Fluidized bed-in-tube solar receiver and the « Next-CSP » solar loop.

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Content

- Concept
- Main objectives and challenges addressed by the Next-CSP EU project
- Critical components
- Prototype development and implementation
- Results of the first test campaign
- Lessons learned

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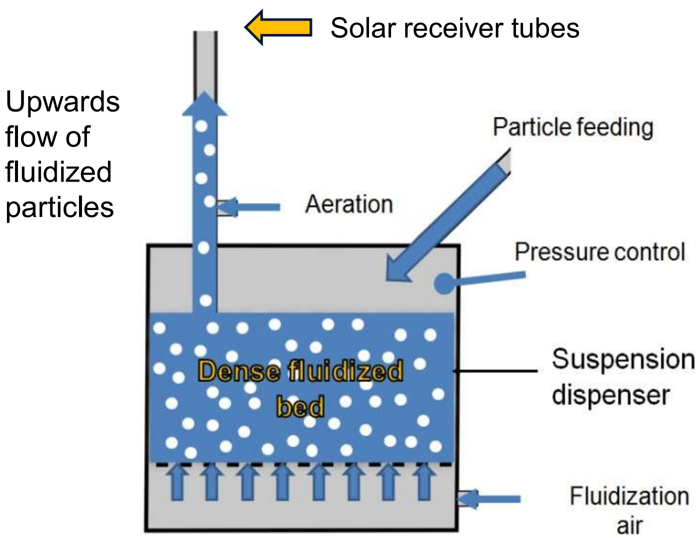
Concept

An upwards flow of fluidized particles is created inside the solar receiver tubes by increasing the pressure in the dispenser. A secondary aeration stabilizes the particle flow

Small size particles (<100 µm) are used.

The tubes are made of refractory alloy.

Only 1 m-long (irradiated part) tubes have been tested before the Next-CSP EU project



Positioning of the fluidized bed technology

- Particles are well mixed in fluidized beds (small thermal gradient)
- Wall-to-bed heat transfer is efficient. FB heat exchanger can be applied
- Dust emission can be controlled because the particle loop is closed
- The concept is scalable

- The maximum solar flux on the tube walls is limited to ~500 kW/m^2 due to wall material issue

Main objectives and challenges of the Next-CSP EU project

Main objectives

To design, construct, implement and test a complete prototype-scale (>1 MW_{th}) particle CSP loop including a solar receiver, a storage, a heat exchanger and a hybrid gas turbine.

To identify the barriers to large scale development.

Main Challenges

- ✓ Particle flow regimes in dense phase inside the solar receiver tubes and associated heat transfer
- ✓ Manufacturing of the compartmented fluidized particle heat exchanger
- ✓ Integration of the components at the Themis solar tower focal area
- ✓ Control of the particle circulation in closed loop and particle conveying
- ✓ Choice of the most promising conversion cycle accounting for the technology particularities
- ✓ Solar receiver and system upscaling

