Berlin led to the conclusion that the results are interesting but there is a big gap between the project results and any potential industrial exploitation. The main reason is that today in the PV industry, the efficiency is the most important factor. Cell efficiencies lower than 20% are not interesting enough for industry. In addition, the cost reduction is another important aspect and nowadays the cost should be or aim to 20 cents

€/Wp. A possible application of the micro concentrator CIGSe concept is in building-integrated PV (BIPV) as “sunny windows”, using the diffused light for lighting and the rest for PV.

Emerging technologies like OPV and Perovskite PV

The insights and discussions at the European Solar Technology Forum (the CHEETAH project’s final public event) on 30 November, 2017, in Berlin led to the conclusion that the results and insights obtained on intrinsic stability and packaging of OPV devices are very relevant for the Perovskite PV research as well. It is generally agreed by the industrial experts that OPV’s do not have the position to compete with Silicon technology in the traditional applications of PV like energy power plants because of a too low performance. However, they could be used in niche applications where flexibility and freedom of design are most important application criteria like indoor energy harvesting, Internet of Things, battery-replacement (low-light), BIPV, automotive. Reliability is one of the key factors for commercial success and could be one of the potential showstoppers for a successful commercial uptake. Hence, it is of crucial importance to generate a better understanding of the correlation between intrinsic lifetime and product lifetime and modelling of accelerated lifetime is critical to demonstrating reliability to potential customers These learnings are extremely useful and can be used for the further development of the more efficient Perovskite PV, that uses similar materials, encapsulation strategies and production technologies (printing, coating). Especially when these perovskites will be integrated in high efficient tandem structures in combination with Silicon, the lifetime should be at the same level as of crystalline Si, i.e. 25 years outdoor stability.

2.4.2 Dissemination and exploitation of results

CHEETAH activities led to the following remarkable results:

- 15 thesis funded,
- 7 common papers (with at least 2 partners) were published,
- 47 peer-reviewed publications / conference proceedings were issued (+60% vs objective),
- 1.581 external and 577 CHEETAH participants registered to participate in 73 webinars offered in 28 different events of which in 2017, 957 external and 245 CHEETAH participated in 36 webinars offered in 19 different events;
- 2 books written,
- More than 240 dissemination and communication actions registered
- 13 exploitable results reported (2 commercial results) and 1 patent.

CHEETAH has then offered clear scientific & technical opportunities to disseminate to the various targeted communities and successfully implied most of partners. High level (quantity and quality) achievements constitute an impressive record of accomplishment of this project.

2.5. Consortium and contact information

Coordinator
Dr. Jan Kroon, ECN, j.kroon@ecn.nl
www.cheetah-project.eu

Partners

1. ECN, Stichting energieonderzoek Centrum Nederland, Netherlands
2. CEA-INES, Commissariat à l'énergie atomique et aux énergies alternatives, France
3. Fraunhofer, Fraunhofer Gesellschaft zur Foerderung der angewandten forschung e.v, Germany
4. DTU, Danmarks Tekniske Universitet, Denmark
5. Helmholtz-Zentrum Be, Helmholtz-Zentrum Berlin fur materialien une energie GmbH, Germany
6. Jülich, Forschungszentrum Juelich GmbH, Germany
7. AIT, Austrian Institute of Technology GmbH, Austria
8. ENEA, Agencia Nazionale per le nuove technologi, l'energia e lo svilippo economico sostenibile, Italy
9. EPFL, Ecole Polythechnique Fédérale de Lausanne, Switzerland
10. IFE, Institutt for Energiteknikk, Norway
11. Forschungsverbund Be, Forschungsverbund Berlin E.V, Germany
12. IMEC, Interuniversitair Micro-electronica Centrum VZW, Belgium
13. NPL, NPL Management Limited, United Kingdom
14. SINTEF, Stiftelsen SINTEF, Norway
15. Tallinna Tehnikaulik, Estonia
16. ZSW, Zentrum for Sonnenenergie und Wasserstoff Forschung Baden Wurttembergstiftung, Germany
17. LNEG, Laboratorio Nacional de Energia e Geologia I.P, Portugal
18. TOR VERGATA, universita Degli Studi di Roma Torvergata, Italy
19. METU, Middle East Technical University, Turkey
20. TECHNALIA, Fundacion Technalia Research & Innovation, Spain
21. UPM, Universidad Politecnica de Madrid, Spain
22. CENTRO DE INVESTIGAC, Centro de Investigaciones Energeticas, Medioambbientles y Technologicas CIEMAT
23. CRES, Center for Renewable Energy Sources and Savings, Greece
24. LU, Loughborough University, United Kingdom
25. EMPA, Eidgenoessische Materialpruefungs und Forschungsanstalt, Switzerland
26. Imperial, Imperial College of Science, Technology and Medicine, United Kingdom
27. JRC, Joint Research Centre - European Commission, Belgium
28. TUBITAK, Turkiye Bilimsel ve Teknolojik Arastirma Kurumu, Turkey
29. VTT, Teknologian Tutkimuskeskus VTT, Finland
30. UPVLC, Universitat Politecnica de Valencia, Spain
31. UNIMIB, Universita' Degli Studi di Milano-Bicocca, Italy
32. SolarPower Europe, Belgium
33. KIC SE, KIC Innoenergy SE, Netherlands
34. Ayming SAS, France

Acknowledgements

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement N° 609788 – CHEETAH.

Section 3 - Use and dissemination of foreground

3.1. Section A: Dissemination (PUBLIC)

3.1.1 List of scientific (peer-reviewed) publications (A1) – Public

Template A1: List of scientific (peer reviewed) publications, starting with the most important ones										
No	**DOI**	**Title**	**Main authors**	**Title of the periodical or the series**	**Number, date or frequency**	**Publisher**	**Place of public-cation**	**Date of publication**	**Relevant pages**	**Open access?**
1	10.1039/c7ee00286f	The impact of silicon solar cell architecture and cell interconnection on energy yield in hot & sunny climates	J. Haschke, J. P. Seif, Y. Riesen, A. Tomasi, J. Cattin, L. Tous, P. Choulat, M. Aleman, E. Cornagliotti, A. Uruena, R. Russell, F. Duerinckx, *et al.*	Energy & Environmental Science	10	The Royal Society of Chemistry	UK	22/03/2017	1196-1206	No
2	10.1016/j.mtener.2017.10.010	Local growth of CuInSe2 micro solar cells for concentrator application	B. Heidmann, F. Ringleb, K. Eylers, S. Levcenco, J. Bonse, S. Andree, J. Krüger, T. Unold, T. Boeck, M.Ch. Lux-Steiner, M. Schmid	Materials Today Energy	Vol. 6	Elsevier	UK	22/10/2017	238-247	No

No	DOI	Title	Main authors	Title of the periodical or the series	Number, date or frequency	Publisher	Place of public-cation	Date of publication	Relevant pages	Open access?
3	10.1002/aenm.201501208	Lifetime of organic photovoltaics: Status and predictions	Suren A. Gevorgyan, Morten V. Madsen, Bérenger Roth, Michael Corazza, Markus Hösel, *et al.*	Advanced Energy Materials	Vol. 6 / Issue 2	WILEY	USA	07/07/2015	N/A	No
4	10.1002/aenm.201600910	Baselines for Lifetime of Organic Solar Cells	Suren A. Gevorgyan, Nieves Espinosa, Laura Ciammaruchi, Bérenger Roth, *et al*.	Advanced Energy Materials	Vol 6	Wiley	Weinheim	22/08/2016	1600910 (1-9)	No
5	10.1039/C5NR08917D	Sinusoidal nanotextures for light management in silicon thin-film solar cells	G. Köppel, B. Rech, C. Becker	Nanoscale	Vol. 8, Issue 16	The Royal Society of Chemistry	UK	01/01/2016	8722-8728	No
6	10.1016/j.solmat.2014.10.049	Kerfless layer-transfer of thin epitaxial silicon foils using novel multiple layer porous silicon stacks with near 100% detachment yield and large minority carrier diffusion lengths	Hariharsudan Sivaramakrishnan Radhakrishnan, Roberto Martinia, Valerie Depauw, Kris Van Nieuwenhuysen, Twan Bearda, Ivan Gordon, Jozef Szlufcik, Jef Poortmans (IMEC)	Solar Energy Materials and Solar Cells	Vol 135	Elsevier	Amsterdam	20/11/2014	113-123	Yes

No	DOI	Title	Main authors	Title of the periodical or the series	Number, date or frequency	Publisher	Place of public-cation	Date of publication	Relevant pages	Open access?
7	10.1088/0022-3727/48/47/475109	Radiative recombination in Cu2ZnSnSe4 thin films with Cu deficiency and Zn Excess	M.V. Yakushev, J. Márquez-Prieto, I. Forbes, P.R. Edwards, V.D. Zhivulko, A.V. Mudryi, J. Krustok and R.W. Martin	Journal of Physics D: Applied Physics	Vol 48 / Issue 47	Institute of Physics Publishing	UK	02/12/2015	475109	No
8	http://dx.doi.org/10.1016/j.mssp.2015.04.055	Temperature dependent electroreflectance study of Cu2ZnSnSe4 solar cells	Jüri Krustok, Taavi Raadik, Maarja Grossberg, Sergio Giraldo, Markus Neuschitzer, Simon López-Marino, Edgardo Saucedo	Materials Science in Semiconductor Processing	Vol 39	Elsevier Limited	UK	29/04/2015	251-254	No
9	10.1063/1.4928747	22.5% efficient silicon heterojunction solar cell with molybdenum oxide hole collector	Jonas Geissbühler, Jérémie Werner, Silvia Martin de Nicolas, Loris Barraud, Aïcha Hessler-Wyser, Matthieu Despeisse, Sylvain Nicolay, Andrea Tomasi, Bjoern Niesen, Stefaan De Wolf, Christophe Ballif	Applied Physics Letters	Vol. 107 / Issue 8	American Institute of Physics Inc.	USA	24/08/2015	081601	Yes
10	10.1039/C5TC01624J	Synergetic Ehancement of organic solar cell thermal stability by wire bar coating and light processing	Ching-Hong Tan, Him Cheng Wong, Zhe Li, David G. Bucknall, James R. Durrant and João T. Cabral	Journal of Materials Chemistry C	Vol. 3 / Issue 37	Royal Society of Chemistry	UK	01/01/2015	9551-9558	Yes

No	DOI	Title	Main authors	Title of the periodical or the series	Number, date or frequency	Publisher	Place of public-cation	Date of publication	Relevant pages	Open access?
11	10.1016/j.solmat.2016.01.036	In-situ, long-term operational stability of organic photovoltaics for off-grid applications in Africa	Christopher J M Emmott, Davide Moia, Philip Sandwell, Nicholas Ekins-Daukes, Markus Hösel, Lukas Lukoschek, Charith Amarasinghe, Frederick C Krebs, and Jenny Nelson	Solar Energy Materials and Solar Cells	Volume 149	Elsevier	Netherlands	01/05/2016	284-293	No
12	http://dx.doi.org/10.1063/1.4943794	Regularly arranged indium islands on glass/molybdenum substrates upon femtosecond laser and PVD processing	F. Ringleb, K. Eylers, Th. Teubner, T. Boeck, C. Symietz, J. Bonse, S. Andree, J. Krüger, B. Heidmann, M. Schmid, and M. Lux-Steiner	Applied Physics Letters	Volume 108 / Issue 11	American Institute of Physics	USA	14/03/2016	111904	No
13	10.1002/adem.201600119	Slot die printed V2O5 as hole transport layer for flexible organic opto-electronics on 3D printed scaffolds: Performance and lifetime	Michail J. Beliatis, Martin Helgesen, Rafael García-Valverde, Bérenger Roth, Jon E. Carlé, Michael Corazza, Mikkel Jørgensen, Frederik C. Krebs, Suren A. Gevorgyan	Advanced Engineering Materials	Online publication date 23 MAY 2016	Wiley	Germany	01/08/2016	1494-1503	No
14	http://dx.doi.org/10.1063/1.4959988	Asymmetric Band Offsets in Silicon Heterojunction Solar Cells: Impact on Device Performance	Johannes Peter Seif, Deneb Menda, Antoine Descoeudres, Loris Barraud, Orhan Özdemir, Christophe Ballif and Stefaan De Wolf (EPFL)	Journal of Applied Physics	Vol. 120	American Institute of Physics Inc.	USA	07/08/2016	54501	Yes

No	DOI	Title	Main authors	Title of the periodical or the series	Number, date or frequency	Publisher	Place of public-cation	Date of publication	Relevant pages	Open access?
15	http://dx.doi.org/10.1016/j.apsusc.2015.09.094	p–n junction improvements of Cu2ZnSnS4/CdS monograin layer solar cells	M. Kauk-Kuusik, K. Timmo, M. Danilson, M. Altosaar, M. Grossberg, K. Ernits	Applied Surface Science	Vol. 357	Elsevier	Netherlands	01/12/2015	795-798	No
16	http://dx.doi.org/10.1016/j.solmat.2016.03.018	Impact of the selenisation temperature on the structural and optical properties of CZTSe absorbers	J. Márquez-Prieto, M.V. Yakushev, I. Forbes, J. Krustok, P.R. Edwards, V.D. Zhivulko, O.M. Borodavchenko, A.V. Mudryi, M. Dimitrievska, V. Izquerdo-Roca, N.M. Pearsall, and R.W. Martin	Solar Energy Materials and Solar Cells	Vol.152	Elsevier	Netherlands	01/08/2016	42-50	No
17	10.1088/0022-3727/49/8/085101	Temperature dependent electrical characterization of thin film Cu2ZnSnSe4 solar cells	E. Kask, J. Krustok, S. Giraldo, M. Neuschitzer, S. López-Marino and E. Saucedo	Journal of Physics D: Applied Physics	Vol. 49	IOP Publishing	UK	02/03/2016	85101	No
18	10.1051/epjpv/2016001	Solution-processed In2S3 buffer layer for chalcopyrite thin film solar cells	L. Wang, X. Lin, A. Ennaoui, C. Wolf, M.Ch. Lux-Steiner and R. Klenk	EPJ Photovoltaics	Volume 7			26.02.2016	70303-70308	Yes

No	DOI	Title	Main authors	Title of the periodical or the series	Number, date or frequency	Publisher	Place of public-cation	Date of publication	Relevant pages	Open access?
19	http://dx.doi.org/10.1016/j.physb.2016.12.011	Low temperature time resolved photoluminescence in ordered and disordered Cu2ZnSnS4 single crystals.	Raadik, T; Krustok, J.; Kauk-Kuusik, M; Timmo, K.; Grossberg M.; Ernits K.; Bleuse J.	Physica B: Condensed Matter	Vol 508	Elsevier	Netherlands	08/12/2016	47-50	No
20	http://dx.doi.org/10.1063/1.4972782	Optical study of local strain related disordering in CVD-grown MoSe2 monolayers.	Krustok, J.; Raadik, T.; Jaaniso, R.; Kiisk, V.; Sildos, I.; Marandi, M.; Komsa, H.-P.; Li, B.; Zhang, X.; Gong, Y.; and Ajayan, P.M.	Applied Physics Letters	Vol 109	American Institute of Physics	USA	20/12/2016	253106	No
21	10.1039/C5TC01624J	Synergetic enhancement of organic solar cell thermal stability by wire bar coating and light processing	Ching-Hong Tan, Him Cheng Wong, Zhe Li, David G. Bucknall, James R. Durrant and João T. Cabral	Journal of Materials Chemistry C	Volume 3	Royal Society of Chemistry	UK	13/08/2015	9551-9558	No
22	http://dx.doi.org/10.1364/OE.25.000A14	Fourier light scattering model for treating textures deeper than the wavelength	F. -J. Haug, M. Bräuninger, C. Ballif	Optics Express	Vol. 25	OSA	USA	03/01/2017	A14-A22	Yes

No	DOI	Title	Main authors	Title of the periodical or the series	Number, date or frequency	Publisher	Place of public-cation	Date of publication	Relevant pages	Open access?
23	10.1039/C6NR04960E	Post passivation light trapping back contacts for silicon wafer based photovoltaics	M. Smeets, K. Bittkau, F. Lentz, A. Richter, K. Ding, R. Carius, U. Rau, U.W. Paetzold	Nanoscale	Vol. 8, Issue 44	Royal Society of Chemistry	UK	21/10/2016	18726-18733	No
24	10.1038/s41598-017-02874-y	Smooth anti-reflective three-dimensional textures for liquid phase crystallized silicon thin-film solar cells on glass	David Eisenhauer, Grit Köppel, Klaus Jäger, Duote Chen, Oleksandra Shargaieva, Paul Sonntag, Daniel Amkreutz, Bernd Rech, and Christiane Becker	Scientific Reports	Vol. 7	Nature Publishing Group		01/06/2017	2658	Yes
25	10.1039/C7CP06783F	Effect of Topography-dependent Light Coupling through a Near-field Aperture on the Local Photocurrent of a Solar Cell	Zhao Cao, Markus Ermes, Stephan Lehnen, Reinhard Carius and Karsten Bittkau	Physical Chemistry Chemical Physics	Vol. 20	Royal Society of Chemistry	UK	14/01/2018	1098-1104	No
No	DOI	Title	Main authors	Title of the periodical or the series	Number, date or frequency	Publisher	Place of public-cation	Date of publication	Relevant pages	Open access?

