Innovative Integration of Compressed Air Energy Storage (CAES) with High-Temperature Concentrated Solar Power (CSP): A Comprehensive Use-Case Study in Spain

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The innovative concept of Horizon Europe ASTERIx-CAESar project

17 Partners | **10** Countries | **4** Years (Oct 23-Sept 27) | **7.2** M€ Budget | **6-7** TRL

ASTERIx-CAESar project focuses on the development of a novel **high-efficiency solar thermal power plant** concept with an integrated electricity storage solution. The project combines **air-based central receiver Concentrated Solar Power** and **Compressed Air Energy Storage** to maximize conversion efficiency and power grid energy management, **enabling a new operation strategy and business model**.

Charging

Advanced solar Receiver

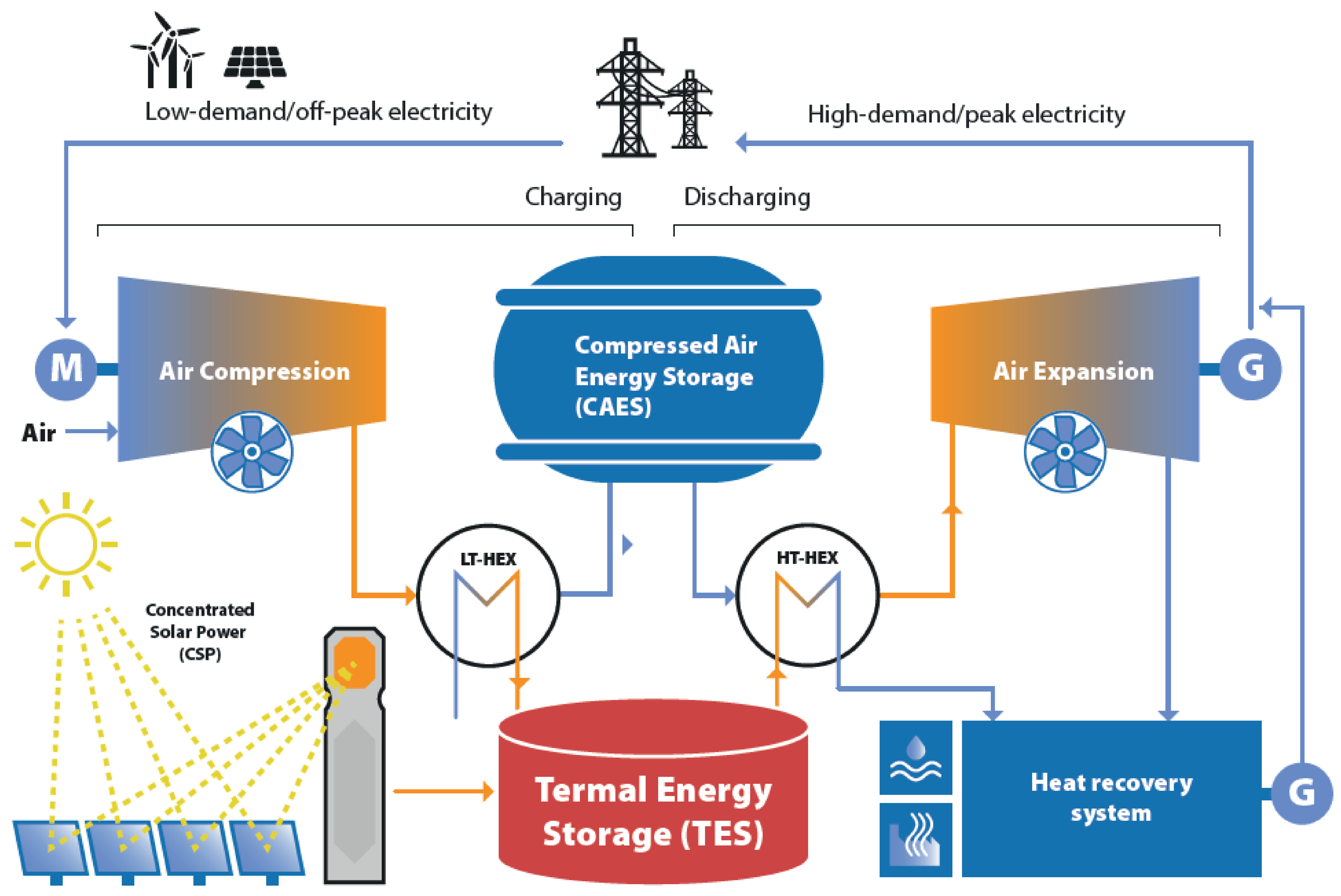
During sunny hours, a **highly efficient solar receiver** heats air to high temperature (800 °C) and is stored using **cost-effective heat storage** technology.

