

Grant Agreement No. 727348

Project Acronym:

**SOCRATCES**

Project title:

**Solar Calcium-looping integRation for Thermo-Chemical Energy Storage.**

**DELIVERABLE D8.4**

**Second Innovation Evaluation report**

|                                   |                                      |                                 |           |
|-----------------------------------|--------------------------------------|---------------------------------|-----------|
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**Table of contents:**

|   |    |
|---|----|
| INTRODUCTION .....  | 3  |
| 1. SOCRATCES: objectives and expected impact.....                             | 4  |
| 1.1. SOCRATCES project .....  | 4  |
| 1.2. SOCRATCES expected impacts .....   | 4  |
| 2. INNOVATION MANAGEMENT .....  | 8  |
| 2.1. SUMMARY OF FIRST EVALUATION REPORT .....                                 | 8  |
| 2.2. INNOVATION EVALUATION DURING THE 2 <sup>ND</sup> YEAR OF SOCRATCES ..... | 9  |
| CONCLUSION .....  | 24 |

## INTRODUCTION

This report is framed in the **Task 8.5 Innovation management activities** of WP8, and it is the Second evaluation made during the project life. Main aim of this task is to define a technology forecasting plan and decision-making mechanisms for innovation management. This mechanism will be used to select and prioritize innovative ideas and project outcomes for the implementation of new features and/or changes that improve the performance of SOCRATCES prototype and other outcomes.

The activities within task 8.5 are strongly linked to other project tasks mainly within WP1 and WP9.

- **Task 1.3 IP, Exploitation and Innovation management.** This task includes the coordination of knowledge management and exploitation of the project results as well as other innovation-related activities.
- **Task 9.4 IPR management and Exploitation Plan.** It involves the design and agreement of the Exploitation Plan, taking into account the agreements on IPR and Exploitation. The exploitation plan will include the description of the exploitation strategy, its implementation as well as market findings of the project. Additionally, the plan will focus on the exploitation opportunities of SOCRATCES, summarizing different possible exploitation scenarios that can be applied. The Innovation Manager will handle with these aspects together with other partners.

BIOAZUL has been assigned as leader of *task 3.1, task 8.5 and WP9* and is working closely with USE, VERTECH and SPI to encourage and stimulate the use of the consortium creative efforts to build new ideas, technical and organizational solutions. BIOAZUL is putting in place a set of working tools that allow all project partners to cooperate with a common understanding of goals and processes.

The work during the second year of SOCRATCES has allowed to obtain important research results and decision about the future implementation of the prototype and SOCRATCES technology evolution (and derived technologies from components development). In this way, the innovations have been described in a detailed way, as well as some new ones has included in the list. In the stage of the project partners has been able to make a first general evaluation to them as well as set references to compare with SOCRATCES results.

## 1. SOCRATCES: OBJECTIVES AND EXPECTED IMPACT

This section provided general information on the SOCRATCES project, its objectives and the expected impacts as foreseen in the DoA, as it was included in the first report. The aim is to have a proper framework to the innovation management which is expected to do within the project life.

### 1.1. SOCRATCES project

SOCRATCES “*SOLar Calcium-looping integRAtion for Thermo-Chemical Energy Storage*” is a research and innovation action (RIA) funded by the European Union’s Horizon 2020 programme and coordinated by the University of Seville.

The **general objective** of SOCRATCES is to demonstrate the practical feasibility of this CaL-CSP integration scheme already obtained at laboratory scale, extending the laboratory research in these very promising field by erecting a pilot-scale plant that uses cheap, widely available and non-toxic materials as well as already mature solar and calcination/carbonation reactors technologies. The pilot plant will be validated in relevant environment to prove it as:

- **Feasible:** SOCRATCES is a combination of a novel integration of systems in CSP/TCES in a configuration that allows using already tested technologies. Therefore, the use of individual technologies and their integration has a controlled risk due to the recent experience of the partners in the consortium.
- **Viable:** SOCRATCES technologies aim to drastically reduce investment and O&M costs. The global integration is expected to reduce the costs in the commercial scale to a LCOE below 7c€/kWh.
- **Sustainable:** SOCRATCES is environmentally sustainable because is based on the use of non-toxic minerals as reactants in the TCES system. It allows long-term solar energy storage in chemical form. SOCRATCES is economically sustainable with reduced investment costs. SOCRATCES is socially sustainable as it is based on a technological framework currently in use and fully accepted by end-users.

The successful realization of a pilot plant will give the EU a leading role in the development of cheap, efficient and non-toxic energy storage of CSP in a chemical form.

SOCRATCES main **commercial objective**, linked to R&D objectives, is to introduce a novel technology (and subsystems) into the CSP tower technology market with a relevant reduction of costs at commercial level (TCES cost <12€/kWh and CSP plant LCOE <7c€/kWh).

SOCRATCES main **social objective** is to provide a new integrated set of affordable, viable and sustainable CSP technology, with outstanding performance and based on renewable sources and abundantly available cheap materials for the cycle.

