Publishable summary – M36

1.1. Summary description of project context and objectives

Today's challenges in PV

Photovoltaics (PV) is one of the most promising renewable energy technologies for Europe. In fact, PV is now, after hydro and wind power, the third most important renewable energy source in terms of global installed capacity. PV can significantly contribute in achieving the EU's 20-20-20 climate change objectives, as well as to the longer-term goal of reducing greenhouse gas emissions by 80-95%, as targeted in the European Energy Roadmap 2050.
For that purpose, the European Commission has challenged the PV industry to set new, ambitious targets for 2020 as part of the Commission's Strategic Energy Technology (SET) – Plan. In this context, the Solar Europe Industrial Initiative (SEII) and the European Energy Research Alliance Photovoltaics Joint Research Programme (EERA-PV) were launched in 2010.

The CHEETAH project is directly linked to the EERA-PV Joint Research Program, 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 of the Solar Europe Industry Initiative.

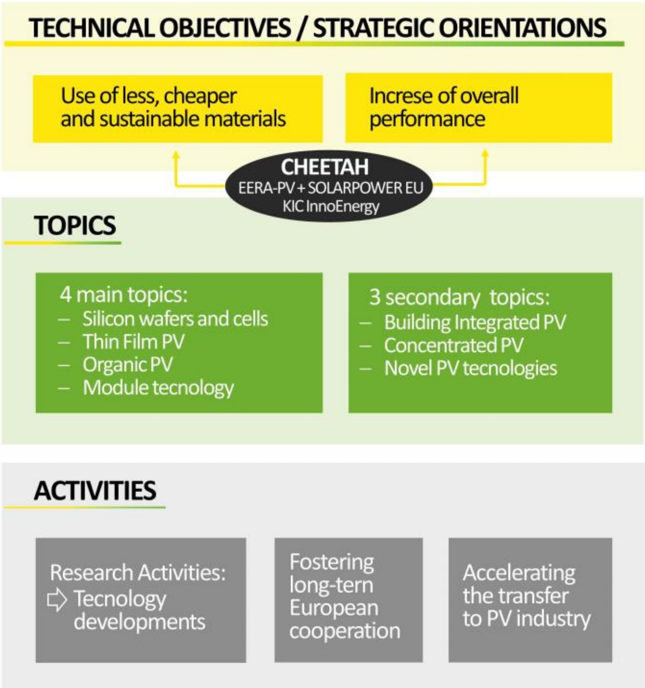
Objectives

The CHEETAH objectives are 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. This is promoted through Joint Support Activities.

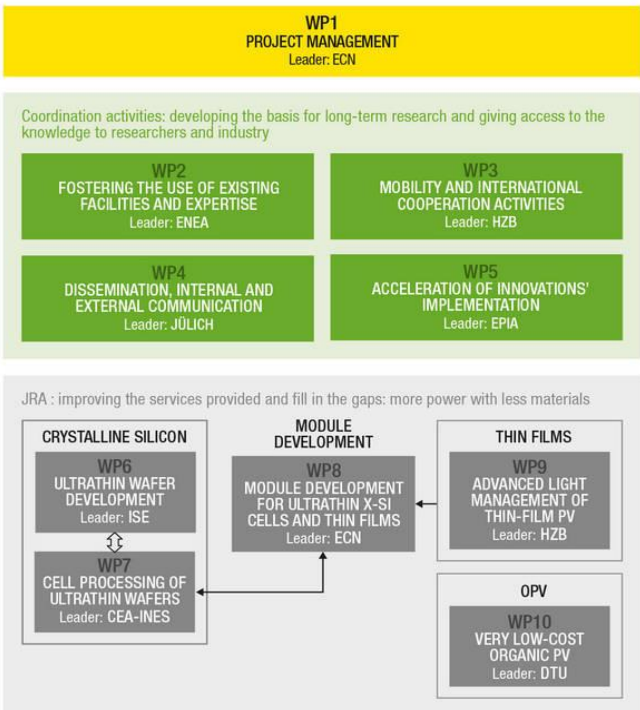
Accelerating the implementation of innovative technologies in the PV industry, by a strong involvement of SolarPower Europe and EIT-KIC InnoEnergy in this program. This is promoted through Joint Support Activities.