Advanced sensor technology and AI-based solar flux control

New **fiber-optic sensors** and **advanced AI-based heliostat field/solar flux control and monitoring system** guarantee a stable and safe solar flux distribution on the receiver and **reduce O&M effort**.

Tailored air compressor Technology

During off-peak hours, **very cheap electricity** is used to compress air to a high pressure. The air is then stored in **underground caverns or artificial pressure vessels**. The heat of compression is also stored, to be used again during discharging.



Discharging

Advanced heat exchanger Technology

During peak hours, the compressed air is heated, discharging the thermal energy storage unit. **Optimized air-to-air heat exchanger** designs guarantee **high conversion efficiency.**

Tailored air expander Technology

During peak hours, the compressed air is expanded in air turbines, generating power. **Turbomachinery architecture is optimized** for covering **a wide range of rated power outputs**, between 1 and 150 MW electric.

Effective exhaust heat recuperation & integration with desalination

Clever use of exhaust heat aims at generating **additional electricity (Rankine steam, ORC)** or **decarbonizing industry** via process heat supply. The project also analyses the **integration of desalination.**

Partners involved

CENER NATIONAL RENEWABLE ENERGY CENTRE ADItech; ESA Chemical; Universidad de Sevilla; DOOSAN Škoda Power; Roma Tre; Fraunhofer IKTS; EURIDA Research Management; AALBORG CSP; ETN Global; imdea energy; Nova Therm Tech; HEDNO; Keramikblech; engionic; apria; SoftInWay; Bluebox Energy Ltd

Main impacts

HIGHER SHARE OF VARIABLE OUTPUT RENEWABLES

ASTERIx-CAESar approach guarantees **24/7 Renewable Energy Sources** coverage by **offering storage capacity and thus provide grid stability**. Moreover, the concept **improves performance regarding start-up, shut-down and load variations.**

HIGHER EFFICIENCY OF CSP PLANTS

The **peak solar-to-electric conversion efficiency is targeted at up to 40%** (double the current state-of-the-art). This can be achieved by **novel volumetric receiver** approach as well as by using cheap off-peak electricity to boost conversion efficiency.

REDUCED OPERATION AND MAINTENANCE COSTS OF CSP PLANTS

Using air instead of molten salts or synthetic oils as heat transfer fluid **brings down significantly the maintenance costs and lowers various risks, too. Operational costs will be reduced thanks to AI-based heliostat control** requiring less personnel on site.

ACHIEVING EU TARGETS FOR GLOBAL LEADERSHIP IN CSP

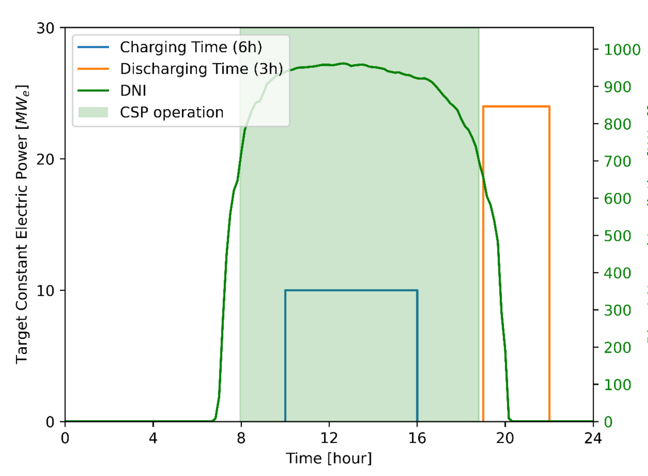
Development of the **next generation CSP/STE** (Concentrated Solar Power/Solar Thermal Electricity) technology that provides cheap energy storage (at very low LCOS of <10-15 c€/kWh) for stabilizing the power grid.

