SOCRATCES

Solar calcium-looping integration for thermo-chemical energy storage

under the funding programme

Horizon 2020

LCE-07-2016-2017

DEVELOPING THE NEXT GENERATION TECHNOLOGIES OF RENEWABLE ELECTRICITY AND HEATING/ COOLING

1. PROJECT SCOPE AND GOALS

Energy storage is the greatest challenge for a short-term deeper penetration of renewable energy sources, which are usually characterized by the intermittency of power production. In regards to Concentrated Solar Power (CSP), ***the Ca-Looping (CaL) process based upon the reversible carbonation/calcination of CaO is one of the most promising technologies for thermochemical energy storage (TCES).*** The wide availability of natural limestone (almost pure CaCO3) and its low price (<10€/ton) are key factors for the feasibility of the CaL process.

SOCRATCES is aimed at demonstrating the feasibility of this integration by erecting a pilot-scale plant that uses cheap, abundant and non-toxic materials as well as mature technologies used in the industry, such as fluidized bed reactor, cyclones or gas-solid heat exchangers.

SOCRATCES global objective is to develop a prototype that will reduce the core risks of scaling up the technology and solve challenges; further understand and optimise the operating efficiencies that could be obtained; with the longer-term goal of enabling highly competitive and sustainable CSP plants.

Table 1: Project general information

Grant Agreement reference	H2020-LCE-2016-RES-CCS-RIA/727348/SOCRATCES
Project total cost	4.975.402,50 €
EU contribution	4.975.402,50 €
Project duration	01/01/2018 – 31/12/20
Coordinator	Ricardo Chacartegui University of Seville c/ San Fernando, 4 – 41004 Seville - Spain Tel.: 0034–954 487 243 email: ricardoch@us.es
Keywords	Energy collection, conversion and storage, renewable energy, CSP, Solar Storage

SOCRATCES will be built on previous R&D results of the project partners indicating that the CaL process can be integrated into CSP plants for thermochemical energy storage and power generation by means of a simple closed CO2 loop. High global efficiencies (>45%) are predicted at industrial scale under new CaL conditions implying carbonation under high temperature (>850ºC) at high CO2 partial pressure compatible with high efficiency power blocks.

2. SOCRATCES TECHNICAL APPROACH

The proposed system works as follows: solar irradiation is used to carry out the calcination of CaCO3 (endothermic reaction) in a solar calciner reactor. According to chemical equilibrium, a broad range of temperatures (725-950ºC) and atmosphere compositions (CO_2 partial pressure [0.05-1]) in the calciner will be tested at lab-scale. Once calcination takes places, the product (CO2 and solid CaO) are stored separately. When power is needed the stored products are brought together into the carbonator reactor, where energy is released through the exothermic carbonation reaction. According to the chemical equilibrium and previous kinetics analysis, carbonation can occur fast at temperatures between 650-1000ºC depending on the CO2 partial pressure, which leads to a power cycle thermodynamic efficiency higher than in currently commercial CSP plants.