No	DOI	Title	Main authors	Title of the periodical or the series	Number, date or frequency	Publisher	Place of public-cation	Date of publication	Relevant pages	Open access?
26	10.1016/j.solener.2016.05.040	Optical model for multilayer glazing systems: Experimental validation through the analytical prediction of encapsulation-induced variation of PV modules efficiency	Maider Machado, Tomás Baenas and Naiara Yurrita	Solar Energy	Solar Energy 135 (2016) 77-83	Elsevier	Netherlands	01/06/2016	77-83	Yes
27	http://dx.doi.org/10.1016/j.jallcom.2017.06.307	Modification of the optoelectronic properties of Cu2CdSnS4 through low-temperature annealing	M. Pilvet, M. Kauk-Kuusik, M. Grossberg, T. Raadik, V. Mikli, R. Traksmaa, J. Raudoja, K. Timmo, J. Krustok	Journal of Alloys and Compounds	723	Elsevier	Netherlands	30/06/2017	820-825	No
28	http://dx.doi.org/10.1016/j.solmat.2017.04.022	Influence of the copper content on the optical properties of CZTSe thin films	M.V. Yakusheva, M.A. Sulimov, J. Márquez-Prieto, I. Forbes, J. Krustok, P.R. Edwards, V.D. Zhivulko, O.M. Borodavchenko, A.V. Mudryi, R.W. Martin	Solar Energy Materials and Solar Cells	168	Elsevier	Netherlands	09/04/2017	69-77	No

No	DOI	Title	Main authors	Title of the periodical or the series	Number, date or frequency	Publisher	Place of public-cation	Date of publication	Relevant pages	Open access?
29	http://dx.doi.org/10.1063/1.4990657	Temperature dependent photoreflectance study of Cu2SnS3 thin films produced by pulsed laser deposition	T. Raadik, M. Grossberg, J. Krustok, M. Kauk-Kuusik, A. Crovetto, R. Bolt Ettlinger, O. Hansen, and J. Schou	Applied Physics Letters	110	American Instutite of Physics	USA	28/06/2017	261105	No
30	http://dx.doi.org/10.1016/j.tsf.2016.10.017	Influence of order-disorder in Cu2ZnSnS4 powders on the performance of monograin layer solar cells	K. Timmo, M. Kauk-Kuusik, M. Pilvet, T. Raadik, M. Altosaar, M. Danilson, M. Grossberg, J. Raudoja, K. Ernits	Thin Solid Films	633	Elsevier	Netherlands	08/10/2016	122-126	No
31	10.1088/1361-6463/aa8ac5	Thermal management approaches of Cu(Inx,Ga1−x)Se2 micro-solar cells	D. Sancho-Martinez, M. Schmid	Journal of Physics D: Applied Physics	vol. 50	IOP Publishing	UK	10/10/2017	445501	No
32	10.1063/1.4940392	Temperature dependence of hydrogenated amorphous silicon solar cell performances	Y. Riesen, M. Stuckelberger, F.-J. Haug, C. Ballif, N. Wyrsch	Journal of Applied Physics	119	American Institute of Physics	USA	27/01/2016	44505	No

No	DOI	Title	Main authors	Title of the periodical or the series	Number, date or frequency	Publisher	Place of public-cation	Date of publication	Relevant pages	Open access?
33	10.1002/smtd.201700285	A Novel Algorithm for Lifetime Extrapolation, Prediction and Estimation of Emerging PV Technologies	Antonio Rizzo, Andrea Cester, Morten V. Madsen, Frederik C. Krebs, and Suren A. Gevorgyan	Small Methods	Vol 2./Issue 1	Wiley	Germany	01/12/2017	eISSN: 1613-6829	No
34	10.1016/j.apsusc.2016.11.135	Growth and shape of indium islands on molybdenum at micro-roughened spots created by femtosecond laser pulses	F. Ringleb, K. Eylers, Th. Teubner, H.-P. Schramm, C. Symietz, J. Bonse, S. Andree, B. Heidmann, M. Schmid, J. Krüger, T. Boeck	Applied Surface Science	418	Elsevier	Amsterdam	01/10/2017	548-553	No
35	10.1016/j.jcrysgro.2016.12.040	Solution growth of Si on reorganized porous Si foils and on glass substrates	C. Ehlers, R. Bansen, T. Markurt, D. Uebel, Th. Teubner, T. Boeck	Journal of Crystal Growth	468	Elsevier	Amsterdam	12/12/2016	268-271	No

No	DOI	Title	Main authors	Title of the periodical or the series	Number, date or frequency	Publisher	Place of public-cation	Date of publication	Relevant pages	Open access?
36	10.1039/C7NR06982K	Coating ZnO nanoparticle films with DNA nanolayers for enhancing the electron extracting properties and performance of polymer solar cells	Janardan Dagar, Guido Scavia, Manuela Scarselli, Silvia Destri, Maurizio De Crescenzi and Thomas M. Brown	Nanoscale	9	Royal Society of Chemistry	UK	09/07/2017	19031-19038	No
37	10.1088/0268-1242/31/10/105003	Electron-collecting oxide layers in inverted polymer solar cells via oxidation of thermally evaporated titanium	A Zampetti, L Salamandra, F Brunetti, A Reale, A Di Carlo and T M Brown	Semiconductor Science and Technology	31	Institute of Physics Publishing	UK	01/09/2016	105003	No
38	10.1002/crat.201600239	Growth of crystalline semiconductor films and micro structures for photovoltaic applications	T. Boeck, R. Bansen, F. Ringleb	Crystal Research and Technology	52	Wiley	Weinheim	10/01/2017	1600239 1-7	No

* A p3ermanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view) or to the final manuscript accepted for publication (link to article in repository). ** Open Access is defined as free of charge access for anyone via Internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

Currently, members of the consortium are working on several scientific (peer reviewed) joint publications. Regardless of project completion, the consortium expects that the dissemination of results will continue and joint papers are expected to be published in the following months. Below, a preliminary list of some of the manuscripts currently under preparation is described (not included on the EC portal):

No	DOI	Title	Main authors	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Date of publication	Relevant pages	Open access**?
39		Evaluation of the PMMA microlens efficiency for the realization of microsolar concentrator array	F. Loffredo, F. Villani, C. Cancro, G. Nenna, A. Borriello, R. Miscioscia, C. Minarini and F. Roca	Applied Optics	To be submitted on or before Feb 7th 2018	OSA-The Optical Society	USA	07/02/2018		No

* A permanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view) or to the final manuscript accepted for publication (link to article in repository). ** Open Access is defined as free of charge access for anyone via Internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

Template A1: List of Project Publications (Thesis/Dissertation)							
No	**DOI**	**Title**	**Authors**	**Date of approval**	**Institution Name**	**Institution Location**	**Open access?**
1		Master thesis “Crescita e caratterizzazione di film sottili di Cu2ZnSnS4 per applicazioni fotovoltaiche”	Alexandra Colombo	21/07/2014	University of Milao Bicocca	Milan, Italy	Yes
2	ISBN 9789949237999 (publication)	Doctoral Thesis: "Application of Modulation Spectroscopy Methods in Photovoltaic Materials Research"	Taavi Raadik	30/06/2015	Tallinn University of Technology	Tallinn, Estonia	Yes
3		Master thesis: Manifold reues of silicon substrate in the layer transfer process with porous silicon	Ivan Sharlandzhiev	20/12/2015	IMEC v.z.w / Tecnico Lisboa	Lisbon, Portugal	No
4		PhD thesis: Silicon epitaxial layers grown on buried porous silicon templates for solar cells	Hariharsudan Sivaramakrishnan Radhakrishnan	26/08/2014	IMEC v.z.w / University of Leuven	Leuven, Belgium	No
5		Master Thesis "Crescita e caratterizzazione di film sottili di calcogenuri per applicazioni fotovoltaiche"	Alberto Lomuscio	14/03/2016	University of Milano Bicocca	Milan, Italy	Yes
6		First level Thesis Deposizione e caratterizzazione di ZnS per applicazioni FV	Lorenzo Pagani	20/07/2016	University of Milao Bicocca	Milan, Italy	Yes

No	DOI	Title	Authors	Date of approval	Institution Name	Institution Location	Open access?
7	ISBN 9789949239498 (publication)	Doctoral thesis ,,Study of Kesterite Solar Cell Absorbers by Capacitance Spectroscopy Methods"	Erkki Kask	07/06/2016	Tallinn University of Technology	Tallinn, Estonia	Yes
8	ISBN 9789949239269 (publication)	Doctoral thesis ,,Temperature Dependent Electrical Properties of Kesterite Monograin Layer Solar Cells"	Mati Danilson	24/05/2016	Tallinn University of Technology	Tallinn, Estonia	Yes
9		Master Thesis " Effetto del Gradiente di Gallio in profondità sulle proprietà eletto-ottiche di film di CIGS"	Matteo Murabito	21/11/2016	University of Milano Bicocca	Milan, Italy	Yes
10		First level Thesis "Simulazione di celle solari cigs mediante software scaps"	Matteo GABARDI	25/10/2016	University of Milano Bicocca	Milan, Italy	Yes
11		Master Thesis "Studi di celle a perovskiti e loro integrazione con altre tecnologie fotovoltaiche"	Ruggero Mazza	20/03/2016	University of Milano Bicocca	Milan, Italy	Yes
12	ISBN 9789949831418 (publication)	Study of Cu2(Zn,Cd)SnS4 Absorber Materials for Monograin Layer Solar Cells	Maris Pilvet	07/09/2017	Tallinn University of Technology	Tallinn, Estonia	Yes
13		Master Thesis "Ottimizzazione dei parametri di crescita di film sottili di Cu(InGa)Se2 per la realizzazione di dispositivi fotovoltaici"	Davide Parini	09/10/2017	University of Milano Bicocca	Milan, Italy	Yes

No	DOI	Title	Authors	Date of approval	Institution Name	Institution Location	Open access?
14		First level thesis "Sintesi di film sottili di cu2znsns4" per applicazioni fotovoltaiche"	Butrichi Fabio	29/09/2017	University of Milano Bicocca	Milan, Italy	Yes
15		Project Thesis "Optimizing the laser processing of SiNx for honeycomb surface texturing of Si"	Jon Anders Danielsen	31/01/2018	Norwegian University of Science and Technology (degree giving institution, but work done at IFE)	Trondheim, Norway	Yes

Template A1: List of publications (project paper in proceedings of a conference/workshop)													
No	**DOI**	**Title**	**Author(s)**	**Proceedings**	**Date of public-cation**	**Start date of Event**	**End date of Event**	**Publi-sher**	**Publi-sher loca-tions**	**ISBN**	**URL**	**Rele-vant pages**	**Open access?**
1	10.4229/EUPVSEC20142014-3DV.4.45	Towards Integration of High Quality Epitaxial Si Foils into Low-Temperature Back-Contacted Solar Devices	K. Van Nieuwenhuysen, V. Depauw, T. Bearda, E. Carnemolla, H. Sivaramakrishnan Radhakrishnan, J. Govaerts, S.N. Granata, *et al.,*	Proceedings of 29th European Photovoltaic Solar Energy Conference and Exhibition EUPVSEC 2014	12/11/2014	22/09/2014	26/09/2014	N/A	N/A	3-936338-34-5	http://www.eupvsec-proceedings.com/proceedings?fulltext=Towards+integration+of+high-quality+epifoils+into+low-temperature+back-contacted+solar+devices&paper=30786	1967 - 1970	No
2	http://cordis.europa.eu/project/rcn/111512_fr.html	CHEETAH - Cost Reduction through material optimisation and higher energy output of solar photovoltaic modules - Joining 3Europe's research and development efforts in support of its PV industry	Ioannis Thomas Theologitis European Photovoltaic Industry Association	The 6th World Conference on Photovoltaic Energy Conversion / 9WePo.11.14LN	26/11/2014	23/11/2014	27/11/2014	N/A	N/A				No

No	DOI	Title	Author(s)	Proceedings	Date of public-cation	Start date of Event	End date of Event	Publi-sher	Publi-sher loca-tions	ISBN	URL	Rele-vant pages	Open access?
3		AO.4.2 - CIGS Thin-Film Solar Cells with an Improved Efficiency of 20.8%	M. Powalla, P. Jackson, D. Hariskos, S. Paetel, W. Witte, R. Würz, E. Lotter, R. Menner, and W. Wischmann; (ZSW)	EU PVSEC 2014 Conference Proceedings	12/11/ 2014	22/09/ 2014	26/09/ 2014	WIP	Munich, Germany	3-93633 8-34-5	http://www.photovoltaic-conference.com/conference/conference-proceedings.html		No
4		SiOxNy/SiNx Stack Anti-reflection Coating with PID-resistance for Crystalline Silicon Solar Cells	Chunlan Zhou, Junjie Zhu, Sean Erik Foss, *et al.* Institute for energy technology	Proceedings of the 5th International Conference on Crystalline Silicon Photovoltaics	15/06/ 2015	23/03/ 2015	25/03/ 2015	Else-vier					Yes
5	10.4229 /EUPVS EC2015 2015-7DV.4.4 8	FP7-CHEETAH project knowledge exchange Portal: an advanced tool to bring efficiently information to the European Photovoltaic RTD Community	ENEA: F. Roca& D. Casaburi, Juelich: K. Bittkau, HZB: M. L.Steiner, I. Lauermann, DTU: S. Gevorgyan-DTU, CEA: P. Malbranche &, *et al.*	European Photovoltaic Solar Energy Conference and Exhibition (EU PVSEC)	12/11/ 2015	14/09/ 2015	18/09/ 2015	WIP	Munich, Germany	3-93633 8-39-6	http://www.eupvsec-proceedings.com	3190 - 3194	No

No	DOI	Title	Author(s)	Proceedings	Date of public-cation	Start date of Event	End date of Event	Publi-sher	Publi-sher loca-tions	ISBN	URL	Rele-vant pages	Open access?
6	10.1109/PVSC.2014.6925586	Parasitic absorption effects in metallic back reflectors with texture	Franz-Josef Haug, Karin Söderström, Christophe Ballif	Photovoltaic Specialist Conference (PVSC), 2014 IEEE 40th	19/09/2014	08/06/2014	13/06/2014	IEEE				3076 - 3079	No
7	10.4229/EUPVSEC20152015-87DV.49.23	Potential for Cost Reduction of PV Technology - Impact of CHEETAH Research Innovations	Ioannis-Thomas Theologitis, SolarPower Europe (EPIA), Gaëtan Masson, Becquerel Institute, Belgium	European Photovoltaic Solar Energy Conference and Exhibition (EU PVSEC)	12/11/2015	14/09/2015	18/09/2015	NA		3-936338-39-6	http://www.eupvsec-proceedings.com	3146 - 3157	No
8	10.1117/12.2184581	Simulation of light in-coupling through an aperture probe to investigate light propagation in a thin layer for opto-electronic application	Markus Ermes, Stephan Lehnen, Zhao Cao, Karsten Bittkau, and Reinhard Carius	Proceedings of SPIE	21/09/2015	23/06/2015	25/06/2015	SPIE	USA		http://dx.doi.org/10.1117/12.2184581	95260W	No