1.2. Description of the work performed since the beginning of the project

The Cheetah project is structured around two blocks of activities:

- **Coordination activities** (CSA): developing the basis for long-term research and giving access to the knowledge to researchers and industry (WP2, WP3, WP4, WP5)
- **Joint research activities** (JRA): improving the services provided and fill in the gaps: more power with less materials (WP6, WP7, WP8, WP9, WP10)



In the third year of the project, the following work was performed:

Coordination activities (WP2 to WP5)

- Further elaboration and improving of impact of the CHEETAH knowledge sharing web platform (http://www.cheetah-exchange.eu). This web platform contains a large interactive database of available expertise, research infrastructure and a complete e-learning platform to offer lectures, courses and remote on-line experiments, on-line forum/fora and on-line poll to foster any internal/external technical/scientific discussions on specific themes (WP2);
    - An increased offering of open technical/scientific webinars presented by CHEETAH partners open also on request to external organizations (WP2, WP4).
    - The e-learning platform and the Knowlede Exchange database realized within CHEETAH are both rated as success stories for the EERA-PV Joint programme. Both will be continued and implemented after CHEETAH within the frame of EERA-PV.
- Identification and implementation of joined CSA related to the best use of infrastructure and equipment (WP2) and mobility exchange (training, education) (WP3);
    - An example of a joint action related to infrastructure: Execution of a Round Robin tandem cell characterization and first evaluation of results aiming at producing a best practice document (WP3, WP9).
- Involvement of an international coordination board (ICB) in solving technical problems and by sharing their outside views;
- Organization of research exchanges, summer schools and training workshops (WP3);
- Dissemination of project results via scientific conferences, peer reviewed papers and technical webinars (WP4);
- Organization of two Technology Transfer Advisory Group webinars for crystalline Silicon and thin film PV in presence of industrial stakeholders (WP5).

Joint research activities (WP6 to WP10)

- Crystalline Silicon (WP6 to WP8)

Development of processes for preparing release layers, epitaxial thickening and layer release resulting in thin epitaxially (EPI) grown Si wafers Development of processes to integrate thin wafers into cells and (mini-)modules to demonstrate technical feasibility

- For the epitaxial thickening and layer release the standard foil size increased from 5x5cm to 12.5 x 12.5cm and several batches of 40um foils for cell processing with good detachment yield (WP6).

- A successful heterojunction cell process integration was done on 40 to 50 µm 125x125 Epifoils (4x4 cm^2 cells) with optimized efficiencies up to 17 % (WP6, WP7).
- Heterojunction (HJ) cells down to 80 µm were processed in automatic mode with minor process adjustments with 21.2 and 22.0 % cells obtained for resp. 96 µm 4 busbar and 82 micron busbar less solar cells. Wafers were chemically thinned from 120 µm sawn wafers (WP7).
- Interdigitated Back Contact (IBC) cells down to 80 µm were processed using a pre-pilot process flow chart (WP7).
- Functional IBC minimodules (2 x 2 cells) and a full sized (60 cells) HJ module based on cells between 80 and 100 µm have successfully been fabricated without detection of cell cracks (WP8): the full sized module consisted of 60 HJ 4 bus bar cells with an average thickness of 93µm (from 86 to 99µm) and following characteristics: **282Wp (Cell to Module loss 95.2%) – 310g Si (93µm) (WP7, WP8)**.

- Thin films (WP9, WP8)

Several advanced thin film device structures (LPC thin film silicon and CIGS microconcentrator cells) and light management strategies (nanotexture, concentrator designs) have been investigated supported by an advanced modelling and characterization platform. (WP9) Development of low cost encapsulation and interconnection designs for advanced thin film concepts (WP8)

- Significant progress has been achieved with respect to top-down and bottom-up formation of micro absorbers from planar inkjet-printed CIGSSe and sequentially processed CISe based on indium islands, respectively. Furthermore, the development of printed polymer lenses on the millimeter-scale was reported and a novel concept for enhanced exploitation of direct and diffuse sun light proposed.

- OPV (WP10)

Improving intrinsic stability of organic PV by cost efficient solutions, establishing link between intrinsic and extrinsic stability of devices and effect of different barrier materials on device lifetime, execution of round robin lifetime studies aiming at demonstrating the most inherently stable device architectures, establishing metrics for stability, direct deposition of barrier layers on directly onto devices utilizing slow rate sputtering processes and LCA development

- Simultaneous improvement of both performance and intrinsic stability for multiple cases based on novel non-fullerene PV acceptors, for example, superior thermal stability without light-induced “burn-in” (WP10).

