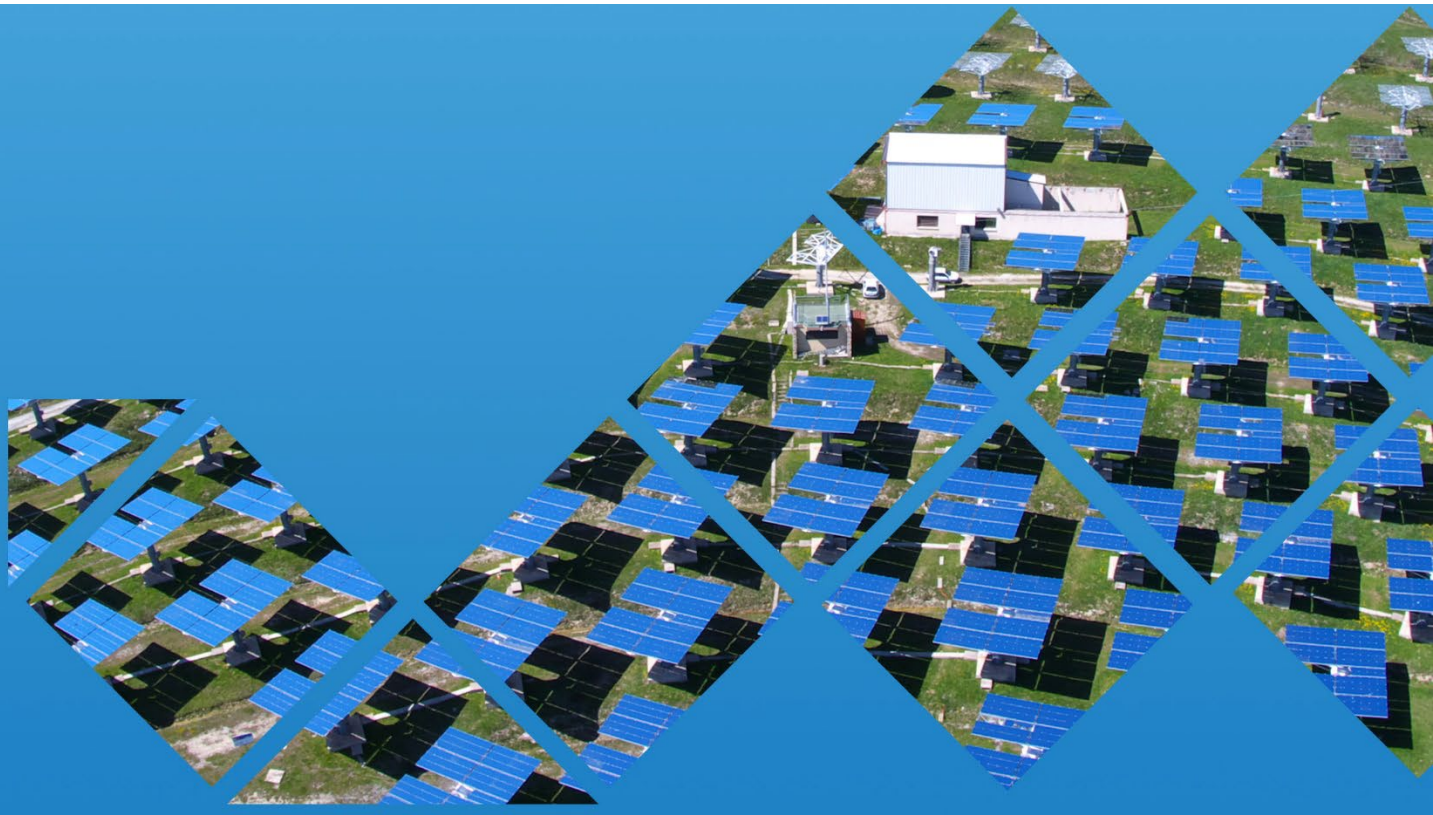
POLYPHEM
THE FUTURE OF SMALL-SCALE CSP PLANTS

POLYPHEM
Small-Scale Solar Thermal Combined Cycle

The future of small-scale Concentrated Solar Power (CSP) plants

PRESS KIT

August 2022



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 764048.