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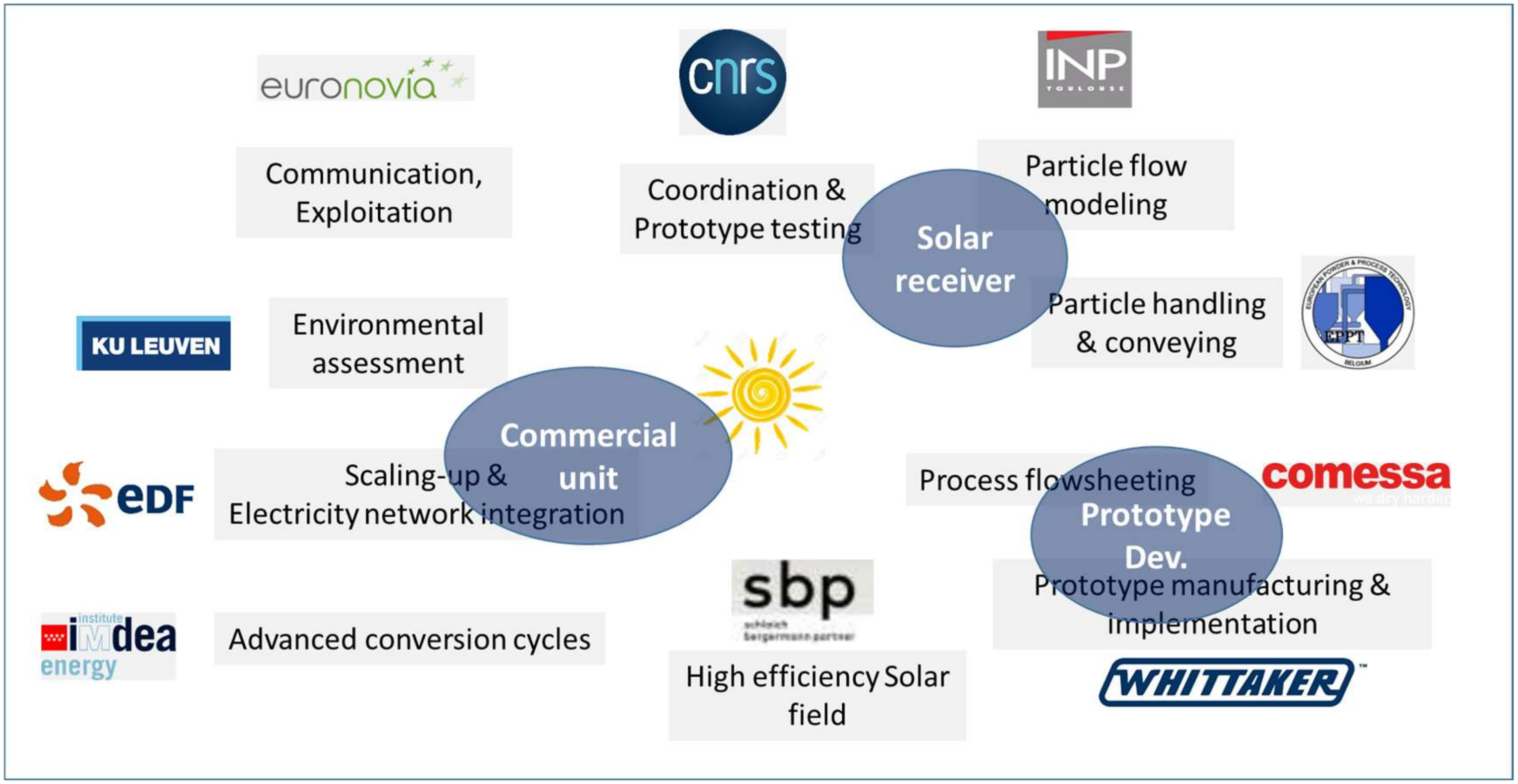
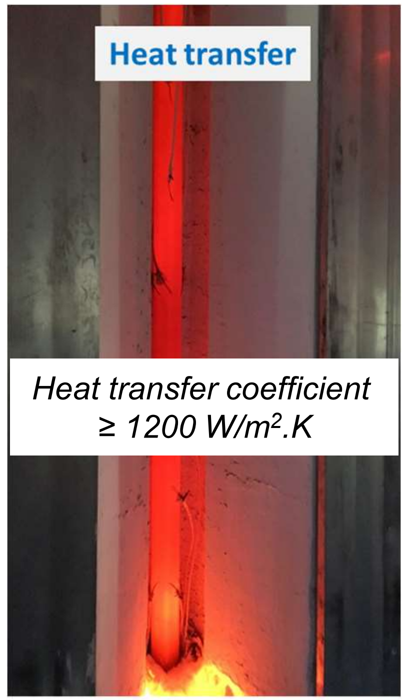
Contribution of the Next-CSP Consortium members

