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

Deliverable

D5.7 - Final public event for disseminating the cheetah results – Report on transfer of knowledge activities to industry and the PV community (minutes)

WP5 – Acceleration of innovations' implementation

Section 1 – Document Status

Document information

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2	14/12/2017	Crystalline silicon session summary	Sean Erik Foss
3	14/12/2017	Thin film session summary	Simona Binetti
4	14/12/2017	Organic PV session summary	James Blakesley
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Section 2 – Table of content

Section 3 – Acknowledgements

On behalf of the project consortium the organizers of the Cheetah final event would like to extend sincerest thanks and appreciation to those who registered, participated and contributed with their inputs or questions to the event. Your interest and active involvement was rather beneficial for the realization of a successful event but moreover for the successful continuation of the Cheetah project.

Special thanks to the project coordinator, the expert speakers, the moderators and the expert panelists on behalf of the industry whose involvement was key for the event.

We are also grateful to the Helmholtz-Zentrum Berlin für Materialien und Energie (HZB) for hosting the event.

Last but not least, this work wouldn't have been realized at this level of quality without the support of the Funding Authority, the European Commission and the guidance of the Project Officer.

The event took place on 30 November 2017 in Berlin, Germany, and was named the first European Solar Technology Forum.

Section 4 – Introduction

This report includes the main highlights (minutes) from the final public event of Cheetah project that was organized 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".

The objective of the event was twofold:

- Disseminate the project results to the public, present the tasks of the project, focusing more on the research activities and expose the future plans and actions towards the main objectives of Cheetah project.
- Discuss the results and innovations of the project with experts outside the consortium from the research community but also from the industry community. The purpose was to run an unofficial public consultation and receive feedback from external research partners and from the industry and discuss implementation possibilities and requirements for implementation.

The target group of the event was researchers working on the solar PV field as well as the industry in an attempt to sustain the links between research and industry community strong.

The event started with a plenary session with welcome speeches from Rutger Schlatmann on behalf of HZB hosting the event, James Watson the Chief Executive Officer of SolarPower Europe and the project coordinator Jan Kroon from ECN. The conference then continued in three technology-specific parallel sessions on crystalline silicon, thin film and organic PV, respectively. After the parallel sessions the participants were reunited in the plenary room for a joint debriefing by the moderators of the three technology-specific sessions, a presentation from JRC's Nigel Taylor on future PV standards and an outlook from Ivan Gordon on the "Way Forward". 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. The participation at the final public event surpassed 100 experts with approximately 25% being industry representatives.

All presentations – part of the event's proceedings - can be found here: http://www.cheetah-project.eu/dissemination-project-results/events/final-event-european-solar-technology-forum.html

The agenda of the meeting, the list of participants as well as a small collection of representative pictures from event are attached at the end of this report. The list of participants is not exhaustive.

This event was covered by press in the following articles:

https://www.pv-magazine.com/2017/12/01/solar-innovations-on-show/

https://www.pv-magazine.de/2017/12/01/cheetah-photovoltaik-innovationen-fuer-guenstigere-zellen-und-module/

https://www.pv-magazine.de/unternehmensmeldungen/auf-dem-hzb-forum-fortschritte-bei-solartechnologien-praesentiert/

Section 5 – Event minutes

5.1. Opening plenary session

After Rutger Schlatmann, director of the Institute for Thin-Film and Nanotechnology for PV, welcomed the participants on behalf of the Helmholtz-Zentrum Berlin für Materialien und Energie (HZB), SolarPower Europe Chief Executive Officer James Watson help an opening speech stressing how important research and development for Europe's industrial competitiveness strategy for solar is. He explained that, "the objective of SolarPower Europe's new Industrial Competitiveness Task Force is for the EU to take the global leadership on the existing and next generation of solar technologies, manufacturing and services. This is why we are so pleased to see so many participants here, also from industry, and this is why we can say: we want to see more projects like CHEETAH in the future."

Project coordinator Jan Kroon gave then a short overview of the highlights of the CHEETAH project's 4 years, covering the following issues:

- The drivers behind the CHEETAH project: costs
- Main results in crystalline silicon, thin film and organic PV
- The link between EERA PV and CHEETAH
- Structure and focus of the CHEETAH project
- The Knowledge Exchange Portal

(See presentation here: http://www.cheetah-project.eu/fileadmin/user/Meeting_Berlin/01_Jan_Kroon.pdf)

5.2. Crystalline silicon PV session

Topic: Crystalline silicon based PV, "Getting below a 100 microns"

Moderator: Ivan Gordon, imec

Input presentations: Kris Van Nieuwenhuysen (imec), Adrian Danel (CEA), Paul Sommeling (ECN)

Download presentation at: http://www.cheetah-project.eu/fileadmin/user/Meeting_Berlin/02_C-SI_Cheetah.pdf

Industry representatives: Wilhelm Stein (Von Ardenne), Lars Oberbeck (Head of Solar R&D, Total), Thomas Söderström (Head of Technology Solar Modules, Meyer Burger), Anna Battaglia (Engineering Manager, 3SUN)

After a summary from each of the CHEETAH work package leaders on the results obtained in the project the panel started discussing the potential impact of these results. The panelists had a very honest and open dialogue between them, the moderator and the audience. Quite a few observations on the technologies developed within the CHEETAH project were made.

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 (comments from producers of PERC cells had been heard about reduced efficiency below 160 µm wafer thickness). Yet the solutions are available already to go towards low cost 100 µm wafers – Meyer Burger has successfully tested diamond wire wafering in this range and wires are likely to become even thinner in the near future, perhaps going from 60 µm to 40 µm diameter. The results from CHEETAH show that you can produce cells and modules on thinned wafers down to 80-90 µm thickness using standard process and standard materials, and may even have close to normal production yield and speed by minor adjustments to existing tools. Wafers at these thicknesses, 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 (wafer, cell, module) 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. At the TW scale, kerf will become a major issue which may force a closer look at kerf-less technologies. These reductions will also enable cost reductions when production is at scale. Thin wafers may enable light weight modules and flexible modules and should therefor 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, however, 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. PERC cells. It has taken roughly 25 years to get PERC technology from lab to volume production. AlO surface passivation and laser processing have in this case been enabling technologies. The same story one could think relevant for Epi-wafers as well, where at a certain stage enabling technologies make Epi-wafers the obvious choice.