### 1.2. SOCRATCES expected impacts

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: 10KWt small prototype, 1 MWt scale pilot plant and commercial demonstrator. In SOCRATCES the small CSP/TCES prototype (10KWt) will represent a first step to demonstrate the technology and will serve to identify and solve challenges and opportunities at the small scale.

The expected impacts are included in the table below:

| EXPECTED IMPACT  | PROPOSAL SOLUTION  | OBJECTIVE   |
|--|--|---|
| Reducing the technological risks for the next development stages   | Natural CaO sorbents and Ca-rich industry waste materials. Low cost, non-toxic, abundant, stable and sustainable   | <ul style="list-style-type: none"> <li>- Prototype demonstration of capacity for energy storage.</li> <li>- Solids and CO2 storage.</li> <li>- Solids conveying and system management.</li> <li>- System tested at TRL5.</li> </ul>   |
|  | Use of mature inexpensive technologies and materials in solar receiver. Potential for integrating future high temperature developments   | <ul style="list-style-type: none"> <li>- Solar calcination. Integration of already available technology at receiver.</li> <li>- Systems design</li> <li>- CaL attrition control</li> </ul>  |
|  | T Carbonation (power cycle loop) > 850°C. High efficiency cycles can be integrated (already commercial as steam) and future ones as SCO2   | <ul style="list-style-type: none"> <li>- Prototype demonstration of high temperature carbonation &gt;850°C and Striling engine. Integration of already available technology for power block.</li> <li>- Carbonator CO2 closed loop control development</li> </ul>   |
| Significant increased technological performance  | <ul style="list-style-type: none"> <li>- Combination of novel (CaL TCES, solar calciner) and commercial technologies (CSP tower plant, fluidized bed reactors, pneumatic conveying, gas turbine power cycle).</li> <li>- New conditions for CSP/CaL integration results in high global system efficiency with two possible power block integrations: indirect and direct.</li> </ul> | <ul style="list-style-type: none"> <li>- Global efficiency: direct integration &gt;46%, indirect integration with high efficiency power block (SCO2)&gt;50%</li> <li>- Reduce prices of receivers by new integration concept on solar-calcination</li> <li>- Tcarbonation&gt;850°C. High efficiency of power cycle</li> </ul> |
|  | Optimized energy storage system. Sensible heat storage plus <u>Thermochemical</u> storage due to CaCO <sub>3</sub> endothermic decomposition reaction plus <u>mechanical energy</u> employed for CO <sub>2</sub> compression and extracted from the cycle operation.   | <ul style="list-style-type: none"> <li>- High density energy storage: 3.2 GJ/m<sup>3</sup></li> <li>- Low materials price: &lt;10 €/ton</li> <li>- Highly stable materials: Residual activity &gt;0.5</li> </ul>  |
|  | Energy management/ storage   | System tested at TRL5   |
| Reducing life-cycle environmental impact;  | Use of abundant natural CaO precursors and Ca-rich industry waste materials.   | System tested at TRL5<br>LCA/LCC analysis   |
| Nurturing the development of the industrial capacity to produce components and systems and opening of new opportunities; | Development of prototype for technology demonstration  | New CSP concept<br>New calcination technology   |
| Contributing to the strengthening the European industrial  | First step to the next generation of SOCRATCES CSP power plants in Europe fully competitive with future  | System tested at TRL5   |

|   |  |   |
|---|--|---|
| technology base, thereby creating growth and jobs in Europe   | fossil fuel plants under market conditions   |   |
| Increasing the reliability and lifetime while decreasing operation and maintenance costs, hence creating new business opportunities;                                      | <ul style="list-style-type: none"> <li>- Moderate temperatures at calciner allow using already available receiver technologies</li> <li>- High temperature carbonator in closed CO<sub>2</sub> loop allows the integration of already existing technologies in indirect integration (steam/Stirling) and future ones (SCO<sub>2</sub>).</li> <li>- Ca-based materials yield limited abrasion compared with other solid particles materials (as SiC)</li> </ul> | System tested at TRL5   |
| Primary energy and GHG emission reductions the global climate and energy challenges   | Optimized integration of several efficient technologies for high efficiency power production from solar energy source with relative low investment costs   | System tested at TRL5   |
| Reducing renewable energy technologies installation time and cost and/or operational costs, hence easing the deployment of renewable energy sources within the energy mix | Capacity for long term storage and 24/365 power operation  | Operation under <b>different long term energy storage strategies.</b>                         |
|   | Optimizing the economic performance under a global approach to all systems (solar field/heat transfer media/storage/power block)   | SOCRATCES costs at commercial scale:<br>Energy Storage <12€/kWh <sub>th</sub><br>LCOE<7c€/kWh |

