IN POWER

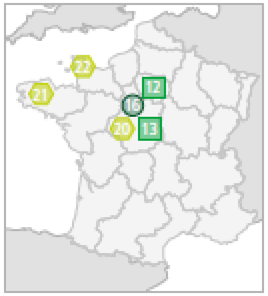
IN POWER Project: TES materials advances

RICAS2020 Symposium

9th May 2018

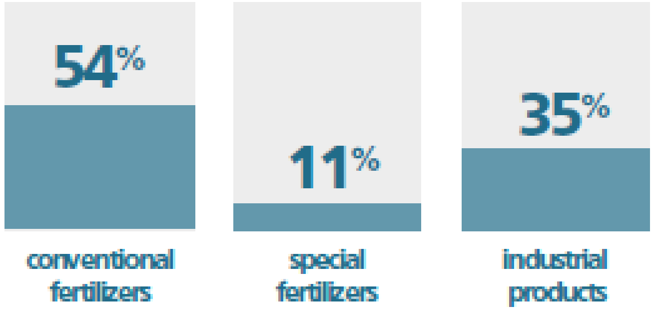
IN POWER

Fertiberia



3,300 employees

Installed capacity of 7.8 million of tons



16 Production sites

Commercial activity in 84 countries

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 720749.

IN POWER

General description: Main objective

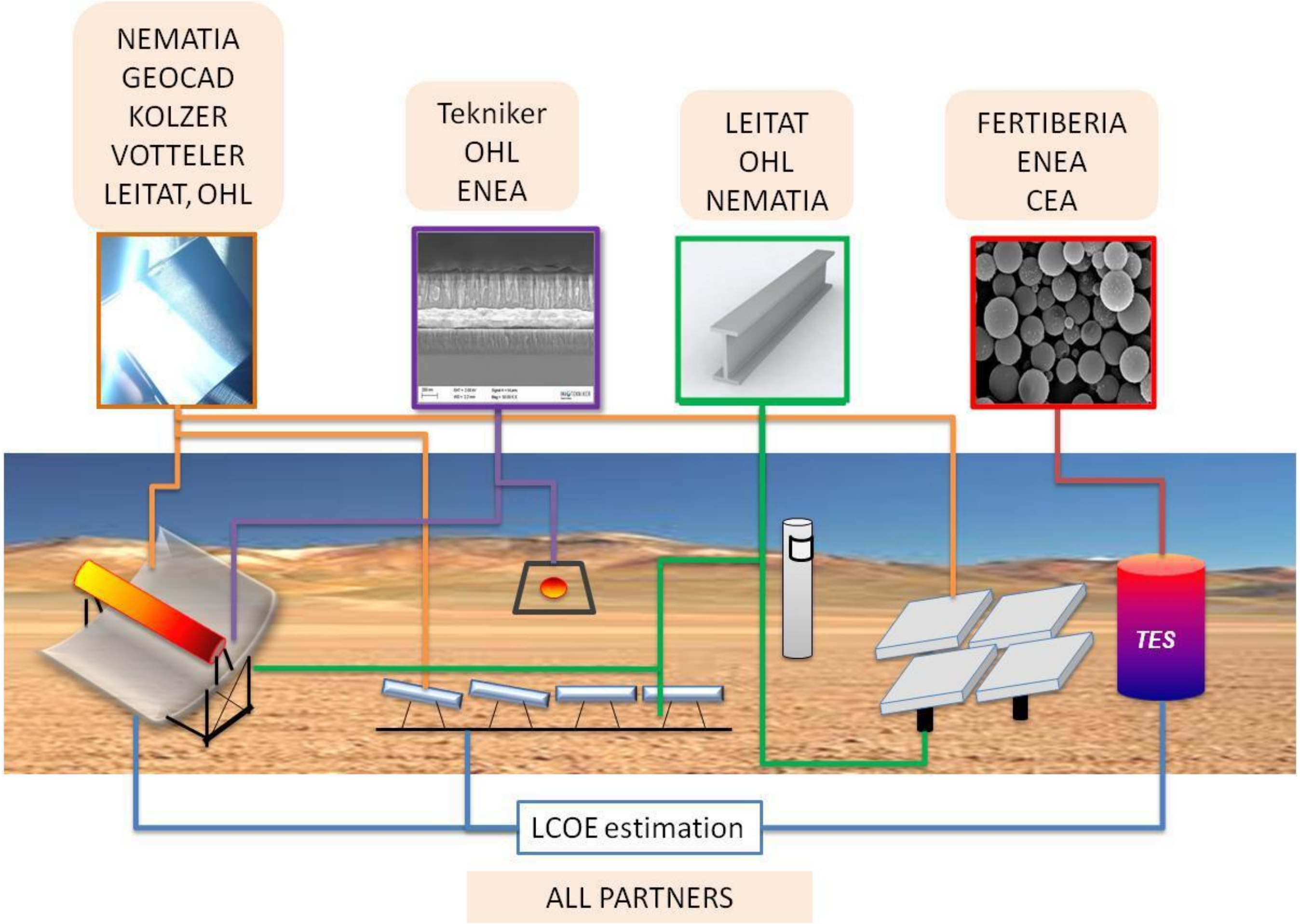
IN-POWER aims at developing and integrating new innovative material solutions into concentrated solar technology to increase the efficiency while simultaneously decreasing the energy production cost. These advanced material solutions consist of:

