NEXT-CSP
A NOVEL CONCEPT

HIGH TEMPERATURE CONCENTRATED SOLAR THERMAL POWER PLANT WITH PARTICLE RECEIVER AND DIRECT THERMAL STORAGE

EU RESEARCH FOR RENEWABLE ENERGIES

THIS PROJECT HAS RECEIVED FUNDING FROM THE EUROPEAN UNION'S HORIZON 2020 RESEARCH AND INNOVATION PROGRAMME UNDER GRANT AGREEMENT NO 727762

Foreword by Gilles Flamant
(CNRS-PROMES),
Coordinator of the project

"The Next-CSP project is the result of more than 40 years of research on the use of particles in concentrated solar energy conversion. I published (in French) the concept of Next-CSP in 1980. Then came the original idea of the fluidized particles-in-tube solar receiver patented in 2010. The CNRS and then the European Union funded the research rapidly in 2011. The CSP2 (Concentrated Solar Power in Particles) European project, funded under FP7, resulted in the successful operation of a 150 kW solar receiver with fluidized particle recirculation.
The Next-CSP project ambition is to demonstrate the project at industrial pilot scale with the testing of a 3-MW solar receiver and the complete solid and conversion loops including a gas turbine. A great challenge that strengthens the leadership position of Europe in the domain of CSP technology innovation."

Concentrated Solar Power to tackle climate change

27%
of renewable energies

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.

The Next-CSP project responds to this need and addresses **significant improvements** related to concentrated solar power (CSP):

- heat transfer fluids, which can be used for direct thermal energy storage;
- solar field;
- high temperature receivers allowing new high efficiency thermodynamic cycles.

WHAT IS CONCENTRATED SOLAR POWER?

Concentrated Solar Power (CSP) plants use **mirrors** to concentrate **sunlight** onto **receivers** where it is converted into **heat**. 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**.

The four main CSP technologies

Parabolic Dish

Parabolic Trough

Linear Fresnel

Solar Tower

Next-CSP: Innovative components for Concentrated Solar Power plants

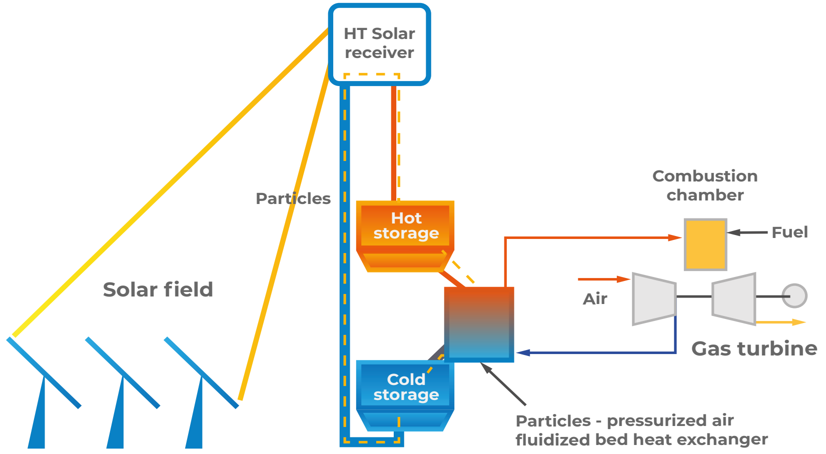
Launched in 2016, the **Next-CSP** project stands for “High Temperature concentrated solar thermal power plan with particle receiver and direct thermal storage”. It responds to **4 main objectives**:

- To improve the reliability and performance of Concentrated Solar Power (CSP) plants
- To develop and integrate a new technology into CSP plants
- To use high temperature particles as heat transfer fluid and storage medium
- To demonstrate the technology in a relevant environment and at the MW size.