No	DOI	Title	Author(s)	Proceedings	Date of public-cation	Start date of Event	End date of Event	Publi-sher	Publi-sher loca-tions	ISBN	URL	Rele-vant pages	Open access?
9	doi: 10.1016 /j.egypr o.2015. 07.123	Solar cells from epitaxial foils: an epifoil epiphany	J. Govaerts, C.Trompoukis, H. S. Radhakrishnan, L. Tous S. N. Granata, E. G. Carnemolla, R. Martini, A. Marchegiani, *et al.*	5th International Conference on Silicon Photovoltaics, SiliconPV 2015	15/06/ 2015	23/03/ 2015	25/03/ 2015	Elsevier			http://www.sciencedirect.com/science/article/pii/S1876610215008917	871-880	Yes
10		Process development for heterojunction IBC cells on thin silicon foils bonded to glass	Bearda, T.; Sivaramakrishnan Radhakrishnan, H.; Granata, S.; Van Nieuwenhuysen, K.; Govaerts, J.; Depauw, V.; Trompoukis, C.; Donerçark, *et al.*	European Photovoltaic Solar Energy Conference and Exhibition (EU PVSEC)	12/11/ 2015	14/09/ 2015	18/09/ 2015	WIP	Munich, Germany	3-93633 8-39-6	http://www.eupvsec-proceedings.com	365 - 368	No
11	10.1016 /j.egypr o.2015. 07.035	Optimization of the antireflection coating of thin epitaxial crystalline silicon solar cells	Josefine K. Selj (IFE), David Young (NREL) and Sachit Grover (NREL)	5th International Conference on Silicon Photo-voltaics, SiliconPV 2015	28/08/ 2015	23/03/ 2015	25/03/ 2015	Elsevier			http://www.sciencedirect.com/science/article/pii/S1876610215008036	248-252	Yes

No	DOI	Title	Author(s)	Proceedings	Date of public-cation	Start date of Event	End date of Event	Publi-sher	Publi-sher loca-tions	ISBN	URL	Rele-vant pages	Open access?
12	10.4229/EUPVSEC20162016-2BO.9.2	How to deal with thin wafers in a heterojunction solar cells industrial pilot line: first analysis of the integration of cells down to 70µm thick in production mode	S. Harrison, O. Nos, A. Danel, D. Munoz, JP. Rakotoniana, J. Gaume, C. Roux, PJ. Ribeyron	European Photovoltaic Solar Energy Conference and Exhibition (EU PVSEC)	01/09/2016	20/06/2016	24/06/2016	WIP	Munich, Germany	3-936338-41-8	http://www.eupvsec-proceedings.com/proceedings?paper=37461	358-362	No
13	10.1117/12.2227761	High-resolution photocurrent mapping of thin-film solar cells using scanning near-field optical microscopy	JÜLICH: Z. Cao, S. Lehnen, R. Carius, K. Bittkau	Proceedings of SPIE	26/04/2016	04/04/2016	07/04/2016	SPIE	USA		http://proceedings.spiedigitallibrary.org/proceeding.aspx?doi=10.1117/12.2227761	98900J	No
14	10.4229/EUPVSEC20162016-1BV.5.35	Thin-film barriers for durable thin-film PV modules	JÜLICH: J. Hüpkes, A. Wrigley, W. Reetz, A.Gerber EPFL: N. Wyrsch, F. Sculati-Meilaud, EXZ: G. Cattaneo	EU PVSEC Conference and Exhibition	01/09/2016	20/06/2016	24/06/2016	WIP	Munich, Germany	3-936338-41-8	http://www.eupvsec-proceedings.com/proceedings?paper=37818	173-175	No
15	10.1109/PVSC.2016.7750077	Backside Contacted Solar Cells with Heterojunction Emitters and Laser Fired Absorber Contacts for Crystalline Silicon on Glass	Tim Frijnts, Stefan Gall, Holger Rhein, Paul Sonntag, Luana Mazzarella, Simon Kirner, Costantino Matarazzo, *et al.*	Photovoltaic Specialist Conference (PVSC), 2016 IEEE 43th	20/07/2016	05/07/2016	10/07/2016	IEEE	Portland, USA	978-1-5090-2724-8	http://ieeexplore.ieee.org/document/7750077/	2425-2429	No

No	DOI	Title	Author(s)	Proceedings	Date of public-cation	Start date of Event	End date of Event	Publi-sher	Publi-sher loca-tions	ISBN	URL	Rele-vant pages	Open access?
16		Identification of Loss Mechanisms in CIGS Micro-Cells for Concentrator Applications	E. Lotter, P. Jackson, S. Paetel, W. Wischmann	EU PVSEC Conference and Exhibition	01/09/2016	20/06/2016	24/06/2016	WIP	Munich, Germany	3-936338-41-8	http://www.eupvsec-proceedings.com/proceedings?paper=36909	1156-1160	No
17	10.1117/12.2238056	Concentrating light in Cu(In,Ga)Se2 solar cells	M. Schmid ; G. Yin ; M. Song ; S. Duan ; B. Heidmann ; D. Sancho-Martinez ; S. Kämmer ; T. Köhler ; P. Manley ; M. Ch. Lux-Steiner	Proc. SPIE 9937, Next Generation Technologies for Solar Energy Conversion VII	23/09/2016	28/08/2016	01/09/2016	SPIE	USA	not found	http://proceedings.spiedigitallibrary.org/proceeding.aspx?articleid=2557270	993703-1-7	No
18		Innovation Brought by FP7-CHEETAH Project in Management of Knowledge Exchange for PV RTD	F. Roca, D. Casaburi, F. Beone, K. Bittkau, I. Lauermann, P. Malbranche, I.T. Theologitis, N. Taylor, J.M. Kroon, M.C. Lux-Steiner, M. Drießen, I. Gordon, S.A. Gevorgyan, K. Van Nieuwenhuysen, *et al*.	32nd European Photovoltaic Solar Energy Conference and Exhibition (EUPVSEC2016)	01/09/2016	20/06/2016	24/06/2016	WIP	Munich, Germany	3-936338-41-8	www.eupvsec-proceedings.com/proceedings?fulltext=ROCA&paper=39534		No

No	DOI	Title	Author(s)	Proceedings	Date of public-cation	Start date of Event	End date of Event	Publi-sher	Publi-sher loca-tions	ISBN	URL	Rele-vant pages	Open access?
19	10.4229/EUPVSEC20162016-2BO.2.6	Multiple reuse of the silicon substrate in a porous silicon based layer transfer process	A. Hajijafarassar, K. Van Nieuwenhuysen, I. Sharlandziev, V. Depauw, *et al.*	EU PVSEC 2016 Conference and Exhibition	01/09/2016	20/06/2016	24/06/2016	WIP	Munich, Germany	3-936338-41-8	https://doi.org/10.4229/EUPVSEC20162016-2BO.2.6	313 - 316	No
20	10.4229/EUPVSEC20162016-2BO.3.3	Process development of silicon heterojunction interdigitated back-contacted (SHJ-IBC) solar cells bonded to glass	M. Xu, T. Bearda, H. Sivaramakrishnan Radhakrishnan, S. Jonnak, M. Filipic, V. Depauw, *et al.*	EU PVSEC 2016 Conference and Exhibition	01/09/2016	20/06/2016	24/06/2016	WIP	Munich, Germany	3-936338-41-8	https://doi.org/10.4229/EUPVSEC20162016-2BO.3.3	328 - 330	No
21	10.1364/PV.2016.PW3B.1	A Fourier Scattering Model Without Paraxial Error	F.-J. Haug	Optical Nanostructures and Advanced Materials for Photovoltaics (PV)	01/12/2016	14/11/2016	17/11/2016	OSA	Leipzig, Germany	978-0-960038-0-4-6	https://doi.org/10.1364/PV.2016.PW3B.1	PW3B.1	No
22	10.4229/EUPVSEC20172017-1CO.1.2	FEM-based development of novel back contact PV modules with ultra-thin solar cells	A. J. Beinert, R. Leidl, P. Sommeling, U. Eitner & J. Aktaa	EU PVSEC 2017 Conference and Exhibition	27/09/2017	25/09/2017	29/09/2017	WIP	Munich, Germany	3-936338-47-7	http://www.eupvsec-proceedings.com/proceedings?paper=43185	42 - 47	No

No	DOI	Title	Author(s)	Proceedings	Date of public-cation	Start date of Event	End date of Event	Publi-sher	Publi-sher loca-tions	ISBN	URL	Rele-vant pages	Open access?
23		Limitations to sawing of ultrathin wafers by diamond multi wire saw	Birgit Ryningen, Pål Tetlie, Halvor Dalaker, Eivind Øvrelid	Norwegian Solar Cell Conference 2017	09/05/ 2017	09/05/ 2017	10/05/ 2017	NA					NO
24	10.4229 /eupvse c201720 17-3cv.1.48	Micro Concentrator Concept for Cost Reduction and Efficiency Enhancement of Thin-Film Chalcopyrite Photovoltaics: Results from EU Joint Research Program CHEETAH	M. Schmid, E. Lotter, X. Lin, L. Wang, R. Klenk, K. Eylers, F. Ringleb, T. Boeck, B. Heidmann, G. Nenna, F. Loffredo, F. Villani, T. Köhler, D. Sancho-Martinez, *et al.*,	EU PVSEC 2017 Conference and Exhibition	25/09/ 2017	29/09/ 2017	27/09/ 2017	WIP	Munich, Germany	3-93633 8-47-7	https://www.eupvsec-proceedings.com/proceedings/checkout.html?paper=42624	1077 - 1080	No
25	10.4229 /EUPVSE C201720 17-7EO.3.5	Highlights from the FP7 Project on Photovoltaics CHEETAH: More Power with Less Material	J.M. Kroon, F. Roca, I. Lauermann, K. Bittkau, M. Heisz, K. Van Nieuwenhuysen, *et al.*,	EU PVSEC 2017 Conference and Exhibition	01/10/ 2017	25/09/ 2017	29/09/ 2017	WIP	Amsterdam, Netherlands	3-93633 8	http://www.eupvsec-proceedings.com/proceedings?paper=41694	2844-2848	No
26	10.4229 /EUPVSE C201720 17-7DV.1.3 0	FP7-CHEETAH Knowledge Exchange Platform: Results and their Exploitation	F. Roca, D. Casaburi, F. Beone, C. Diletto, I. Falcone, A. De Girolamo, R. Miscioscia, K. Bittkau, *et al.*	EU PVSEC 2017 Conference and Exhibition	27/09/ 2017	25/09/ 2017	29/09/ 2017	WIP	Amsterdam, Netherlands	3-93633 8-47-7		2888 - 2894	No

No	DOI	Title	Author(s)	Proceedings	Date of public-cation	Start date of Event	End date of Event	Publi-sher	Publi-sher loca-tions	ISBN	URL	Rele-vant pages	Open access?
27	10.4229/EUPVSEC20172017-2CV.2.15	Growth of silicon on reorganized porous silicon substrates by steady-state solution growth for photovoltaic applications	C. Ehlers, R. Bansen, D. Uebel, Th. Teubner, T. Boeck	Proceedings of the EU PVSEC	09/11/2017	25/09/2017	29/09/2017	WIP	Munich, Germany	3-936338-47-7	http://www.eupvsec-proceedings.com/proceedings?paper=43656	820 - 822	yes
28	10.4229/EUPVSEC20172017-1CV.3.92	Polymeric Microlenses for Photovoltaic Microconcentrator Applications: Prototype Characterization and Simulation	F. Loffredo, F. Villani, G. Nenna, R. Miscioscia, C. Minarini, F. Roca	33nd European Photovoltaic Solar Energy Conference and Exhibition (EUPVSEC2017)	26/09/2017	25/09/2017	29/09/2017	WIP	Munich, Germany	3-936338-47-7	http://www.eupvsec-proceedings.com/proceedings?fulltext=ROCA&paper=43101	187-190	Yes
29		Towards industrialization of heterojunction with thin and ultra-thin wafers	S.Harrison, A.Danel, J.Gaume, H.Robin, C.Roux, M.Joanny	27th International Photovoltaic Sience and Engineering Conference	17/11/2017	12/11/2017	17/11/2017	PVSEC-27	Shiga, Japan				

Template A1: List of project publications (article / section in an edited book or book series)												
No	DOI	Title	Author(s)	Title of the book (series)	Volume	Date of publication	Publisher	Publisher location	ISBN	URL	Rele-vant pages	Open access?
1	10.1007/978-981-287-724-6_8	Environmental Stability of Organic Semiconductors for Use in Optoelectronic Devices	George F. A. Dibb, James C. Blakesley, Fernando A. Castro (NPL)	Materials for Energy Infrastructure	Chapter 8	01/01/2016	Springer Singapore	Singapore	978-981-287-723-9	http://link.springer.com/10.1007/978-981-287-724-6	73-81	No
2		Future renewable energy costs: solar photovoltaics How technology innovation is anticipated to reduce the cost energy from European photovoltaic installations	Paolo V. Chiantorre - Kenergia Sviluppo, Ivan Gordon - IMEC, Winfried Hoffmann - ASE, Emiliano Perezagua - Consultores de Energia Fotovoltaica, Simon Philipps - Fraunhofer ISE, Eduardo Roman - Tecnalia, Eric Sandre - EDF R&D, Wim Sinke - ECN, Emilien Simonot - KIC InnoEnergy, Antoni Martinez - KIC InnoEnergy	Future renewable energy costs: solar photovoltaics	-	01/01/2016	KIC InnoEnergy	Europe	978-949-205-604-7	www.kic-innoenergy.com/reports	All	Yes

3.1.2 List of dissemination actions (A2) - Public

Template A2: List of dissemination activities								
No	**Type of activities***	**Main leader**	**Title**	**Date**	**Place**	**Type of audience****	**Size of audience**	**Countries addressed**
1	Organisation of Workshops	HZB	Workshop on analytical tools for photovoltaics	25/06/2014	Berlin, Germany	Scientific Community (higher education, Research) Industry	14	Europe
2	Organisation of Workshops	HZB	International Summer University ISUenergy	24/08/2014	Falera, Switzerland	Scientific Community (higher education, Research)	54	World
3	Organisation of Conference	IMEC	Symposium Y on "Advanced materials and characterization techniques for solar cells II" at the MERS Spring meeting 2014	26/05/2014	Lille, France	Scientific Community (higher education, Research), Industry	200	World
4	Oral presentation to a scientific event	IMEC	Symposium Y on "Advanced materials and characterization techniques for solar cells II" at the MERS Spring meeting 2014, Novel porous silicon stacks for layer transfer of epitaxial silicon foils resulting in large minority carrier diffusion lengths	28/05/2014	Lille, France	Scientific Community (higher education, Research),Industry	200	World
5	Posters	IMEC	29th European Photovoltaic Solar Energy Conference, Towards integration of high-quality epifoils into low-temperature back-contacted solar devices	22/09/2014	Amsterdam, The Netherlands	Scientific Community (higher education, Research), Industry	1500	World

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
6	Organisation of Workshops	HZB	Autumn School on Microstructural Characterization and Modelling of Thin-Film Solar Cells	02/11/2014	Berlin, Germany	Scientific Community (higher education, Research)		Europe
7	Oral presentation to a scientific event	LNEG	The Portuguese participation in EERA Joint Programmes of Wind and PV (in Portuguese). Note: explicit mention to CHEETAH project and its objectives.	19/06/2014	Lisbon, Portugal	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	100	Portugal
8	Organisation of Workshops	LNEG	National Workshop on Research and Development of Photovoltaics : Portuguese participation in EERA PV Joint Programme and CHEETAH project	09/02/2015	INL - International Iberian Nanotechnology Laboratory in Braga, Portugal	Scientific Community (higher education, Research)	40	Portugal
9	Posters	EPIA	CHEETAH - Cost Reduction through material optimisation and higher energy output of solar photovoltaic modules - Joining Europe's research and development efforts in support of its PV industry	26/11/2014	Kyoto, Japan	Scientific Community (higher education, Research), Industry, Medias	5000	World
10	Flyers	EPIA	CHEETAH	26/11/2014	Kyoto, Japan	Scientific Community (higher education, Research), Industry, Medias	5000	World