- (1) High reflectance, tailored shapes, self-healing and anti-soiling coated, **light glass-free smart mirrors,**
- (2) Optimized and lighter **mirror support** structure
- (3) **High-operational-temperature absorber coating** in new **vacuum-free-designed receiver**
- (4) **Novel modular solar field architecture and design** achievable by these new components. Having the identical **low associated environmental impact**, this promising technology is expected to decrease **the land use by four-time**
- (5) high-operating-temperature thermal storage materials (TES) that will guarantee up to **three-time increase in thermal capacity** respect to standard TES, depending on Heat Transfer Fluid (HTF), also leading to the reduction of thermal storage system size.

IN-POWER will validate these novel functional materials and new manufacturing processes will guarantee decrease in **Levelised Cost of Electricity below 0.10 €/KWh** beyond 2020 by validating these technologies in Lineal Fresnel Collector and Parabolic through Collector pilot plants under 2100-2700 kWh/(m^2a)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 720749.

Partners



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 720749.

IN POWER

TES Specific objectives

<u>Innovative thermal storage materials for medium and high temperature thermal storage systems</u>: Support by TES systems, thermocline and multitank modelling and material compatibility behaviour simulation, Thermal Energy Storage (TES) material capabilities will be increased **up to three times.** Two high-temperature TES developments will be done: (1) for CSP plants with oil or molten salts as HTF, **high temperature molten salts and encapsulated phase change material** will be used in a thermocline tank to maintain a constant temperature during discharge; (2) for CSP plants with direct steam generation (DSG), a combination of latent heat storage tank and **high temperature molten salts** sensible heat storage tanks will be developed.

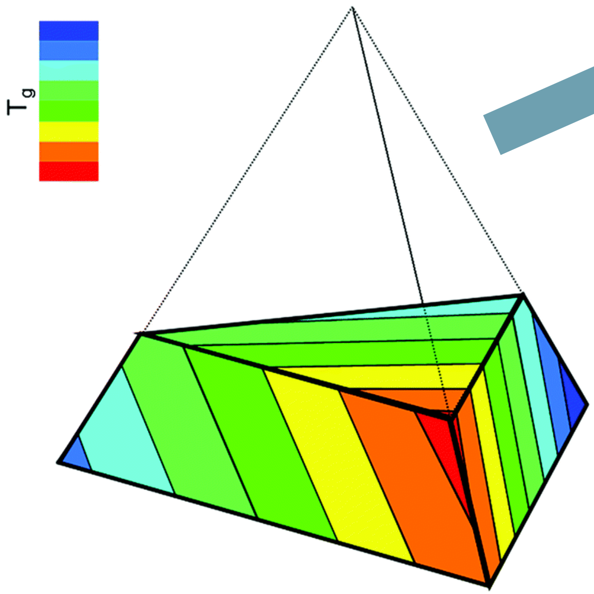
IN-POWER eutectic mixture will allow:

- Thermal storage capacity increase from $\Delta T<100°C$ to $\Delta T>300°C$ with optimised low melting point, stable, affordable and non toxic salt formulation.
- Manufacturing cost reduction up to 20%
- High conductivity PCM suitable to store heat from high temperature HTF above 500°C
- Size reduction of TES system, with CAPEX reduction by 20% and AEP improvement by 15% at 500°C cycle working (actual cycle is working at 400°C).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 720749.

TES Eutectic Mixture Research

Quaternary component salt system (alkaline & alkaline-earth nitrates)



Requires deep comprehension of basic subsystems (6 binary + 4 ternary phase diagrams)

Huge amount of experimental results are needed (+10000)

Phase diagram modellization is mandatory

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 720749.