Medium-Scale Use-Case Study in Spain

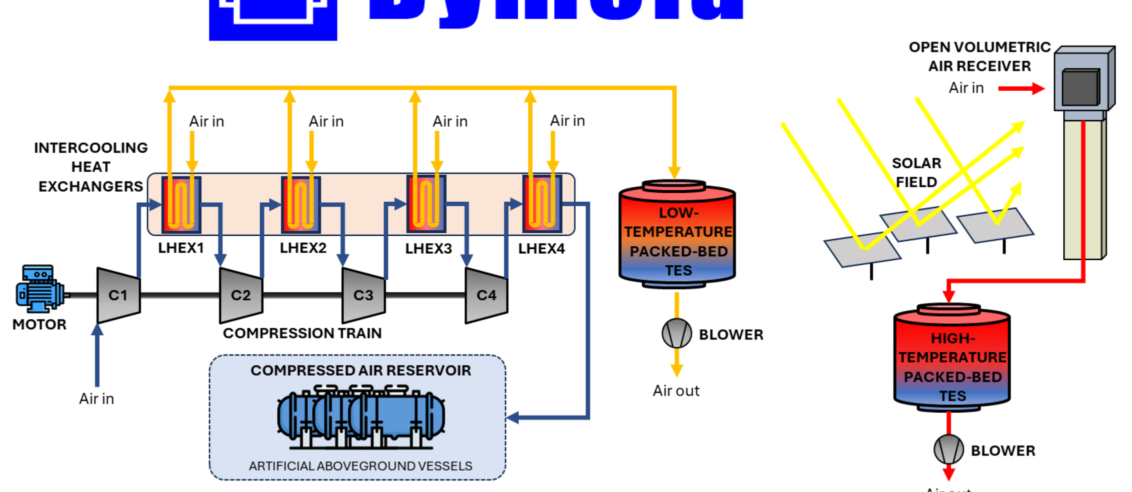
System Description

It is conducted an extensive analysis of the **thermodynamic performance** of the ASTERIXs concept, considering a **25 MWe plant** in the south of Spain with **artificial above ground vessels** and a bottoming **Rankine cycle**. The model has been implemented in **Dymola.**