In addition, the following table summarises the expected impact per partner:

| Partner       | Publications | Expected Patents | R&D installations                        | New Knowledge in  | Personnel | Product/ Modules                  |
|---------------|--------------|------------------|--|---|-----------|-----------------------------------|
| <b>USE</b>    | >6           | YES(>2)          | Prototype Solar field<br>Final Prototype | TCES/reactors / Solids pneumatic conveying/solar integration /Grid integration/ He-Steam calcination/ Solids/gas storage/ heat exchangers | >3        | TCES / Power Unit/ control system |
| <b>POLITO</b> | >4           | YES (1)          | NO                                       | Power block integration/solids conveying/ CO <sub>2</sub> storage/ Heat exchangers  | >2        | -                                 |
| <b>ZAR</b>    | >3           | YES (1)          | NO                                       | Systems integration/control/ Solids/gas storage/ heat exchangers  | >1        | -                                 |

|              |    |         |                              |  |    |  |
|--------------|----|---------|------------------------------|--|----|--|
| <b>CERTH</b> | >3 | YES (1) | Prototype carbonator reactor | Carbonator design/control  | >4 | Carbonator reactor                                   |
| <b>CLX</b>   | >2 | YES (2) | Prototype calciner           | Solar conveying/ He calcination/ systems integration/ Solids pneumatic conveying/ Grid integration, energy integration | >4 | Calciner reactor / Flash Calcination/ He Calcination |
| <b>CSIC</b>  | >5 | NO      | NO                           | TCES/reactors development/ Solids pneumatic conveying/ CaL attrition / He-Steam calcination                            | >1 | TCES   |
| <b>TTZ</b>   | >4 | YES (1) | NO                           | Power block/LCA/ energy integration/ reactors design   | >2 | Power Unit/ control system/LCA                       |
| <b>BIO</b>   | NO | NO)     | NO                           | energy integration/ systems management   | >1 | -  |
| <b>CNR</b>   | >3 | YES (1) | NO                           | CaL attrition control /reactors development/ Solids pneumatic conveying  | >1 | -  |
| <b>VER</b>   | >1 | NO      | NO                           | SOCRATCES components and global LCC, Risk  | >1 | LCC, Risk analysis                                   |
| <b>SPI</b>   | NO | NO      | NO                           | SOCRATCES components and global business model   | >1 | Business Model,                                      |
| <b>ISI</b>   | NO | YES (1) | NO                           | Control technology/ integration  | >1 | control system                                       |
| <b>AUTH</b>  | >3 | YES (1) | NO                           | Carbonator design/ CaO sorbents  | >2 | Carbonator reactor                                   |
| <b>VM</b>    | 1  | YES (1) | Prototype solar power system | TCES/power cycles,/ Grid integration/ energy integration   | >2 | Solar power/control                                  |

## 2. INNOVATION MANAGEMENT

The aim of this action is to design a **decision-making mechanism** to select new ideas and project outcomes - INNOVATIONS- for which there is a real demand for further development.

### 2.1. SUMMARY OF FIRST EVALUATION REPORT

The proposal after the first year of the project was to develop a multicriteria decision matrix for the evaluation of the innovation degree/innovation potential of the project INNOVATIONS developed in the different WPs. The work done to prepare the matrix was structured in the following steps:

- STEP 1: Select the criteria for comparison.

It was selected four kind of criteria: technical, economic, environmental and social. They take into account several aspects, but the ones considered more relevant were **engineering specifications** (technical issues) and **customer needs** (economic and market issues).

| CRITERIA               | INDICATORS   |
|------------------------|--|
| Technical innovation   | Effectiveness  |
|                        | Efficiency   |
|                        | Novelty  |
|                        | Implementation cost                                  |
|                        | Ease of implementation                               |
|                        | Applicability and suitability at a different scale   |
|                        | Compatibility  |
|                        | Sensitiveness to changes in operating conditions     |
|                        | Long term effect and the impact on system complexity |
|                        | Reliability  |
| Economic criteria      | TCES Investment costs.                               |
|                        | Long term storage / energy.                          |
|                        | Storage capacity.                                    |
|                        | Levelized cost of energy (LCOE).                     |
|                        | O&M costs per kWh.                                   |
|                        | Quality of service.                                  |
| Environmental criteria | Cumulative energy demand                             |
|                        | Depletion potential                                  |
|                        | Emission values                                      |
|                        | Land Use   |
|                        | Toxicity potential                                   |
|                        | Risk potential                                       |
| Social criteria        | Equity   |

**Table 1: Criteria and indicators choose within the 1<sup>st</sup> Evaluation report**

- STEP2: Select the innovations to be compared.

The partners were requested to identify the main innovations as outcomes of their work. In the first report, project partners identified **28 innovation**. The innovations identified were not listed on D8.1 because of the public nature of this deliverable. They should be kept confidential in order to avoid any conflict of interest related to their commercial exploitation and their protection, especially if partners are planning to apply for patents.

- STEP3: Score the selected innovations.

From that moment, a **continuous monitoring** of the innovations was proposed to be carried out. To do this, they will be followed up using the indicators defined for the technical, economic, environmental and social criteria.

## 2.2. INNOVATION EVALUATION DURING THE 2<sup>ND</sup> YEAR OF SOCRATCES

The second year of the project has brought great progress in the development of technologies and results of the different models proposed. This work has made the consortium reconsider the technical indicators proposed in the previous report.

The variety of innovations that arose during the project requires a regrouping of them, not only as WP, but also by the nature of innovation. For that reason, it has changed the strategy for evaluating innovations according to the following scheme:



SOCRATCES partners revised the innovations according to the work developed during the year and the result was the identification and description of **33 innovations** (5 more than in the first report) and grouped them according the nature of each innovations, in order to be able to set suitable references comparable with the innovations as well as indicator which allow to score the innovation of the ideas in a proper way.