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
11	Media briefings	EPIA	EPIA Solaris Newsletter, March 2014, April 2014, July 2014, February 2015	15/03/2014	Mail sent to a contact list	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	15000	World
12	Web sites/Applications	EPIA	News item / "EPIA welcomes the new project CHEETAH" / "CHEETAH: First months, first deliverables in sight"/"The website of the CHEETAH project is now available" […]	01/03/2014	www.epia.org	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	15000	World
13	Organisation of Workshops	TUT	5th European Kesterite Workshop	13/11/2014	Tallinn, Estonia	Scientific Community (higher education, Research)	80	Europe
14	Oral presentation to a scientific event	TUT	Kesterite absorber materials and their applications in monograin layer solar cells	02/04/2014	Berlin, Germany	Scientific Community (higher education, Research), Industry	100	Europe
15	Organisation of Workshops	TUBITAK	Photovoltaic Workshop 2014	16/06/2014	Istanbul, Turkey	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers	119	Turkey, Germany, The Netherlands, Switzerland
16	Oral presentation to a scientific event	EPFL	High- Efficiency Thin-Film Silicon Triple and Quadruple Junction Solar Cells	23/01/2015	Amsterdam, The Netherlands	Scientific Community (higher education, Research), Industry	300	World

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
17	Oral presentation to a scientific event	EPFL	New Opportunities for Thin Film Silicon Technology	25/11/2014	Kyoto, Japan	Scientific Community (higher education, Research), Industry	350	World
18	Oral presentation to a scientific event	TECNALIA	SPANISH SOLAR FORUM- Challenges of the PV Energy without Public Economic Support . How will be the future of photovoltaic integration into the grid and into Smart grids?	18/11/2014	Madrid, Spain	Industry, Civil Society, Policy makers, Medias	150	Spain
19	Web sites/Applications	ENEA	CHEETAH Knowledge Exhange Web Area	01/08/2014	http://www.cheetah-exchange.eu	Scientific Community (higher education, Research), Industry Civil Society Policy makers Medias	2000	World
20	Oral presentation to a scientific event	ENEA	Webinar - Wet-chemistry deposition of semiconductor nanostructures for IR photovoltaics	09/05/2014	http://www.cheetah-exchange.eu/webinars.asp?i=2&t=Wet-chemistry_deposition_of_semiconductor	Scientific Community (higher education, Research), Industry	60	World
21	Oral presentation to a scientific event	HZB	Webinar - Extraction of refractive index data from optical measurements of flat, rough and inhomogeneous thin films (speakers M.Schmid, P. Manley, HZB) […]	22/05/2014	http://www.cheetah-exchange.eu/webinars.asp	Scientific Community (higher education, Research), Industry	100	World

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
22	Organisation of Workshops	HZB	Short online course - Characterization of thin film solar cell layers by x-ray based spectroscopy (speakers Britta HÖPFNER, Iver LAUERMANN , W. CALVET HZB) […]	23/04/2014	http://www.cheetah-exchange.eu/webinars.asp	Scientific Community (higher education, Research) Industry	100	World
23	Oral presentation to a scientific event	ZSW	CIGS Thin-Film Solar Cells with an Improved Efficiency of 20.8%	22/09/2014	Amsterdam, The Netherlands	Scientific Community (higher education, Research), Industry, Policy makers	300	World
24	Oral presentation to a scientific event	ECN	Back Contact PV Module Technology - Lowering the costs of foil-based back-contact PV	16/06/2014	Istanbul, Turkey	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers	119	Turkey, Germany, The Netherlands, Switzerland
25	Oral presentation to a scientific event	DTU	Joint JRC/DTU webinar - OPV Testing and Existing Standards	06/05/2014	[…] http://www.cheetah-exchange.eu/webinars.asp?i=5&t=OPV_Testing_and_Existing_Standards__	Scientific Community (higher education, Research), Industry	92	World
26	Posters	HZB	Modelling and fabrication of a photovoltaic Cu(Inx,Ga1-x)Se2 micro solar cell under different light concentration fluxes	14/04/2015	CPV-11, Aix-les-Bains, France	Scientific Community (higher education, Research), Industry	200	Europe

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
27	Posters	HZB	Comparison of two growth processes for Cu(InxGa1-x)Se2 micro-absorbers for concentrator solar cells	11/05/2015	E-MRS Spring Meeting, Lille, France	Scientific Community (higher education, Research) Industry	300	Europe
28	Posters	IKZ/FVB	Indium Precursors for CIGSe Micro-Concentrator Solar Cells	17/03/2015	DPG Spring Meeting, Berlin, Germany	Scientific Community (higher education, Research)	1000	Europe, US, India, China
29	Posters	IKZ/FVB	Indium Precursors for CIGSe Micro-Concentrator Solar Cells	25/04/2015	CPV-11, Aix-les-Bains, France	Scientific Community (higher education, Research), Industry	200	Europe, China, US
30	Organisation of Workshops	IKZ/FVB	Summer Course on Crystal Growth	13/07/2015	Berlin, Germany	Scientific Community (higher education, Research)	30	Europe
31	Oral presentation to a scientific event	TECNALIA	Simple analytical determination of PV modules efficiency for different encapsulation schemes, CHEETAH project workshop on advanced characterisation for PV	14/01/2016	Freiburg, Germany	Scientific Community (higher education, Research)	60	Europe
32	Oral presentation to a scientific event	NPL	Stability and lifetime of organic PV materials and devices	26/02/2015	NPL, Teddington, UK	Scientific Community (higher education, Research), Industry	100	Europe, UK, Korea
33	Oral presentation to a scientific event	NPL	Methods to characterise the intrinsic stability of organic solar cells	01/10/2014	Barcelona, Spain	Scientific Community (higher education, Research) Industry	100	World

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
34	Organisation of Conference	NPL	8th International Symposium on the stability of organic and hybrid photovoltiacs (ISOS-8)	27/09/2015	Rio de Janeiro, Brazil	Scientific Community (higher education, Research), Industry	100	World
35	Posters	NPL	Environmental Degradation of Organic Photovoltaic Devices	27/09/2015	Rio de Janeiro, Brazil	Scientific Community (higher education, Research), Industry	100	World
36	Oral presentation to a wider public	NPL	Decoupling the elements of device degradation: Stability testing in precise environments	03/03/2015	LOPEC, Munich, Germany	Scientific Community (higher education, Research), Industry, Medias	100	World
37	Oral presentation to a scientific event	NPL	In-situ measurement of the environmental degradation of organic photovoltaic devices in highly controlled atmospheres	01/05/2015	EMRS, Lille, France	Scientific Community (higher education, Research), Industry, Medias	200	World
38	Oral presentation to a scientific event	NPL	Environmental Stability of Organic Semiconductors for Use in Optoelectronic Devices	01/09/2014	WMRIF Workshop for Young Scientists, Boulder, Colorado, USA	Scientific Community (higher education, Research) Industry	200	World
39	Oral presentation to a scientific event	NPL	Stability of Polymer:Fullerene Solar Cells: Exposure to Highly Controlled Oxygen and Water Environments	11/05/2014	HOPV, Lausanne, Switzerland	Scientific Community (higher education, Research), Industry	200	World
40	Oral presentation to a scientific event	NPL	Solar cells: the importance of reliable characterisation methods	15/09/2015	ISOPHOS 2015, Castiglione della Pescaia	Scientific Community (higher education, Research), Industry	100	World

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
41	Oral presentation to a scientific event	Julich	Photon tunneling in tandem solar cell	18/06/2015	New Orleans, USA	Scientific Community (higher education, Research) Industry, Civil Society, Policy makers, Medias	2000	World
42	Oral presentation to a scientific event	Julich	Nano-Imprint Textured Intermediate Reflectors for Advanced Light Management in Multi-Junction Solar Cells	17/09/2015	Hamburg, Germany	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers; Medias	2500	World
43	Oral presentation to a scientific event	EPFL	Nanometer-scale doped microcrystalline Triple- and quadruple-junction thin-film silicon solar cells	18/09/2015	Aachen, Germany	Scientific Community (higher education, Research)	500	World
44	Organisation of Conference	IMEC	Symposium C "Advanced inorganic materials andf structures for photovoltaics" at the EMRS Spring Meeting 2015	11/05/2015	Lille, France	Scientific Community (higher education, Research)	300	World
45	Posters	IMEC	Solar cells from epitaxial foils: an epifoil epiphany	23/03/2015	Konstanz, Germany	Scientific Community (higher education, Research)	400	World
46	Oral presentation to a scientific event	IMEC	Process development for heterojunction IBC cells on thin silicon foils bonded to glass	14/09/2015	Hamburg, Germany	Scientific Community (higher education, Research) Industry	2500	World

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
47	Flyers	VTT	Flyers distribution - CHEETAH	28/01/2015	Nanotech 2015, Tokyo, Japan	Scientific Community (higher education, Research), Industry, Medias	48000	World
48	Flyers	VTT	Flyers distribution - CHEETAH	03/03/2015	LOPE-C 2015, Munich, Germany	Scientific Community (higher education, Research), Industry, Medias	2300	Europe
49	Flyers	VTT	Flyers distribution - CHEETAH	27/04/2015	Printed Electronics Europe, Berlin, Germany	Scientific Community (higher education, Research), Industry, Medias	2000	Europe
50	Flyers	VTT	Flyers distribution - CHEETAH	11/06/2015	PrintoCent Innofest, Oulu, Finland	Scientific Community (higher education, Research), Industry, Civil Society, Medias	300	Finland
51	Flyers	VTT	Flyers distribution - CHEETAH	18/11/2015	Printed Electronics USA 2015, Santa Clara, USA	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	3000	USA
52	Flyers	VTT	Flyers distribution - CHEETAH	03/12/2015	VTT-FinSolar seminar, Espoo, Finland	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	130	Finland

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
53	Oral presentation to a scientific event	HZB	On the role of sodium in the morphology and device properties of inkjet-printed Cu2ZnSn(S,Se)4 absorbers	14/09/2015	EU PVSEC conference 2015Hamburg, Germany	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	2500	World
54	Posters	HZB	Inkjet-printed Cu2ZnSn(SxSe1-x)4 thin film absorbers for photovoltaics	06/04/2015	2015 MRS Spring Meeting & Exhibit San Francisco, USA	Scientific Community (higher education, Research), Industry	200	World
55	Oral presentation to a scientific event	LNEG	A Future with PV Energy (in Portuguese)	27/05/2015	Portalegre, Portugal	Scientific Community (higher education, Research)	40	Portugal
56	Oral presentation to a wider public	LNEG	PV in Europe and in Portugal: challenges and achievements to be accomplish in the near future.	09/12/2015	LNEG-Lisbon, Portugal	Policy makers	15	USA, Portugal
57	Oral presentation to a scientific event	DTU	The impact of different organic photovoltaic architectures on the stability of encapsulation-less devices	29/09/2015	ISOS conference, Rio De Janeiro, Brazil	Scientific Community (higher education, Research), Industry	50	World
58	Oral presentation to a scientific event	DTU	Lifetime of Organic Photovoltaics: Status and Predictions	29/09/2015	ISOS conference Rio De Janeiro, Brazil	Scientific Community (higher education, Research), Industry	50	World

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
59	Organisation of Workshops	NPL	FP7 Cheetah Round Table: Reduction of the encapsulation cost versus improvement of intrinsic stability - Chair: Suren Gevorgyan (DTU)	29/09/2015	ISOS conference session, Rio De Janeiro, Brazil	Scientific Community (higher education, Research), Industry	50	World
60	Oral presentation to a wider public	ECN	Cheetah project introduction, Dissemination of WP8 project results	16/09/2015	EU PVSEC 2015, Hamburg, Germany	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	70	World
61	Flyers	EPIA	CHEETAH	09/06/2015	Intersolar Europe, Munich, Germany	Industry,Scientific Community (higher education, Research), Civil Society, Policy makers, Medias	30000	World
62	Flyers	EPIA	CHEETAH	14/09/2015	EU PVSEC 2015, Hamburg, Germany	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	200	World
63	Posters	EPIA	Potential for Cost Reduction of PV Technology - Impact of CHEETAH Research Innovations, EUPVSEC conference	14/09/2015	EU PVSEC 2015, Hamburg, Germany	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	200	World

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
64	Posters	EPIA	Quality for a Sustainable Future in Solar / DuPont Event - http://www.solarpowereurope.org/events/events-page/news/quality-for-a-sustainable-future-in-solar-event-at-eu-pvsec/	16/09/2015	EU PVSEC 2015, Hamburg, Germany	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	200	World
65	Media briefings	EPIA	EPIA Solaris Newsletter, March 2014, April 2014, July 2014, February 2015, July 2015, September 2015, November 2015; EPIA Monthly policy round-up November 2014, January 2015, November 2015	15/03/2014	Mail sent to a contact list	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	15000	World
66	Organisation of Workshops	EPIA	CHEETAH mid-term event - http://www.solarpowereurope.org/events/events-page/news/cheetah-event-at-eu-pvsec/	16/09/2015	EU PVSEC 2015, Hamburg, Germany	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	200	World
67	Posters	IMPERIAL	PC60BM Morphological Stability in Polymer Bulk Heterojunctions	06/04/2015	Corsica, France	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	200	World
68	Posters	IMPERIAL	Photo-oxidation of the PCBM electron acceptor	06/04/2015	Corsica, France	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	200	World

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
69	Oral presentation to a scientific event	IMPERIAL	Morphological stability of organic solar cells	10/01/2015	Barcelona, Spain	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	200	World
70	Web sites/Applications	ENEA	New version of CHEETAH Knowledge Exhange Web Area having new ICT tools (News, webinars, external partners) and new info content proposed to external organziations by circular email	01/09/2015	http://www.cheetah-exchange.eu	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	2500	World
71	Oral presentation to a wider public	ENEA	Presentation of CHEETAH Knowledge Exchange Area Portal at KnowRES, the Knowledge Centre for Renewable Energy Jobs, parallel event	16/09/2015	EU PVSEC 2015, Hamburg, Germany	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	200	World
72	Oral presentation to a scientific event	CEA	Ultrathin wafer development and Cell processing	16/09/2015	EU PVSEC 2015, Hamburg, Germany	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	200	World
73	Oral presentation to a wider public	DTU	Presentation of WP10 activities at a satellite event of EU PVSEC 2015 conference	16/09/2015	EU PVSEC 2015, Hamburg, Germany	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	200	World

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
74	Oral presentation to a wider public	TUBITAK	New trends, materials in PV cell and module development	19/11/2014	İzmir, Turkey	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	80	Turkey
75	Oral presentation to a wider public	TUBITAK	Research and development challanges and photovoltaic market in Turkije	20/06/2015	Eindhoven, The Netherlands	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	25	Europe
76	Oral presentation to a wider public	TUBITAK	Research and development challanges and photovoltaic market in Turkije	05/10/2015	Bleskensgraaf, The Netherlands	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	20	The Netherlands
77	Oral presentation to a scientific event	EPFL	Crystalline Silicon Solar Cells: Temperature Dependencies and Impact of Device Architecture	12/03/2016	Silicon PV 2016 conference, Chambéry, France	Scientific Community (higher education, Research), Industry	150	World
78	Posters	ENEA	7DV.4.48- Innovation brought by FP7-CHEETAH project in management of knowledge exchange for PV RTD	23/06/2016	EU PVSEC 2016, Munich, Germany	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	2500	World
79	Posters	HZB	Microconcentrator thin film devices based on CIGSe concept and first results from WP 9	23/06/2016	IW-CIGSTech 7 workshop, Munich, Germany	Scientific Community (higher education, Research), Industry	140	World

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
80	Posters	IKZ/FVB	Indium island growth on molybdenum at micro-roughened spots created by femtosecond laser pulses	04/05/2016	EMRS-Spring Meeting, Lille, France	Scientific Community (higher education, Research), Industry	2500	World
81	Posters	IKZ/FVB	CISe micro-absorber islands for concentrator photovoltaic applications	09/05/2016	PVTC 2016, Marseille, France	Scientific Community (higher education, Research), Industry	1000	World
82	Oral presentation to a scientific event	UNIMIB	Photoluminescence and Raman spectroscopy for defect identification in Silicon, Cu(In,Ga)Se2 and Cu2ZnSnS4 materials	14/01/2016	Cheetach Workshop: Advanced Characterization Methods for PV, Freiburg, Germany	Scientific Community (higher education, Research), Industry	100	World
83	Oral presentation to a wider public	HZB	Thin Film and Advanced light management	16/09/2015	EU PVSEC 2015, Hamburg, Germany	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	70	World
84	Oral presentation to a scientific event	UPM	Characterization of intermediate band materials and solar cells	14/01/2016	Cheetach Workshop: Advanced Characterization Methods for PV, Freiburg, Germany	Scientific Community (higher education, Research), Industry	100	World
85	Oral presentation to a scientific event	CRES	CRES's labs for PV system characterization and analysis	14/01/2016	Cheetach Workshop: Advanced Characterization Methods for PV, Freiburg, Germany	Scientific Community (higher education, Research), Industry	100	World

