NEWSLETTER

February 2025| No. 1

ASTERIx-CAESar introduction

The ASTERIx-CAESar project is a Horizon Europe funded project that started in October 2023.

The project's main goal is to develop a novel high-efficiency solar thermal power plant concept with an integrated electricity storage solution.

ASTERIx-CAESar: Air-based Solar Thermal Electricity for Efficient Renewable Energy Integration & Compressed Air Energy Storage

A few words from the project coordinator

Fritz Zaversky, Project Manager - Principal Research Engineer - Head of Thermal Simulation, CENER

The specific problem we are tackling is twofold: (1) The energy storage issue of the power grid, which limits the maximum capacity of non-dispatchable renewable technologies, and (2) the low conversion efficiency of concentrated solar power (CSP) plants. To counter this problem, we propose the innovative combination of a Concentrated Solar Power (CSP) combined cycle plant integrating the compressed air energy storage (CAES) technology, to provide electricity storage and maximise solar to-electric energy conversion

(Excerpt from the March 2024 interview. Read the complete text here.)

CENER | NATIONAL RENEWABLE ENERGY CENTRE

Find more information about us!

- The project website 🌍 is accessible via the link www.asterix-caesar.eu and is regularly updated
- Our leaflet, poster, roll-up, and the public presentation are available for download here 🪧
- Check out our official project video as well as other short films on our YouTube channel 🎞️
- Follow us on social media: LinkedIn and X

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ASTERIx-CAESar update

WP1 – Concept definition and Techno-economic Optimisation

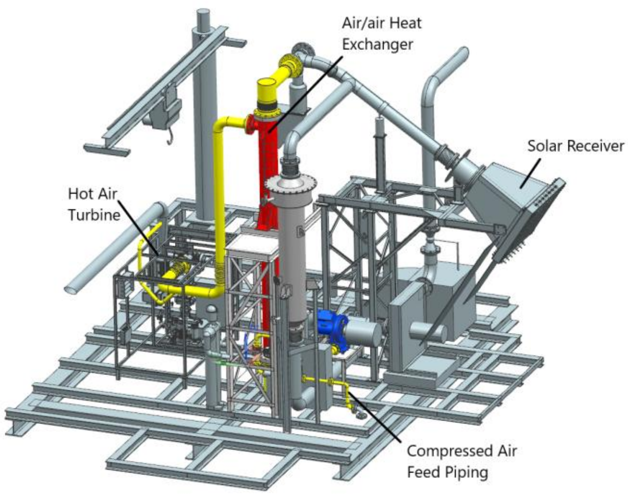
The activities can be divided into two areas:

1. Definition and optimisation of the ASTERIx-CAESar power plant concept

Since the project start, the WP1 working group has been focused on defining all main power plant working parameters, such as the optimal charging and discharging times according to power grid demands, maximum CAES pressure, CAES vessel design and design parameters of compressor train and expansion train. For instance, we have been comparing constant pressure and sliding pressure turbine inlet conditions in terms of conversion efficiency as well as turbine design impact. Additionally, different bottoming Rankine cycle architectures have been analysed, including the organic Rankine cycle at small and intermediate scale. A detailed system-level performance model has been developed in Modelica, which allows the performance assessment and optimisation under different boundary conditions. A specific case study is now being summarised and will be the 1st journal publication.

2. Definition of the ASTERIx-CAESar project's prototypes

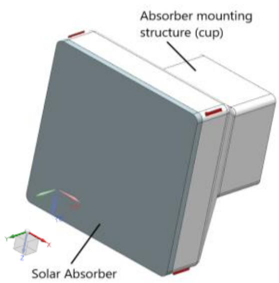
Experimental testing will be done at different scales. The working group will test small solar absorbers (12x12 cm) in the solar furnace at CIEMAT-PSA. Then, larger absorber samples (25x25 cm) will be tested at the solar tower at IMDEA. Finally, during the last project year, a 300 kW_{th} receiver with approximately 1 m^2 of aperture area will be tested at a solar tower at CIEMAT-PSA.

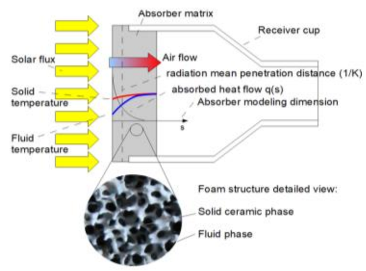


This receiver will power a hot air turbine that will be connected to a small-scale CAES unit, providing between 1 or 2 hours of nominal turbine mass flow. During the first project year, all prototypes have been defined and specified in detail. For example, the complete 3D model of the final ASTERIx-CAESar prototype is now available as of January 2025.