What has been shown in the CHEETAH project in addition to the possibility of producing Heterojunction cells with Epi wafers in a standard process is the relatively small changes in cell performance compared to a conventional wafer using an non-optimized cell process. Given a medium quality wafer one would gain efficiency by using a thinner wafer due to increased Voc, while for a high quality wafer the current loss would be somewhat larger than the Voc gain, however, with appropriate light management this could be overcome. Tests done by Meyer Burger confirms these findings as they have compared modules with different wafer thickness down to 100 µm and see an increase in efficiency with thinner wafers. The CHEETAH results and the panel discussion show that Heterojunction and Interdigitated back contact cell architectures are well suited for thin wafers. Further benefits of the Epi-wafer include avoided oxygen in the wafer as well as the possibility of in-situ formation of an emitter.

With regards to the competitiveness of European manufacturing it was pointed out that the universities and research institutes in Europe could play a more significant role if collaboration and sharing of knowledge was done more openly with the industry. For instance in China there is a broader and quicker sharing of competence and ideas due to a more mobile workforce and a stronger focus on solving problems observed on the factory floor. The European universities and research institutes need to discuss the most important issues for the industry and help them solve these and avoid unnecessary competition. In this way innovation could still happen in Europe in the future which is necessary as there is little point in competing with Asian producers on standard products. Looking at China again, cheap electricity, easily accessible and efficient local supply chain and easily accessible financing are competitive advantages. Even in this setting the situation is not so bad in Europe, with an increasing production at the medium and small scale. This should continue as there is a need for the type of products made in Europe.

5.3. Thin film PV session

Topic: Thin film PV – „Thinner and more efficient through smart cells"

Moderator: Dr. Rutger Schlatmann from the Helmholtz-Zentrum Berlin für Materialien und Energie (HZB), Berlin, Germany

Input presentations: Martina Schmid (HZB/University of Duisburg), Guillermo Farias Basulto (HZB)

Download presentation at: http://www.cheetah-project.eu/fileadmin/user/Meeting_Berlin/03_THIN_FILM_.pdf

Industry representatives: Andreas Wade (PVthin / First Solar), Michael Bauer (Calyxo GmbH), Lars Stolt (Solbiro)

The session starts with the presentation given by Prof. Martina Schmid now at University of Duisburg-Essen, but previously researcher at Helmholtz-Zentrum Berlin.

The title of her presentation was "Chalcopyrite Microconcentrator Solar Cells "and it is related to the work carried out in WP9 of the CHEETAH project. Martina Schmid started reminding the main aim of CHEETAH project: realizing solar cells with less material but with higher efficiency. In this context, the WP9 aimed to use the concept of microconcentration on chalcopyrites based solar cells (CIGSe, and CIS). The motivation of using less material is related to the supply risk of elements contained in CIGS (like Ga and In) that may become limiting when aiming at production on the GW scale.

In the frame of Cheetah two approaches have been developed to realize CIGS micro cells: top down ad bottom up.

In the top down approach, the absorber was deposited via drop-on-demand inkjet-printing, a vacuum-free and scalable deposition route. The precursor ink, which shows long-term stability in air at room temperature, is formulated by dissolving metal nitrate salts in alcohol-based solvents. Crack free CIGSSe absorbers consisting of a layer with large grains at the surface and a layer with small grains at the back have been prepared by annealing the inkjet-printed Cu–In–Ga nitrate precursors in a Se/H2S containing atmosphere. A solar cell with a total area efficiency of 11.3% under standard AM 1.5 illumination has been achieved based on the printed CIGSSe absorbers. By a selective etching of front contact for restriction of active absorber area 0,06 mm^2 cells were obtained. They achieved 22, 5 % @100 suns.

As far as the bottom up approach is concerned, micro-absorbers are developed from indium precursor islands, which are deposited on a molybdenum coated glass substrate (back contact), followed by deposition of copper on top and subsequent selenization as well as selective etching of copper selenides. The PL signal obtained by the microabsorber is comparable with the one obtained on conventional large area CISe films. Preliminary devices for micro-concentrator solar cell applications have been fabricated. The resulting micro solar cells provide a characteristic I–V curve under standard

illumination conditions. Printing has proven feasible for micro lens fabrication, too. Lens were made by deposition of PMMA solution by drop-casting process to achieve dimensions in mm range.

Eventually, for a combined exploitation of direct and diffuse light components an angular splitting concentrator based on chalcopyrite and kesterite absorber material was investigated.

CZTS monograin layer solar cells under increased illumination intensities revealed a decrease rather than an increase in efficiency. The major reason was a significant drop in fill factor (FF) with enhanced illumination intensity above one sun, which directly translates to a decrease in efficiency. From these measurements it was clear that CZTS solar cells are not suitable for operation under concentrated sun light. In contrast, a reduced illumination intensity improves their performance. Kesterite material thus appears predestined to be operated under reduced rather than enhanced illumination intensity. This observation lead to the development of a combined CIGSe-CZTS direct-diffuse micro concentrator concept and to the realization of a first prototype. This first prototype devices take into account that concentrator optics are only able to focus direct irradiation, whereas the significant part of diffused light contained in the solar radiation incident in our latitudes cannot be concentrated. Exploitation of both radial and diffused parts of the solar spectrum in these devices is obtained by placing CIGSe micro cells in the concentration regions and filling the spaces in between the micro cells by CZTS cells. This combined device may be beneficial aiming at efficiency enhancement whilst minimizing additional fabrication costs at the expense of material saving.

The second presentation was given by Dr. Guillermo Farias Basulto from the Helmholtz-Zentrum Berlin related to the work was carried out in the frame of WP8 and WP9 of Cheetah project

He presented and discussed the realization of Interconnection schemes and modules for µ-CPV devices. Two approaches have been realized and tested.

The 1D-concentration approach with Array of (7 rows of) 20 interconnected cells. Each section = 10 mm x 3 mm and an Active area of 10 mm x 100 µm² for concentration factor up to 30 suns. The 2D concentration: Array of 67 rows made up of 21 interconnected cells each. Each section = 1x1 mm² and an Active area of ≈ 100 x 100 µm² for a higher concentration factor (100 suns)

With this work, it has been proven that functional interconnected CIGSe micro-concentrator modules of 16 % conversion efficiency are feasible. However the work pointed out some still open issues, mainly related to the necessity of the requirement of a single-Axis or double tracking system and the fact that the quality of lenses can limit total light concentration.

At the end of the presentations Dr. Rutger Schlatmann invited the Dr, Andreas Wade, President, PV thin, Dr. Michael Bauer, Managing Director of Calyxo and Dr. Lars Stolt CTO of Solibro to join the round table.