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
86	Posters	HZB	Microconcentrator thin film devices based on CIGSe concept and first results from WP 9 of the FP7 CHEETAH project	23/06/2016	EU PVSEC 2016, Munich, Germany	Scientific Community (higher education, Research), Industry	140	World
87	Flyers	VTT	Flyers distribution - CHEETAH	05/04/2016	LOPE-C 2016, Munich, Germany	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	4000	Europe, USA, Japan, China, Korea
88	Flyers	VTT	Flyers distribution - CHEETAH	27/04/2016	Printed Electronics Europe, Berlin, Germany	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	3000	Europe, USA, Japan, China, Korea
89	Flyers	VTT	Flyers distribution - CHEETAH	24/05/2016	International Wood Biorefining Week, Stockholm, Sweden	Scientific Community (higher education, Research), Industry, Medias	2000	Europe, USA, Japan, China, Korea
90	Flyers	VTT	Flyers distribution - CHEETAH	07/06/2016	Prinse'16 seminar, Oulu, Finland	Scientific Community (higher education, Research), Industry, Policy makers, Medias	500	Europe, USA, Japan, China, Korea
91	Posters	ZSW	Identification of loss mechanisms in CIGS micro-cells for concentrator applications	22/06/2016	EU PVSEC 2016, Munich, Germany	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	500	World

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
92	Posters	TUT	Low temperature time resolved photoluminescence in ordered and disordered Cu2ZnSnS4 single crystals	04/05/2016	E-MRS Spring Meeting, Lille, France	Scientific Community (higher education, Research), Industry	300	Europe
93	Posters	TUT	Influence of order-disorder in Cu2ZnSnS4 powders on the performance of monograin layer solar cells	04/05/2016	E-MRS Spring Meeting, Lille, France	Scientific Community (higher education, Research), Industry	300	Europe
94	Posters	TUT	KI Treatment for CZTS Monograin Layer Solar Cells to Improve Photocurrent	04/05/2016	E-MRS Spring Meeting, Lille, France	Scientific Community (higher education, Research), Industry	300	Europe
95	Oral presentation to a wider public	DTU	Characterization of organic solar cells: Mechanical, electrical and photovoltaic stability	14/01/2016	Cheetach Workshop: Advanced Characterization Methods for PV, Freiburg, Germany	Scientific Community (higher education, Research), Industry	100	World
96	Oral presentation to a scientific event	Julich	High-resolution photocurrent mapping of thin-film solar cells using scanning near-field optical microscopy	06/04/2016	SPIE Photonics Europe	Scientific Community (higher education, Research)	200	World
97	Posters	Julich	Thin-film barriers for durable thin-film PV modules	21/06/2016	EU PVSEC 2016, Munich, Germany	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	200	World

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
98	Oral presentation to a scientific event	Julich	Electro-optical Characterization of Thin-film Solar Cells and Modules: From nanophotonic cell characterization to macroscopic module characterization	14/01/2016	Cheetach Workshop: Advanced Characterization Methods for PV, Freiburg, Germany	Scientific Community (higher education, Research), Industry	100	World
99	Organisation of Workshops	Julich	Advanced Characterization Methods for PV	14/01/2016	Freiburg, Germany	Scientific Community (higher education, Research) Industry	100	World
100	Media briefings	SolarPower Europe	Dissemination of CHEETAH results in EPIA Solaris Newsletter, January 2016, April 2016, June 2016 / EPIA Monthly policy round-up February 2016, June 2016	18/01/2016	Mail sent to a contact list	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	15000	World
101	Flyers	SolarPower Europe	CHEETAH	02/03/2016	SolarPower Europe Annual Market Workshop, Brussels, Belgium	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	200	World
102	Oral presentation to a wider public	KIC SE	Cost reduction approach in Cheetah project – ongoing work and results part of the How technology innovation is anticipated to reduce the cost from PV installations	23/05/2016	Webinar	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	100	World
103	Organisation of Workshops	SolarPower Europe	CHEETAH - 1st Technology Transfer Advisory Board meeting	25/05/2016	Online meeting	Industry	10	Europe

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
104	Oral presentation to a scientific event	SolarPower Europe	PV technology and market status – The challenges for OPV market uptake and lessons learnt from the Cheetah Project	27/05/2016	MatHero Industrialisation Workshop, Barcelona, Spain, http://www.mathero.eu/index.php	Scientific Community (higher education, Research), Industry	60	World
105	Flyers	SolarPower Europe	CHEETAH	21/06/2016	Intersolar Europe, Munich, Germany	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	30000	World
106	Posters	HZB	Backside Contacted Solar Cells with Heterojunction Emitters and Laser Fired Absorber Contacts for Crystalline Silicon on Glass - A Detailed Resistance Analysis	05/06/2016	IEEE PVSC 2016, Portland, US	Scientific Community (higher education, Research), Industry	1000	World
107	Posters	HZB	Surface Analysis of Inkjet-printed In2S3 Buffer Layers for CIGSe Thin Film Solar Cells	02/05/2015	EMRS, Lille, France	Scientific Community (higher education, Research), Industry	500	World
108	Posters	HZB	Effect of Na-Sb doping on solution processed CZTS films for solar photovoltaics	13/01/2016	Next generation materials for Solar Photovoltaics, London, UK	Scientific Community (higher education, Research), Industry	200	World
109	Oral presentation to a scientific event	HZB	Concentrating light in Cu(In,Ga)Se2 solar cells	21/08/2016	SPIE Optics and Photonics, San Diego	Scientific Community (higher education, Research), Industry	200	World

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
110	Oral presentation to a scientific event	HZB	Laser Processing of Solar Cells on Laser Crystallized Silicon	28/06/2016	Laser Tech 2016, Berlin	Scientific Community (higher education, Research), Industry	300	World
111	Web sites/Applications	ENEA	New version of CHEETAH Knowledge Exhange Web Area proposed and disseminated externally to project partners by circular email	01/05/2016	http://www.cheetah-exchange.eu	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers	2700	World
112	Oral presentation to a wider public	ENEA	Presentation during Official Meeting of the Sector Group Intelligent Energy EEN of CHEETAH KEAP during Round table chaired by F.Roca "How improve collaboration among Research Community and SME in Renewables and sustainable development"	06/04/2016	Larnaca, Cyprus	Scientific Community (higher education, Research) Industry	50	Europe
113	Oral presentation to a scientific event	NPL	Stability of Printed Photovoltaics: In situ environmental measurments for the identification of degradation pathways	01/07/2016	ISFOE, Thessaloniki, Greece	Scientific Community (higher education, Research) Industry	50	World
114	Oral presentation to a scientific event	NPL	Identification of degradation and manufacturing issues using multi-parameter mapping of organic solar cells	14/01/2016	Advanced Characterisation Methods for Photovoltaics, Freiburg, Germany	Scientific Community (higher education, Research) Industry	50	Europe

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
115	Oral presentation to a scientific event	CEA	Characterization of oxygen-related defects in high-efficiency Czochralski silicon wafers	14/01/2016	Cheetach Workshop: Advanced Characterization Methods for PV, Freiburg, Germany	Scientific Community (higher education, Research) Industry	100	World
116	Web sites/Applications	METU	Dissemination of CHEETAH project information	01/04/2015	METU web-page	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers	450	World
117	Web sites/Applications	METU	A technical info including infrastructure, main features, etc. was prepared for Cheetah KEAP	01/03/2015	http://www.cheetah-exchange.eu/infrastructure.asp?i=29	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers	160	World
118	Press releases	METU	"Solar Enegys should be handled more strategically" (Güneş enerjisine daha stratejik ve ciddi yaklaşmak gerek- http://www.tenva.org/odtu-gunam-gunes-enerjisine-daha-stratejik-ve-ciddi-yaklasmak-gerek/)	20/03/2015	21st issue of Enerji Panorama “the monthly magazine that published by foundation of Turkish Energy”	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers	800	Turkey
119	Organisation of Conference	METU	Solar TR-3 Conference	27/04/2015	Ankara,Turkey	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers	500	Turkey and Europe

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
120	Organisation of Conference	METU	Conference "Photovoltaics: Power Source for the Future" within "ODTU 60.yil Davetli Konusmalar Dizisi" organised by METU	13/06/2015	Ankara,Turkey	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers	1000	Turkey and Europe
121	Organisation of Conference	METU	Turkish Universities in the European Research Area organised by METU	08/10/2015	Ankara,Turkey	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	850	Turkey and Europe
122	Oral presentation to a wider public	METU	Dissemination of CHEETAH in H2020 info-day (…)	27/02/2015	Ankara,Turkey	Scientific Community (higher education, Research)	40	Turkey
123	Oral presentation to a wider public	METU	Dissemination of CHEETAH in H2020 info-day (…)	06/03/2015	Ankara,Turkey	Scientific Community (higher education, Research)	40	Turkey
124	Oral presentation to a wider public	METU	Dissemination of CHEETAH in H2020 info-day (…)	20/03/2015	Ankara,Turkey	Scientific Community (higher education, Research)	50	Turkey
125	Oral presentation to a wider public	METU	Dissemination of CHEETAH in H2020 info-day (…)	22/05/2015	Ankara,Turkey	Scientific Community (higher education, Research)	40	Turkey
126	Oral presentation to a wider public	METU	Dissemination of CHEETAH in H2020 info-day (…)	13/05/2015	Ankara,Turkey	Scientific Community (higher education, Research), Industry, Civil Society, Medias	180	Turkey

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
127	Oral presentation to a scientific event	AIT	Degradation and electric behavior in thin film photovoltaic devices	14/01/2016	Cheetach Workshop: Advanced Characterization Methods for PV, Freiburg, Germany	Scientific Community (higher education, Research) Industry	100	Europe
128	Oral presentation to a scientific event	EPFL	Impact of Solar Cell Architecture on the Temperature Dependency of Electrical Performance	21/06/2016	EUPVSEC 2016 conference, Munich, Germany	Scientific Community (higher education, Research) Industry	1000	World
129	Oral presentation to a scientific event	HZB	Forming the active layers of a chalcopyrite solar cell by printing and reactive annealing	08/09/2016	SPINS16, Berlin, Germany	Scientific Community (higher education, Research)	50	World
130	Posters	HZB	Low band gap CuIn(S,Se)2 thin film solar cells prepared using a stable molecular ink	05/09/2016	ICTMC-20, Halle	Scientific Community (higher education, Research)	100	World
131	Posters	HZB	Local Growth of CuInSe2 Micro-Absorbers	05/09/2016	ICTMC-20, Halle	Scientific Community (higher education, Research)	100	World
132	Oral presentation to a wider public	UPM	Webinar "Nanotechnology in Photovoltaics In search of the elusive concept of Density-of-States"	27/10/2016	Ciberspace	Scientific Community (higher education, Research) Industry	60-70	Worldwide
133	Oral presentation to a wider public	UPM	Webinar "Electrical characterization of multijunction solar cells"	13/12/2016	Ciberspace	Scientific Community (higher education, Research) Industry	60-70	Worldwide

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
134	Oral presentation to a scientific event	ECN	Highlights of the IRP project on PV Cheetah	24/11/2016	EERA conference 2016, Birmingham	Scientific Community (higher education, Research)	100	Europe
135	Oral presentation to a scientific event	ECN	MWT Silicon Heterojunction A Simple Technology Integrating High Performance Cell and Module Technologies (including CHEETAH WP8 module results)	11/10/2016	HERCULES, final workshop, Berlin	Scientific Community (higher education, Research), Industry	70	Europe, Japan, US
136	Oral presentation to a scientific event	ECN	Review on n-type module technology, Integrated approaches to crystalline Si-PV modules + particuiaption in a panel discussion with other Project coordinators and Industry (Hercules, Cabriss)	10/03/2016	nPV workshop, Chambery	Scientific Community (higher education, Research), Industry,	100	World
137	Oral presentation to a scientific event	ECN	Accurate yearly yield calculation using fingerprint method	14/01/2016	Cheetah Workshop: Advanced Characterization Methods for PV, Freiburg, Germany	Scientific Community (higher education, Research)	100	Europe
138	Posters	TUT	Low temperature time resolved photoluminescence in ordered and disordered Cu2ZnSnS4 single crystals.	04/05/2016	EMRS 2016, Lille, France	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	500	World

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
139	Posters	TUT	Influence of order-disorder in Cu2ZnSnS4 powders on the performance of monograin layer solar cells	04/05/2016	EMRS 2016, Lille, France	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	500	World
140	Flyers	VTT	Flyers distribution - CHEETAH	13.-15. 9. 2016	ICFPE2016, Yonezawa, Japan	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	500	World
141	Flyers	VTT	Flyers distribution - CHEETAH	11.-12.10.2016	OE-A working group meeting, Frankfurt, Germany	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	100	World
142	Flyers	VTT	Flyers distribution - CHEETAH	31.10.-1.11. 2016	PrintoCent Industry Cluster Meeting, Oulu, Finland	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	100	World
143	Flyers	VTT	Flyers distribution - CHEETAH	16.-17. 11. 2016	Printed Electronics USA 2016, Santa Clara, USA	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	3000	World

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
144	Flyers	VTT	Flyers distribution - CHEETAH	28.11-2.12. 2016	MRS Fall Meetting 2106, Boston, USA	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	5000	World
145	Oral presentation to a scientific event	HZB	Nano- and microconcentrating for the next generation of chalcopyrite solar cells	27/10/2016	PVSEC 2016, Singapore	Scientific Community (higher education, Research)	100	World
146	Oral presentation to a scientific event	SolarPower Europe	EPIA Solaris Newsletter October 2016	01/10/2016	Mail sent to a contact list	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	15000	World
147	Flyers	UNIMIB	Flyers distribution - CHEETAH	17/03/2016	Lombardy Energu cleantech cluster . Annual workshop	Industry, Civil Society Policy makers, Medias	100	Italy
148	Posters	AIT	Defect analysis in ultrathin x-Si photovoltaic cells	29/11/2016	Villach, Carentia, Austria	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	260	Europa
149	Oral presentation to a scientific event	NPL	Comparing the intrinsic stability metrics of different active materials	11/10/2016	Freiburg, Germany	Scientific Community (higher education, Research) Industry	120	World

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
150	Oral presentation to a scientific event	NPL	Advanced In-Situ Characterization Methods to Identify Degradation Pathways	27/11/2016	Boston, USA	Scientific Community (higher education, Research) Industry, Policy makers, Medias	100	World
151	Organisation of workshops	NPL	Energy Rating for Photovoltaics	22/11/2016	London, UK	Scientific Community (higher education, Research), Industry	40	Europe
152	Oral presentation to a scientific event	CEA	How to deal with thin wafers in a heterojunction solar cells industrial pilot line: first analysis of the integration of cells down to 70µm thick in production mode	20/06/2016	EUPVSEC 2016, Munich, Germany	Scientific Community (higher education, Research) Industry, Policy makers, Medias	500	World
153	Oral presentation to a scientific event	DTU	Baselines for Lifetime of Organic Photovoltaics	12/10/2016	ISOS conference Freiburg, Germany	Scientific Community (higher education, Research), Industry	70	World
154	Organisation of Workshops	DTU	Application & Markets for OPV & Perovskite Solar Cells	12/10/2016	Breakout session in ISOS conference Freiburg, Germany	Scientific Community (higher education, Research), Industry	20	World
155	Oral presentation to a scientific event	DTU	Very low cost organic PV	22/11/2016	Technology Transfer Advisory Board meeting: Thin Film and Organic PV Innovations	Scientific Community (higher education, Research) Industry, Policy makers, Medias	10	World