In order to maintain confidentiality and at the same time to show the impact of innovations developed within the project, the innovations has been codified and not fully described within this deliverable because of the public nature of the deliverable. These codes are related to the internal confidential documents describing the innovations within the consortium. They are fully available for revision under request and always within the confidential framework of the Grant Agreement. It is planned to update this information related to innovation evaluation in order to change the dissemination level of the next related deliverables to “confidential” according to INEA’s indications to maximize possibilities of innovations exploitation.

This is the list and groups of innovations resulting after the second year of SOCRATCES:

| WP  | GROUPS      | CODE INNOVATIONS                               |
|-----|-------------|--|
| WP2 | Models      | 01_1; 01_3; 01_5, 04_13                        |
|     | Equipment   | 03_10, 03_11, 01_32, 04_12, 04_15              |
|     | Studies     | 10_25, 14_27                                   |
| WP3 | Models      | 01_1, 06_17, 15_31                             |
|     | Designs     | 01_2, 01_32, 05_16, 06_18, 14_28, 14_29, 15_33 |
|     | Studies     | 10_24, 14_27                                   |
| WP4 | Integration | 02_6, 08_19                                    |
|     | Carbonator  | 08_20, 08_21                                   |
|     | Stirling    | 02_7, 02_8, 08_22, 08_23                       |
| WP5 | Control     | 01_4, 03_9, 04_14, 13_26                       |
| WP7 |             | 15_30  |

The resulting groups has been evaluated separately. In this way, the specific references for each of them have been established and the technical indicators have been revised, with the aim of showing the degree of innovation of each of the ideas.

Each group is shown below with the appropriate references and a first qualitative evaluation of the ideas.

| WP2-SPECIFIC MODELS  |   | INNOVATIONS  |  |   |   |   |
|----------------------|---|--|--|---|---|---|
| Criteria             | Indicators  | BENCHMARKING <sup>1</sup>  | 01_1   | 01_3  | 04_13   | 01_5  |
| Technical Innovation | Novelty<br>(High/Medium/Low)  | [1], [2], [3], [4]<br>(There is not similar mathematic model for CaO Carbonation specified in TCES conditions) | Medium. Novel models with specifics data for TCES: particle size, reaction kinetics, reactor conditions. The models have been developed before, but not specifically for this application. | Medium. Novel models with specifics data for TCES: particle size, reaction kinetics, reactor conditions. The models have been developed before, but not specifically for this application | Medium. Novel models with applications in gas-solids reaction systems. Drop-tube reactor models specified in CaL-TCES systems. Reactor kinetics; particle size, reactor conditions, Mass-momentum-energy conservation. The model can be applied in every gas-solid application in a drop-tube reactor | High. There is not carbonator for fines with vertical flow as large as in SOCRATCES (around 10 m of vertical falling) for 10 kWth. It means change typical Fluidized Bed FB reactors technology for Entrained Bed (EB) Reactors. Other reactors have been proposed at lab-scale as in the reference |
|                      | Implementation cost<br>(High/Medium/Low)                                |  | Does not apply   | Does not apply  | Does not apply  | High. These are the main reactors of the plant.   |
|                      | Ease of implementation<br>(High/Medium/Low)                             |  | Does not apply   | Does not apply  | Does not apply  | Difficult. One important objective of the project is achieve relevant knowledge about the scaling up of the reactors  |
|                      | Applicability and suitability at a different scale<br>(High/Medium/Low) | [2]  | Models will be validated at lab scale to achieve important parameters for the scale-up of the technology   | Models will be validated at lab scale to achieve important parameters for the scale-up of the technology  | Models will be validated at prototype scale to achieve important parameters for the scale-up of the technology  | Difficult. One important objective of the project is achieve relevant knowledge about the scaling up of the reactors  |
|                      | Compatibility with the project goals<br>(High/Medium/Low)               |  | The approach is 100% compatible with the goals of the project.   | The approach is 100% compatible with the goals of the project.  | The approach is 100% compatible with the goals of the project.  | The approach is 100% compatible with the goals of the project.  |
|                      | Sensitiveness to changes in operating conditions<br>(High/Medium/Low)   |  | Highly sensitive, this is the reason of the novelty, there are models focused on specific conditions for TCES  | Highly sensitive, this is the reason of the novelty, there are models focused on specific conditions for TCES   | Highly sensitive, this is the reason of the novelty, there are models focused on specific conditions for TCES   | Highly sensitive. Along the project will be evaluated operation ranges for the main parameters  |
|                      | Reliability<br>(High/Medium/Low)  |  | Does not apply   | Does not apply  | Does not apply  | High. These reactors are currently used for other industrial applications   |