WP2 – Solar Receiver Development

The working group has prepared various absorber samples to be tested at the solar furnace at CIEMAT-PSA. Different porosity levels are to be tested under high flux conditions and at temperatures up to 800°C. Additionally, large effort was spent on the numerical simulation of different sizes of solar absorbers. The objective is to increase the solar absorber module size to reduce costs. Computational Fluid Dynamic (CFD) simulations and mechanical Finite Element Method (FEM) simulations were done at CENER as well as Fraunhofer IKTS to estimate thermal stress and to be able to select the best suitable absorber geometry. Furthermore, the absorber module and receiver geometry has been designed and optimised considering an advanced ceramic composite material (developed by Walter E.C. Pritzkow Spezialkeramik). Currently, 25x25 cm absorber modules are being manufactured and to be tested in late spring 2025.





CENER is preparing a transportable solar absorber test loop that can test single absorber modules up to a thermal power of approximately 50 kW. The test loop will be installed at the solar tower of IMDEA.

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WP3 – Advanced Heat Exchangers

WP3 activities are addressed to the optimised design of the equipment to accomplish heat transfer processes. The ASTERIx-CAESar plant concept requires two separate heat transfer systems: a Low Temperature Heat Exchanger (LTHE) system to carry out the intercooled/ aftercooled compression, and the High Temperature Heat Exchanger (HTHE) system to heat and re-heat the compressed air before the expansion. For both systems, two different concepts will be explored: the classic regenerative concept, where heat transfer occurs between streams separated by a heat transfer surface, and the innovative regenerative concept, where air is cooled/heated in a single vessel by passing through a porous heat storage medium.

The regenerative concept is assumed as the reference one and therefore, it has been addressed first. As agreed in WP1, medium size plant (i.e. 20 MW output power) has been primarily considered. For both LTHEs and HTHEs, design specifications imply a counter-flow arrangement, a reduced temperature differences between hot and cold fluid and a really small allowable shell side pressure drop to limit the power absorbed by fans to circulate the atmospheric air flow. Commercial (CC-THERM) as well as in house developed computer codes have been used.

The four LTHEs have been successfully sized. As expected, relevant heat transfer surfaces (in the range of 2500-3000 m^2) have been found as a consequence of the reduced LMTD (logarithmic mean temperature difference) design values and the relatively low heat transfer coefficient resulting from the low shell side velocity required to fulfil the pressure drop requirements. The off design LTHEs performance during the entire charging phase has been successfully checked.

Similarly, HTHEs for pressurised air heating and reheating after expansion in High Pressure Turbine (HPT) have been sized. Heat transfer coefficient values are higher than those evaluated for LTHEs. The air re-heater requires a relevant heat transfer area (about 2800 m^2), as a consequence of the relevant heat duty (air heating from 250 to 750°C). The heat duty can be met by a single unit, i.e. there is no need to arrange multiple units in parallel.

At present, a promising concept based on the proven Heat Recovery Steam Generator (HRSG) technology to accomplish the compressed air heating and re-heating is under investigation.

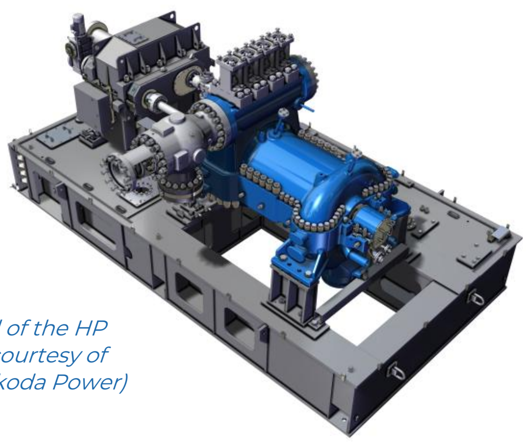
WP4 – Advanced CAES and power cycle development and Optimisation

WP4 is responsible for the development of turbomachinery and the associated integrated systems in ASTERIx-CAESar. This implies three main modules (islands) of the facility: the compression train charging the storage system (whether underground or on surface), the expansion train converting the mechanical (pressurised air) and thermal (high temperature storage medium) energy stored in the system into electricity, and bottoming heat recovery system harvesting any remaining thermal energy downstream of the expanders to produce additional electric power.