All the industrial representatives said the results are very interesting but all they agree on the big gap between the project results and any industrial potential exploitation. The main reason is that nowadays, in PV industry, the efficiency is the most important factor as Lars Stolt claimed. Any concepts or process with cell efficiency lower than 20 % cannot be taken into account, 14-15 % of efficiency is irrelevant. Dr. Michael Bauer added that to face the economic reality, also the cost reduction is another important

aspect and nowadays the costs should be or aim to 20 cents euro Wp. Very strong statements but they are what the industrials need.

Dr. Rutger Schlatmann introduced the importance of the eco footprint of the process and the problem of material availability and the use of less materials and invited the guests to comment this important aspect. They recognized that if you have a process or particular results with low environmental impact, those results are important values. Nevertheless, the long lifetime and recycling possibility are very interesting aspects but at the moment these criteria are not sufficient for an industrial application. Eventually a positive note about a possible niche application in BIPV of the CIGSe-CZTS direct-diffuse micro concentrator concept developed in CHEETAH suggested by Dr. Lars Stolt. The idea is to potentially apply them in BIPV as “sunny windows”, using the diffused light for lighting and the rest for PV.

5.4. Organic PV / Perovskite PV session

Topic: Organic and Perovskite PV: "Intrinsic long-term stability without special encapsulation"

Moderator: Sjoerd Veenstra (ECN/Solliance)

Input presentations: Suren Gevorgyan (DTU) (on OPV), Aldo di Carlo (UTV) (on Perovskite PV)

Download presentation at: http://www.cheetah-project.eu/fileadmin/user/Meeting_Berlin/04_OPV-PSK.pdf

Industry representatives: Andre Weiß (Heliatek), Erik Gabrielsson (Dyenamo), Chris Case (Oxford PV)

1. Input presentation: "Reduction of cost via improvement of stability / WP10"

The session began with a presentation by Suren A. Gevorgyan, Technical University of Denmark, who summarised the efforts of work package 10 of the FP7 CHEETAH project. This work package aimed to accelerate cost reductions in organic PV (OPV) by addressing the issue of device degradation. In order to achieve the low-cost potential of roll-to-roll coated OPV, it is necessary to encapsulate devices with low-cost flexible barrier layers. This requires a greater understanding of the degradation processes, and how these are affected by the quality of encapsulation, such that more intrinsically stable device structures can be fabricated. Highlights of the research included:

2. **E-infrastructure:** An open database of lifetime studies has been created to allow meta-analyses of large quantities of lifetime data. This is being used within the OPV research community to accelerate research on device lifetime. It enables the publication of a record-lifetime chart, analogous to the NREL record efficiency chart that has driven PV efficiency research for decades.

3. **Advanced characterisation suite:** The National Physical Laboratory (NPL) of the UK has developed a unique infrastructure to characterise unencapsulated devices under precisely controlled conditions using a system of portable environmental chambers coupled to a suite of *in-situ* measurements. It enables more rapid screening of materials for stability and provides deep insight into the causes of degradation.

4. **Intrinsic vs extrinsic stability study:** A very challenging study was conducted to compare the stability of a range of different active polymers in devices with different levels of encapsulation. It was found that device lifetime depended somewhat on the choice of polymer when active layers were exposed to UV light, but, when UV barriers were used, the lifetime was almost independent of polymer choice.

5. **Further improvements to device stability:** Improvements to device stability were achieved by a) reducing the amount PEDOT:PSS b) developing a less-permeable adhesive; c) improving the edge-seals and contacting methods. So far DTU has reached 13,000 hours outdoor lifetime without significant degradation after initial burn-in. Effective encapsulation by direct sputtering of conformal barriers has been also demonstrated by ENEA and Jülich.

6. **Encapsulation guidelines:** A set of guidelines (named ISOS-e) for encapsulation of lab-test cells have been produced to harmonise research on lifetime of printed PV. These will facilitate best practice in lab studies, and will lead to generation of more consistent lifetime data.

7. **Input presentation "**Perovskites - stability and up-scaling"

A presentation was given by Aldo di Carlo, Centre for Hybrid and Organic Solar Energy, Dept. Elect. Eng. University of Rome Tor Vergata. At the inception of the CHEETAH project, perovskite PV (PkPV) was trailing behind OPV in terms of efficiency. PkPV have now demonstrated efficiencies of more than 22 %. OPV and PkPV. Aldo began with a review of recent progress in PkPV stability:

1. Initial work using methyl-ammonium-lead-iodide (MAPI) with glass encapsulation showed good shelf-life, but elevated temperatures and light-soaking caused rapid degradation.

2. The next stage improved the thermodynamic stability of the crystal by introducing mixed cations. Quaternary cation mixtures of Rb, Cs, formamidinium and methyamonium, gave lifetimes of > 500 hours under light soaking.

3. TEM studies showed bubble formation in soft hole-transporting layers (HTLs). The use of solid HTLs greatly improved lifetime, but only when combined with a reduced graphene oxide (other 2D materials work too) buffer between the HTL and electrode to reduce gold migration.

4. Solaronix have demonstrated a device with 90 % performance after 10,000 hours light soaking using a nanocarbon HTL/electrode layer.

Another challenge of PkPV is upscaling. Solliance, who are leaders in this field, have achieved modules with 95 % geometric fill factors and efficiencies of nearly 10 % on large-area modules. By combining with Si bottom-cells, it is anticipated that efficiencies of tandem devices will reach 30 % on maturity.

Industry responses

Responses to the presentations were given by four representatives from industry:

Andre Weiß, VP R&D, Heliatek: Heliatek produces OPV using a 30 cm pilot line, and will soon upgrade to a 1 m line with a capacity of 1,000,000 m^2 per year. They are targeting the building-integrated market, which is very conservative. Their aim is to achieve full IEC 61416/61225 qualification of their products. Good stability can be achieved with very good encapsulation, but that encapsulation is more costly than the active layers. Andre praised the achievements of CHEETAH. He stressed that harmonisation of guidelines is important go get comparability across the research landscape. He stated that the work on *in-situ* characterisation in controlled environments is critically important to understand which factors cause degradation (oxygen vs. water vs. temperature *etc.*) and thereby optimise materials and manage barrier costs. Understanding the failure mechanisms is crucial.

Erik Gabrielsson, CTO, Dyenamo: Dyenamo is a small company that produces materials for customers who are upscaling PV production. Erik praised the work presented. He observed that there is a lot of cross-pollination between OPV, PkPV and dye-sensitised PV. The study of intrinsic stability is very

important for all types of PV - the ability to separate out the effects of encapsulation. It is impossible to have a long-term future for large-scale PkPV unless it can be demonstrated that these materials can be intrinsically stable. For tandem devices, the PkPV component must have comparable stability to the bottom cell (*i.e.* on the scale of 20 years). Erik believes that encapsulation is an industrial problem; intrinsic stability studies are more important than studies on encapsulated devices. Harmonisation of intrinsic test methods and common encapsulation will help. Stability tests take a long time to perform. The ability to model and predict lifetime from accelerated tests would be a major achievement. Finally, he believes that the issue of Pb toxicity haunts PkPV development. There is a high political risk associated with this unresolved issue.