Foreword

Alain Ferriere
CNRS-PROMES
POLYPHEM coordinator

It is a great honour and a big pleasure to coordinate this exciting European R&D action.

The project POLYPHEM is carried out by a group of highly qualified and enthusiast persons from European research centers and the industry sector. In total, nine partners from four European countries are in charge of the execution of the workplan. A large range of scientific and technical topics are covered in this project: thermal, mechanical and material engineering, process control, numerical simulation, measurement techniques. With the project POLYPHEM, this dynamic international group paves the way to the solar tower plants of future generation.

Despite a major technical issue on the solar receiver, we succeeded having many specific results. The main achievements are the selection of alloys and concrete materials, the design, modelling and construction of new components, and the assessment of performance with simulation or testing. Finally, the project could bring the technology from TRL3 to TRL4 or TRL5!

The deployment of the technology is considered. Due to the simplicity, large parts of the plant can be produced and erected in the target country as local content. Also, maintenance can be done locally by trained personnel. So large parts of rural areas without proper energy infrastructure can gain power independence without harming the environment by transporting diesel over long distances.

This project was very challenging for all of us, even more in the international context of Covid. Although all the objectives could not be reached, it was successful in many aspects. The collaboration between the partners was necessary to address all the technical issues and to propose and develop appropriate solutions. We are convinced that the outcomes of the POLYPHEM project will allow in the short term to reinforce the competitiveness of this new low carbon energy technology, to favour its integration in the medium term in the worldwide energy mix and to contribute to the mitigation of climate change.

Table of contents

CONCENTRATED SOLAR POWER: CHALLENGES & SOLUTIONS

Fighting climate change: a global challenge

As climate change and global warming threaten our societies, the European Union committed to reducing greenhouse gas emissions by at least 40% by 2030. Among the objectives: improving energy efficiency by 27% and increasing the share of renewable and greener energy sources to 27% of final consumption, such as solar energy.

SOME CONTEXT

To accelerate the fight against climate change and to reach the EU target of 27% of renewable energies by 2030, Europe needs to rapidly expand the use of all renewable energy sources, such as solar energy. However, this requires developing further new solutions that are emerging today, particularly technologies that solve the key issue of energy storage.

What is Concentrated Solar Power (CSP)?

Concentrated Solar Power (CSP) technologies use mirrors or lenses to concentrate sunlight onto a small area receiver where sunlight is converted into thermal energy. A **heat transfer fluid** transports the **thermal energy** to a **storage system** or a **power block** where it is used to produce steam that drives a steam turbine to generate **electricity**. The integration of a **storage system** enables power production during cloudy periods and **after sunset**.

According to how sunlight is concentrated, CSP technologies are classified into line-focusing and point-focusing technologies. The main line-focusing CSP technologies are parabolic trough and linear Fresnel, whereas the main point-focusing technologies are parabolic dish and central receiver.

The four main CSP technologies

Parabolic Dish

Parabolic Trough

Linear Fresnel

Solar Tower

Challenges for CSP development: Storage, dispatchability and costs

Nowadays, R&D efforts mostly focus on thermal energy storage (TES) for largescale plants, even though small/medium scale CSP installations have a large potential. This limitation is due to the lack of technical solutions of TES specialised for this size of plants and validated in a relevant industrial environment.

In this range of size, in order to make the CSP systems more competitive than the Photovoltaic (PV) systems, the TES has to allow the operators of the solar power plant to adjust the electricity production for matching consumer demand, so enabling the sale of electricity during peak demand periods for boosting plant revenues.

At the same time, there is a need to lower the TES weight in the capital costs of the overall system: in fact, one of the limits in the use of a TES system in a mid-size power plant is due to its high capital costs.