Different layouts of the compressor train for large and small-scale facilities have been analysed by University of Seville, where preliminary design of the individual compressors (casings) is currently being performed. This preliminary design phase has also been completed for the expander train, where DOOSAN Škoda Power and SoftInWay are working hand in hand to design the high- and low-pressure axial turbines, respectively. For small-scale facilities, Bluebox Energy has also completed the design phase of a radial expansion train and is currently working on the manufacturing and assembly of the machines that will be tested at the demo site of CIEMAT.

The design of the waste heat recovery system is being carried out jointly by the WP4 partners: solutions based on steam turbine technology (CENER) and Organic Rankine Cycle (University of Seville) systems running on different working fluids, both making use of innovative heat recovery steam/vapour generator concepts developed by University of Roma Tre.

Thanks to the above-described activities, performance maps of critical components have been produced and are currently being used by WP1 focused on system simulation.



3D model of the HP turbine (courtesy of DOOSAN Škoda Power)

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WP5 – Automatization and improved plant operation and monitoring via AI methods

WP5 focuses on innovative approaches for improving plant operation and monitoring and addresses three main activities:

High-accuracy & high-precision aiming strategy generation method enhanced with artificial intelligence algorithms has initially led to Dijkstra's and Nelder-Mead algorithms adaptation (used in the CENER's CAPTure project) to consider different configurations of receiver discretisation and type of heliostat (e.g. tilt-roll heliostats as those installed at IMDEA). Then, static and dynamic strategies have been calculated with different setting up of maximum flux, spillage and receiver discretisation. In addition, new methodologies based on reinforcement learning and metaheuristics algorithms are in progress, as well as algorithm codes improvements to speed up the numerical calculations. In parallel, IMDEA and CENER have defined the database that will be used for training and testing of the developed methodologies.

Activity on **Advanced optical sensors for monitoring high-concentration solar thermal systems** has focused on the use of optical fibers. An optical fiber-based radiometer for measuring direct normal irradiance has been currently developed, which has required specific characterisation of several device components and establish a methodology for suitable device calibration under sunlight. Besides, high-temperature optical fibers supplied by engionic have successfully tested in a high-flux solar simulator by US and IMDEA researchers measuring up to 200 kW/m². Experiments have demonstrated the application of high-temperature optical fibers to measure high flux densities and provided valuable information as basis for next developments.

Optical sensors (courtesy of engionic)

AI-based heliostat tracking control system for low-cost operation requires an intensive campaign to collect and label images to store a comprehensive training and validation dataset, enabling improved model performance and greater generalisation across diverse conditions. In this respect, images have been collected every 10 minutes over the first year of the project. Additionally, CIEMAT-PSA has developed a new main control algorithm and a device prototype (named Heliot) that is now implemented in a heliostat at PSA. These systems are expected to allow enhancing heliostat efficiency and safety.

WP6 – Validation & Demonstration of receiver and power cycle

Within the framework of WP6, significant progress has been made in evaluating the thermal behaviour and scaling up the ASTERIx-CAESar solar absorbers and complete prototype. The work package, aimed at validating the concept under real-world conditions, is currently advancing through its initial tasks.

Under Task 6.1, focusing on solar furnace testing of the receiver prototypes (10 kW thermal), critical preparatory steps have been completed. The new absorbers and cups were delivered to PSA, where facilities were adapted for testing. Before thermal testing, the optical properties of the samples (absorptance and emittance) were measured, with plans for post-testing reassessment to analyse their evolution. Initial thermal tests have now commenced, marking a key milestone in validating the absorber's performance.

In Task 6.3, efforts have centered on advancing the adaptation of the CAPTure prototype to incorporate CSP-CAES functionalities. Non-operational components such as pipes, regenerators, and valves were dismantled, while the turbine was sent to Bluebox Energy (UK) for fine-tuning. Additionally, absorbers and cups from the previous CAPTure receiver were sent to IKTS in Germany for detailed performance evaluation. The consortium, led by CENER and CIEMAT, coordinated the location where the CAES system will be installed near the CRS tower, including the placement of a low-pressure pipeline from the ground level to a height of 45 meters.