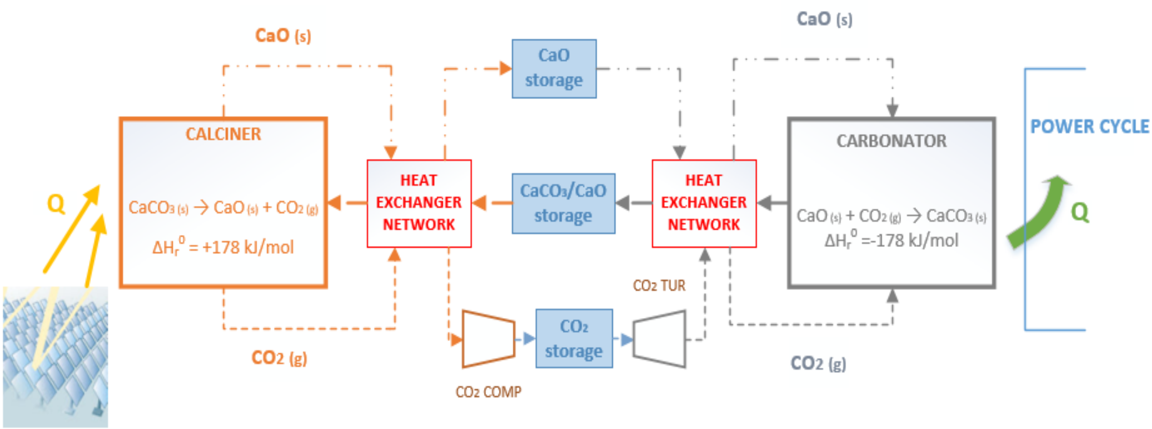

Figure 1: SOCRATCES conceptual scheme

The SOCRATCES concept stems from laboratory results of the partners in the consortium (TRL4) for testing the concept in relevant environment (TRL5). This concept goes beyond the current most advanced projects for developing next generation CSP concerning:

- ***Integrated systems concept is used to redefine the TCES design*** conditions allowing to use very cheap, abundant and non-toxic materials as heat transfer media.
- Solar receiver design to reduce the scale-up risk. ***Temperature in the solar particle receiver could reach 1000ºC.***
- Higher temperature in the carbonator (>700ºC) usable for power generation. ***High efficiencies of power cycle.***
- ***High density seasonal energy storage*** (theoretically ~3.2 GJ/m3).
- ***Potential integration with commercially available technologies*** (real gas turbines in direct integration, Stirling, Rankine cycles for indirect integration) at commercial scale.
- The use of ***cheap, abundant and non-toxic materials*** minimizes plant construction impact on the full life-cycle assessment (LCA).

Core activities of SOCRATCES for CSP-Storage-power cycles integration to advance in the next generation of CSP tower plants are divided into five main methodological groups (MG): MG1. ***New materials***; MG2. ***Reactions (chemistry/physics)***; MG3. ***Power systems technologies***; MG4. ***Systems integration and control***; and MG5. ***Systems development.***

Consequently, to achieve the technological development according to the proposed methodology, SOCRATCES project is structured in the following work packages (WP):

- WP1: Project management
- WP2-WP5: 4 work packages oriented to the study and development of the modules. The objective of each one is to advance in the equipment from laboratory to prototype before integration into the final prototype. It includes fundamental research, models and designs for carbonator (WP2), calciner (WP3), power cycle (WP4) and integrated system (WP5).
- WP6: work package for modules and prototypes construction, separated in two parts: modules to be tested individually and integration in final prototype.
- WP7: work package for modules and final prototype testing.
- WP8: LCA, Economic assessment, Business development, Risk analysis and Technology Watch
- WP9: Dissemination and exploitation of results