Chris Case, CTO, Oxford PV: Chris stressed that climate change is the global motivation for this work. He noted that the price of PV has dropped by factor of 200 over last 40 years. Now PV is cheaper than any other form of energy without subsidy across most of the world. Oxford PV aims to commercialise PkPV by using it to increase the efficiency of silicon modules in a tandem device. Chris praised the work of the consortium. Oxford PV also agrees on the importance of intrinsic stability testing; they have developed an intrinsic test of their own to separate out the effects of encapsulation. Direct deposition of barriers is feasible; Chris suggested that cost would not be a barrier, as there are many examples of low-cost scale up of direct-sputtered barriers. Chris does not believe that the Pb content of PkPV is an issue, as this is lower than the amount of Pb already in the solder joints of solar panels.

Konrad Wojciechowski, Scientific Director, Saule Technologies: Saule is developing flexible PvPK using solution-processed (currently ink-jet) methods. Their target market is value-added applications where PV is not yet being used, *e.g.* indoor energy harvesting, Internet of Things, battery-replacement (low-light), BIPV, automotive. Key factors are economy, scalability, stability. They see the rapid rise of PkPV performance as largely due to knowledge transfer between from the OPV and dye-sensitised communities. Konrad praised the progress of CHEETAH. In particular, the work on e-infrastructure, encapsulation protocols, test protocols and data analysis techniques are valuable outputs of the project. Similar to Heliatek, he believes that 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; researchers should focus on this, although it is highly time-consuming. Nevertheless, arbitrary test protocols are still useful to distinguish between different materials/ stacks. He also believes that more in-depth environmental studies are required to understand the toxicity, which will determine how much mitigation is needed.

Open discussion

The presentations were followed by an open discussion moderated by Sjoerd Veenstra, ECN. Interesting discussion points included:

- The importance of intrinsic stability was discussed, and whether field trials are also important. “No large-volume buyer will purchase without confidence from field trials. It’s also the simplest way to test the technology.” Chris Case

- The discussion moved on to the topic of reshoring the European PV industry. The challenge is competing with the economies of scale of the Far-Eastern silicon PV business. Theoretically, PkPV could be produced at a fraction of the cost, but only after scale up. Konrad Wojciechowski pointed out that the low capex of printed PV could incentivise a return to Europe.
- Finally the impact of stability of levelised cost was discussed. It was pointed out that most investors have a much shorter time horizon than the lifetime of PV modules. Generally the levelised cost is the most important figure of merit in comparing different energy technologies. However, Birger Zimmermann of the Fraunhofer-ISE stressed that the research community should take a holistic view of the environmental impact of technologies, considering the environmental impact of manufacture, toxicity of components and end-of-life.

5.5. Closing plenary session

After the technology-specific parallel sessions the participants gathered in the plenary room and each of the three moderators gave a 5-minute summary of their respective session.

Nigel Taylor then held a presentation on the "Priorities for new and improved PV standards". His presentation was based on a survey carried out by the JRC and SolarPower Europe in September-October 2017 and whose results will be published in CHEETAH deliverable 5.9. "Guidelines for standards for next generation PV technologies". Survey participants were asked to identify areas to be prioritised for further work under 6 themes: i) PV cells and modules, ii) inverters, iii) trackers, iv) building integrated products, v) systems and vi) integrated applications. A key finding of the survey was that "Reliability degradation and lifetime" is seen as key priority for all components and indeed for systems.

Download presentation at: http://www.cheetah-project.eu/fileadmin/user/Meeting_Berlin/06_Nigel_Taylor.pdf

As the Coordinator of the Joint Program on Photovoltaics of the European Energy Research Alliance (EERA), Ivan Gordon from IMEC then gave a presentation on "After CHEETAH – The Way Forward". He explained that similarly to the SOPHIA project (GA 262533, FP7 Infrastructure project), the CHEETAH project had resulted from an initiative of the EERA-PV and that both projects allowed EERA-PV to function properly. He also underlined that in order to be able to continue operating properly, EERA-PV is planning to propose a new Horizon 2020 project call. He also stressed that EERA-PV would build on the achievements of SOPHIA and CHEETAH and ensure that these achievements are not lost: the CHEETAH Knowledge Exchange Portal would be continued and further extended, similarly to webinars and worshops organised by EERA-PV.

Download presentation at: http://www.cheetah-project.eu/fileadmin/user/Meeting_Berlin/05_Ivan_Gordon.pdf

Section 6 – Participants' feedback

After the final public event, a questionnaire survey was sent to the participants to get their feedback. A total of 26 responses were registered which represents approximately one fourth of the total number of participants in the event. The respondents' overall assessment of the event was 4.2 on a scale of 1 (poor) to 5 (excellent).

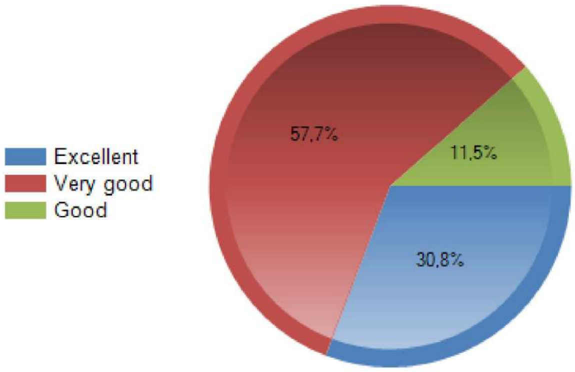


Figure 1 - How would you rate the CHEETAH final event overall?

According to the survey circulated after the final event, 28% of industry representatives and 88% of R&D representatives believes CHEETAH results may have an impact on PV development in Europe.

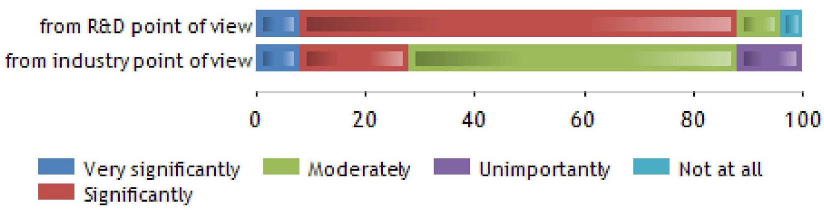


Figure 2 - To what extent do you think that CHEETAH results may have an impact on PV market development in Europe?