[continued on the next page]

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[continued from page 4]

A key development in this task involves collaboration between APRIA and CIEMAT on designing a Piping and Instrumentation Diagram (P&ID) for an ad-hoc desalination pilot plant. This plant integrates a reverse osmosis (RO) desalination unit powered by compressed air from the CAES system. Detailed specifications for instrumentation, control systems, and operational parameters have been finalised, along with layout designs, pipe dimensions, and concrete slab requirements for installation at PSA.

These achievements represent important strides towards demonstrating a TRL 6/7 solar-powered CAES plant in a relevant environment.

Specific topics

Social aspects (WP1)

The sustainability and longevity of the ASTERIx-CAESar CSPs will strongly depend on the acceptance of a wide range of stakeholders, among those policymakers and the general public. Therefore, EURIDA started assessing potential social impacts that may either

- present opportunities to maximise the future positive impacts on a more sustainable society

or

- have negative effects on the wide acceptance of the CSP-CAES technology in the long term.

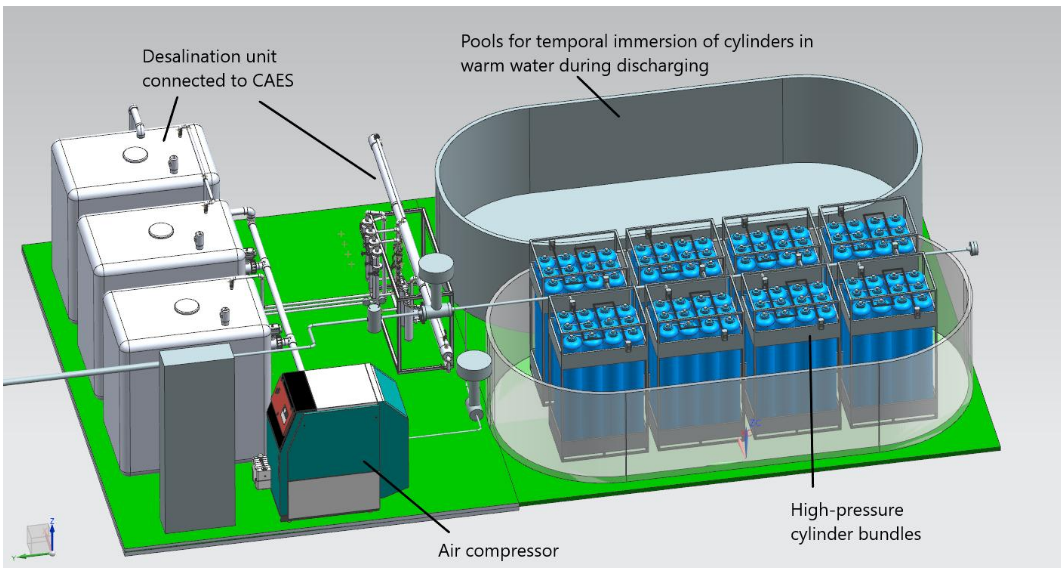
We took first steps by searching social data and indicators from literature and public databases, such as the Social Hotspot Database and ecoinvent, while assessing their relevance for the CSP-CAES technology. This work will be coupled with input from key stakeholders which will be collected in interviews, questionnaires, and dedicated meetings.

Interested parties are invited to contact Rita Clancy from EURIDA for further information at r.clancy@eurida.at.

Exploitation & Innovation Management (WP7)

Based on its technical progress, ASTERIx-CAESar focuses on developing novel concepts and credible exploitation pathways for the targeted CSP-CAES technology and innovative concepts & components that we expect to be of interest for future commercialisation, scale-up and other exploitation pathways.

EURIDA and Aalborg CSP have started developing the project business case by collecting and assessing those project results that have the highest innovation potential and could extend the product and service portfolios of companies involved in the project. In parallel, a market watch is ongoing, enabling us to react quickly on changing market conditions. Based on first assessments of innovative results and technology maturity levels, we shaped an exploitation roadmap with a realistic timeframe for the market entry of the novel CSP-CAES technology within the next 10 years.



3D view of the desalination system together with the CAES

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Interview with ASTERIx-CAESar partners – University of Seville, DOOSAN Škoda Power, and SoftInWay Switzerland

What role does Turbomachinery design and integration (WP4) play in ASTERIx-CAESar and how does it interact with the other technical WPs?