THE POLYPHEM PROJECT IN A NUTSHELL

POLYPHEM
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POLYPHEM is a project funded by the European Union's Horizon 2020 research and innovation programme.

It aims to improve:

- the performance of small-scale Concentrated Solar Power (CSP) plants
- their flexibility to generate power on demand.

To this end, a new technology is proposed: a **solar-driven combined cycle** with **integrated thermal energy storage**.

The **power block** considered in POLYPHEM is a **combined cycle** intended to be used for decentralised small-scale power generation in the range **40 kW to 2000 kW** in remote areas. The purpose is to meet the **variable demand of energy** of a mini-grid. The baseline technology consists of an **air Brayton cycle** as top cycle and an **Organic Rankine Cycle** (ORC) as bottom cycle.

POLYPHEM broadens this technology by driving the top cycle with solar energy through the development of an **advanced technology of pressurized air solar receiver** and by including an **innovative thermal energy storage unit** between both cycles.

Besides electricity generation, other applications are considered for future developments, such as heating/cooling of multi-family buildings or water desalination for small communities.

Targeted results

The POLYPHEM project will build a 60 kW prototype plant with a 1,3 MWh thermal storage unit and will validate this innovative power cycle in a relevant environment (TRL 5), at the Themis solar tower in Targassone.

POLYPHEM CONCEPT & INNOVATION

Three highly innovative ideas bear the POLYPHEM concept

01

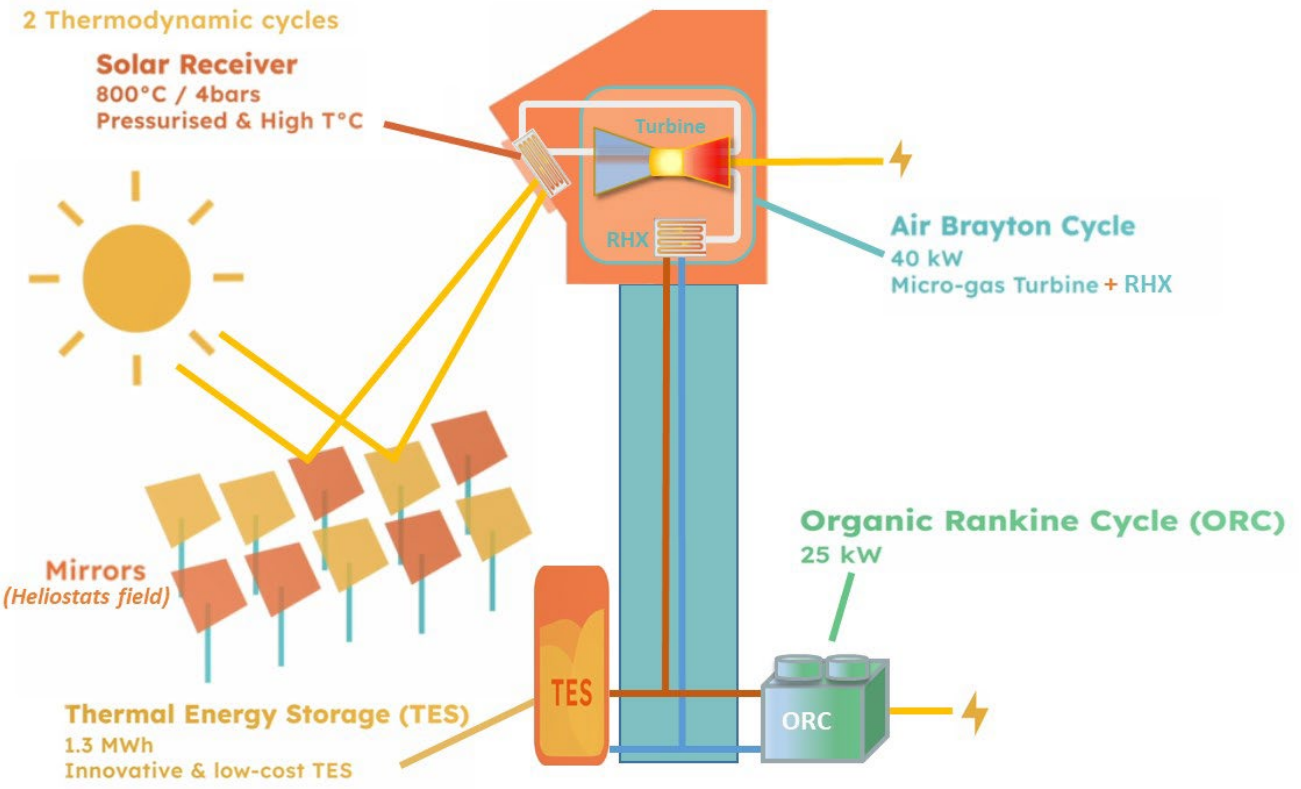
Coupling a small-scale Organic Rankine Cycle (ORC) with an open Brayton cycle (micro gas-turbine - µGT) to make a novel combined cycle