<sup>1</sup> [1] DOI: 10.1016/j.ces.2011.10.041

[2] DOI: 10.1016/j.fuel.2013.07.036

[3] DOI: 10.1039/C9RE00015A

[4] DOI: 10.1021/acs.iecr.8b02918

| WP2-EQUIPMENT        |   | INNOVATIONS   |  |  |   |   |   |
|----------------------|---|---|--|--|---|---|---|
| Criteria             | Indicators  | BENCHMARKING <sup>2</sup>                             | 03_10  | 03_11  | 01_32   | 04_12   | 04_15   |
| Technical Innovation | Novelty<br>(High/Medium/Low)                              | There is not any carbonator reactor with fins.<br>[2] | Does not apply   | High. It is the main innovation. It is a novel approach for controlling carbonator temperature and enhance heat transfer | High. It consists of an optimal integration of solar volumetric receiver and high temperature CO <sub>2</sub> flow along the reactor. | High. Only one drop-tube carbonator reactor have been constructed. Novel configuration specified in TCES conditions                     | High. There is no similar designs in literature for cooling drop-tube carbonators                                   |
|                      | Collection efficiency by particle size (%)                | High. 80% [1]   | Increase efficiency up to 85-90% for particle sizes below 5 microns  | Does not apply   | Does not apply  | Does not apply  | Does not apply  |
|                      | Implementation cost<br>(High/Medium/Low)                  | Medium. Not yet evaluated at this stage               | Medium. Not yet evaluated at this stage                              | Medium. Not yet evaluated at this stage  | Medium. Not yet evaluated at this stage   | Medium. Not similar data are available to compare   | Medium. Not similar data are available to compare   |
|                      | Compatibility with the project goals<br>(High/Medium/Low) | No compatible with project goals                      | High. The approach is 100% compatible with the goals of the project. | High. The approach is 100% compatible with the goals of the project.   | High. The approach is 100% compatible with the goals of the project.  | High. The approach is 100% compatible with the goals of the project.  | High. The approach is 100% compatible with the goals of the project.  |
|                      | Dimensions of the carbonator. Length (m2)                 | High. Not yet evaluated in the scale-up at this stage |  | Reduction of 10% of length area due to fins  |   | Does not apply  | Does not apply  |
|                      | Respond to operational conditions changes (s)             | Medium. Not yet evaluated at this stage               |  | Reduction of the time of transient processes   |   | High. Flexible construction for flexible operation  | High. Constructed to be flexible in operation   |
|                      | Effectiveness<br>(High/Medium/Low)                        | [2]   |  |  |   | Not tested yet. There is only one similar drop-tube carbonator with electric furnaces. Novel configuration specified in TCES conditions | Medium. Even though it is not tested yet, it is expected to be effective. There is no similar designs in literature |

<sup>2</sup> "[1] John Dirgo & David Leith (1985) Cyclone Collection Efficiency: Comparison of Experimental Results with Theoretical Predictions, Aerosol Science and Technology, 4:4, 401-415,"

[2] DOI: 10.1021/acs.iecr.8b02918

| WP2-EQUIPMENT |   | INNOVATIONS               |       |       |  |  |   |
|---------------|---|---------------------------|-------|-------|--|--|---|
| Criteria      | Indicators  | BENCHMARKING <sup>3</sup> | 03_10 | 03_11 | 01_32  | 04_12  | 04_15   |
|               | Sensitiveness to changes in operating conditions<br>(High/Medium/Low)   |                           |       |       | High sensitivity. The control strategy is developed to allow fast response to operating conditions | High. Flexible construction for flexible operation | High. Constructed to be flexible in operation   |
|               | Ease of implementation<br>(High/Medium/Low)                             |                           |       |       | Medium. Not yet evaluated at this stage  | Medium. Not implemented yet                        | Low. Not easy to be constructed   |
|               | Applicability and suitability at a different scale<br>(High/Medium/Low) |                           |       |       | High. The CO2 mass flow circulating among the components can be increased with the CSP plant size  | Not estimated yet.                                 | Not estimated yet.  |
|               | Efficiency<br>(High/Medium/Low)   |                           |       |       | High   | Not tested yet.                                    | Medium. Even though it is not tested yet, it is expected to be efficient. There is no similar desings in literature |

<sup>3</sup> "[1] John Dirgo & David Leith (1985) Cyclone Collection Efficiency: Comparison of Experimental Results with Theoretical Predictions, Aerosol Science and Technology, 4:4, 401-415,"