David Sánchez, University of Seville

David: The singularity of ASTERIx-CAESar is found in the integration of renewable energy collection, storage and dispatch, as opposed to many energy-storage concepts under development which harvest electrical energy produced by remote renewable energy technologies. This is key to alleviating the congestion of the grid, hence enabling a higher penetration of renewables. At the same time, it opens more opportunities for the integral optimisation of the charging and discharging processes, and this is where the interaction between WPs comes into play. In short, the heat produced during the intercooled compression (WP4) is harvested and stored by a low-storage thermal energy storage system designed in WP3, to be later delivered during discharge.

Tereza Kubíková, DOOSAN Škoda Power

What are the most critical challenges in the project?

Tereza: Design of the High-Pressure air Turbine (HPT) is comparable to steam turbine design. The correct design, features and function of the control stage is crucial. One of the main objectives is to properly understand the operation, i.e. the charging/discharging of the Low-Temperature Thermal Energy Storage (TES), to which the HPT must respond in a timely and correct manner. In standby storage mode, the turbines must be preheated to the correct temperature for rapid start-up and minimum thermal stress.

We are currently working with SoftInWay on the design of the turbomachinery, including the location of the generator, gearbox and other downstream systems. So, for us, the challenge is not so much designing the turbine as understanding the interconnectedness and complexity of the entire Compressed Air Energy Storage (CAES) system.

Theunis du Toit, SoftInWay Switzerland

Theunis: An interesting technical opportunity and challenge for the LPT is the high-temperature air supply from the CAES, theoretically reaching almost 800 °C. To maximise the use of the available energy, the LPT will most likely incorporate superalloys. Even with the use of these advanced materials, the operational requirements pose serious design challenges, particularly the rapid and frequent startup/shutdown cycles.

Like the HPT, to extend the LPT's life, careful consideration is given to optimising the startup temperature during charging/standby periods and balancing the use of limited hot air, which could otherwise be used during the discharge cycle to produce energy. This implies another difficult trade-off between potential energy production and turbine life.

The Doosan's steam turbine with the gearbox (right), assembled turbine (left), and the oil frame (depicted in brown). A very similar high-pressure (HP) air turbine will be developed for ASTERIx-CAESar project.

Read the entire interview here

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Project management

Meetings

The **Kick-off meeting** took place on 14 & 15 November 2023 in Pamplona (Spain) and was hosted by the project coordinator CENER.

Apart from in-person meetings, the project has regular meetings restricted to individual **Working Groups**, as well as **Steering Committee** meetings.

The **first General Assembly** was held at 13 & 14 November 2024 in Madrid (Spain) and kindly hosted by our partner CIEMAT.

ASTERIx-CAESar on the stage

- IGTC – International Gas Turbine Conference (10-11 October 2023, Brussels, BE) – project expo
- ETN Global AGM (19-21 March 2024, Leiden, NL) – project expo
- Transfiere 2024 (20-22 March 2024, Malaga, ES) – project expo
- Ceramitec 2024 (9-12 April 2024, Munich, DE) – project expo
- Workshop on EU High-Temperature Thermal Energy Storage Projects (29 April 2024, online) – project presentation
- XIX Congresso Ibérico e XV Congresso Iberoamericano de Energia Solar (19-21 June 2024, Evora, PT) – project presentations
- ASME Turbo Expo 2024 (24-28 June 2024, London, UK) – project expo
- Optica Sensing Congress 2024 (15-19 July 2024, Toulouse, FR) – presentation of a paper
- 2024 Thermal Mechanical Chemical Energy Storage Workshop (31 July – 1 August 2024, Charlotte, US) – project presentation
- 4th International Workshop on Carnot Batteries (23-25 September 2024, Stuttgart, DE) – EU project session participation
- ETN Global October Workshop (8-10 October 2024, Stuttgart, DE) – project expo
- 30th SolarPACES Conference (8-11 October 2024, Rome, IT) – 3 posters presentation
- all.for Power2025 conference (20-21 November 2024, Prague, CZ) – project presentation
- CellMAT 2024 (27-29 November 2024, Magdeburg, DE & online) – lecture with the project reference
- 12th Conference on EU Horizon Europe in Spain (28 November 2024, Oviedo, ES) – project expo
- Facing High-Temperature CSP for energy applications (30 January 2025, online) – webinar participation

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