02

Integrating a low-cost thermal energy storage (TES) between both cycles

03

Integrating a high temperature solar receiver in the top cycle



The POLYPHEM concept

The top cycle of POLYPHEM is the air Brayton cycle of the micro gas-turbine. This engine is operated on-sun and generates power. The heat recovered at the exhaust of the gas-turbine is directed to the Thermal Energy Storage. The heat is discharged from the storage and is converted into power on-demand by the Organic Rankine Cycle. In option for future commercial versions of POLYPHEM plant, the bottom cycle may be replaced by a heating/cooling or water desalination unit to satisfy alternate energy needs. This innovative power cycle will be validated in a relevant environment (TRL 5) at the Thémis solar tower in Targassone, France. It will also establish the guidelines for the commercial Deployment of this technology in the long term.

Prototype plan	Thermal storage unit	Technology Readiness Level
60 kW	1.3 MWh	4 - 5 level

A COLLABORATIVE PROJECT EU-FUNDED PROJECT

POLYPHEM has been supported by the European Union's Horizon 2020 research and innovation programme. The project was funded by the "Secure, clean and efficient energy" programme, under the specific topic "Developing the next generation technologies of renewable electricity and heating/cooling" (LCE-07-2016-2017).

The consortium was coordinated by CNRS-PROMES and implemented by a total of 9 partners from 4 EU member countries. POLYPHEM involves a consortium composed of 3 public research centres (CNRS-PROMES, CEA-LITEN, CIEMAT-PSA), 1 non-profit research organization (FRAUNHOFER ISE), 4 SMEs (ARRAELA, ORCAN Energy AS, EURONOVIA and AALBORG CSP) and 1 company (KAE). All of them were selected for their skills and complementarities to reach and achieve the expected objectives of the project.

TOTAL BUDGET
€ 4,975,961

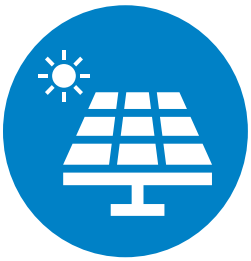
EU CONTRIBUTION
€ 4,975,961

CONSORTIUM
9 Partners
4 Countries

COORDINATOR
CNRS-PROMES
France

DURATION
53 Months
from April 2018
to August 2022

RESULTS & MAIN ACHIEVEMENTS



SOLAR ENERGY TECHONOLOGY

- The Ni-based alloy 230™ (Ni-Cr-W-Mo) has been selected for the construction of the solar receiver.
- The concrete grades used for the construction of the thermocline tank wall and for the storage filler are identified. These materials have been characterized and the compatibility with the thermal oil has been proven.

DESIGN, DEVELOPMENT AND MANUFACTURING OF NEW COMPONENTS

- The initial design of the solar receiver is completed. This key component is made of absorber modules arranged in a surface receiver. The air flows into the modules through manifolds placed on each side of the absorber plane.
- The engineering for the solarization of the gas turbine is done. Air ducts connect the engine to the solar receiver.
- The design of the storage tank is completed.
- The overall plant layout is established.
- The system modelling is completed.