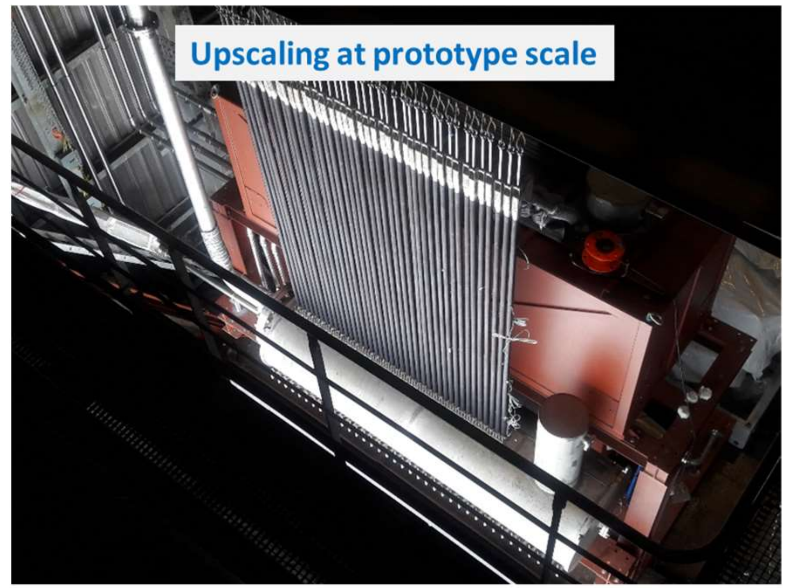


Critical components Solar receiver

Cold mockup
3-8m-long tubes

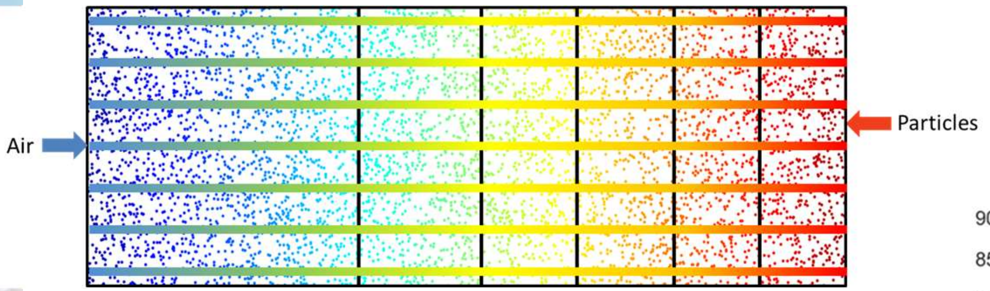


Hot mockup
1m-long tubes



2.5 MW_{th} 3m-long solar receiver (40 tubes)

Critical components Heat exchanger

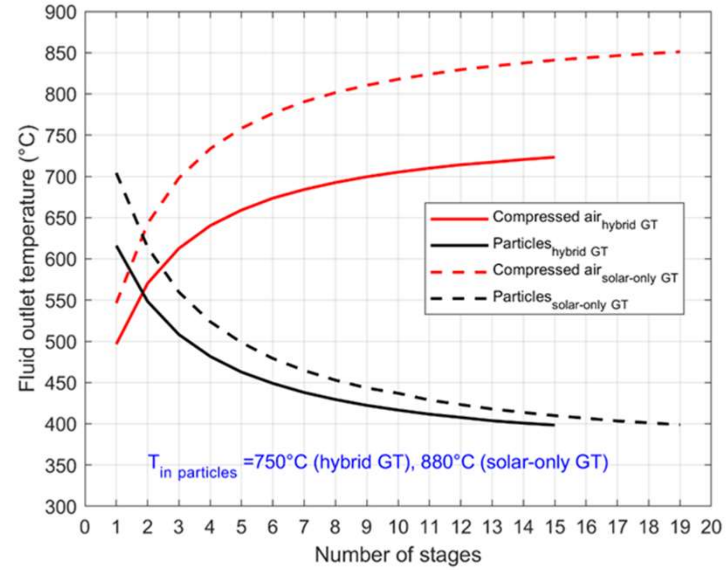


Multi-stage compartmented fluidized bed concept with compressed air in tubes

Approximately 15 stages for 30°C ΔT

ΔT = temperature difference between inlet particle and outlet air

Variation of air and particle temperature with the number of stages



Critical components   Particle conveying

Issue:

- The size of a single solar receiver is limited to approximately 50 MW_{th} due to the limitation of the tube length (8 m).
- Cavity type is needed for thermal efficiency ≥ 80%

➢ **For a single tower**, only vertival elevation of the particles must be considered

➢ **For a multi-tower concept**, horizontal and vertical conveying are necessary

Critical components

Conversion cycle

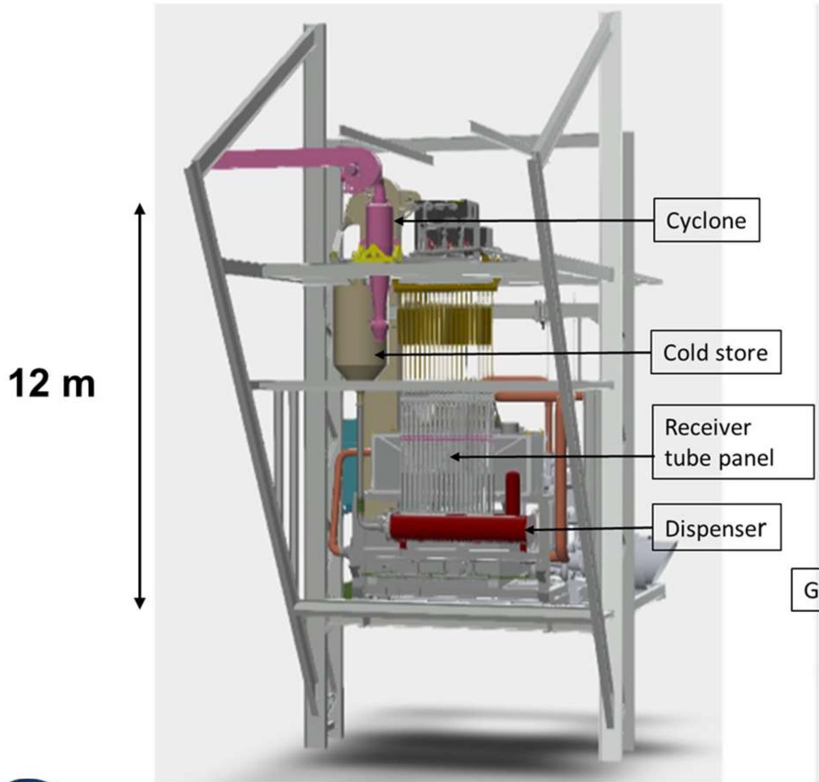
Three options studied:

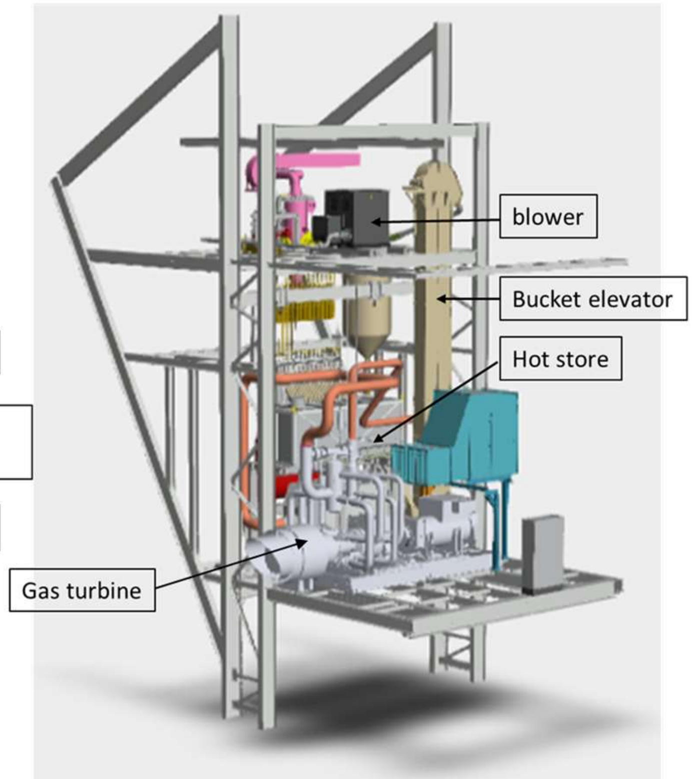
- Combined cycle
- Supercritical steam
- Supercritical CO_2