84% of the respondents said the networking possibility offered by the conference was "excellent" or "very good" and 64% of the respondents said they had identified potential collaborations thanks to the networking during the CHEETAH final public event (66% of industrial organizations answering to the survey)..

Section 7 – Agenda and flyer of the event

European Solar Technology Forum-From Research to Industrial Application // CHEETAH's Final Event

30 November 2017
Helmholtz-Zentrum Berlin für Materialien und Energie (HZB), Berlin, Germany

This event is a unique networking opportunity to get to know leading experts from research and also industry. It summarises 4 years' research results, how to implement and continue the innovations in the years to come. Key innovations include:

• Water based Crystalline silicon - « Getting below a 100 microns »

• Thin film PV - « Thinner and more efficient through smart cells »

• Organic PV & Perovskite - « Instrinsic long term stability without special encapsulation »

One of the core objectives of the CHEETAH project is to accelerate the implementation of innovative technologies in the PV industry. SolarPower Europe and EIT-InnoEnergy support the project consortium in establishing the link between research and industry by the organisation of public conferences and the publication of reports demonstrating the commercial value of technologies developed in the CHEETAH project. CHEETAH research institutes are keen to discuss and launch partnerships with companies to commercialise new solutions developed in the CHEETAH project.

CHEETAH is a combined collaborative project (CP) and coordination and support action (CSA) funded under the European Commission's 7th Framework Programme (2014 – 2017). CHEETAH's aims to solve specific R&D issues in the EERA-PV Joint Program and 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.

With 16 nationalities represented in the consortium, CHEETAH's ambition is to develop technology and foster innovative manufacturing capabilities and photovoltaic products so that Europe can develop its technological and industrial capacity in all parts of the value chain.

CHEETAH's objectives for the 4 years of the program 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, exchange and training researchers inside and outside Europe, efficient use of infrastructures, promoting best practices and standards.
- Accelerating the implementation of innovative technologies in the PV industry, by a strong involvement of SolarPower Europe and IT-InnoEnergy in this program.

Speaker's biographies

Dr. Anna Battaglia has a Master's and a PhD in the field of materials modification induced by ion implantation from the University of Catania. Having worked for several manufacturers in technology management support, she has more than 20 years of experience in the semiconductor industry. In 2012 she joined 3SUN to oversee industrial research on thin film silicon PV and coordinate two EUFP7 projects (Fast-Track, Agatha). She is author of several articles and patents.

Michael Bauer has a degree in Process and Mechanical Engineering from Martin-Luther-University of Halle and Technical University Braunschweig with a dissertation on the theoretics of scale up of heat transfer mechanisms in tubular fixed bed reactors. After being in charge of process development at various organisations such as Bayer CorpScience and later McKinsey Inc, he joined Calyxo GmbH, a former subsidiary of Q-Cells SE, in 2008 as CTO/COO. In 2017 he became Managing Director of Calyxo GmbH.

Christopher Case is the Chief Technology Officer at Oxford PV, a spin-out of Oxford University that is commercialising perovskites for PV applications. Most recently, he was the Chief Technology Officer for Linde Electronics and the former Chief Scientific Officer of The BOC Group. Earlier, he was engineering professor at Brown University and spent 10 years AT&T Bell Labs.

Adrien Danel holds a master's degree in physics and a Ph.D. degree in microelectronics from INPG Grenoble. From 2004 to 2008 he was leading the team in charge of metrology and trace analysis in CEA-LETI's cleanrooms. In 2009, he joined INES focusing on heterojunction crystalline cells and contributing to technology transfer and industrialization as process integration leader in the CEA-INES heterojunction pilot line.

Aldo Di Carlo is full professor of Optoelectronics and Nanoelectronics at the University of Rome "Tor Vergata" (Italy). Since 2006 he is director of the Centre for Hybrid and Organic Solar Energy (CHOSE) which involves more than 30 researchers for the development and industrialization of the organic and hybrid organic/inorganic photovoltaic technologies. Di Carlo is author/coauthor of more than 350 scientific publications on international journals, 13 patents and several book chapters.

Guillermo A. Farías Basulto was born in 1987 in Guadalajara, Mexico. He studied industrial engineering at the University of Guadalajara and a MSc. in Global Production Engineering-Solar at Technical University Berlin. In 2016, he joined HZB-PVcomB, where he works developing ideas and concepts for both micro-concentration of solar energy and topics related to laser patterning for thin film photovoltaics.

Dr. Erik Gabrielsson has been the Chief Technology Officer of Dyenamo since August 2014 and is responsible for the company's R&D activities in the fields of Dye-Sensitized (DSSC) and Perovskite Solar Cells (PSC). Dr. Gabrielsson holds a PhD in organic chemistry from the Royal Institute of Technology (KTH) in Stockholm.

Suren Gevorgyan is a senior scientist at the Technical University of Denmark. He received his PhD from the Technical University of Denmark in 2010. From the early years of his career Suren has been working in the field of organic photovoltaics and specializing in characterization and stability improvements of the devices. His main research interests include device engineering and optimization, encapsulation, device lifetime, standard testing procedures and electro-optical characterization.

Dr. Ivan Gordon has a PhD in the field of novel magnetic materials for sensor applications GORDON Ivan Manager Silicon Photovoltaics Group at IMEC copie from the University of Leuven. He joined IMEC in 2003 where he leads the Silicon PV group. He is also editor of the journal Solar Energy Materials and Solar Cells and associate editor of the IEEE Journal on PV. He authored and co-authored more than 200 scientific papers. Since 2016 he is the coordinator of EERA-PV and steering committee member of ETIP-PV.

Senior Research Scientist **Dr. Jan Kroon**, studied chemistry at the University of Amsterdam and received his PhD in the field of Physical Organic Chemistry. He joined ECN in 1996 where he worked as project manager for Organic PV until 2013. Since then, he is senior project manager in the PV module technology and reliability group and program coordinator for back contact x-Si cells and modules. He is an experienced manager of national and international projects including CHEETAH.

Kristin Lüdemann did her Thesis at UNSW, Australia, about Thin Silicon PV on glass. She has spent 15 years at Roth & Rau GmbH (today, Meyer Burger Germany), latest position "Head of Strategic Product Marketing" (before positions in Technology development, Project Management and "Head of Sales AMER/EMEA"). Currently, 3 years at Von Ardenne GmbH as "Vice President Crystalline Photovoltaic".