TES Eutectic Mixture Research

Phase diagram determination via total Gibbs energy minimization: ThermoCalc Software

$$G_{\mathrm{m}}^{\theta} = {}^{\mathrm{srf}}G_{\mathrm{m}}^{\theta} + {}^{\mathrm{phys}}G_{\mathrm{m}}^{\theta} - T \cdot {}^{\mathrm{cnf}}S_{\mathrm{m}}^{\theta} + {}^{\mathrm{E}}G_{\mathrm{m}}^{\theta}$$

$$G_{\mathrm{m}}^{\theta} - \sum_i b_i H_i^{\mathrm{SER}} = a_0 + a_1 T + a_2 T \ln(T) + a_3 T^2 + a_4 T^{-1} + a_5 T^3 + \cdots, \quad T_1 < T < T_2$$

$$H_{\mathrm{m}}^{\theta} - \sum_i b_i H_i^{\mathrm{SER}} = a_0 - a_2 T - a_3 T^2 + 2a_4 T^{-1} - 2a_5 T^3 \cdots$$

$$S_{\mathrm{m}}^{\theta} = -a_1 - a_2(1 + \ln(T)) - 2a_3 T + a_4 T^{-2} - 3a_5 T^2 \cdots$$

$$C_p^{\theta} = -a_2 - 2a_3 T - 2a_4 T^{-2} - 6a_5 T^2 \cdots$$

Model each phase diagram by adjustment of parameters, based on experimental results i.e. DTA, TGA, DSC

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 720749.

TES Eutectic Mixture Research

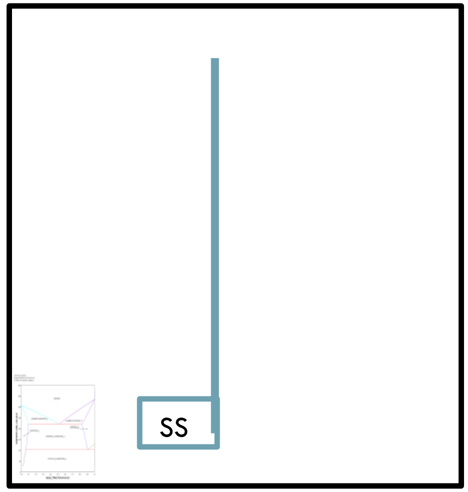
1. First experimental + bibliographic results for coarse adjustment

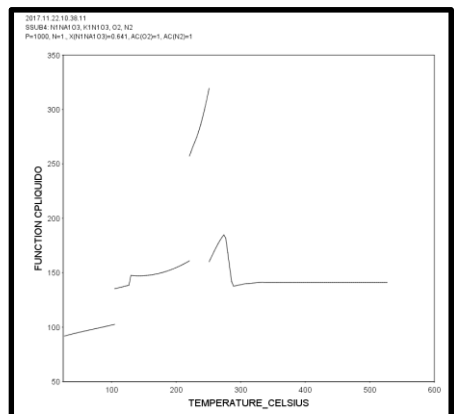
2. Re-tuned model again validated via fine experimental results

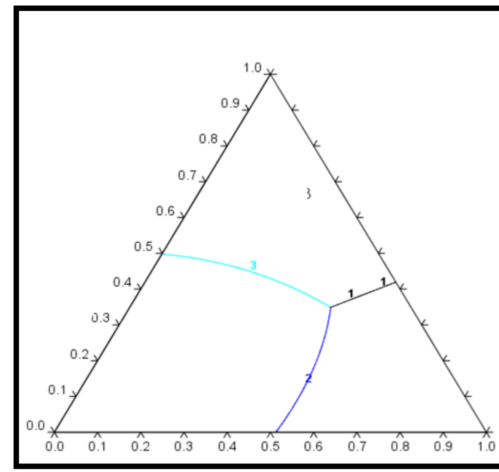
3. Additional experimental results for singular compositions (i.e. eutectics)

Process repeated for each subsystem

Each time the subsystem complexes, make It more challenging!