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
156	Organisation of Conference	UTV	Organization of the International School on Hybrid and Organic Photovoltaics	11-15/09/2016	Castiglione della Pescaia, Italy	Scientific Community (higher education, Research) Industry, Policy makers, Medias	50	Europe
157	Oral presentation to a scientific event	EPFL	A Fourier scattering model without paraxial error	14-17.11.2016	OSA Light, Energy and the Environment Congress	Scientific Community (higher education, Research) Industry, Policy makers, Medias	1000	World
158	Oral presentation to a wider public	METU	Dissemination of CHEETAH in TUBITAK, H2020 Programme Research Infrastructures, 2016-2017 Calls Info Day (Agenda: http://www.h2020.org.tr/sites/default/files/u135/ankara_gundem_-_genel.pdf)	6 January 2016	Ankara,Turkey	Scientific Community (higher education, Research) Industry, Policy makers, Medias	100	Turkey
159	Organisation of workshops	METU	Dissemination of CHEETAH in PV Summer School 2016 (International Summer School&Workshop on Photovoltaics Science and Technology)	12-25 June 2016	Ankara,Turkey	Scientific Community (higher education, Research), Medias	80	Turkey and Europe
160	Oral presentation to a wider public	METU	Dissemination of CHEETAH Project as a success story in IRSEC 2016 - 4th International Renewable and Sustainable Energy Conference (…)	14-17 November 2016	Marrakech, Morocco	Scientific Community (higher education, Research) Industry, Policy makers, Medias	150	Worldwide

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
161	Organisation of workshops	METU	Dissemination of CHEETAH Project in the activity "Science at Home" to the teenagers and all related students. This activity had both theoretical and practical content and organized by METU within European Researchers' Night 2016 (…)	30 September 2016	Ankara,Turkey	Scientific Community (higher education, Research), Civil Society, Medias	500	Turkey
162	Oral presentation to a scientific event	METU	Dissemination of CHEETAH Project as a success story to Ministry of Energy and Natural Resources of Turkey	15 November 2016	Ankara,Turkey	Scientific Community (higher education, Research), Civil Society	20	Turkey
163	Oral presentation to a wider public	ENEA	Presentation during Official Meeting of the Sector Group Intelligent Energy EEN of CHEETAH KEAP during Round table chaired by F.Roca "How improve collaboration among Research Community and SME in Renewables and sustainable development"	06/04/2016	Larnaca, Cyprus	Scientific Community (higher education, Research), Industry	50	Europe
164	Web sites/Applications	ENEA	New release of CHEETAH Knowledge Exhange Web Area with improved content for the managemement of webinar and introduction of reserved areas disseminated externally to project partners by circular email list (…)	10/11/2016	http://www.cheetah-exchange.eu	Scientific Community (higher education, Research), Industry, Civil Society, Medias	3850	world

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
165	Web sites/Applications	ENEA	Creation of CHEETAH webinar Youtube channel to disseminate lectures r at the pubblic at large	30/12/2016	https://www.youtube.com/channel/UCzaOGpmO139GXvJ23PHvxuw	Scientific Community (higher education, Research), Industry, Civil Society, Medias	1000	world
166	Web sites/Applications	ENEA	Creation of CHEETAH Knowledge exchange Twitter group	31/12/2016	https://twitter.com/cheetah_kEAP/	Scientific Community (higher education, Research), Industry, Civil Society, Medias	1000	world
167	Web sites/Applications	ENEA	Creation of CHEETAH Knowledge Exchange Linkedin Group	31/12/2016	https://www.linkedin.com/groups/8588104	Scientific Community (higher education, Research), Industry, Civil Society, Medias	1000	world
168	Web sites/Applications	ENEA	Creation of CHEETAH Knowledge Exchange ResearchGate Group	31/12/2016	https://www.researchgate.net/project/FP7-CHEETAH-Knowledge-Exchange-Platform	Scientific Community (higher education, Research), Industry, Civil Society, Medias	500	world
169	Media briefings	ENEA	News on "Knowledge for a common vision: the CHEETAH KEAP e-learning platform" uploaded in Linkedin Platform & its dissemination Via Linkedin Solar Energy Network (…) Horizon2020 FP for Research. Thin Film Forum, Thin Film Solar	30/12/2016	https://www.linkedin.com/pulse/knowledge-common-vision-cheetah-keap-e-learning-platform-roca	Scientific Community (higher education, Research), Industry, Civil Society, Medias	5000	world

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
170	Oral presentation to a scientific event	ENEA	F. Roca Presentation CHEETAH network and distribution of CHEETAH Project flyer @ 20th Sede Boqer Symposium on Solar Electricity Production,The Annual Nano-Day and ENEA Workshop	27/09/2016	Sda Boqer, Israel http://in.bgu.ac.il/en/solar/Pages/20th-presentations.aspx	Scientific Community (higher education, Research)	150	Europe, Israel
171	Flyers	ENEA	Preparation in collaboration with EERA-PV and its project Coordinator (I.Gorodon, IMEC) of a flyer included in the partecipant pack of the EERA conference in Birmingham and as part of EERA's promotional materials of best practice of EERA PV JP. Flyer is available on a dedicated page on the EERA website too	24-25/11/2016	University of Birmingham (UK)	Scientific Community (higher education, Research), Industry, Civil Society, Medias	300	Europe
172	Oral presentation to a scientific event	TUT	CHEETAH Webinar " Optical and electrical characterization of micro-concentrator solar cells" Maarja Grossberg- TUT	10/10/2016	http://www.cheetah-exchange.eu/webinars.asp?i=5&t=OPV_Testing_and_Existing_Standards__	Scientific Community (hogher education, Research)	40	World
173	Oral presentation to a scientific event	ENEA	CHEETAH Webinar " Printed polymeric microlenses for solar microconcentrators " Giuseppe Nenna, ENEA	10/10/2016	http://www.cheetah-exchange.eu/webinars.asp?i=5&t=OPV_Testing_and_Existing_Standards__	Scientific Community (hogher education, Research)	40	World

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
174	Oral presentation to a scientific event	IMEC	Multiple reuse of the silicon substrate in a porous silicon based layer transfer process	21/06/2016	EUPVSEC 2016 conference, Munich, Germany	Scientific Community (higher education, Research) Industry	1000	World
175	Oral presentation to a scientific event	IMEC	Process development of silicon heterojunction interdigitated back-contacted (SHJ-IBC) solar cells bonded to glass	21/06/2016	EUPVSEC 2016 conference, Munich, Germany	Scientific Community (higher education, Research) Industry	1000	World
176	Oral presentation to a scientific event	ECN	Highlights from the FP7 project on photovoltaics CHEETAH: more power with less material	25/09/2017	EUPVSEC 2017, Amsterdam, The Netherlands	Scientific Community (higher education, Research)	100	World
177	Flyers	VTT	Flyers distribution - CHEETAH	28-30/03/2017	LOPEC-C 2017, Munich, Germany	Scientific Community (higher education, Research), Industry, Civil Society, Medias	4000	Europe, USA, Japan, China, Korea
178	Flyers	VTT	Flyers distribution - CHEETAH	6-7/04/2017	EPIC general annual meeting, Eindhoven, Netherlands	Scientific Community (higher education, Research), Industry, Civil Society, Medias	400	Europe
179	Flyers	VTT	Flyers distribution - CHEETAH	30-31/05/2017	Finnish Photonics Days 2017, Oulu, Finland	Scientific Community (higher education, Research), Industry, Civil Society, Medias	150	Finland

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
180	Flyers	VTT	Flyers distribution - CHEETAH	19-21/06/2017	Flex2017, Monterey, CA, USA	Scientific Community (higher education, Research), Industry, Civil Society, Medias	3500	Europe, USA, Japan, China, Korea
181	Flyers	VTT	Flyers distribution - CHEETAH	26-28/06/2017	NAMIS Workshop, Daejeon, Korea	Scientific Community (higher education, Research), Industry, Civil Society, Medias	100	Europe, USA, Japan, China, Korea
182	Flyers	VTT	Flyers distribution - CHEETAH	04-06/09/2017	ICFPE2017 conference, Jeju, Korea	Scientific Community (higher education, Research), Industry, Civil Society, Medias	600	Europe, USA, Japan, China, Korea
183	Oral presentation to a scientific event	VTT	CHEETAH Webinar "Roll-to-roll processes for printed OPV" Jukka Hast, Pälvi Apilo, Sami Ihme, VTT (…)	23/10/2017	CHEETAH Webinar by VTT - https://connect.portici.enea.it/pl12ti30gft5/	Scientific Community (hogher education, Research)	76	World
184	Posters	Julich	Sub-Micrometer Resolved Light-Coupling Efficiency and Charge-Carrier Generation in Silicon-Based Thin-Film Solar Cells	27/09/2017	EUPVSEC 2017, Amsterdam, The Netherlands	Scientific Community (higher education, Research), Industry	1000	World
185	Oral presentation to a scientific event	CIEMAT	CHEETAH Webinar "Solar Resource Knowledge for PV applications: current tools and needs" Jesús Polo-CIEMAT (…)	04/04/2017	https://www.cheetah-exchange.eu/webinars.asp?i=20	Scientific Community (hogher education, Research)	89	World

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
186	Oral presentation to a scientific event	TUT	CHEETAH Webinar "Kesterite Solar Cells: state of art and perspective" Simona Binetti (UNIMIB), Maarja Grossberg (TUT) and Stefan Haass (EMPA) (…)	03/11/2017	https://www.cheetah-exchange.eu/webinars.asp?i=48	Scientific Community (higher education, Research)	105	world
187	Oral presentation to a scientific event	TUT	CHEETAH Webinar "Photovoltaic Materials Research in Tallinn University of Technology" - Maarja Grossberg (TUT) (…) Event offered also on site @ ENEA Portici	03/05/2017	https://www.cheetah-exchange.eu/webinars.asp?i=23	Scientific Community (higher education, Research)	40	world
188	Posters	TUT	Photoluminescence study of deep donor- deep acceptor pairs in Cu2ZnSnS4 - Maarja Grossberg (TUT)	09/11/2017	8th European Kesterite Workshop, Barcelona, Spain	Scientific Community (higher education, Research) Industry	100	world
189	Flyers	SolarPower Europe	Conference flyer including project description, call for partnerships, research speakers' and industry speakers' biographies, agenda	30/11/2017	CHEETAH final event "European Solar Technology Forum"	Scientific Community (higher education, Research) Industry Medias	120	World
190	Organisation of Conference	SolarPower Europe	CHEETAH final event "European Solar Technology Forum"	30/11/2017	HZB Berlin	Scientific Community (higher education, Research) Industry Medias	120	World

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
191	Media briefings	SolarPower Europe	SolarPower Europe SOLARIS newsletter and targeted emails August 2017, September 2017, October 2017, November 2017	21/11/2017	Mail sent to a contact list	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	15000	World
192	Posters	HZB	Cigse-Microcells: Thermal and Opto-Electronic Analysis and Fabrication	03/05/2017	CPV-13, Ottawa, Canada	Scientific Community (higher education, Research), Industry	200	Europe
193	Oral presentation to a scientific event	HZB	Fabrication of CuInSe2 Micro Absorbers for Concentrator Solar Cells	22/05/2017	E-MRS Spring Meeting, Strasbourg, France	Scientific Community (higher education, Research), Industry	100	Europe
194	Posters	HZB	Micro Concentrator Concept for Cost Reduction and Efficiency Enhancement of Thin-Film Chalcopyrite Photovoltaics: Results from EU Joint Research Program CHEETAH	27/09/2017	EU-PVSEC, Amsterdam, Netherlands	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	200	Europe
195	Oral presentation to a scientific event	DTU	Consensus packaging procedure for organic and hybrid photovoltaics: ISOS-E	18/10/2017	ISOS-10 International Symphosium	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	100 + online broadcast	World
196	Oral presentation to a wider public	ECN	Highlights from the FP7 project on photovoltaics CHEETAH: more power with less material + WP8 results	30/11/2017	European Solar Technology Forum, Berlin, Germany	Scientific Community (higher education, Research), Industry, Civil Society, Medias	100	Europe

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
197	Oral presentation to a wider public	UNIMIB	"Our Common Future: Energy, Environment & Development" Workshop, Chalcogenide thin film solar cells: research activity at UNIMIB-MIBSOLAR center	31/08/2017	Italian-Kazak bilateral workshop, Astana Kazakistan (…)	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	80	World
198	Oral presentation to a scientific event	UNIMIB	Kesterite Solar Cells: state of art and perspective (756 accesses to Event web page as Jan. 15th 2018)	03/11/2017	CHEETAH Webinar	Scientific Community (higher education, Research), Industry	109	World
199	Oral presentation to a wider public	UNIMIB	Hybrid organic-inorganic photovoltaics: from molecules to devices characterization (Dr. Norberto Manfredi) (1247 accesses to Event web page as Jan. 15th 2018)	16/02/2017	CHEETAH Webinar	Scientific Community (higher education, Research), Industry	80	World
200	Posters	UNIMIB	In situ gel formation of high quality Cu2ZnSnS4 thin films	30/11/2017	European Solar Technology Forum – From Research to Industrial Application // CHEETAH final event	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	100	World
201	Oral presentation to a wider public	UNIMIB	Hybrid Halide Perovskite for Photovoltaic Applications (Dr. Vanira Trifiletti, UNIMIB) (1247 accesses to Event web page as Jan. 15th 2018)	28/04/2017	https://www.cheetah-exchange.eu/webinars.asp?i=21	Scientific Community (higher education, Research), Industry	96	World

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
202	Flyers	UNIMIB	Flyers distribution - CHEETAH	30-31/08/2017	Italian-Kazak bilateral workshop, Astana, Kazakastan "Our Common Future: Energy, Environment & Development" (…)	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	100	World
203	Oral presentation to a scientific event	CEA	Towards industrialization of heterojunction with thin and ultra-thin wafers	27/11/2017	27th PVSEC, Shiga, Japan	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	300	Worldwide
204	Oral presentation to a wider public	CEA	Highlights from the FP7 project on photovoltaics CHEETAH: summary of WP7 results	30/11/2017	European Solar Technology Forum, Berlin, Germany	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	100	Europe
205	Oral presentation to a wider public	METU	Role of R&D Activities on Solar Energy Conversion Technologies and the Role of German Experience (Conference on Powering the energy transition: The role of renewable energy and energy efficiency, organized by German Embassy-DAAD-GÜNAM-Ankara University)	7-8/09/2017	Ankara,Turkey	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	250	Germany-Turkey

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
206	Oral presentation to a wider public	METU	R&D and Investments Perspectives of Solar Energy	6-7/07/2017	Turkis Akademy of Science (TUBA) Workshop on Solar Energy Technologies, Ankara, Turkey	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	150	Turkey
207	Media briefings	METU	Dissemination of CHEETAH to Turkish Universities and Aircraft and Automotive industry representatives in 2nd Battery Technologies Workshop	21/12/2017	Ankara,Turkey	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	100	Turkey
208	Oral presentation to a wider public	METU	Dissemination of Cheetah and importance of R&D Approach based on cooperation in the field of enegry	04/05/2017	R&D Collaboration Summit and Fair, Istanbul, Turkey	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	5000	Turkey
209	Organisation of workshops	METU	GUNAM's second internal workshop (Cheetah project is also dissemianted during workshop)	26/5/2017	Ankara,Turkey	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	85	Turkey
210	Oral presentation to a scientific event	AIT	Defect Analysis in ultra-thin X-SI Photovoltaic cells	24-26 Apr. 2017	PVTC 2017, Marseille, France	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	117	World

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
211	Posters	AIT	Defect analysis of IBC cells	13-14 Nov. 2017	PV-Tagung, Vienna, Austria	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	150	Europe
212	Posters	ENEA	FP7-CHEETAH Knowledge Exchange Platform: Results and their Exploitation	27/09/2017	EUPVSEC 2017, Amsterdam, The Netherlands	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	200	World
213	Oral presentation to a wider public	UPM	Fundamentals of the lock-in technique and its application to solar cell characterization (Dr, Iñigo Ramiro González, UPM.ICFO) (…)	05/10/2017	https://www.cheetah-exchange.eu/webinars.asp?i=46	Scientific Community (higher education, Research)	49	World
214	Web sites/Applications	UPM	CHEETAH nano-MOOC Learning PV at CHEETAH Speed - Designing dopant diffusions for silicon solar cells prof. Carlos del Cañizo, UPM (…)	07/12/2017	https://www.cheetah-exchange.eu/webinars.asp?i=50	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	52	World
215	Web sites/Applications	UPM	CHEETAH nano-MOOC Learning PV at CHEETAH Speed - Fundamentals of photovoltaics - advanced concepts prof. Antonio Marti, UPM (…)	14/12/2017	https://www.cheetah-exchange.eu/webinars.asp?i=51	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	53	World