ASSESSMENT OF PERFORMANCE

- Performances were assessed through extended simulation covering various operating strategies and resource conditions.
- Testing of the filler material for thermal energy storage was successfully completed.
- The gas-turbine was tested and validated.

COMMERCIAL DEVELOPMENT

- Simplicity in the production and construction of the prototype plant
- Need for cost reduction to compete with other renewable electricity generation systems in most emote areas situations
- Combined heat and power opens attractive market opportunities for the technology
- Trained personnel for maintenance
- Power independence for rural areas

Most of the technical issues were successfully addressed by the consortium. Relevant solutions were implemented to meet the objectives. The lessons learned during the execution of the programme of work significantly improved the skills of the partners.

IMPACTS OF THE PROJECT

TECHNOLOGY IMPACT

- A new design and the next generation of small-scale CSP plants with high performance combined cycle and flexible generation of renewable electricity with firm capacity.
- Reduced water requirement compared to steam Rankine cycle.
- A higher optical efficiency than any other solar field.
- An extended range of configurations by varying the size of the components, each configuration being optimized for a specific need (power generation, cogeneration, heating/cooling, water desalination).

EUROPEAN COMPETITIVENESS

- Strengthening competitiveness and growth of European companies already engaged in CSP related activities.
- Supporting the business activity of SMEs by opening a new field in which the early movers will have a decisive competitive advantage over potential competitors.
- New business opportunities for industries developing products such as: technical concrete, organic Rankine cycles, high temperature and high-performance heat exchangers, insulating materials, thermal processes.

ECONOMIC IMPACT

- The Levelized cost of electricity (LCOE) estimated for the POLYPHEM technology developed at the end of the project (2020-2025) is 21 c€/kWh in sunny regions (2600 kWh/m2/y).
- When commercial technology will be ready in 2030-2040, the LCOE is expected to drop down to 16.5 c€/kWh which will be competitive with the cost of electricity generation in remote areas in Africa, Middle East or India.
- High local content during the construction of the facility: carpentry, boiler making, pipes, light equipment.

ENVIRONMENTAL IMPACT

- A solar technology for clean power and process heat generation
- Supply of electricity on-demand through Exploitable Results which will:
  - increase electricity generation based on Concentrated Solar Power (CSP)
  - develop Thermal Energy Storage (TES) systems and integrated energy solutions
  - supply Green technologies
  - use desalination in order to increase water availability
  - contribute to sustainable agricultural and food production
  - reduce CO2 emissions

TIMELINE OF THE PROJECT

WHAT IS NEXT? THE FUTURE OF POLYPHEM

The commercial deployment of the POLYHEM technology is an ambitious objective for future research and innovation actions or more advanced research and development projects. The implementation of the POLYPHEM project was the first step of the pathway to reach this goal.

The TRL of some components of POLYPHEM was improved during the execution of the project, but no time was left for conducting the experimental part of the equipment that were installed. The work on the solar receiver should be continued in a future project to achieve a significant progress of TRL.

The electricity generation should not be the only utilization of the POLYPHEM technology. The generation of combined heat and power appears as much more attractive. A demonstration plant must be designed and operated to push the POLYPHEM technology towards commercialization.

To this end, a careful sizing of the gas-turbine and ORC must be made, as well as the appropriate selection of the location with regards to the solar resource, the energy demand and other local economic factors.

COMMUNICATION & DISSEMINATION MATERIALs

PRINT MATERIAL

POLYPHEM Brochure
Download here.

POLYPHEM Flyer
Download here.

POLYPHEM timeline infographic
Download here.

VIDEOS

An **animated video** presenting the POLYPHEM project.
Watch here.

A **video** presenting the main results of the project with interviews of the partners.
Watch here.

WEBINARS

A **1-hour webinar** presenting the key information on the challenges and opportunities offered by Concentrated Solar Power and the application at small-scale.
Watch here.

