FINAL PROJECT FACT SHEET

EUROPEAN UNION CO-FUNDED PROJECT

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Horizon 2020

SOLAR ENERGY

Project acronym:

next-CSP

High Temperature concentrated solar thermal power plant with particle receiver and direct thermal storage

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1. SUMMARY

According to the Integrated Roadmap of the Set-plan, and to reach the new EU target of 27% of renewable energies in 2030, there is the need to rapidly expand the use of all renewable energy sources in Europe to accelerate the fight against global climate change. This requires the acceleration of development of new options that are emerging today, particularly, technologies that solve the key issue of energy storage. The next-CSP Project is a response to this need and addresses significant improvements in all three elements targeted by the LCE-07-2016 call related to concentrated solar power: heat transfer fluids, which can be used for direct thermal energy storage; the solar field; and high temperature receivers allowing for new cycles. The proposed fluidized particle-in-tube concept is a breakthrough innovation that opens the route to the development of a new generation of CSP plants allowing high efficiency new cycles (50% and more) and 20% improvement of CSP plant efficiency. The Next-CSP technology that cumulates the know-how acquired during the CSP2 FP7 EU project on the particle-in-tube technology can be rapidly cost-competitive and introduced in the market. A cost reduction by 38% is expected with respect to current CSP electricity cost.
The Next-CSP Project will demonstrate at industrial pilot scale (TRL5) the validity of the particle-in-tube concept atop the *Themis* facility solar tower. A 4-MW_{th} tubular solar receiver able to heat particles up to 800°C will be constructed and tested as well as the rest of the loop: two-tank particle heat storage and a particle-to-pressurized air heat exchanger coupled to a 1.2 MW_{el} gas turbine. A commercial scale power plant (150 MW_{el}) will also be designed on the basis of experimental and simulation results and associated costs assessed. The consortium includes 6 companies that will lead the development of the first worldwide demonstration of this innovative technology and pave the way for future exploitation.
The project started October 1st 2016.

2. PROJECT SCOPE

The main objective of the Next-CSP project is to improve the reliability and performance of Concentrated Solar Power (CSP) plants through the development and integration of a new technology based on the use of high temperature (800°C) particles as heat transfer fluid and storage medium. To achieve this objective, the project will demonstrate the technology in a relevant environment (TRL5) and at a significant size (4 MW_{th}).

The approach consists of four main steps:

- Researches to improve the performances of key components by modeling and experimental works (Components such as the solar field, the solar receiver, the particle-to-air heat exchanger are concerned) and to assess the environmental impact.
- Design of the components and integration of the various sub-systems that constitute the solar loop and the heat conversion loop. Design for the scaling up to commercial size in order to size the components and estimate the cost of electricity (LCOE).
- Technology development and testing to validate the feasibility of manufacturing the plant components accounting for the strong thermal constraints: high flux and high temperature.
- Demonstration of the complete solar loop including power production during daytime and night-time, i.e. using the thermal storage.

Consequently the methodology includes:

- Modeling and numerical simulation (optics, fluid dynamics, heat transfer, optimization);
- Experimental measurements at laboratory scale;
- Computed Aided Design (CAD) of components and of the complete loop to be integrated atop the tower (x20 with respect to CSP2 FP7 project components);
- Manufacturing, assembling and cold testing of the components using high temperature materials;
- On-sun testing of the solar loop and demonstration of the complete solar-to-electricity conversion system (4 MWth nominal at the receiver aperture, 1.2 MW gas turbine);
- Examination of the potential improvement of the plant efficiency using innovative HT cycles;
- Scaling-up to commercial size of a HSGT solar plant based on the particle receiver technology.

Main innovations are the following:

- Use particle as heat transfer fluid (HFT) instead of molten salt in solar power tower and develop the adapted solar receiver (new product);
- Increase the HTF temperature by about 250°C;
- Use the same solid particles used as HTF to store thermal energy;
- Recover energy in a multi-stage fluidized bed heat exchanger;
- 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
- Integrate the particle loop (solar receiver + TES) with the energy conversion loop (particle heat exchanger + hybrid gas turbine) in a single industrial pilot.

Consequently the main deliverable will be a complete industrial scale pilot that will be tested for measuring the performance of the concept. This loop should be used for testing high temperature CSP components and in solar thermochemical processes involving particle looping.

3. *PROJECT TECHNICAL DESCRIPTION & IMPLEMENTATION*

The system is composed of two sub-systems: the solar loop and the heat conversion loop. The former sub-system consists of a concentrating solar system (a heliostat field in our case), a solar receiver and a two-tank heat storage system. The latter sub-system consists of a heat exchanger and a gas turbine (power block) working in the hybrid mode (not represented). This architecture is similar to that of molten salt power towers where molten salt is replaced by fluidized particles and the steam turbine is replaced by a gas turbine. in the proposed concept, the particles (silicon carbide or cristobalite) coming from the cold storage are heated in the solar receiver located atop the tower.