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
216	Web sites/Applications	UPM	CHEETAH nano-MOOC Learning PV at CHEETAH Speed - Simulation of solar cells and modules with equivalent circuits prof. David Fuertes , UPM (…)	19.12.2017 - 15.01.2018	https://www.cheetah-exchange.eu/webinars.asp?i=52	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	36	World
217	Posters	IKZ	Growth of Silicon on Reorganized Porous Silicon Substrates by Steady-State Solution Growth for Photovoltaic Applications	27/09/2017	33rd European Photovoltaic Solar Energy Conference and Exhibition (EU PVSEC 2017); Amsterdam, The Netherlands	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	2500	World
218	Posters	IKZ	Monocrystalline thin-film absorbers by steady-state solution growth	14/11/2017	27th Photovoltaic Science and Engineering Conference (PVSEC-27); Otsu, Japan	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	850	World
219	Oral presentation to a scientific event	IKZ	In situ removal of a native oxide layer on silicon subtrates by UV-laser for epitaxial applications	08/03/2017	5th German Swiss Conference on Crystal Growth GSCCG-5/DKT 2017; Freiburg, Germany	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	200	Europe
220	Oral presentation to a scientific event	IKZ	In-Ga precursor islands for CIGSe micro-concentrator solar cells	26/06/2017	44th IEEE Photovoltaic Specialists Conference; Washington, DC, USA	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	1500	World

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
221	Posters	IKZ	Solution growth of Si on reorganized porous Si foils and on glass substrates	08/08/2016	18th International Conference on Crystal Growth and Epitaxy (ICCGE18); Nagoya, Japan	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	1200	World
222	Posters	IKZ	Growth of silicon on porous silicon and glass substrates from Sn solution	28/10/2016	26th Photovoltaic Science and Engineering Conference (PVSEC-27); Singapore	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	1700	World
223	Oral presentation to a scientific event	TECNALIA	CHEETAH Webinar "Simulation of heterogeneous PV systems and storage in self-consumption scenarios" Ricardo Alonso - TECNALIA (…)	30/12/2017	CHEETAH Webinar by ENEA - https://www.cheetah-exchange.eu/webinars.asp?i=55	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	34	World
224	Organisation of Workshops	TECNALIA	"BFIRST Final workshop", presented by CRES, participated by TECNALIA, CRES, ENEA (…)	27/04/2017	CHEETAH workshop by TECNALIA (KEP). Participation also of ENEA and CRES.	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	109	World
225	Posters	JRC	2017 Survey on Priorities for Standards and Best Practices: Quick Look Report and Poster	30/11/2017	European Solar Technology Forum, Berlin, Germany	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	100	Europe

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
226	Oral presentation to a wider public	JRC	2017 Survey on Priorities for Standards and Best Practices: Quick Look Report and Poster	30/11/2017	European Solar Technology Forum, Berlin, Germany	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	100	Europe
227	Oral presentation to a wider public	UTV	Organic PV and Perovskite	30/11/2017	European Solar Technology Forum, Berlin, Germany	Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias	50	Europe
228	Flyers	ENEA	Dissseminaton of CHEETAH Knowledge Exchange Platforms and CHEETAH Project duiring the workshop held at Annual Conference Enterprise Europe Network.- Tallinn Estonia . GreenEconomy4SMEs: (…)	21/11/2017	Tallinn Estonia	Scientific Community (higher education, Research) Industry	1200	Europe
229	Web sites/Applications	ENEA	New release of CHEETAH Knowledge Exhange Web Area with improved content for the managemement of webinar and new procedures to access to reserved areas disseminated externally to project partners by circular email list (…)	09/01/2017	http://www.cheetah-exchange.eu	Scientific Community (higher education, Research), Industry, Civil Society, Medias	4000	World
230	Web sites/Applications	ENEA	New release of CHEETAH Knowledge Exhange Web Area with new Cataloguing criteria and simplified procedurer to access/register	05/06/2017	http://www.cheetah-exchange.eu	Scientific Community (higher education, Research), Industry, Civil Society, Medias	4600	World

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
231	Web sites/Applications	ENEA	New release of CHEETAH Knowledge Exhange Web Area to inform about the offer of CHEETAH nano-MOOCS learning at CHEETAH speed and PV Academy	01/12/2017	http://www.cheetah-exchange.eu	Scientific Community (higher education, Research), Industry, Civil Society, Medias	5000	World
232	Web sites/Applications	ENEA	CHEETAH webinar posts via Linkedin and Solar Energy Network, PhD Physicists, Materials Research Society, Thin Film forum	14/01/2017	https://www.linkedin.com/in/francesco-roca-2a15651b/detail/recent-activity/posts/	Scientific Community (higher education, Research), Industry, Civil Society, Policy, makers, Medias	20000	World
233	Web sites/Applications	ENEA	CHEETAH Webinar posts via Research gate	12/01/2017	https://www.researchgate.net/project/FP7-CHEETAH-Knowledge-Exchange-Platform	Scientific Community (higher education, Research), Industry, Civil Society, Policy, makers, Medias	5000	World
234	Oral presentation to a scientific event	AIT	CHEETAH Webinar UV-Fluorescence Analysis and comparison with other optical characterization methods Bernhard Kubicek, AIT (…)	27/01/2017	https://www.cheetah-exchange.eu/webinars.asp?i=14	Scientific Community (higher education, Research), Industry, Civil Society, Policy, makers, Medias	81	World
235	Oral presentation to a scientific event	IMEC	CHEETAH Webinar Overview of lift-off technologies for kerfless crystalline silicon material for PV applications Dr. Kris Van Nieuwenhuysen Dr. Hariharsudan Sivaramakrishnan Radhakrishnan) No access by streaming (…)	12/01/2017	https://www.cheetah-exchange.eu/webinars.asp?i=18	Scientific Community (higher education, Research), Industry, Civil Society, Policy, makers, Medias	85	World

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
236	Oral presentation to a scientific event	LNEG	CHEETAH Webinar PV modelling: from cells to grid integration (Dr.antonoio Joe, LNEG) (…)	31/12/2917	https://www.cheetah-exchange.eu/webinars.asp?i=54	Scientific Community (higher education, Research), Industry, Civil Society, Policy, makers, Medias	34	World
237	Oral presentation to a scientific event	EMPA	CHEETAH Webinar Electrical characterization of thin film solar cells and absorbers (Thomas P. Weiss, EMPA) (…)	10/05/2017	https://www.cheetah-exchange.eu/webinars.asp?i=22	Scientific Community (higher education, Research), Industry, Civil Society, Policy, makers, Medias	137	World
238	Oral presentation to a scientific event	SINTEF	CHEETAH Webinar Dislocations in multicrystalline silicon (Dr. Birgit Ryningen, SINTEF) (…)	09/06/2017	https://www.cheetah-exchange.eu/webinars.asp?i=24	Scientific Community (higher education, Research), Industry, Civil Society, Policy, makers, Medias	46	World
239	Oral presentation to a scientific event	CRES	CHEETAH Webinar Outdoor I-V characterization and Long term PV modules testing (Dr. Georgios Halabalakis, Dr. Kyritsis Anastasios - CRES) (…)	14/09/2017	https://www.cheetah-exchange.eu/webinars.asp?i=45	Scientific Community (higher education, Research), Industry, Civil Society, Policy, makers, Medias	186	World
240	Oral presentation to a scientific event	IFE	CHEETAH Webinar Advanced modelling of photovoltaic devices (Dr. Ørnulf Nordseth ,IFE , Dr. Halvard Haug, IFE) (…)	06/12/2017	https://www.cheetah-exchange.eu/webinars.asp?i=49	Scientific Community (higher education, Research), Industry, Civil Society, Policy, makers, Medias	131	World

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
241	Posters	ENEA	Polymeric Microlenses for Photovoltaic Microconcentrator Applications: Prototype Characterization and Simulation	26/09/2017	EUPVSEC 2017, Amsterdam, The Netherlands	Scientific Community (higher education, Research), Industry, Civil Society, Policy, makers, Medias	200	World
242	Oral presentation to a scientific event	ISE	FEM-based development of novel back contact PV modules with ultra-thin solar cells	27/09/2017	EUPVSEC 2017, Amsterdam, The Netherlands	Scientific Community (higher education, Research), Industry, Civil Society, Policy, makers, Medias	200	World
243	Web sites/Applications	ENEA	Final release of CHEETAH Knowledge Exchange Web realized in December 2017 and tested in January 2018 with a "Career Area" " addressed to offer job opportunities in PV RTD Community, (…)	25/01/2018	https://www.cheetah-exchange.eu/	Scientific Community (higher education, Research), Industry, Civil Society, Policy, makers, Medias	20000	World
244	Oral presentation to a scientific event	ISE	Origin and Impact of crystallographic defects in epitaxially grown Si wafers	26/09/2017	EUPVSEC 2017, Amsterdam, The Netherlands	Scientific Community (higher education, Research), Industry, Civil Society, Policy, makers, Medias	200	World
245	Oral presentation to a scientific event	ISE	Rapid Vapour-Phase Direct Diffused Emitter for Solar Cell Applications	27/09/2017	EUPVSEC 2017, Amsterdam, The Netherlands	Scientific Community (higher education, Research), Industry, Civil Society, Policy, makers, Medias	250	World

No	Type of activities*	Main leader	Title	Date	Place	Type of audience**	Size of audience	Countries addressed
246	Oral presentation to a scientific event	SINTEF	Limitations to sawing of ultrathin wafers by diamond multi-wire-sawing	09/05/2017	Norwegian Solar Cell Conference 2017 - Son, Norway	Scientific Community (higher education, Research), Industry, Civil Society, Policy, makers, Medias	106	Norway
247	Oral presentation to a scientific event	IMPERIAL	Photooxidation of fullerenes as a key degradation pathway of Organic Solar cells	30/6/2016	HOPV 2016, Swansea	Scientific Community (higher education, Research), Industry, Civil Society, Policy, makers, Medias	500	world
248	Oral presentation to a scientific event	IMPERIAL	Non-fullerenes: A Universal approech of "Burn-in"	10/01/2017	ISOS-10 International Symphosium, Malta	Scientific Community (higher education, Research), Industry, Civil Society, Policy, makers, Medias	100	world
249	Oral presentation to a scientific event	IMPERIAL	Role of fullerenes on the environmental stability of organic solar cells	10/01/2016	ISOS-9 International Symphosium, Freiburg	Scientific Community (higher education, Research), Industry, Civil Society, Policy, makers, Medias	100	world
250	Oral presentation to a scientific event	IMPERIAL	Stability of Organic Solar Cells	08/01/2017	EAMC 2017 in Stockholm	Scientific Community (higher education, Research), Industry, Civil Society, Policy, makers, Medias	500	world

.

3.2. Section B: Use (CONFIDENTIAL)

3.2.1 List of applications for patents, trademarks, registered design… (B1) – Confidential

Template B1: List of applications for patents, trademarks, registered designs, etc.									
No	**WP**	**Type of IP Rights***	**Application reference(s) (e.g. EP123456)**	**Intellectual Property Organization**	**Subject or title of application**	**Confidential (Yes / No)**	**Foreseen embargo date (DD/MM/YYYY)**	**Applicant(s) (as on the application)**	**URL of application**
	WP9	Patents	DE102014224004 (A1)	TUT	Elektronisches Bauteil mit Zwischenschicht zwischen n- und p-dotierter Halbleiterschicht	No		Applicant: crystalsol OÜ. Inventors: Dieter Meissner, Marit Kauk-Kuusik, Kaia Ernits, Axel Neisser	http://www.google.com/patents/DE102014224004A1?cl=de

3.2.2 List of exploitable foreground (B2) - Confidential

Template B2: List of exploitable foreground										
No	**WP**	**Type of Exploitable Foreground***	**Exploitable foreground (description)**	**Confi-dential (Yes/No)**	**Foreseen embargo date**	**Exploitable product(s) or measure(s)**	**Sectors of application****	**Timetable for commercial or any other use**	**Patents or other IPR exploitation (licences)**	**Owner & Other Beneficiarys involved**
1	WP9	General advancement of knowledge	Development of triple and quadruple thin-film Si solar cells with high output voltage	No		Devices well suited for water splitting application	Energy (water spitting)	Depending on the development of fully integrated water splitting devices	No	EPFL
2	WP10	General advancement of knowledge	Online lifetime database	No	Available any time	Online lifetime database	In the research of thin film emerging PV technologies	Not available	No	DTU
3	WP9	General advancement of knowledge	Development of chemical etching treatment of CZTS monograin powders surface. Treatment described in paper http://dx.doi.org/10.1016/j.apsusc.2015.09.094	No	Available any time	Chemical etching treatment of CZTS monograin powders surface.	Monograin powder technology for CZTS absorber production	Used by crystalsol OÜ and crystalsol GmbH, exploiting monograin powder technology for CZTS monograin solar cell producion developed by the research group of TUT. More information: www.crystalsol.com	No	TUT

No	WP	Type of Exploitable Foreground*	Exploitable foreground (description)	Confi-dential (Yes/No)	Foreseen embargo date	Exploitable product(s) or measure(s)	Sectors of application**	Timetable for commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiarys involved
4	WP9	General advancement of knowledge	jV sun simulator with illumination intensities variable from 0.1 - 100 suns for solar cell testing	No	Available any time	(Micro) concentrator solar cell characterisation	Photovoltaics, solar fuels, high intensity devices in general	Semi-commercial: purchase from US company + own development, thus ready for further use	No	HZB + supplier
5	WP7	Commercial exploitation of R&D results	Know-how for processing thin cells on CEA-INES Heterojunction pilot line	Yes		Application of thin cells for specific products (ultra-light modules, high perfomances modules)	PV technologies, generic and niche products	CEA & Industrial partners bilateral contracts	No	CEA
6	WP6	General advancement of knowledge	Process and know-how for making porous silicon stacks that allow the growth of high-quality epitaxial silicon layers and subsequent high-yield detachment of large-area silicon foils	Yes	Available any time	Thin high-quality silicon wafers	Photovoltaics	Depending on the availability of commercial high-throughput porous silicon formation and epitaxial silicon deposition tools	No	IMEC

No	WP	Type of Exploitable Foreground*	Exploitable foreground (description)	Confi-dential (Yes/No)	Foreseen embargo date	Exploitable product(s) or measure(s)	Sectors of application**	Timetable for commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiarys involved
7	WP6	General advancement of knowledge	Adapted process for making porous silicon stacks that allows the growth of high-quality epitaxial silicon layers in an in-line high-throughput reactor and subsequent detachment of large-area silicon foils	Yes	Available any time	Thin high-quality silicon wafers	Photovoltaics	Depending on when we can achieve high enough quality and detachment yield in this particular reactor (ProConCVD)	No	IMEC, ISE
8	WP9	General advancement of knowledge	Development of low-temperature annealing treatment for optimization of disordering level in CZTS monograins, thermal treatment described in paper http://dx.doi.org/10.1016/j.tsf.2016.10.017	No	Available any time	Low-temperature thermal treatment of CZTS monograin powders	Monograin powder technology for CZTS absorber production	Used by crystalsol OÜ and crystalsol GmbH, exploiting monograin powder technology for CZTS monograin solar cell producion developed by the research group of TUT. More information: www.crystalsol.com	No	TUT
9	WP9	General advancement of knowledge	Subwavelength characterization of optoelectronic devices by scanning near-field optical microscopy combined with rigorous optical simulations	No	Available any time	Electrooptical device performance on the nanoscale	Solar cells, light emitting diodes, sensors	Available at JÜLICH	No	Jülich