[2] DOI: 10.1021/acs.iecr.8b02918

| WP2- STUDIES         |   | INNOVATIONS                   |  |   |
|----------------------|---|-------------------------------|--|---|
| Criteria             | Indicators  | BENCHMARKING <sup>4</sup>     | 10_25  | 14_27   |
| Technical Innovation | Effectiveness<br>(High/Medium/Low)  | [1], [2]: Medium<br>[3]       | High. Studies have shown that calcination and carbonation are significantly enhanced in a sound-assisted fluidised bed.  | High: There are a range of sorbents which could hold greater residual carrying capacity than natural limestone. |
|                      | Novelty<br>(High/Medium/Low)  | [1], [2]: Medium<br>[3],[4]   | Medium. Sound-assisted tests have been performed on fluidised beds before, but not in a CSP context  | High. Many of these materials have not been studied for this particular use before.                             |
|                      | Implementation cost<br>(High/Medium/Low)  | [1], [2]: Medium              | Does not apply   | High. They are carbonate materials (at least in part), so can be calcined and recarbonated.                     |
|                      | Ease of implementation<br>(High/Medium/Low)   | [3],[4]                       | High. All the equipment (signal generator, audio amplifier loudspeaker and oscilloscope) required are for sound generation is very easily available on the market and can be easily implemented. | Does not apply  |
|                      | Applicability and suitability at a different scale<br>(High/Medium/Low)               | [1], [2]: Medium<br>[3],[4]   | High. This technology can be easily scalable.  | High. Simply more sorbent is required, and the amounts available are high.                                      |
|                      | Compatibility with the project goals<br>(High/Medium/Low)                             | SOCRATCES Description of Work | Medium. Although it improves calcination and carbonation, it is relevant to fluidised beds which are not being used in the project.  | High. The project has a specific mandate to study alternatives to limestone                                     |
|                      | Sensitiveness to changes in operating conditions<br>(High/Medium/Low)                 | [1], [2]: Medium              | Does not apply   | High. These sorbents are generally relevant over the same operating conditions as limestone.                    |
|                      | Ability to measure a wide range of relevant operating conditions<br>(High/Medium/Low) | [3],[4]                       | High. The sound frequency and amplitude can be altered depending on different particle and gas properties.   | Does not apply  |
|                      | Relevance to resulting designs/reactions/processes<br>(High/Medium/Low)               | [3],[4]                       | Medium. This is mainly relevant to calcination and carbonation in fluidised beds but there are some applications in drop tube reactors which should be studied further.                          | Does not apply  |

<sup>4</sup> [1] Meier et al., "Multitube Rotary Kiln for the Industrial Solar Production of Lime", Transactions of the ASME, August 2005 Vol 127, p386-395  
 [2] Meier et al., "Economic evaluation of the industrial solar production of lime", Energy Conversion & Management, Vol 46 Issue 6, April 2005, P905-926  
 [3] Valverde et al., Enhancement of CO2 Capture at Ca-Looping Conditions by High-Intensity Acoustic Fields. Appl. Energy 2013, 111, 538–549. <https://doi.org/10.1016/j.apenergy.2013.05.012>.  
 [4] Raganati et al., CO2 Adsorption on Fine Activated Carbon in a Sound Assisted Fluidized Bed: Effect of Sound Intensity and Frequency, CO2 Partial Pressure and Fluidization Velocity. Appl. Energy 2014, 113, 1269–1282. <https://doi.org/10.1016/j.apenergy.2013.08.073>.

| WP3- MODELS          |  | INNOVATIONS               |  |   |   |
|----------------------|--|---------------------------|--|---|---|
| Criteria             | Indicators   | BENCHMARKING <sup>5</sup> | 01_1   | 06_17   | 15_31   |
| Technical Innovation | Effectiveness<br>(High/Medium/Low)   | [1]: Medium               | High. These models have been critical for unit design.   | High. These models have been critical for unit design.  | High. These models have been critical for unit design.  |
|                      | Novelty<br>(High/Medium/Low)   | [1]: Medium               | Medium. The models have been developed before, but not specifically for this application.  | Medium. We have developed models which are similar to those in general CaL. However, there are some innovations around fast calcination and focusing on CSP-CaL conditions      | High. This kind of calciner (with an irradiating cavity) is new and so similar simulations have not been made before.                                       |
|                      | Ease of implementation<br>(High/Medium/Low)                                      | [1]: Low                  | High. The models are developed specifically for the calciner and carbonator as designed.   | High. The models are very relevant to SOCRATCES and were developed with implementation within the project.  | High. The models are very relevant to SOCRATCES and were developed with implementation within the project.  |
|                      | Applicability and suitability at a different scale<br>(High/Medium/Low)          | [1]: Medium               | High. The models have a few geometrical parameters, but these are flexible and can be altered depending on the reactor dimensions. This is more relevant than 1D models. The models are specific for TCES. | High. The models are fundamental and so relevant at all scales from crystal/grain (some nm) up to full-scale plants (some metres).  | Medium. The models are generally relevant but scale-up will require some reworking.   |
|                      | Compatibility with the project goals<br>(High/Medium/Low)                        | [1]: Low                  | High. These models have been critical for unit design.   | High. The kinetics are crucial to the success of SOCRATCES and the model is applicable. The models were a key part of D3.2.   | High. The heat transfer inside the calciner is crucial for calcination to occur. The geometry is new so there are no older models to fall back on.          |
|                      | Ability to be modified and validated with experimental data<br>(High/Medium/Low) | [1]: High                 | High. These models will use process data to be improved.   | High. The kinetic models are of a flexible format which allows fitting of experimental data to modify the 2-3 parameters. These parameter values are then used for predictions. | High. The model should be modified to take account of real process data when they are available. The model is easily configurable to accommodate these data |
|                      | Long term effect and the impact on system complexity                             | [1]: High                 | High. It is necessary for the better design of the process   | High. Although the models themselves are complex, understanding the kinetics reduces the uncertainty elsewhere in the process.  | Medium. Little effect on system complexity, but important for the long-term development of the technology.  |
|                      | Reliability<br>(High/Medium/Low)   | [1]: Medium               | TBD during the operational period.   | TBD during the operational period.  | TBD during the operational period.  |