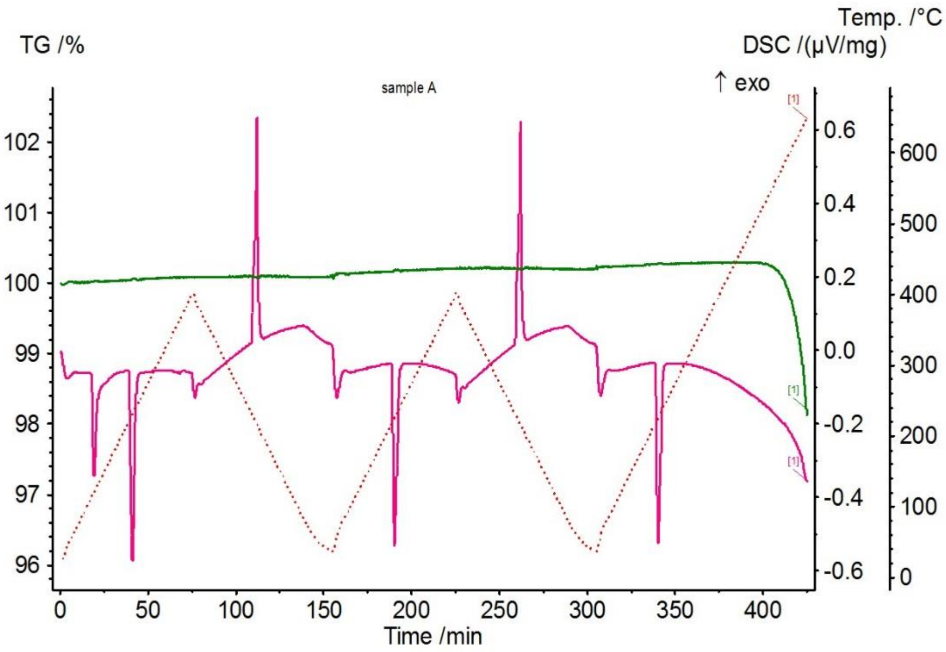




This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 720749.

TES Eutectic Mixture Research

- DSC analysis (melting point, peak of fusion, enthalpy in J/g, beginning and end of fusion and crystallisation)
- TGA : loss mass between 500°C to 600°C – Temperature when loss mass > 0,1% (beginning of the degradation)



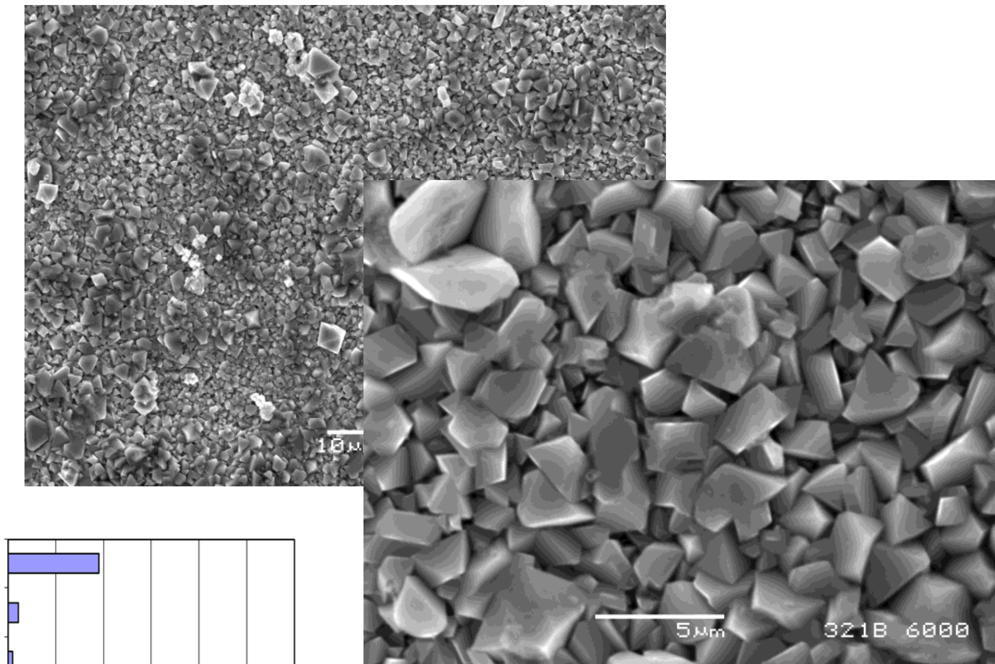
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 720749.