The solar receiver (4 MW_{th} at the aperture and about 3 MW_{th} net) absorbs the concentrated solar radiation reflected by the heliostat field and transfers heat to the moving particles (nominal flow rate of about 24 T/h). Hot particles are stored in a hot storage tank that feeds a fluidized bed heat exchanger. This heat exchanger transfers the heat from the particles to the pressurized air exiting the compressor of the gas turbine (at 280°C, 5.6 bar). Air can be heated up to 700°C for particles fed at 750°C. Preheated air is then supplied to the combustion chamber of the gas turbine (1.2 MW_e nominal power) to be heated up to the nominal inlet temperature (about 1000°C) of the expansion stage. Particles exiting the heat exchanger at 400 to 450°C are stored in the cold storage. Under these nominal conditions the solar fraction[1] (or "solar share") is about 55% (and 63% for pressurized air heated at 750°C).

The work plan of the Next-CSP project is divided in 10 work packages, 8 are devoted to S&T development and 2 are related to communication, dissemination and exploitation of results, and management respectively (WP9 and 10). The first WPs, WP1 and WP2, of the work plan address the issues related to the use of solid particles as heat transfer fluid and thermal energy storage, and the solar field respectively. The design, construction, testing and performance measurement of the pilot loop at the *Themis* solar tower are developed in work packages 3 to 5. WP6 and WP7 are devoted to the assessment of high efficiency thermodynamic cycles and to the scaling up to the commercial size (typically 150 MW_{el}) including cost reduction estimation respectively. WP8 addresses the environmental life cycle assessment of solar power production using the Next-CSP technology by comparison with current solar thermal technologies.

The critical milestone of the project is proposed in month 24 with the implementation of the complete pilot loop atop the solar tower and ready for operation. In the perspective of future development of high temperature solar power towers based on the Next-CSP technology,

The next steps that are envisioned after the end of the project are:

1. 2021-2025: Construction of a "First-of-its-kind" combined cycle hybrid (solar+fuel) 30-80 MW commercial plant using the next-CSP technology and a commercial gas turbine (GT).
2. 2023-2026: Construction and testing of a tailor-made GT to be operated with low turbine inlet temperature (TIT).
3. 2026-2030: Construction of a "First-of-its-kind" combined cycle solar-only 30-80 MW commercial plant using the next-CSP technology and the low TIT gas turbine.

[1] Fraction of total power output due to concentrated solar energy. In a hydrid solar power plant, both solar energy and combustion of fuel (either fossil or renewable) contribute to power production.

4. 2030: Start of the large expansion of the technology.

4. RESULTS ACHIEVED

Kick-Off: The kick-off meeting was organized October 2016.

5. IMPACT

The Next-CSP project proposes to develop up to TRL5 a breakthrough innovative technology for solar thermal power plants that can result in an increase of solar-to-electricity conversion efficiency by 20% and electricity cost reduction by 38%. The specific advantages of this new technology, which uses fluidized particles as heat transfer fluid and the same particles for thermal energy storage, are demanded by the CSP market. This will open the route for new unique high temperature, high efficiency cycles which will contribute to make CSP a cost attractive and more competitive renewable energy, thus paving the way for large deployment of solar energy and reduction of CO_2 reduction emission.

The main Expected impact of the Next-CSP project with respect to the LCE-7-2016.17 call are the following.

Expected impact stated in the Call	**Project achievement**
Reduce the technological risks for the next development stages	The project proposes to fill the gap between the laboratory scale experiments (already done) and the industrial pilot scale level with a dedicated WP on the design of the scaling-up, including risks analysis
Significantly increased 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.
Reducing life-cycle environmental impact.	Particles are less hazardous materials than other standard storage media such as molten salts
Nurturing the development of the industrial capacity to produce components and systems and opening of new opportunities	The complete solar loop will be designed and manufactured by a European consortium composed of research centers and industries and will pave the way for the next generation of solar power plants. The project's partners are able to shift towards production at higher levels once the technology is validated.
Contributing to strengthening the European industrial technology base, thereby creating growth and jobs in Europe	The proposed design is unique and original with respect to other approaches to develop particle receivers worldwide that are not proven yet. Moreover, the technology we propose is already proven and patented, contrarily to the other initiatives. Our design will provide a head start to the European industry with a big potential for building plants to high-DNI areas, thus creating job creation opportunities for European engineering and manufacturing companies.
Reducing renewable energy technologies installation time and cost and/or operational costs, hence easing the deployment of renewable energy sources within the energy mix	The heliostat field accounts for about 40% of the CAPEX and OPEX of a solar tower power plant. It will be downsized by 20% thanks to the increased conversion efficiency and accounts for 32% reduction of CAPEX with the Next-CSP technology. Besides, the CAPEX per kWe of a combined cycle is lower than that of a steam Rankine power block. A massive thermal storage using particles is also cheaper than one using Nitrate molten salts. 23% cost reduction is envisioned in 2030.
Increasing the reliability and lifetime while decreasing operation and maintenance costs, hence creating new business opportunities	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. As mentioned above, the downsizing of the solar field will reduce – almost proportionally – its operation and maintenance costs and will enable the companies to go for new competitive development and business options