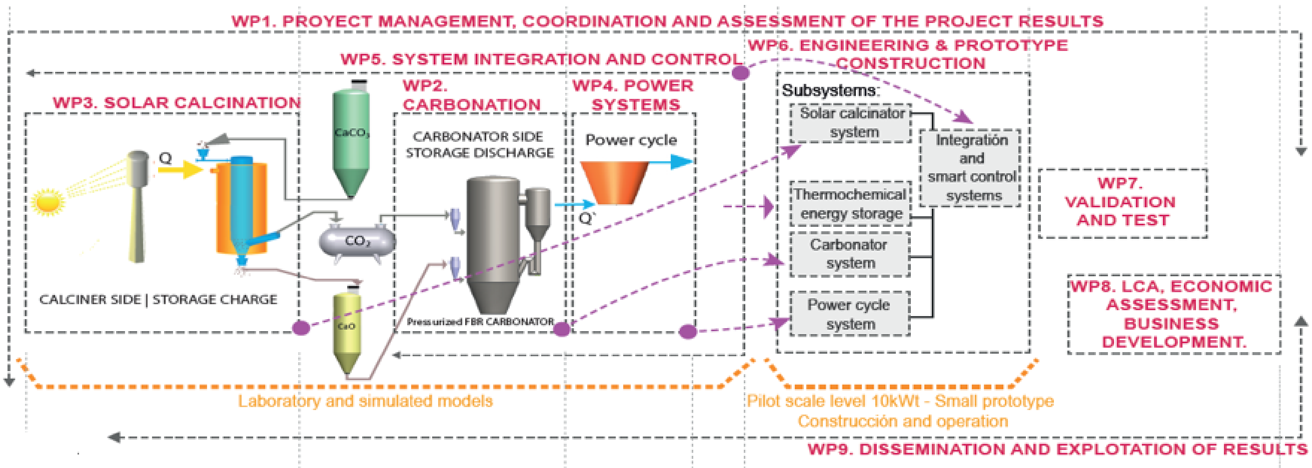

Figure 2: SOCRATCES integration and connection between work packages and methodology.

With the proposed technology and project methodology, ***SOCRATCES will be built upon robust results already obtained at laboratory scale to design and construct a small prototype for technology demonstration at the pilot scale level (10 kWth)***. Prototype construction and operation will serve as a feedback to identify and solve challenges and opportunities. A main general goal is to open a new pathway to the next generation of CSP plants with a high market share in 10 years.

3. EXPECTED RESULTS AND IMPACT

Main expected results are:

During the SOCRATCES project:

- Prototype demonstration of capacity for energy storage. System tested at TRL5. Solids and CO2 storage.
- Successful calcination at prototype scale by means of flash calcination technology.
- Successful carbonator design with possibility for the scale-up. Integration of high temperature carbonator (>850ºC) and Stirling engine for power production.
- Particles attrition, agglomeration and fouling analysis. Successful solids conveying and control system management.
- Study of CaO precursor and process conditions to allow high and stable stable multicycle activity

At commercial scale, after the three stages and scale up, breakthrough performance and costs are expected:

- At commercial design, high CaL-power cycle efficiencies expected (>45%)
- Energy storage TCES cost <12€/kWh
- Commercial global system CSP/CaL SOCRATCES Concept LCOE<7c€/kWh.

SOCRATCES is intended to open a new pathway for next generation of CSP tower plants, technologically feasible, economically viable and sustainable (environmental, social and economic). The roadmap for advancing from the concept to commercial technology is conceived in three stages to be developed in a period of 10 years: 10KWth small prototype, 1 MWth scale pilot plant and commercial demonstrator.

Main expected impacts are:

- Improvement on the reliability and CSP plants lifetime while decreasing operation and maintenance costs, hence creating new business opportunities
- Development of a new generation of CSP tower with energy storage technology.
- To create a pathway to fostering the use of solar energy and reduce the EU energy dependency, thus improving security.

4. SOCRATCES CONSORTIUM

SOCRATCES is an integral and multidisciplinary approach where different knowledge areas are involved: thermal machines, electronics engineering, solar energy, control, physics, chemistry, power generation, materials, reactors, LCA, etc. It integrates ***multidisciplinary R&D groups, SMEs and companies in an equilibrated structure*** where all the required skills for the adequate development of the project are fully covered