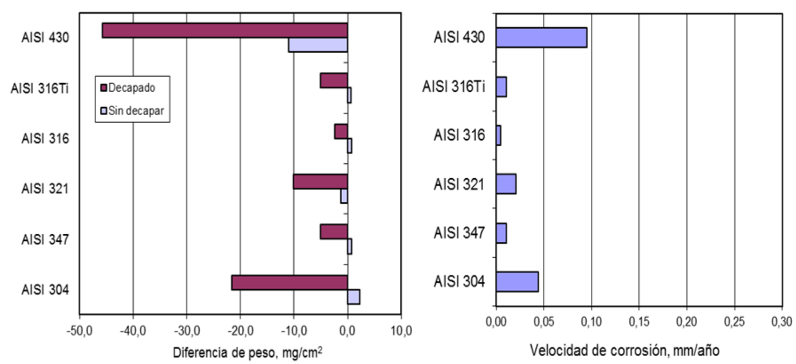
IN POWER

TES Eutectic Mixture Research

Fertiberia

- Corrosion studies for +5400h @ degradation temperatures (SEM, EDX, Raman)
- Corrosion mechanism equal to Solar Salt (Intergranular & Crystal twinning corrosion)
- Austenitic stainless steels best option!





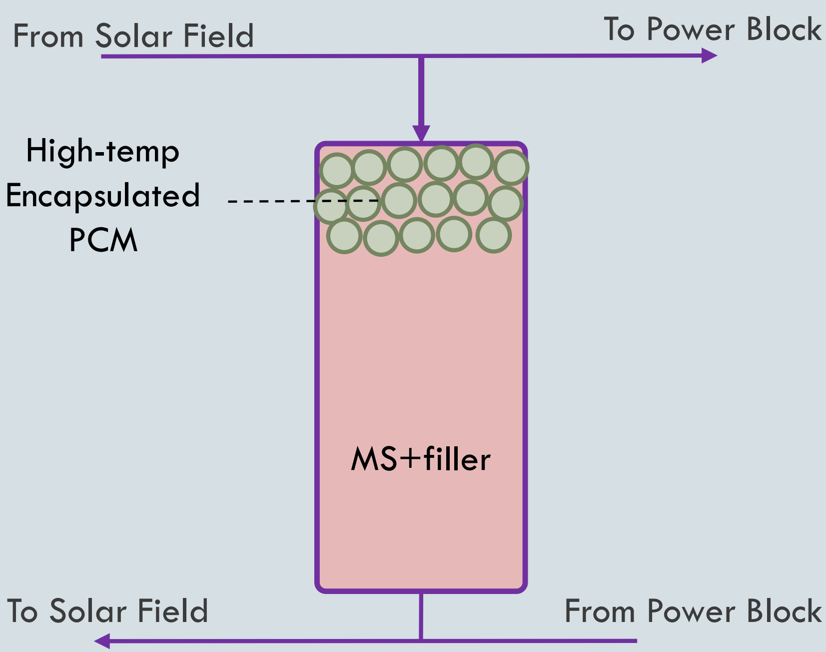
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 720749.

TES SYSTEM SELECTION

Definition of two TES systems able to achieve

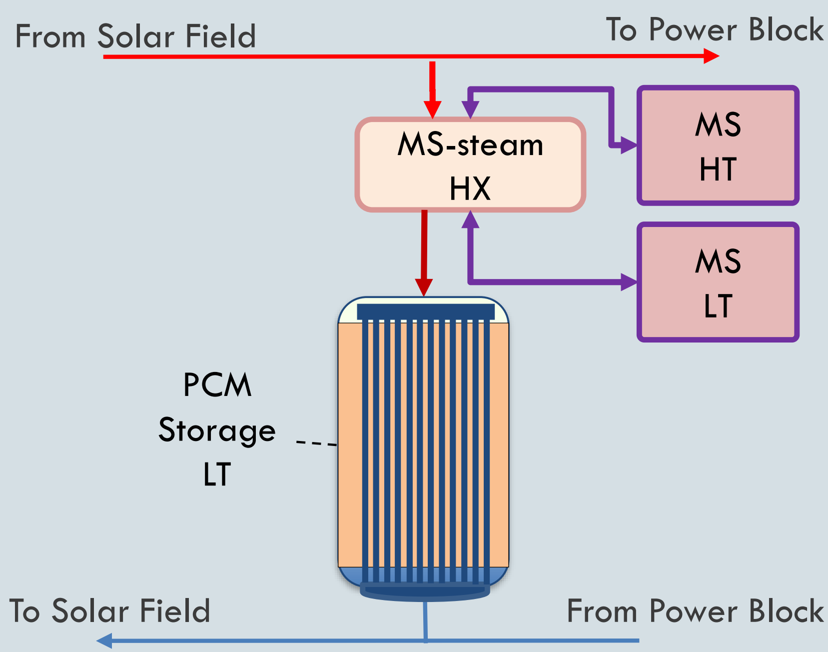
PCM used as a top layer in a thermocline tank to maintain a constant temperature during discharge