Lars Oberbeck has 20 years of experience in Si PV and semiconductor research and development. He has a diploma in Physics from the University of Hanover and a PhD in Electrical Engineering from the University of Stuttgart in the field of c-Si PV. Following his post-octoral research at the University of New South Wales (Australia) he worked for Infineon and later for SolarWorld and joined Total in 2012 as Head of the solar R&D department.

Prof. ***Dr. Rutger Schlatmann*** has a PhD from the FOM Institute Amolf in Amsterdam. He is director of the Institute for Thin-Film and Nanotechnology for PV at the Helmholtz-Zentrum Berlin and full professor at the Hochschule fuer Technik und Wirtschaft Berlin. He is also member of the ETIP-PV steering committee and vice-president of the Berlin Brandenburg Energy Network. His research focuses on thin film and nanotechnology for Si-based and compound semiconductor solar energy. He also works on the generation of integrated PV and electrolysis systems to produce 'solar fuels'.

Martina Schmid holds a PhD from Freie Universität Berlin, receiving the Carl-Ramsauer Award of the German Physical Society (DPG) and the DGM Young Researcher Award of the German Society of Material Science. After postdoctoral stays at the University of Ljubljana and the California Institute of Technology, she started a Young Investigator Group at HZB in 2012. In 2013 she became Junior Professor at Freie Universität Berlin. Since 2017 she is Professor for Experimental Physics at the University of Duisburg-Essen. Her research interests include photonics, plasmonics, PV and renewable energy devices with a focus on nano and microoptical concepts for light guiding and concentration.

With more than 10 years' experience in solar industry, ***Thomas Söderström*** has been with Meyer Burger for 6 years leading the Innovation and Technology Solar module department and developing Bifacial Smart Wire Technology. His previous positions were research and academic oriented in Switzerland where he obtained his PhD from the IMT of Neuchâtel, now EPFL, and at UNSW in Australia. His scientific contributions achieving an impact factor above 20 and working with companies such as Flexcell, Bosch, Oerlikon and Suntech.

Paul Sommeling (MSc, chemistry) started working at ECN in 1996 in the unit Solar Energy. He is experienced in durability testing and module encapsulation and participated in a number of EU projects involving both technology development and fundamental research. He joined the Module Technology group since 2011, working on thin film and x-Si back contact modules.

Lars Stolt graduated in electronics at Uppsala University in 1982. After his PhD, he did research on CIGS solar cells at the Institute of Microlelectronics in Stockholm and later at Uppsala University, where he was appointed as professor in 1998. In 2003 he started Solibro, a spin-out company based on the CIGS technology, which formed a joint venture with Q-Cells in 2007 with Lars Stolt as CTO. Since 2014 he is also part-time professor at the Solar Cell Group at the Ångström Laboratory.

Nigel Taylor leads the JRC's internal research project on renewables resources in Europe and beyond, and its Low Carbon Energy Observatory which tracks the progress of a broad range of technologies impacting energy transition policies. He graduated with a degree in mechanical engineering from Dublin University, Trinity College in 1982 and was awarded his Ph.D. also from Trinity in 1987. After jobs in industrial R&D in Germany and Italy, he joined the European Commission in 1997.

Kris Van Nieuwenhuysen obtained her degree in engineering in 2000. She then joined the Si solar cell group of imec, where she has been the main expert in Si epitaxial CVD processes for solar cell fabrication. She was the main responsible for the realization of the >16% efficient full epitaxial solar cell at imec. She developed several epi processes both in low-pressure and atmospheric pressure CVD systems and was involved in several European projects.

Sjoerd Veenstra, researcher at ECN/Solliance, has a passion for photovoltaics (PV). After his PhD (2002), he went to ECN in Petten (NL) to work on Organic PV. In 2011 he moved to Eindhoven where the regional (B., D., NL.) thin film PV research is clustered. The focus of his work is now on perovskite PV for application in single and tandem junctions.

Andreas Wade holds a Master of Engineering degree from the Technical University Clausthal (Germany) and is Environmental Process Engineer by Education. After working in various organisations as an expert for recycling, emissions reduction and life cycle management strategy, he joined First Solar where is currently Global Sustainability Director. He is also President of the International Thin-Film Solar Industry Association (PVthin) and elected Vice-Chair of the SolarPower Europe Strategy Committee.

James Watson is the CEO of SolarPower Europe. He joined SolarPower Europe in July 2014 after seven years of working in the energy sector in Brussels with consultancy Weber Shandwick. Earlier in his career Dr Watson worked for the European Commission and various UK government bodies and worked as a lecturer in Environmental Law at the University of Manchester.

Andre Weiss holds a PhD in Chemistry from the University of Heidelberg. Between 2002 and 2008 he oversaw Research and Product Management for dyes, pigments and polymer additives at Clariant GmbH. In 2008 he joined Heliatek as Head of the Chemistry Department and in 2017 he became Vice President for R&D.

CHEETAH

Agenda

11:00-11:30	Registration	

Opening Plenary Session: CHEETAH – Four Years of PV Research Innovations

Moderator: Jan Kroon, ECN and CHEETAH Project Coordinator

11:30-12:00	Welcome notes	James Watson, CEO, SolarPower Europe
12:00-12:30	The CHEETAH project – Four years of PV research innovations	Jan Kroon, ECN and Project Coordinator
12:30-14:00	Lunch break	

Parallel Round Table Debates

	Crystalline silicon based PV "Getting below a 100 microns" *Moderator: Ivan Gordon (imec)*	Thin film PV "Thinner and more efficient through smart cells" *Moderator: Rutger Schlatmann (HZB)*	Organic PV + Perovskite "Intrinsic long term stability without special encapsulation" *Moderator: Sjoerd Veenstra (ECN/Solliance)*
14:00-14:30	Input presentations *Kris Van Nieuwenhuysen (imec), Adrien Danel (CEA), Paul Sommeling (ECN)*	Input presentations *Martina Schmid (University of Duisburg-Essen), Guillermo Farias Basulto (HZB)*	Input presentations *Suren Gevorgyan (DTU) – OPV* *Aldo di Carlo (UTV) – Perovskites*
14:30-15:00	Reactions from the industry Confirmed speakers: - Kristin Lüdemann, VP cSi PV, Von Ardenne - Lars Oberbeck, Head of Solar R&D, Total - Thomas Söderström, Head of Technology Solar Modules, Meyer Burger - Anna Battaglia, Engineering Manager, 3SUN	Reactions from the industry Confirmed speakers: - Andreas Wade, President, PVthin - Michael Bauer, Managing Director, Calyxo - Lars Stolt, CTO, Solibro	Reactions from the industry Confirmed speakers: - Andre Weiß, VP R&D, Heliatek - Erik Gabrielsson, CTO, Dyenamo - Chris Case, CTO, Oxford PV
15:00-16:00	Open discussion – *All participants*	Open discussion – *All participants*	Open discussion – *All participants*