No	WP	Type of Exploitable Foreground*	Exploitable foreground (description)	Confi-dential (Yes/No)	Foreseen embargo date	Exploitable product(s) or measure(s)	Sectors of application**	Timetable for commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiarys involved
10	WP10	General advancement of knowledge	Procedures and know-how for characterisation of degradation of PV devices under controlled environmental conditions.	Yes		Services for comparison of intrinsic lifetime of PV materials	Photovoltaics, Printed electronics	Depending on customer requirements	No	NPL
11	WP10	Commercial exploitation of R&D results	Characterisation of environmental characteristics of unique large portable test chamber.	Yes		Large portable environmental chamber available for purchase under license.	Photovoltaics, Printed electronics	Chamber design licensed to exploitation partner	Yes	NPL
12	WP8	General advancement of knowledge	Know-how for integration of thin cells into modules (back contact/smart wire)	Yes	Available any time	Application of thin cells for modules, cost reduction by lower Si use	Photovoltaics	depending on market introduction of back contact and smart wire technology	No	ECN, CEA-INES
13	WP8	General advancement of knowledge	Thermomechanical model for back contact PV module	Yes		Forecast for thermomechanical stability of modules, depending on composition	Photovoltaics	Available at ISE	No	ISE

Additional Template B2: Overview table with exploitable foreground		
No	**Description of Exploitable Foreground**	**Exploitable Foreground (explanation)**
1	**WP9** Development of triple and quadruple thin-film Si solar cells with high output voltage	Water splitting requires relatively high voltage (≥1.8 V) that cannot be provided by single or tandem junction solar cell device directly. Triple and quadruple junction device can provide the necessary output voltage (1.7 - 2.3 V) at maximum power point to fabricate fully integrated water splitting devices. Total efficiency from sun to fuel close to 10% is feasible as demonstrated by several research groups. Further development of this integrated device is necessary (optimization of configuration, electrodes, etc) for the exploitation of the present results. Potential impact will depend on the cost effectiveness of a fully integrated water splitting solution compared to a standard solution (PV system separated from the electrolyzer).
2	**WP10** Online lifetime database	**Its purpose:** To help community in understanding the limiting mechanisms of lifetime of organic solar cells and other technologies alike, to compare and predict the lifetime under different test conditions **How the foreground might be exploited, when and by whom:** Can be utilized by researchers in the field of emerging thin film technonologies **IPR exploitable measures taken or intended:** No **Further research necessary, if any:** No
3	**WP9** Development of chemical etching treatment of CZTS monograin powders surface. Treatment described in "p–n junction improvements of Cu2ZnSnS4/CdS monograin layer solar cells" http://dx.doi.org/10.1016/j.apsusc.2015.09.094	**Its purpose:** To improve CZTS monograin solar cell performance by improving the properties of the p-n junction. **How the foreground might be exploited, when and by whom: D**eveloped chemical etching treatment could be exploited any time to improve p-n junction in CZTS monograin layer solar cells. The treatment is already used by crystalsol OÜ and crystalsol GmbH, www.crystalsol.com **IPR exploitable measures taken or intended:** No **Further research necessary, if any:** not for this specific treatment **Potential/expected impact (quantify where possible):** Improvement of CZTS monograin layer solar cell efficiency and eventually produced CZTS solar modules cost/efficiency

No	Description of Exploitable Foreground	Exploitable Foreground (explanation)
4	**WP9** jV sun simulator with illumination intensities variable from 0.1 - 100 suns for solar cell testing	**Its purpose:** Measurement of micro concentrator solar cells **How the foreground might be exploited, when and by whom:** Any time by groups working on concentration of solar illumination in particular for micro solar cells **IPR exploitable measures taken or intended:** No **Further research necessary, if any:** Improved automation of measurment, extended flexibility of setup and combination with lens testing + alginment **Potential/expected impact (quantify where possible):** Testing of various materials and different illumination conditions to foster application under low, medium and high concentration
5	**WP7** Know-how for processing thin cells on CEA-INES Heterojunction pilot line	**Its purpose:** Heterojonction cell elaboration in production mode on 80 to 110µm wafers **How the foreground might be exploited, when and by whom:** Bilateral project between CEA and industrial partner for application using thin PV cells (weight and flexibility issues) **IPR exploitable measures taken or intended:** no (know how specific to CEA-INES pilot line) **Further research necessary, if any:** no **Potential/expected impact (quantify where possible):** >= 2 contracts - projects per year
6	**WP6** Process and know-how for making porous silicon stacks that allow the growth of high-quality epitaxial silicon layers and subsequent high-yield detachment of large-area silicon foils	**Its purpose:** Process and detailed know-how on how to make large-area ultra-thin (<80 um) silicon wafers without kerf loss. Such thin wafers cannot be produced by traditional wire sawing of ingots. The main advantages of such thin epitaxial wafers in the PV industry would be a substantial cost reduction by using much less silicon material and the possibility to reduce the number of cell processing steps due to the use of in-situ grown emitter and/or BSF layers. **How the foreground might be exploited, when and by whom:** Can be used by industry on the condition that high-throughput porous silicon formation and silicon epitaxy systems are available. Possible users of the technology are wafer providers that currently use traditional ingot fabrication and wire sawing to make the wafers. Can also be used for research when small quantities of wafers are needed with specific combinations of thickness and doping profiles. **IPR exploitable measures taken or intended:** First contacts made with interested companies, research is partially paid by industry via imec Industrial Affiliation Program, we do not disclose all know-how and process parameters to the public. **Further research necessary, if any:** Further optimization towards higher yield and material quality is still needed, as well as upscaling towards high-throughput large area. **Potential/expected impact (quantify where possible):** A cost reduction at the level of the wafers used in PV imdustry up to 50%.

No	Description of Exploitable Foreground	Exploitable Foreground (explanation)
7	**WP6** Adapted process for making porous silicon stacks that allows the growth of high-quality epitaxial silicon layers in an in-line high-throughput reactor and subsequent detachment of large-area silicon foils	**Its purpose:** Process and detailed know-how on how to make large-area ultra-thin (<80 um) silicon wafers without kerf loss. Such thin wafers cannot be produced by traditional wire sawing of ingots. The main advantages of such thin epitaxial wafers in the PV industry would be a substantial cost reduction by using much less silicon material and the possibility to reduce the number of cell processing steps due to the use of in-situ grown emitter and/or BSF layers. **How the foreground might be exploited, when and by whom:** Can be used by industry on the condition that high-throughput porous silicon formation systems are available. Possible users of the technology are wafer providers that currently use traditional ingot fabrication and wire sawing to make the wafers. Can also be used for research when small quantities of wafers are needed with specific combinations of thickness and doping profiles. **IPR exploitable measures taken or intended:** Patents about the ProConCVD system used for epitaxial growth. Creation of a spin-off company NexWafe GmbH that targets to make inexpensive 156x156 mm2 wafers for PV industry based on porous silicon and epitaxy using ProConCVD. **Further research necessary, if any:** Further optimization towards higher yield and material quality is still needed. Demonstration of high-throughput production of large area wafers is still needed. **Potential/expected impact (quantify where possible):** A cost reduction at the level of the wafers used in PV imdustry up to 50%.
8	**WP9** Development of low-temperature annealing treatment for optimization of disordering level in CZTS monograins leading to improved solar cell performance. Thermal treatment is described in “in Cu2ZnSnS4 powders on the performance of monograin layer solar cells. Thin Solid Films (accepted), http://dx.doi.org/10.1016/j.tsf.2016.10.017	**Its purpose:** To improve CZTS monograin solar cell performance by optimizing the defect structure of CZTS. **How the foreground might be exploited, when and by whom:** Developed low-temperature thermal treatment could be exploited any time to improve CZTS monograin layer solar cell performance through improvement of Voc. The treatment is already used by crystalsol OÜ and crystalsol GmbH, www.crystalsol.com **IPR exploitable measures taken or intended:** No **Further research necessary, if any:** not for this specific treatment, detailed study has been made **Potential/expected impact (quantify where possible):** Improvement of CZTS monograin layer solar cell efficiency and eventually produced CZTS solar modules cost/efficiency.

No	Description of Exploitable Foreground	Exploitable Foreground (explanation)
9	**WP9** Subwavelength characterization of optoelectronic devices by scanning near-field optical microscopy combined with rigorous optical simulations	**Its purpose:** Characterization of optoelectronic devices with very high spatial resolution. Measurement of local light coupling efficiencies and charge carrier generation. Characterization of local defects. **How the foreground might be exploited, when and by whom:** Bilateral projects between Jülich and partners from research or industry at any time **IPR exploitable measures taken or intended:** No **Further research necessary, if any:** Only necessary, if other quantities of the devices needs to be investigated. **Potential/expected impact (quantify where possible):** Increased knowledge about local variations of device performance which can be used as feedback for device optimization.
10	**WP10** Procedures and know-how for characterisation of degradation of PV devices under controlled environmental conditions.	**N/A**
11	**WP10** Characterisation of environmental characteristics of unique large portable test chamber.	**N/A**
12	WP8 Know-how for integration of thin cells into modules (back contact/smart wire)	**N/A**
13	Thermomechanical model for back contact PV module	**Its purpose:** Quantification of stress in thin solar cells within back contact modules. **How the foreground might be exploited, when and by whom:** Projects between ISE and partners from research or industry at any time. **IPR exploitable measures taken or intended:** No **Further research necessary, if any: No** **Potential/expected impact (quantify where possible):** easy and straight forward virtual prototyping of the simulated back contact PV module design.

Section 4 - Report on societal implications

A General Information *(completed automatically when **Grant Agreement number** is entered.*

Grant Agreement Number:	609788
Title of Project:	CHEETAH
Name and Title of Coordinator:	Jan Kroon

B Ethics

1. Did your project undergo an Ethics Review (and/or Screening)? • If Yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final project reports? Special Reminder: the progress of compliance with the Ethics Review/Screening Requirements should be described in the Period/Final Project Reports under the Section 3.2.2 *'Work Progress and Achievements'*	**No**
2. Please indicate whether your project involved any of the following issues (tick box) :	
RESEARCH ON HUMANS	
• Did the project involve children?	**No**
• Did the project involve patients?	**No**
• Did the project involve persons not able to give consent?	**No**
• Did the project involve adult healthy volunteers?	**No**
• Did the project involve Human genetic material?	**No**
• Did the project involve Human biological samples?	**No**
• Did the project involve Human data collection?	**No**
RESEARCH ON HUMAN EMBRYO/FOETUS	
• Did the project involve Human Embryos?	**No**
• Did the project involve Human Foetal Tissue / Cells?	**No**
• Did the project involve Human Embryonic Stem Cells (hESCs)?	**No**
• Did the project on human Embryonic Stem Cells involve cells in culture?	**No**
• Did the project on human Embryonic Stem Cells involve the derivation of cells from Embryos?	**No**

PRIVACY	
• Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	**No**
• Did the project involve tracking the location or observation of people?	**No**
RESEARCH ON ANIMALS	
• Did the project involve research on animals?	**No**
• Were those animals transgenic small laboratory animals?	**No**
• Were those animals transgenic farm animals?	**No**
• Were those animals cloned farm animals?	**No**
• Were those animals non-human primates?	**No**
RESEARCH INVOLVING DEVELOPING COUNTRIES	
• Did the project involve the use of local resources (genetic, animal, plant etc)?	**No**
• Was the project of benefit to local community (capacity building, access to healthcare, education etc)?	**No**
DUAL USE	
• Research having direct military use	**No**
• Research having the potential for terrorist abuse	**No**

C Workforce Statistics

3. Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).

Type of Position	Number of Women	Number of Men
Scientific Coordinator		**1**
Work package leaders	**2**	**7**
Experienced researchers (i.e. PhD holders)	**33**	**110**
PhD Students	**3**	**9**
Other	**14**	**25**

4. How many additional researchers (in companies and universities) were recruited specifically for this project?	**12**
Of which, indicate the number of men:	**9**

D Gender Aspects

5. Did you carry out specific Gender Equality Actions under the project?	○ ☑	**Yes** No

6. Which of the following actions did you carry out and how effective were they?

	Not at all effective				Very effective
❑ Design and implement an equal opportunity policy	**N/A**	○	○	○	○
❑ Set targets to achieve a gender balance in the workforce	**N/A**	○	○	○	○
❑ Organise conferences and workshops on gender	**N/A**	○	○	○	○
❑ Actions to improve work-life balance	**N/A**	○	○	○	○

○ Other:

7. Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?

○ Yes- please specify

☑ **No**

E Synergies with Science Education

8. Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?

○ Yes- please specify

☑ **No**

9. Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?

☑ **Yes**- please specify

One website: http://www.cheetah-project.eu/

One exchange knownledge exchange platform: https://www.cheetah-exchange.eu/

○ No

F Interdisciplinarity

10. Which disciplines (see list below) are involved in your project?

○ Main discipline[16]: **2.3 Other Engineering Sciences**

○ Associated discipline16: **1.3 Chemical Sciences**

○ Associated discipline16: **1.4 Earth and related environmental Sciences**

G Engaging with Civil society and policy makers

11a	**Did your project engage with societal actors beyond the research community?** *(if 'No', go to Question 14)*	☑ ○	**Yes** No

11b If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?

○ No

○ Yes- in determining what research should be performed

○ Yes - in implementing the research

☑ **Yes, in communicating /disseminating / using the results of the project**

11c	**In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?**	○ ☑	Yes **No**

12. Did you engage with government / public bodies or policy makers (including international organisations)

○ No

○ Yes- in framing the research agenda

○ Yes - in implementing the research agenda

☑ **Yes, in communicating /disseminating / using the results of the project**

13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers?

○ Yes – as a **primary** objective (please indicate areas below- multiple answers possible)

☑ **Yes – as a secondary objective (please indicate areas below - multiple answer possible)**

○ No

[16] Insert number from list below (Frascati Manual).

13b If Yes, in which fields?					
Agriculture		Energy		Human rights	
Audiovisual and Media		Enlargement		Information Society	
Budget		Enterprise		Institutional affairs	
Competition		Environment		Internal Market	
Consumers		External Relations		Justice, freedom and security	
Culture		External Trade		Public Health	
Customs		Fisheries and Maritime Affairs		Regional Policy	
Development Economic and Monetary Affairs		Food Safety		**Research and Innovation**	☑
Education, Training, Youth		Foreign and Security Policy		Space	
Employment and Social Affairs		Fraud		Taxation	
		Humanitarian aid		Transport	

13c If Yes, at which level?

Local / regional levels

National level

☑ **European level**

International level

H Use and dissemination

14. How many Articles were published/accepted for publication in peer-reviewed journals?	**84**
To how many of these is open access[17] provided?	**25**
How many of these are published in open access journals?	**5**
How many of these are published in open repositories?	**6**
To how many of these is open access not provided?	**59**
Please check all applicable reasons for not providing open access:	
☑ **publisher's licensing agreement would not permit publishing in a repository** ❑ no suitable repository available ❑no suitable open access journal available ☑ **no funds available to publish in an open access journal** ❑ lack of time and resources ❑ lack of information on open access ❑ other[18]: ……	

15. How many new patent applications ('priority filings') have been made? *("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).*		**1**
16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark	**0**
	Registered design	**0**
	Other	**0**
17. How many spin-off companies were created / are planned as a direct result of the project?		**0**
Indicate the approximate number of additional jobs in these companies:		**0**

18. Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project:

❑	Increase in employment, or	❑	In small & medium-sized enterprises
❑	Safeguard employment, or	❑	In large companies
❑	Decrease in employment,	☑	None of the above / not relevant to the project
☑	Difficult to estimate / not possible to quantify		

19. For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (*FTE = one person working fulltime for a year*) jobs:	*Indicate figure:*
Difficult to estimate / not possible to quantify	*0* ☑

[17] Open Access is defined as free of charge access for anyone via Internet.
[18] For instance: classification for security project.

I Media and Communication to the general public

20. As part of the project, were any of the beneficiaries professionals in communication or media relations?

○ Yes ☑ No

21. As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?

○ Yes ☑ No

22 Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?

☑	Press Release	❑	Coverage in specialist press
❑	Media briefing	❑	Coverage in general (non-specialist) press
❑	TV coverage / report	❑	Coverage in national press
❑	Radio coverage / report	❑	Coverage in international press
☑	Brochures /posters / flyers	☑	Website for the general public / internet
❑	DVD /Film /Multimedia	☑	Event targeting general public (festival, conference, exhibition, science café)

23 In which languages are the information products for the general public produced?

❑	Language of the coordinator	☑	English
☑	Other language(s)		

Section 5 Report on the distribution of the European union financial contribution between beneficiaries

This report shall be submitted to the Commission within 30 days after receipt of the final payment of the European Union financial contribution.

Table will be completed on the EC platform.