High temperature thermocline TES system



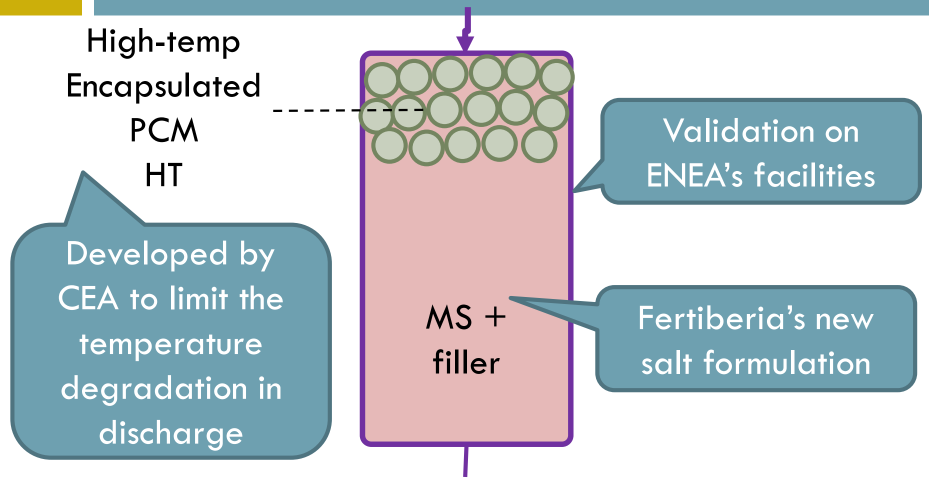
Latent heat storage tank with PCM + high temperature molten salts sensible heat storage tanks

Multitank TES system for DSG



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 720749.

HIGH TEMPERATURE THERMOCLINE TES SYSTEM



Modelling

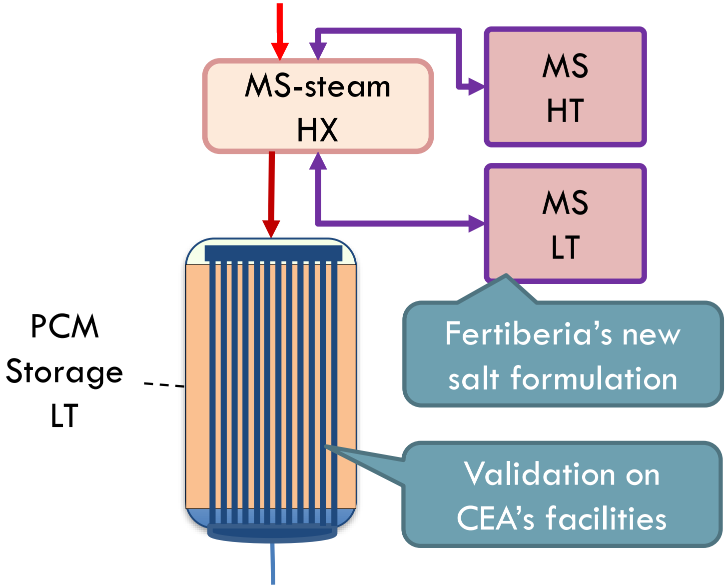
Development and validation of a cost-performance model to determine the unit cost of storage capacity (€/KWh) for a given operating temperature range and storage materials combination

Encapsulated PCM design and testing – *Selection : PCM, anticorrosive layer and container*

- *High specific energy density and volumetric heat of fusion, good thermal conductivity and low cost per unit of energy stored.*
- *Anti-corrosive layer*
- *Choice of the container material*

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 720749.

MULTITANK TES SYSTEM FOR DSG



Modelling

Development and validation of a cost-performance model to determine the unit cost of storage capacity (€/KWh) for a given operating temperature range and storage materials combination

PCM storage extensive testing

Durability and tests will be performed at pilot scale on the CEA's facility to demonstrate that the lifetime of such storage systems can be 25 years

Corrosion of tubes and shell, PCM degradation, and thermal performances will be monitored

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 720749.

THANK YOU FOR THE ATTENTION

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 720749.