VISUALS

The **POLYPHEM Logo.**
Download **here**.

A selection of pictures.
Download the image file **here**.

All the communication material are also available on the POLYPHEM website:
www.polyphem-project.eu/dissemination/#communication

DELIVERABLES

Title	Partner Authors	Published link
Report on the benchmark of high temperature oxidation resistant materials and thermo-mechanical test campaign	CEA	Download in PDF
Recovery heat exchanger	AALBORG	Download in PDF
Turbine – Receiver Interconnection tubing	KAEFER	Download in PDF
Programmable Logic Controller (PLC) board	KAEFER	Download in PDF
Enclosure for the gas turbine	KAEFER	*To be available soon*
Factory-pre-test of gas turbine package and ORC module	KAEFER	*To be available soon*
Report on the design and specifications of filler, tank and foundations	ARRAELA	Download in PDF
Report on the design and specifications for the integration of the whole TES in the POLYPHEM system	CIEMAT	Download in PDF
Report on the filler material	CEA	Download in PDF
Report on the lab test of the thermocline storage system	CNRS	*To be available soon*
Report on the modelling for thermohydraulic and ratcheting behaviours	CIEMAT	*To be available soon*
Report on the overall plant layout	FRAUNHOFER	Download in PDF
Manufacturing/ Installation of the thermal storage	ARRAELA	*To be available soon*
Manufacturing/Installation of the solar receiver	KAEFER	*To be available soon*
Installation of the power block	KAEFER	*To be available soon*
Piping, auxiliary equipment and cable connections	KAEFER	*To be available soon*
Commissioning	KAEFER	*To be available soon*
Measurement technique and experimental protocols for the testing and evaluation of the prototype of plant	CNRS	*To be available soon*
Selected dataset of experimental data	CNRS	*To be available soon*
Report on performance assessment and model validation	FRAUNHOFER	*To be available soon*
Final report on system model	FRAUNHOFER	*To be available soon*
Report on results of Life Cycle Assessment analysis	FRAUNHOFER	*To be available soon*
Report on the market analysis and benchmarking with competing technologies	FRAUNHOFER	*To be available soon*
Report on the financial model of the technology	KAEFER	*To be available soon*
Report on the roadmap to a commercial deployment	KAEFER	*To be available soon*
Data Management Plan	CNRS	Download in PDF
Final report on the project exploitation initiatives and related impacts on innovation, including D&C activities	EURONOVIA	*To be available soon*

Please note that a Summary of **Confidential deliverables** are available for download in open access on the website with non-confidential information (introduction/conclusion).

Get access to the latest scientific publications of the project which have been published in open access so that the scientific community can benefit from the project results on our website https://www.polyphem-project.eu/progress/#publication

Open data resulting from the publications are also published on the open repository platform, Zenodo https://zenodo.org/communities/polyphem/

SCIENTIFIC PUBLICATIONS

Title	Partner Authors	Published in / DOI
Optimization of Solar Tower molten salt cavity receivers for maximum yield based on annual performance assessment (Open Access)	F-ISE	Solar Energy Materials and Solar Cells (2020), 199, 278-294 https://doi.org/10.1016/j.solener.2020.02.007
Emissivity at high temperature of Ni-based superalloys for the design of solar receivers for future tower power plants (Open Access)	CNRS-PROMES CEA	Solar Energy Materials and Solar Cells (2021), 227, 111066 https://doi.org/10.1016/j.solmat.2021.111066
Erratum to 'Emissivity at high temperature of Ni-based superalloys for the design of solar receivers for future tower power plants' [Solar Energy Mater. Solar Cells, 227, (2021), 111066] (Open Access)	CNRS-PROMES CEA	Solar Energy Materials and Solar Cells (2021), 230, 111228 https://doi.org/10.1016/j.solmat.2021.111228