16:00-16:30	Coffee break	

Closing Plenary Session: CHEETAH – The Way Forward

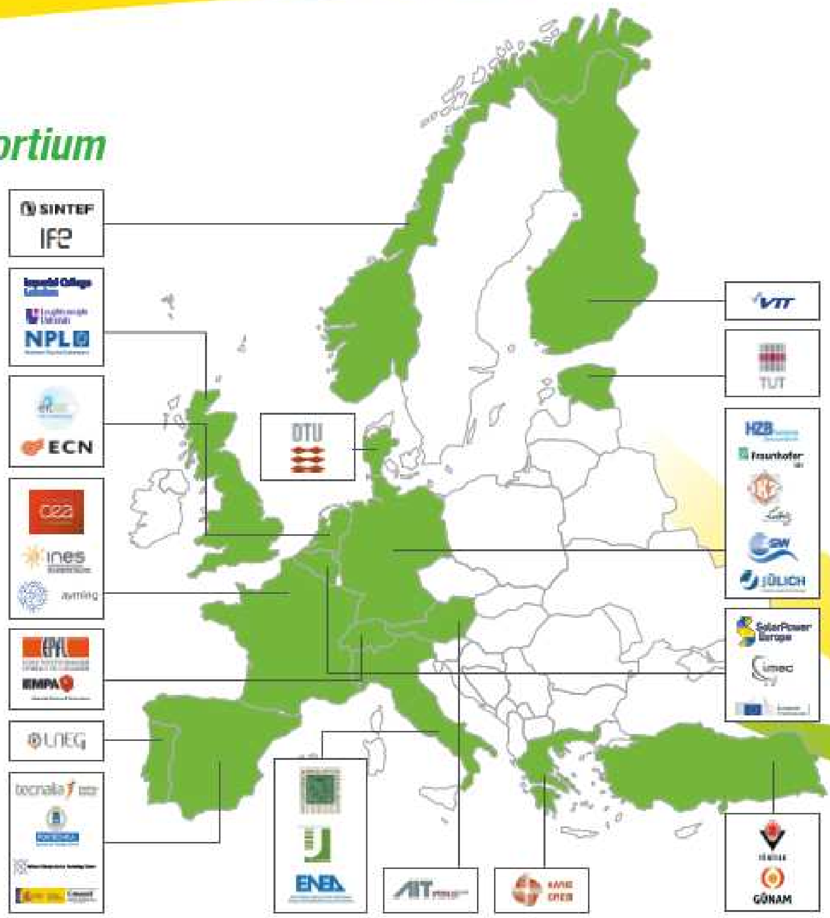
Moderator: Jan Kroon, ECN and CHEETAH Project Coordinator

16:30-16:45	Insights from the round table debates	*Moderators*
16:45-17:00	After CHEETAH – The Way Forward	*Ivan Gordon, imec, Coordinator of the Joint Program on Photovoltaics, EERA*
17:00-17:15	Priorities for new and improved PV Standards	*Nigel Taylor, Joint Research Centre, European Commission*
17:15-17:30	Q&A	*All participants*

Networking Session

17:30-18:45	Networking Reception

Consortium



The CHEETAH consortium is composed of 34 partners from 16 European countries (Netherlands, France, Estonia, Spain, Germany, Italy, Switzerland, Greece, Portugal, Turkey, Belgium, Austria, Denmark, Finland, UK and Norway). The partnership gathers partners having scientific excellence and complementarity in all important domains of the PV field (silicon, thin-films, organic PV, novel technologies).

Acknowledgment

The CHEETAH project is supported by the European Commission through the Seventh Framework Programme for Research and Technological Development with up to 9.7 Mio €, out of a total budget of 13.3 Mio €. This 4 years project will run from 1st January 2014 to 31st December 2017.

ECN

Project coordinator
ECN – Stichting Energieonderzoek Centrum Nederland
Jan Kroon, j.kroon@ecn.nl

www.cheetah-project.eu

Section 8 – Attendance list

First Name	Last Name	Organisation
Alessandro	Abbotto	UNIMIB
Bruben	Abraham	BSW Solar
Maurizio Filippo	Acciarri	UNIMIB
Ali	Ajao	Computer Village
Roman	Bansen	IKZ/FVB
Claudia	Barolo	Università di Torino
Luc	Barrovecchio	ENGIE
Anna	Battaglia	3SUN S.r.l.
Michael	Bauer	Calyxo GmbH
Oliver	Beckel	Hanwha Q CELLS
Ian	Bennett	DSM Advanced Solar
Karl	Berger	AIT
Simona	Binetti	UNIMIB
Karsten	Bittkau	JÜLICH
James	Blakesley	NPL
Torsten	Boeck	IKZ/FVB
Romain	Bouchet	AYMING
Fabienne	Brutin	AYMING
Stephan	Buecheler	EMPA
Kris	Cannaerts	IMEC
Paco	Cano	TECNALIA
Christopher	Case	Oxford PV
Adrien	Danel	CEA
Francesca	De Rossi	Swansea University
Carlos	del Cañizo	UPM
Aldo	Di Carlo	Università degli Studi di Roma
Marisa	Di Sabatino	NTNU
Jens	Dittrich	CLERE AG
Christian	Ehlers	IKZ/FVB
Jan	Elmiger	HZB
Sandra	Enkhardt	PV Magazine
Guillermo	Farias Basulto	HZB
Sean Erik	Foss	IFE
Loïc	Francke	Total SA
Erik	Gabrielsson	DYENAMO
Stefan	Gall	HZB
Suren	Gevorgyan	DTU
Ivan	Gordon	IMEC
Ralph	Gottschalg	Loughborough University