The project proposes a **breakthrough innovation**: a **fluidised particle-in-tube concept**, which opens the route to the development of a new generation of CSP plants. It would allow:

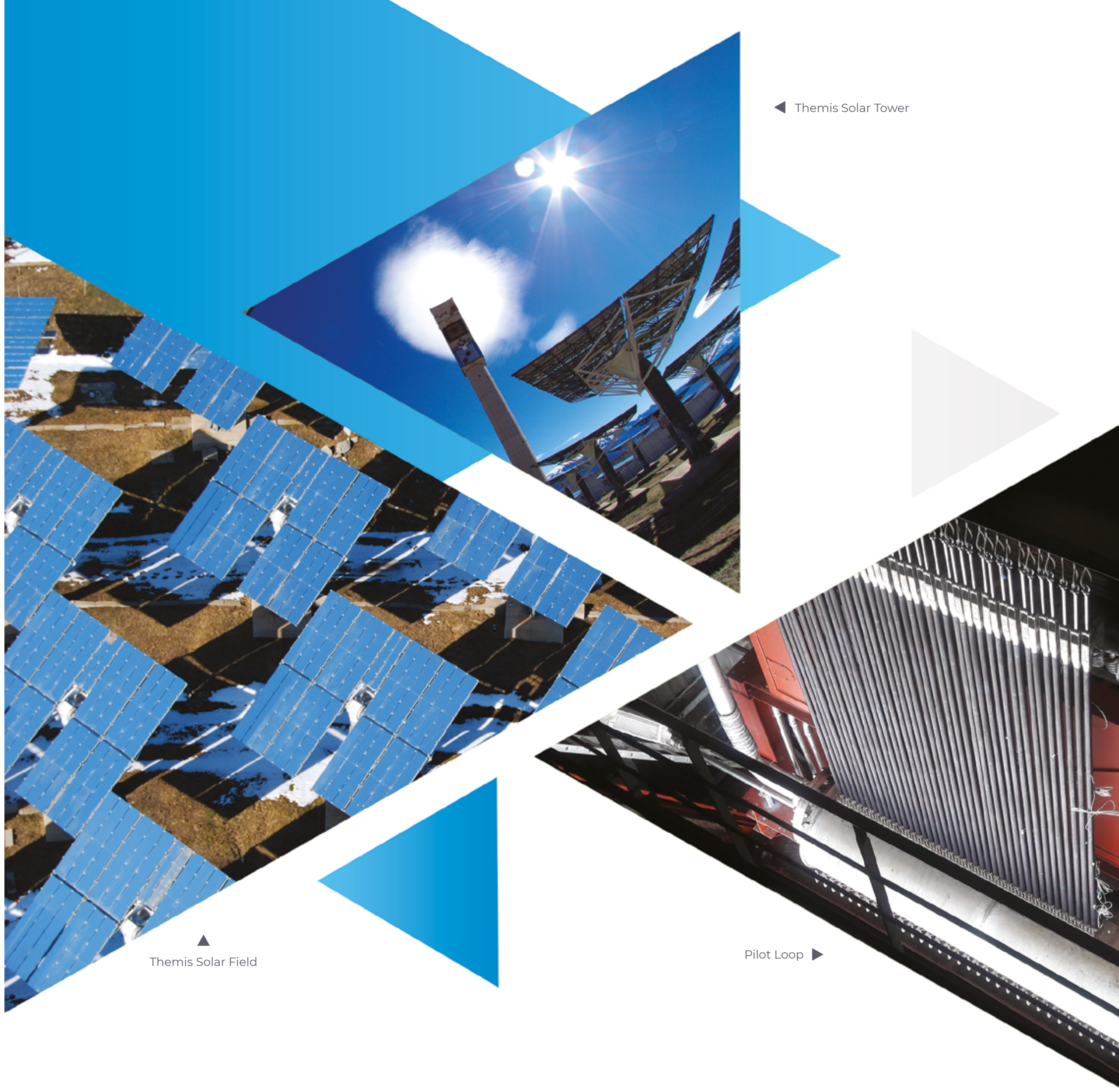
- **high efficiency new cycles** (50% and more),
- a 20% improvement of **CSP plant efficiency**,
- a modular concept
- and an **electricity cost reduction by about 38%**.