With cycle efficiency ~50%

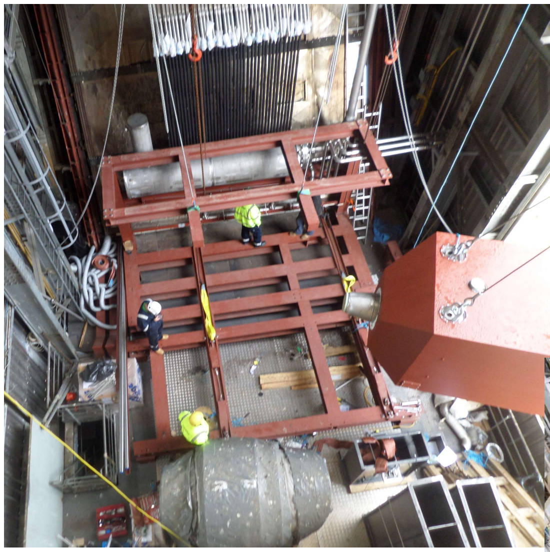
Prototype development

All the components are integrated atop the tower



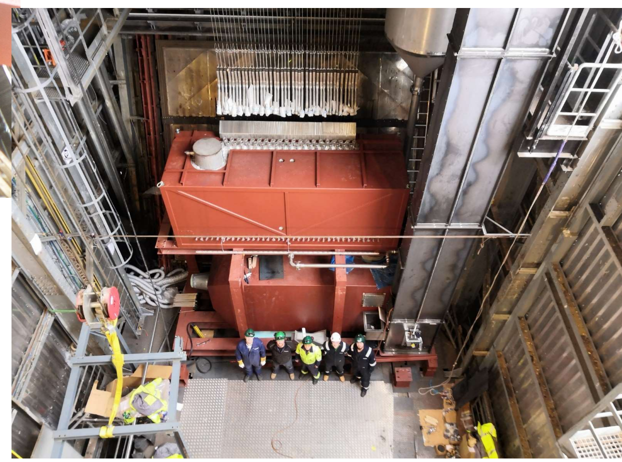


Prototype implementation



Heat exchanger lifted at the tower top

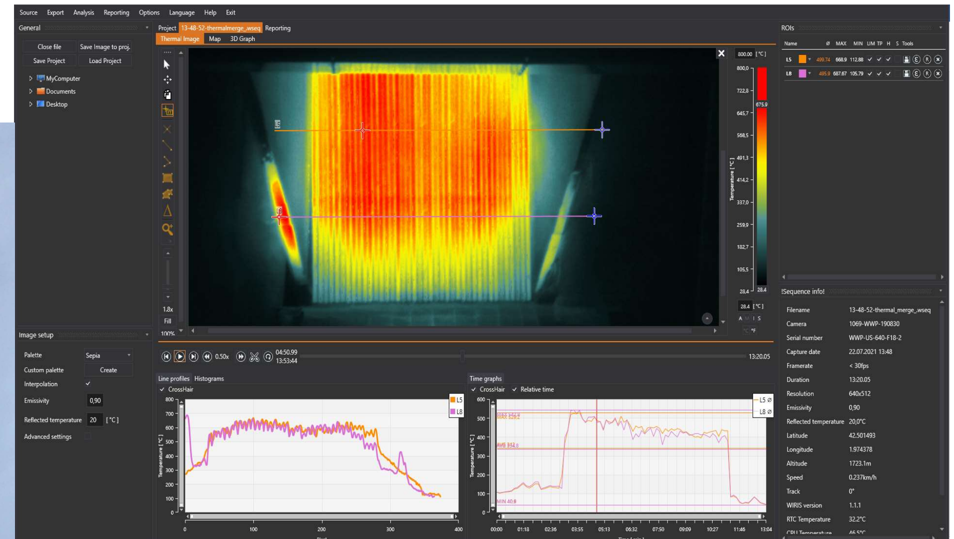
The complete particle loop



Pressurized air connexion between the heat exchanger and the gas turbine

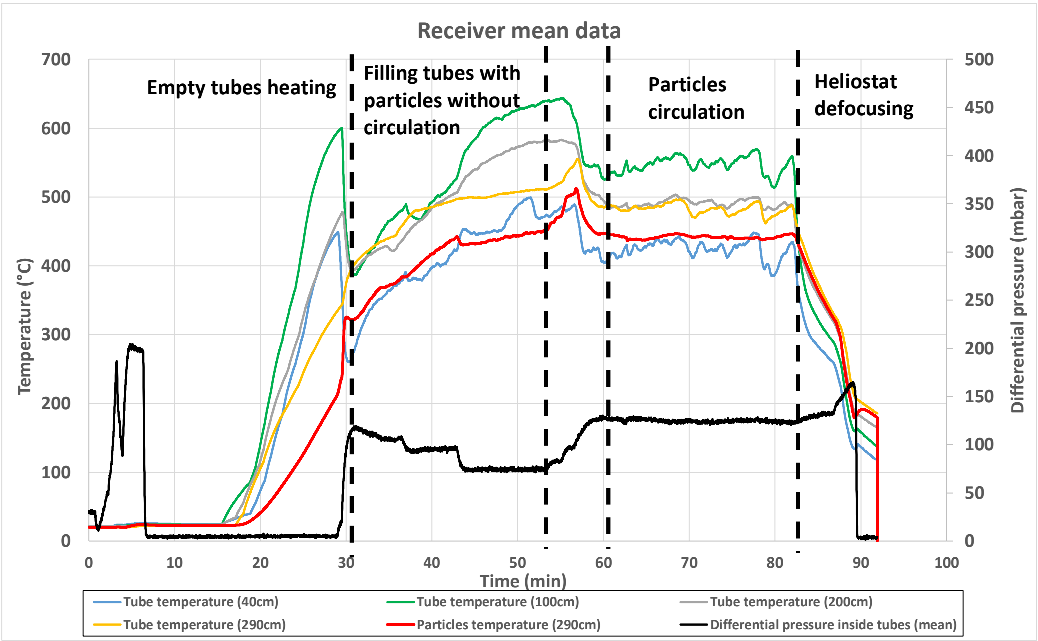
Results of the first solar receiver test campaign

The solar receiver



IR image of the tube temperature (measured by a drone)

Results of the first solar receiver test campaign



Particle mass flow rate: 0,6-3,5 kg/s

P_{solar} : 550-850 kW

ΔT particle : 100-400°C

Efficiency: 40-75%

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Lessons learned

- The instrumentation developed proved to be accurate and reliable
- Tuning aeration mass flow rate resulted in a precise control of particle mass flow rate
- Particle temperature increase as large as 400°C have been measured
- Solar receiver starting and shut down are very fast (10-15 minutes)

- Unexpected issue: large difference of solar flux distribution on tubes can result in particle circulation stop due to air velocity difference

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