CONFERENCE PROCEEDINGS

SolarPACES 2018

- The POLYPHEM project: An innovative small-scale solar thermal combined cycle (CONSORTIUM) | https://doi.org/10.1063/1.5117534

SolarPACES 2019

- Prediction of thermocline zone development at the beginning of dynamic processes in single storage tanks with liquid media (CIEMAT) | https://doi.org/10.1063/5.0028900

SolarPACES 2020

- Simulation-Based Comparison of Different Operating Strategies for a Dispatchable Solar-Driven CCGT Plant with Stratified Thermal Storage (Fraunhofer ISE) | https://doi.org/10.1063/5.0028900

SolarPACES 2021

- The Conference Proceedings for the 2021 edition have not been published yet.
- However, POLYPHEM has presented 1 paper entitled:
  - Techno-Economic Performance Analysis of a CSP-Driven CCGT with Stratified TES at Various DNI Levels and Demand Conditions Based on Transient Simulation (Fraunhofer ISE, CNRS-PROMES)

SolarPACES 2022

- The Conference Proceedings for the 2022 edition have not been published yet.
- However, POLYPHEM will present 1 paper entitled:
  - Thermocline storage tank with concrete filler: Lessons learnt during the commissioning and first experimental results of the POLYPHEM project (CIEMAT, CNRS-PROMES, ARRAELA)

Sustainable Places (SP 2019)

- Next Generation of Concentrated Solar Power Technologies (CNRS-PROMES) | https://doi.org/10.3390/proceedings2019020007

The list and all the abstracts of the POLYPHEM publications are available on our **Website**: https://www.polyphem-project.eu/progress/#publication

POLYPHEM IN THE MEDIA

European Energy Innovation (2021 and 2022)

The POLYPHEM project was featured in the Autumn 2021 and 2022 edition of the magazine of European Energy Innovation. **LINK**.

ENLIT 2021 & EU Projects Zone: Interview with Alain Ferriere (2021)

The EU Projects Zone Podcast published an interview with Alain Ferriere from CNRS-PROMES about the POLYPHEM project. **LINK**.

Climate, Environment, Infrastructure & Environment Executive Agency - CINEA (2021)

POLYPHEM was featured in the brochure of Horizon 2020 Energy project examples of innovative solutions for smart grids and storage of CINEA. LINK.

Rural Digital Europe (2020)

Presentation of the POLYPHEM project in the DESIRA platform that provide access to publications, research data, projects and software for assessing the socio-economic impact of digitalisation in rural areas in Europe . **LINK**.

European Commission – CORDIS Results Pack (2020)

European Commission's primary source of results of the POLYPHEM project (Fact sheet, reporting, results, news and multimedia). **LINK**.

CSP Focus (November 2019)

All you ever wanted to know about the origins of POLYPHEM and the motivation behind the project told by our partner KAEFER (Germany). **LINK**

Knowledge Center Organic Rankine Cycle – KCORC (2019)

Presentation of the POLYPHEM project in the R&D projects section of the website. **LINK**.

Wikipedia (2019)

Presentation of the POLYPHEM project in the « Thémis (solar power plant) » official webpage. **LINK**.

UMI Community (2019)

Presentation of the POLYPHEM project in the R&D projects section of the website. **LINK**.

K-WERT Kaefer Magazine (2018-2019)

'POLYPHEM' – How two KAEFER engineers are planning to change the world! **LINK**.

Aalborg CSP (2018)

Presentation of the POLYPHEM project in the « EU and Co-funded projects » section of their official website. **LINK**.

CIEMAT - ALMACENAMIENTO TÉRMICO Y COMBUSTIBLES SOLARES (2018)

Presentation of the POLYPHEM project in the « Research projects » section of their official website. **LINK**.