Next-CSP will demonstrate the validity of the fluidized particle-in-tube (PIT-CSP) concept atop the **THEMIS solar power tower** in France, at **large prototype scale** (TRL5 [1]). A **3-MWth tubular solar receiver** able to heat particles up to **650-750°C** will be tested, as well as the rest of the **conversion loop** (a two-tank particle heat storage and a particle-to-pressurized air heat exchanger coupled to a 1.2 MWel gas turbine). The **full system** will be tested and evaluated in 2020 and will pave the way for future prototype **demonstration and commercial development**.



NEXT-CSP project

[1] Technology readiness level 5 : technology validated in relevant environment



Themis Solar Tower

Themis Solar Field

Pilot Loop

A collaborative project funded by the European Union

The Next-CSP project has been supported by **Horizon 2020**, the European Union's Framework Programme for Research and Innovation. It 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).

TOTAL BUDGET
€ 4,947,420

EU CONTRIBUTION
€ 4,947,420

CONSORTIUM
10 PARTNERS - 5 COUNTRIES

COORDINATOR
CNRS-PROMES FRANCE

DURATION
58 MONTHS
FROM OCT. 2016 TO JULY 2021

Main innovations and results of the project

SOLAR RECEIVER

- Develop an innovative solar receiver using fluidized particles that circulate in 40 solar irradiated tubes at pilot scale,
- Manufacture a 3 MWth solar receiver and test it in a wide range of operation parameters,

HEAT TRANSFER FLUID

- Use particle as heat transfer fluid (HTF) instead of molten salt in solar power tower and develop the adapted solar receiver (new product),
- Increase the HTF temperature by about 200°C,
- Identify the main limitations of the fluidized particle-in-tube technology (PIT-CSP techno-logy) with respect to the scaling-up issues and propose solutions to overcome them.

STORAGE

- Use the same solid particles used as HTF to store thermal energy in a close loop without dust emission,
- Increase the storage capacity of the two-tank thermal energy storage (TES) by increasing the temperature difference between the hot and cold tanks: about 400°C instead of 270°C for molten salt,
- Prove and identify the issues related to the storage technology principle, in particular the hot particles handling and conveying.

POWER BLOCK

- Design and test a multistage fluidized bed heat exchanger that transfers the energy from the particles to the working fluid,
- Construct a 2.5 MWth particle-to-pressurized air fluidized bed heat exchanger and assess its performance,
- Operate a solarized 1.2 MWel gas turbine in hybrid mode

INTEGRATION

- Integrate the particle loop (solar receiver + TES) with the energy conversion loop (particle heat exchanger + hybrid gas turbine) in a single industrial pilot,
- Measure the performance of the complete system at Themis solar tower,
- Design a commercial scale (150 MWel) power plant on the basis of the technology and estimate the cost,
- Identify the main bottlenecks for large-scale development of the particle-in-tube technology (PIT) technology,
- Analyse the environmental impact of the technology and compare it to the state-of-the-art.

Impacts of the project

CSP TECHNOLOGY PERFORMANCE	→	The project prepares the next generation of CSP plants with high performance thermodynamic cycles at temperature higher than 650°C. 50% efficiency is targeted by comparison with 42% for state-of-the-art CSP technology.
REDUCTION OF CO2 EMISSION	→	While operating, CSP is a CO2 free technology that can produce dispatchable electricity. The project features a 40% emissions reduction target.
COMPETITIVENESS AND INCREASE OF SOLAR ENERGY USE	→	The Next-CSP technology will provide optimised dispatchability thanks to thermal storage at reasonable cost. The cost target is about 80 €/MWhel (LCOE) in 2030. This cost depends of the operation mode of the plant, higher costs are acceptable for a plant operating as a peaker.
REDUCTION OF OPERATIONAL COSTS	→	The heliostat field accounts for about 40% of the CAPEX (Capital expenditure) and OPEX (Operating expense) of a solar tower power plant. This field be downsized by 20% thanks to the increased conversion efficiency thus reducing considerably the CAPEX.
INCREASING THE RELIABILITY AND LIFETIME OF CSP PLANTS	→	Replacing molten salt with particles as storage medium and heat transfer fluid eliminates the risk of freezing that can cause severe damage to the receiver tubes.