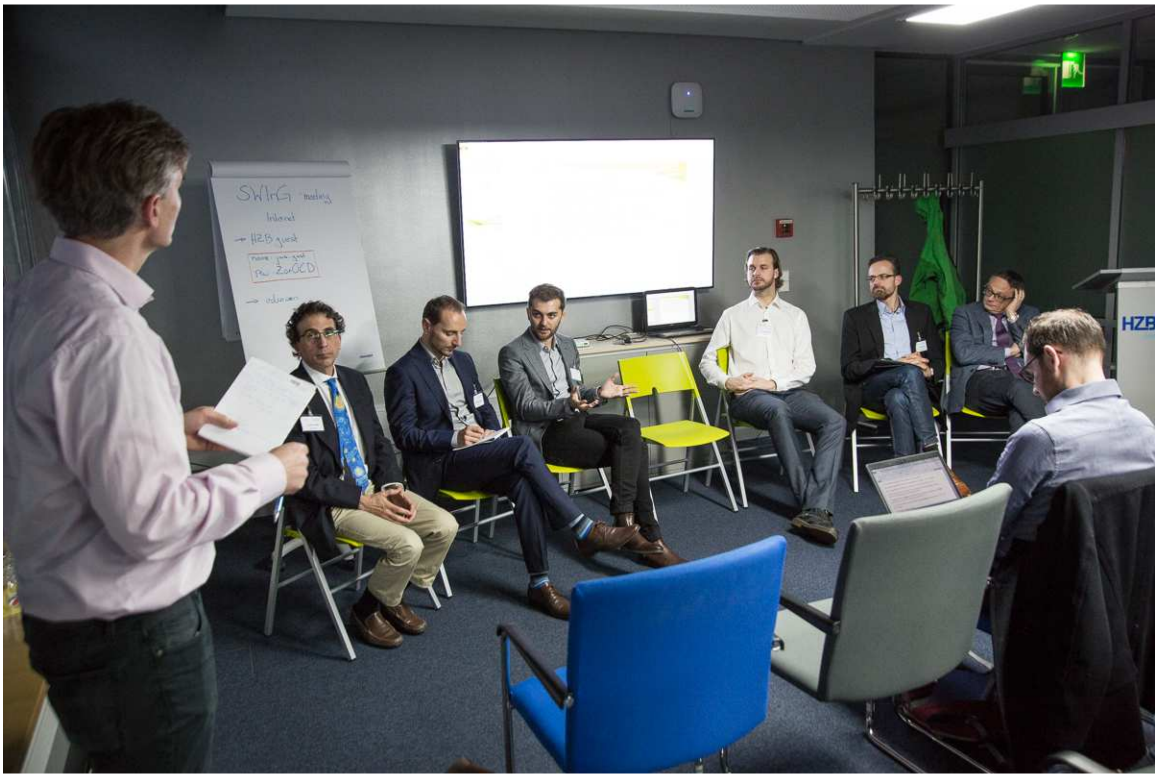
Imco	Goudswaard	DSM
Maarja	Grossberg	TUT
Gorkem	Gunbas	Middle East Technical University
Georgios	Halabalakis	CRES
Jan	Haschke	EPFL
Hanspeter	Haseloff	Private
Jukka	Hast	VTT
Maté	Heisz	SolarPower Europe
Pierre-Emmanuel	Hickel	TOTAL
Mark	Hutchins	PV Magazine
Bengt	Jäckel	UL International Germany
António	Joyce	LNEG
Roman	Kemmler	Greateyes GmbH
Joergen	Klammer	ELK-Erneuerbar
Reiner	Klenk	HZB
Jan Michael	Knaack	German Solar Association
Tristan	Koehler	HZB
Jan	Kroon	ECN
Rannveig	Kvande	SINTEF
Iver	Lauermann	HZB
Zhe	Li	Swansea University
Erwin	Lotter	ZSW
Kristin	Lüdemann	Von Ardenne GmbH
Martha	Lux-Steiner	HZB
Marine	Manzinello	CEA
Christoph	Mayr	AIT
Matthias	Meier	JÜLICH
Guillermo	Montalt	AYMING
Michelet	Montina	US-African and European Business Group
Pasquale	Morvillo	ENEA
Hans-Christoph	Neidlein	PV Europe
Giuseppe	Nenna	ENEA
John	Nikoletatos	CRES
Lars	Oberbeck	Total
Eivind	Ovrelid	SINTEF
Taavi	Raadik	TUT
Marcus	Rennhofer	AIT
Franziska	Ringleb	IKZ/FVB
Francesco	Roca	ENEA
Eduardo	Roman	TECNALIA
Maria	Roos	BSW Solar
Andrei	Salavei	Calyxo GmbH

Guillermo	Sanchez	NTC / UPVLC
Thomas	Schedel	HZB
Rutger	Schlatmann	HZB / PVcomB
Martina	Schmid	HZB
Thomas	Soderstrom	Meyer Burger
Paul	Sommeling	ECN
Rune	Søndenå	IFE
Wim	Soppe	ECN
Bernd	Stannowski	HZB
Josef	Stenzenberger	Wacker Chemie AG
Lars	Stolt	Solibro Research AB
Dheepika	Tamilselvann	Brandenburg Technical University
Nigel	Taylor	JRC
Juan Francisco	Trigo	CIEMAT
David	Uebel	IKZ/FVB
Sjoerd	Veenstra	ECN/Solliance
Pepijn	Veling	Eternal Sun Spire Solar
Alex	Verba	Solar Spectrum
Andrea	Viaro	Jinko Solar
Tommi	Vuorinen	VTT
Andreas	Wade	First Solar
Yajie	Wang	HZB
James	Watson	SolarPower Europe
Thomas	Weber	PI Photovoltaik-Institut Berlin AG
Andreas	Weiss	Heliatek GmbH
Wiltraud	Wischmann	ZSW
Paul	Wyers	ECN
Nicolas	Wyrsch	EPFL
Selcuk	Yerci	Middle East Technical University
Okan	Yilmaz	TUBITAK
Shokufeh	Zamini	AIT
Guillaume	Zietek	AYMING
Birger	Zimmermann	ISE

Section 9 – Pictures


History and European context
European 20-20-20 targets
Solar Europe Industry Initiative
SET plan for PV for 2020
European Energy Research Alliance (EERA-PV). Established 2010
Definition of Joint Programme for PV
Accelerate PV development in Europe through R&D alignment
First examples of joint projects in support of EERA-PV:
SOPHIA 2012-2015
CHEETAH 2014-2017


FP7-CHEETAH project:
34 partners from 16 European countries
http://www.cheetah-project.eu/
Grant agreement no: 609788
FP7-CHEETAH KNOWLEDGE EXCHANGE (KEP) Platform
A web portal for the European photovoltaics community to support training, share knowledge and research infrastructures and foster collaboration opportunities at EU scale
CHEETAH KEP platform represents a significant step forward in the knowledge exchange in the PV RTD sector because it's based on the development and utilization of user-friendly and dedicated ICT media tools comparable in their performance to more diffused social, scientific and professional networks.
Cheetah knowledge exchange cataloguing criteria


HZB


CHEETAH
Thank you!
Any questions for our experts?