<sup>5</sup> [1] Reich L., Design and Modelling of a Solar Reactor for Thermochemical Carbon Dioxide Capture, Thesis, Univ. Minnesota, 2015

| WP3- DESIGNS         |  | INNOVATIONS                                     |  |  |  |  |   |   |
|----------------------|--|---|--|--|--|--|---|---|
| Criteria             | Indicators                               | BENCHMARKING <sup>6</sup>                       | 01_2   | 05_16  | 06_18  | 14_28  | 14_29   | 01_32   |
| Technical Innovation | Effectiveness<br>(High/Medium/Low)       | [1]: 96% calcined                               | High. The design should be effective at calcining, but questions remain about whether the bed can be sufficiently penetrated by the radiation.                   | High. The design should allow flash calcination of sorbent, reducing the time spent at the harsh conditions which cause annealing and sintering. The small size of the particles reduces the amount and effect of any attrition. | High. As a result of their being optimum, they will be effective.  | Reactor design for agglomeration avoidance.  | Solids flow distribution for decreasing fouling in the reactors.  | High. The design should be effective at calcining, but questions remain about whether the high CO2 mass flow at high temperature can be conveyed to the reactor |
|                      | Efficiency<br>(High/Medium/Low)          | [1]: 31%  | Medium. While the solar energy can be well distributed, the nature of the bed may cause the top layer to be sintered while the bottom layer is still uncalcined. | Medium/high. The concept should be able to provide a cavity wall at a temperature which allows for high heat transfer. Some losses will occur out of the cavity aperture.  | High. As a result of their being optimum, they will be efficient. (There may, however, be some trade-off with effectiveness.)              | High. The CaCO3 sorbents have the tendency to agglomerate due to cohesive forces at elevated temperatures. An effective reactor design should reduce this phenomenon avoiding further risks. | Medium. Materials deposition on the heat transfer surface could reduce thermal transfer efficiency. Modelling of fouling in the reactors would mitigate risks during operation. | Medium. Not yet evaluated at this stage   |
|                      | Novelty<br>(High/Medium/Low)             | [1]: High                                       | High. This is a new invention that is not seen elsewhere.  | High. This is a new invention that combines two fields (flash calciners and CSP) in a new way  | Medium. The conditions will be new, but the concept of running at optimum conditions is a long-held approach.                              | High. Agglomerated large sorbents particles may significantly drop the efficiency due to difficult convention and lower reaction rates in the reactors.                                      | Low. The efficiency is not significantly affected as the fouling is controlled.   | High. No previous solar receivers based on this technology  |
|                      | Implementation cost<br>(High/Medium/Low) | [2]: 85 €(2018) per tonne lime at 25 MWth scale | Medium. There is significant cost in installing vibration units, but the rest will be relatively cheap   | Low. It is a double-walled vessel made of steel.   | Low. There will be some initial outlay to determine these conditions, but after that the cost is zero but the returns could be very large. | Medium. This is an invention related mainly to the carbonation reactor and the outlet conditions of the materials.   | Medium. Similar CFD studied have been done in the past for different systems, such as fouling in heat exchangers.   | Medium. Not yet evaluated at this stage   |

<sup>6</sup> [1] Meier et al., "Multitube Rotary Kiln for the Industrial Solar Production of Lime", Transactions of the ASME, August 2005 Vol 127, p386-395

[2] Meier et al., "Economic evaluation of the industrial solar production of lime", Energy Conversion & Management, Vol 46 Issue 6, April 2005, P905-926

| WP3- DESIGNS |   | INNOVATIONS                   |  |   |  |   |  |   |
|--------------|---|-------------------------------|--|---|--|---|--|---|
| Criteria     | Indicators  | BENCHMARKING                  | 01_2   | 05_16   | 06_18  | 14_28   | 14_29  | 01_32   |
|              | Ease of implementation<br>(High/Medium/Low)                             | [1]: Medium                   | Medium. While the design is theoretically simple, running a vibratory table at high temperature an airtight environment with powder may present significant operability challenges | Medium. It is easy to install, but there is a need to carefully control the CSP beams to spread the energy around the cavity wall   | Unknown. The optimum conditions need to be specified, and the ability to run at them will be tested in the pilot.  | Medium. The reactor outlet part should operate as a heat exchanger for materials cooling below the agglomeration temperature. | Low. CFD studies and lab-scale experiments are needed.   | Medium. Not yet evaluated at this stage   |
|              | Applicability and suitability at a different scale<br>(High/Medium/Low) | [1]: Low                      | Medium. The process is scalable but is modular, i.e. there would be relatively small savings from scale.   | High. The design is more suited to larger size systems, where the cavity can be made larger whilst keeping the >900 C temperature required for calcination. This would increase residence time. | Medium. Whilst the fundamentals of an optimum condition for calcination are easy to determine, the exact heating rates, powder flow rates per unit area etc will vary according to scale. Process model validation using pilot scale data will help to increase the applicability. | Medium. The complexity of design could be elevated by incorporating heat integration of other streams.                        | Medium. CFD modelling is a common tool for modelling such phenomena.   | Not applicable.   |
|              | Compatibility with the project goals<br>(High/Medium/Low)               | SOCRATCES Description of Work | Medium. While it should calcine, it is not of flash calciner design as per the grant   | High. The design fulfils all requirements of the specification as set out in the grant  | High. Optimal conditions will increase efficiency and thus the relevance of the process to commercial scale up activities.   | High. The process is considered scalable.   | High. CFD modelling could be applied at different scales providing reliable results.   | Not applicable.   |
|              | Sensitiveness to changes in operating conditions<br>(High/Medium/Low)   | [1]: High                     | Medium. All systems involving high temperature calcination are sensitive to such changes; 10 C can double (or halve) reaction rates  | Medium. All systems involving high temperature calcination are sensitive to such changes; 10 C can double (or halve) reaction rates   | Low. The optimum conditions are not affected by non-optimal conditions.  | High. Limestone should be conveyed without problems from one reactor to the other.  | Medium. Fouling is not a risk directly related to SOCRATCES. Despite that, the project aims at identifying risks related to higher TRLs. | High. The control of the different gas injections must allow to give a rapid respond to changes in operating conditions |