POLYPHEM Press Release: POLYPHEM Final General Assembly & Final Info Day

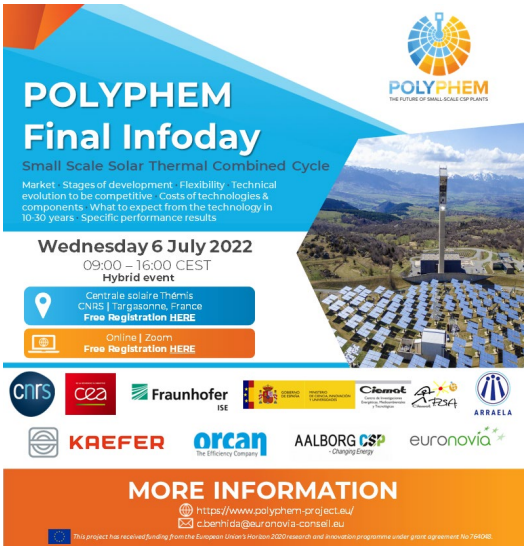
The POLYPHEM **Final General Assembly** and **Info Day** was organised on the **5th** and **6th of July 2022** by **CNRS PROMES** at the **Centrale Solaire Thémis**, in **Targasonne**.

On Tuesday, 5 July, the **Final General Assembly** gave us the occasion to meet again to prepare the end of the project, the road ahead towards the finalization of the last deliverables, the final report, and the preparation of the project review with the European Commission in the Fall 2022.

On Wednesday, 6 July, the **Final Infoday** was an amazing opportunity to present and explain the **innovative technologies** for Concentrated Solar Power as well as the **main challenges, results** and **perspectives** of the project!

Due to the health context, the Info Day was organised as a **hybrid** event: **online**, through the Zoom platform and **on site** at the CNRS-PROMES facilities in Font Romeu Targasonne, France (limited). **Registration** was free, but mandatory for all participants.

With more than **50 participants online** and **onsite**, POLYPHEM partners delivered interesting presentations together with an enriching panel discussion. In the programme,



09:00	**Introduction & presentation of POLYPHEM** Alain Ferriere, POLYPHEM Project Coordinator, CNRS-PROMES
10:00	**Panel discussion with our POLYPHEM team of experts**
12:30	**Lunch Break**
14:00	**Visit of POLYPHEM facilities** Centrale solaire Thémis, CNRS-PROMES
16:00	**Q&A and closing session**

All the contents of the event including the **presentations** of the **key results of the project** is available on the project website at the following link: https://www.polyphem-project.eu/2022/07/27/polyphem-final-project-meeting-and-infoday/

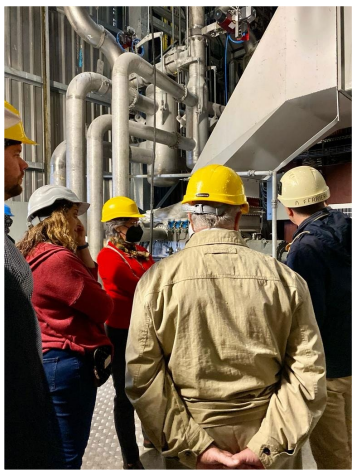



After 53 months of collaborative research in Concentrated Solar Power energy, POLYPHEM came to an end on 31 August 2022. As a way of conclusion, all the relevant reports and documents of interest regarding the project are available on our website https://www.polyphem-project.eu/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 764048.

POLYPHEM Press Release: POLYPHEM Final General Assembly & Final Info Day

Finally, all the participants wrapped the Final Info Day with a visit of the facilities in the afternoon.



Once again, thank to the organizers, Alain Ferriere and Lauriane Gonzalez from PROMES CNRS for their warm welcome, as well as the eight other partners of the project, Sébastien Chomette from CEA-LITEN, Esther Rojas and Margarita Rodriguez Garcia from CIEMAT, Nicholas Chandler from Fraunhofer-Institute für Solare Energiesysteme ISE, Simon Schütrumpf from KAEFER, Richard Aumann from Orcan Energy AG, Jens Jørgen Falsig and Peter Badstue Jensen from Aalborg CSP A/S, Juan Manuel Caruncho from Arraela, S.L. and Virginie Robin and Camélia Benhida from Euronovia!

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