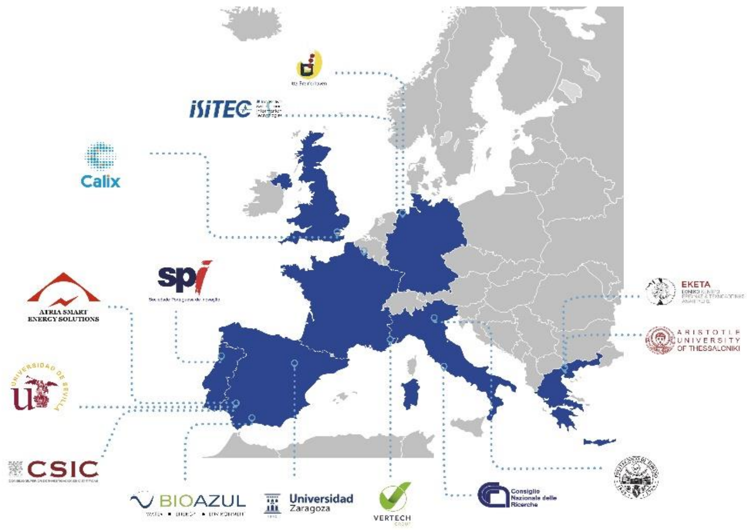

Figure 3: SOCRATCES consortium

The consortium comprises all the involved fields and assures the fulfilment of the full value chain within the project with R&D groups and companies. Each one of these has a different role and their commercial and industrial experience will facilitate and enhance the exploitation of the results. In addition, ***Associations and Stakeholders offer the opportunity for wide dissemination of the project and will link the consortia with the relevant industries in Europe.***

Figure 4: SOCRATCES kick-off meeting celebrated in Seville (January 2018)

5. BUDGET

The total overall budget of SOCRATCES is 4,975,402 € with a total staff effort 666 person/month. The resources of the project have been optimised for maximum coherence and utilisation of critical mass, the integration of resources and the avoidance of unnecessary cost and overhead. The consortium has carefully aligned the necessary and adequate resources needed for the 36-month project according to its nature. Budget distribution in SOCRATCES among the work packages is presented in Figure 5.

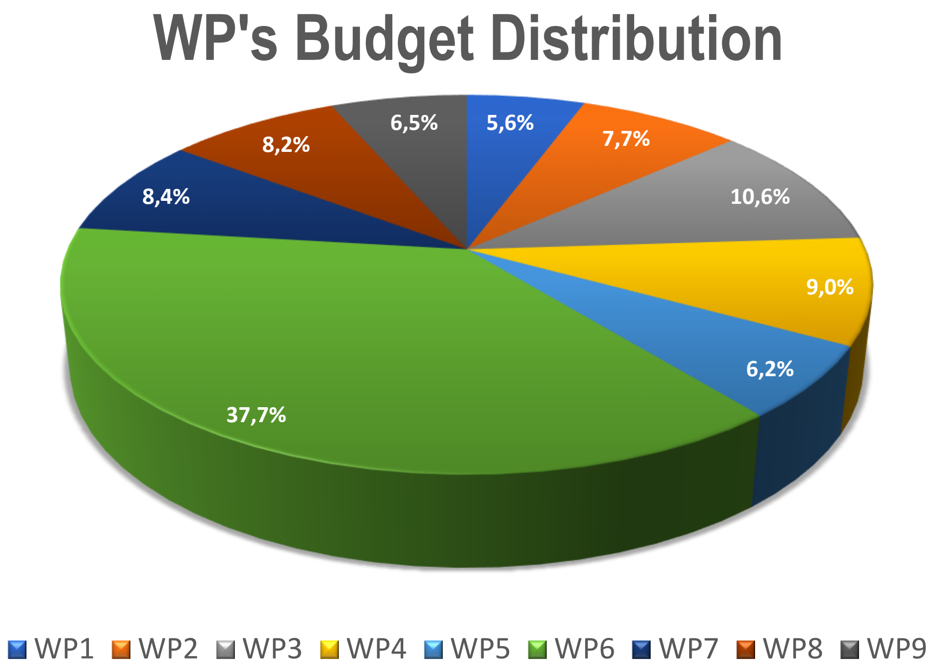

Figure 5: SOCRATCES Budget distribution between work packages.

The staff effort is well balanced between WPs with a higher effort in WP3 (solar calciner) due to the novelty of the concept and WP6 (prototypes construction). ***The R&D core WPs of the project WP2 to WP5, have a relative weight of 50.2% of the staff effort while prototypes construction and validation, WP6 and WP7, requires 28,7 % of the resources of the project.*** Partners' budget is equilibrated and well-balanced in the assignment of resources for the activities to be developed in SOCRATCES.