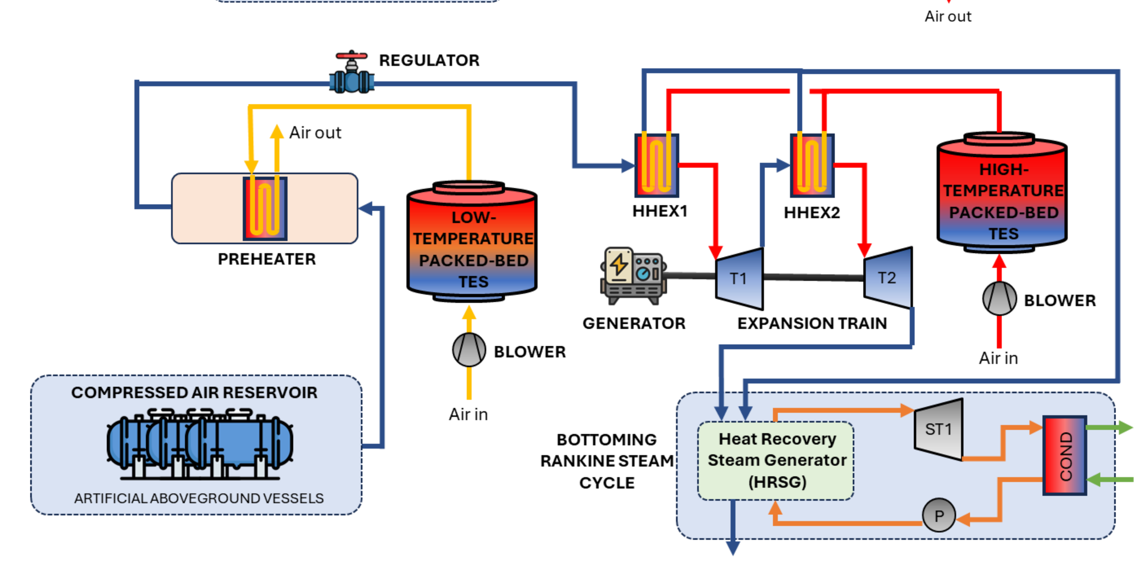
Dymola



CHARGING

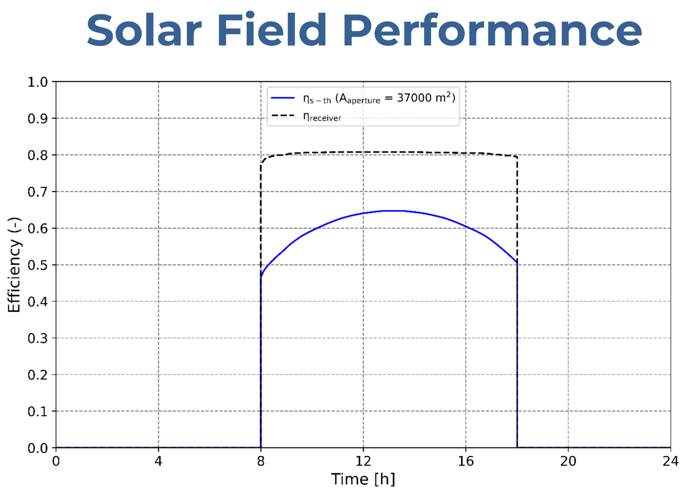


DISCHARGING



Results

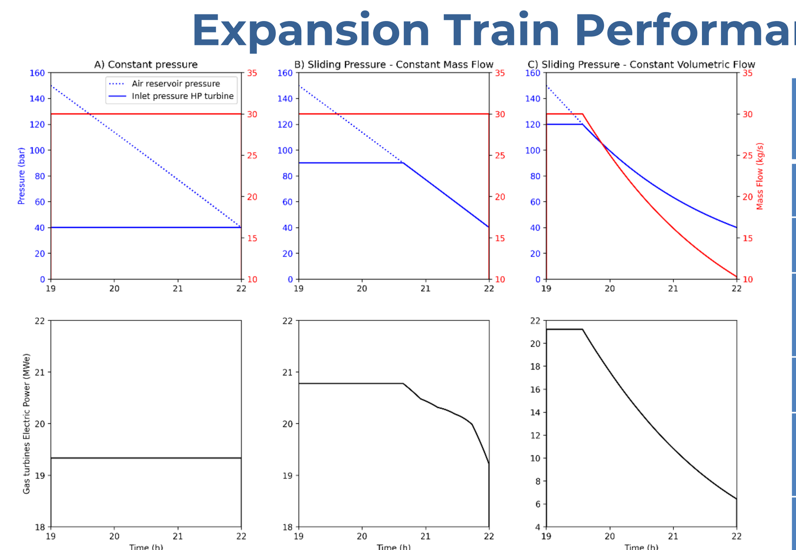
Solar Field Performance



Conclusions

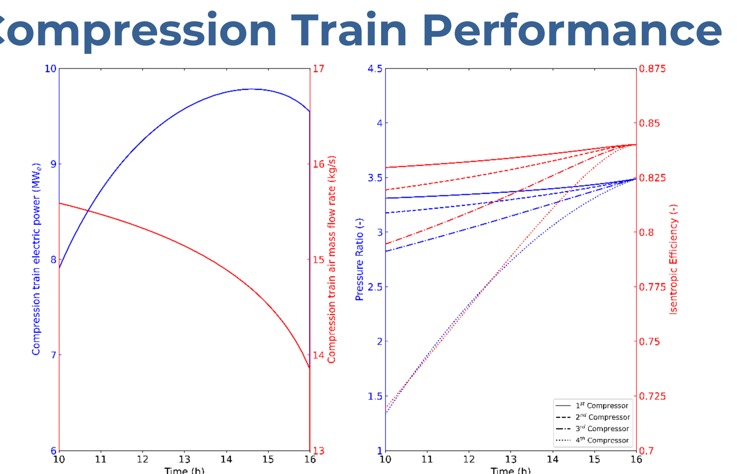
- A **detailed design of the main components** - compression train, expansion train, heat exchangers, thermal energy storage, bottoming cycle - has been carried out, and a **system-level model has been developed**.
- A **comparison between constant pressure and sliding pressure operation** modes for the expansion train revealed an efficiency improvement of **6-6.8%**. However, further research is required to assess whether this improvement justifies the higher costs and complexity associated with sliding pressure mode.
- The **optimal inlet pressure for the low-pressure turbine** was identified at **6 bar**.
- For the **future work**, an **economic evaluation and multi-objective optimization** of the concept will be conducted to further build on the previous findings.