Timeline of the project: Next-CSP key achievements

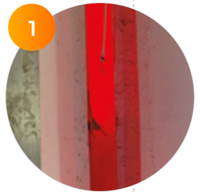
HIGH TEMPERATURE CONCENTRATED SOLAR THERMAL POWER PLANT WITH PARTICLE RECEIVER AND DIRECT THERMAL STORAGE

PROJECT START OCTOBER 2016

2017 – 2018 – 2019 – 2020 – 2021

PROJECT ENDING JULY 2021

1



Heat transfer in solar-heated 1m-long receiver tube

Bare tube and fine tube testing. Temperature ditribution and heat transfer coefficient.

June 2017 - January 2019

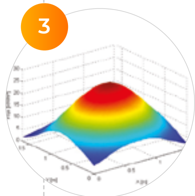
2

High efficiency thermodynamic cycles

Selection of various cycles that can reach 50% efficiency.

November 2017

3

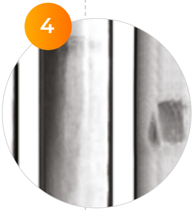


Solid flow regime in long tubes

Measurement of the transition between bubbling and slugging regimes.

December 2017

4

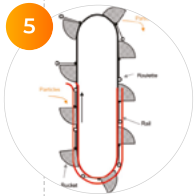


Design of the pilot loop to be tested

Design of all the components of the loop to be tested atop the Themis solar tower and integration in the focal zone.

March 2018

5

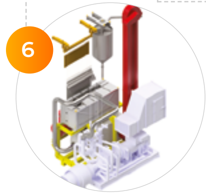


Concept for a 150MW solar power plant based on the particle technology

Conceptual design of a multi-tower 150 MW solar power plant with particle circulation.

November 2018

6



Themis solar field performance assessment

Design, construction and implementation of a moving bar for measuring the solar flux distribution at the solar receiver aperture.

December 2018

7

Construction of the solar loop components

Manufacturing of the solar receiver, the heat exchanger and the storage bins.

January 2019

8

Delivery of the solar loop components at Themis site

Delivery and lifting of the main solar loop components.

May 2019 - September 2020

9

Starting the pilot loop testing

Definition of the parameters for circulating the particles in close loop.

October 2020

10

Testing of the solar receiver

Measurement of the solar receiver efficiency.

January 2021

11

Complete the solar loop testing

Testing and perfomance evaluation of the particle solar loop.

March 2021

12

Full system testing

Testing and performance evaluation of the complete loop including the turbine.

May 2021

What's coming next?

01 – Install the complete solar loop with the instrumentation at the Themis solar tower.

02 – Define the operation conditions to circulate the particles through the various components in a stable way.

03 – Control the solar flux distribution on the receiver tubes.

04 – Measure the performance of the solar receiver and control the temperature distribution of the receiver tubes.

05 – Test the particle-to-pressurized air heat exchanger.

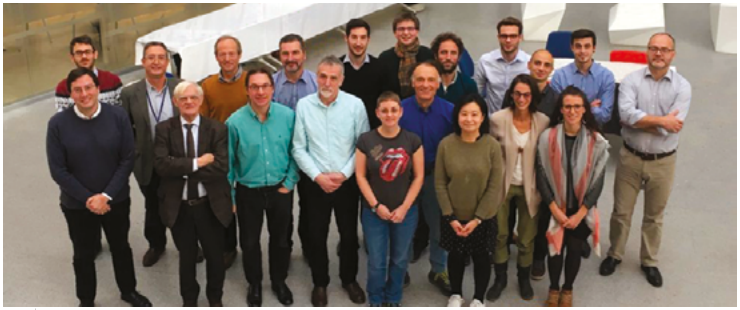
06 – Couple the hybrid gas turbine with the particle loop.

07 – Measure the performance of the complete system.

08 – Develop an engineering model of the pilot Next-CSP facility.

09 – Propose solutions for the architecture of large-scale (> 100 MWel) commercial plant.

10 – Compare the environmental impact of the particle technology with respect to the current central receiver CSP technologies.



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