- Improvement of intrinsic stability via slot die coated protective layer of mixture of epoxy and silica gel. More than 60 times improvement of lifetime compared to unprotected devices was achieved via such a low cost simple solution.
- The protection level of different barriers ranging from simple PET to ultrabarriers was graded via round robin lifetime studies of packaged devices.
- Direct sputtering of SiOxNy or multilayer Al2O3/organic barrier onto organic solar cells has led to improvement of the lifetime, especially pronounced for SiOxNy layer.

1.3. The expected final results and their potential impact and use

As mentioned under the objectives, the technology developments within CHEETAH should lead to the realization of innovative and competitive PV concepts with a significant reduction in cost of materials and increase of the overall performance. These innovative developments should lead to a contribution to an accelerated implementation in the European PV industry, so that Europe can regain and build up own manufacturing capacity in all parts of the value chain in due time.

In addition, the establishment of an effective collaborative platform for the PV R&D sector via the coordinative support actions in CHEETAH will help Europe in realizing these goals.

1.4. Consortium and contact information

Coordinator

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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

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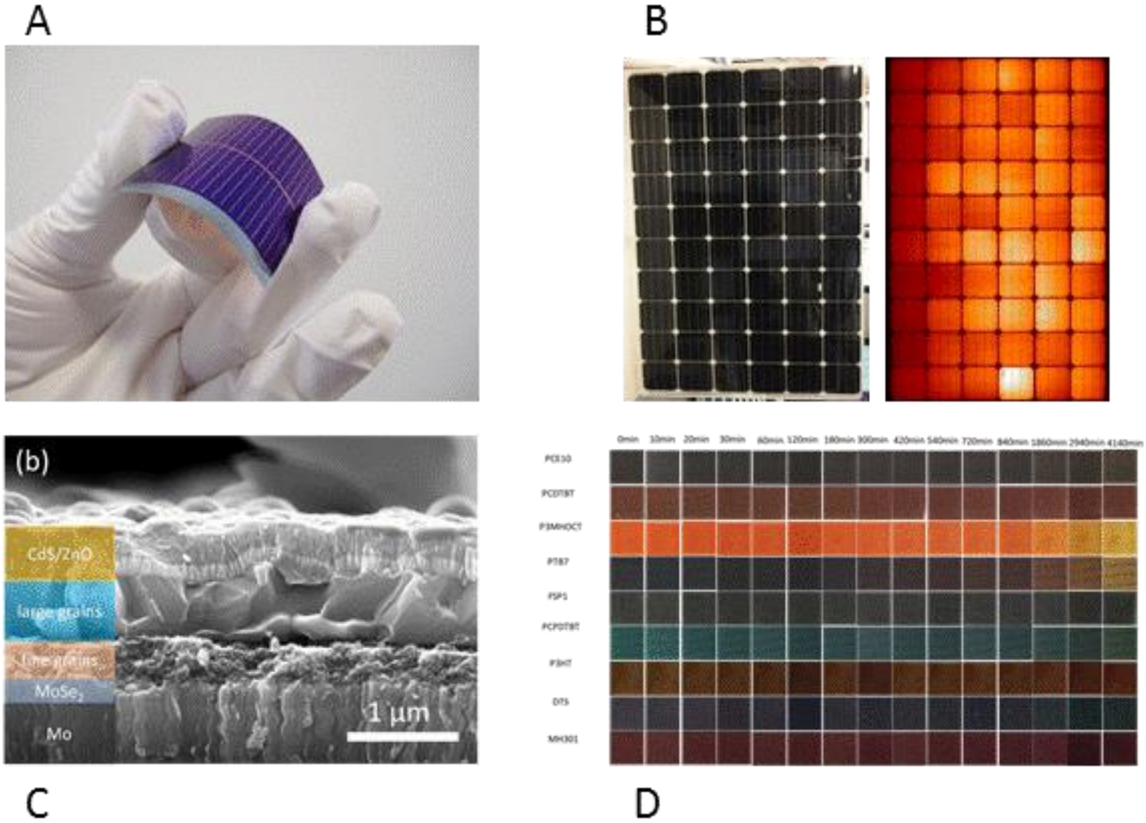

A: Free standing Hetreojunction cell on a 50µm epitaxial Si- foil

B: First 60 cell 282 Wp module + EL image, with 4 bus bar Hetrojunction cells having an average thickness of 93µm, manufactured at CEA-INES

C: 11.3% effiency for planar inkjet printed CIGSSe solar cell

D: Image of 9 benchmark OPV polymers degraded under AM1.5G conditions in dry air, illustrating Methodology to screen materials and layers combinations for enhanced stability