Expansion Train Performance: Constant VS Sliding Pressure

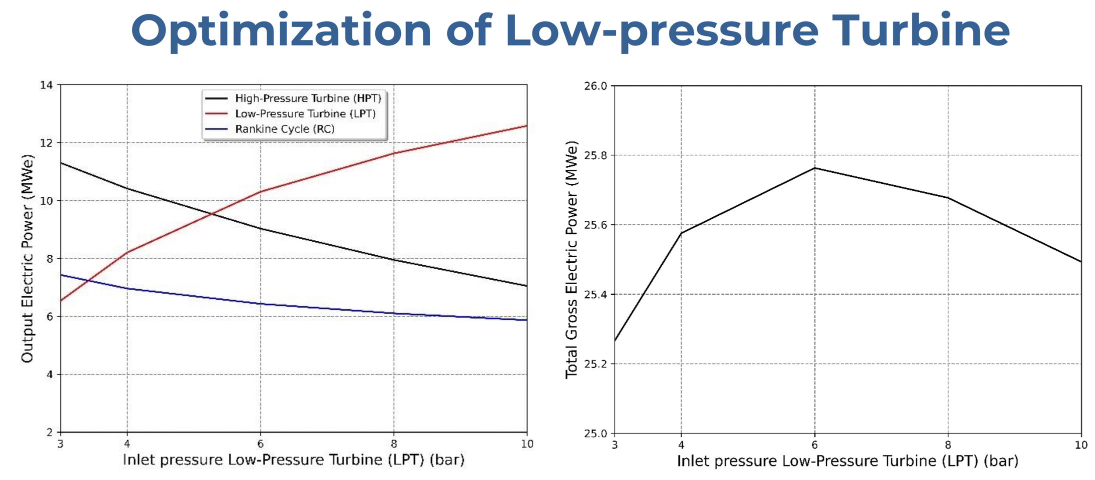


Discharging Strategy	Constant pressure (Reference case)	Sliding Pressure – Constant Mass Flow	Sliding Pressure – Constant Volumetric Flow
Required air reservoir volume (m^3)	2446		1688
Charging mass flow (kg/s)	15.6-13.9		10.8-9.6
Charged energy through compression train (MWh_e)	55.96		38.61
Discharging mass flow (kg/s)	30		30-10.3
Discharged energy through gas expansion train (MWh_e)	57.99	61.47	42.73
Ratio of discharged energy/charged energy	1.036	1.098	1.107

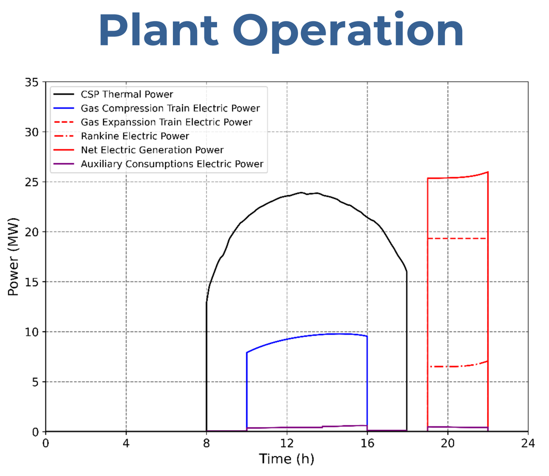
Compression Train Performance



Optimization of Low-pressure Turbine



Plant Operation



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