| WP3- DESIGNS         |  | INNOVATIONS  |   |  |  |   |  |   |
|----------------------|--|--------------|---|--|--|---|--|---|
| Criteria             | Indicators   | BENCHMARKING | 01_2  | 05_16  | 06_18  | 14_28   | 14_29  | 01_32   |
| Technical Innovation | Long term effect and the impact on system complexity             | [1]: High    | Medium. If the operability issues become challenging, the system complexity could rapidly increase.     | Medium. Although the calciner will stay relatively simple, there are knock-on effects for the solar field. These should be easier to overcome in a field-scale trial | High, but in a positive way.   | High. Agglomeration is significantly affected by temperature when the sorbent is in the carbonated form.                  | Medium. Operating conditions are expected to affect fouling. The modelling should be conducted taking into account different operating conditions. | Medium. If the operability issues become challenging, the system complexity could rapidly increase. |
|                      | Reliability (High/Medium/Low)                                    | [1]: Medium  | Medium. Operability of the vibratory tables in a dust-laden, air-tight environment will be a challenge. | Low/Medium. The CSP-cavity interface is the key in this system, and must be kept in an operable state  | Not applicable.  | High. It is crucial for the normal operation of the systems. The complexity is not expected to be significantly elevated. | Medium. Modelling of fouling will give information regarding systems maintenance.  | Medium. Not yet evaluated at this stage   |
|                      | Ability to be validated with experimental data (High/Medium/Low) | [1]: High    | High. If built, the results could be validated quickly and easily.                                      | High. When built, the results could be validated quickly and easily.   | High. The fingerprinting exercise (running the calciner at a range of temperatures and flow rates) will quickly validate whether the optimal conditions predicted by modelling are indeed optimal. | Medium. The agglomeration phenomena have to be tested during the prototype system operation.                              | Medium/High. CFD models are considered reliable as they have successfully used in the past.  | Low. Not yet evaluated at this stage  |

| WP3- STUDIES         |  | INNOVATIONS                   |   |   |
|----------------------|--|-------------------------------|---|---|
| Criteria             | Indicators   | BENCHMARKING <sup>7</sup>     | 10_24   | 14_27   |
| Technical Innovation | Effectiveness (High/Medium/Low)  | [1], [2]: Medium              | High. Studies have shown that calcination and carbonation are significantly faster in a fluidised bed when sound assisted.  | High: There are a range of sorbents which could hold greater residual carrying capacity than natural limestone. |
|                      | Novelty (High/Medium/Low)  | [1], [2]: Medium              | Medium. Sound-assisted trials in FBs have been performed on fluidised beds before, but not in a CSP context   | High. Many of these materials have not been studied for this particular use before.                             |
|                      | Relevance to resulting designs/reactions/processes (High/Medium/Low)               | [1], [2]: Medium              | Medium. This is mainly relevant to calcination and carbonation in fluidised beds but there are some applications in drop tube reactors which should be studied further. | High. They are carbonate materials (at least in part), so can be calcined and recarbonated.                     |
|                      | Applicability and suitability at a different scale (High/Medium/Low)               | [1], [2]: Medium              | High. This technology is easily scalable.   | High. Simply more sorbent is required, and the amounts available are high.                                      |
|                      | Compatibility with the project goals (High/Medium/Low)                             | SOCRATCES Description of Work | Medium. Although it improves calcination and carbonation, it is relevant to fluidised beds which are not being used in the project.                                     | High. The project has a specific mandate to study alternatives to limestone                                     |
|                      | Ability to measure a wide range of relevant operating conditions (High/Medium/Low) | [1], [2]: Medium              | High. The frequency and amplitude can be altered to account for different particle properties or gas densities.   | High. These sorbents are generally relevant over the same operating conditions as limestone.                    |

<sup>7</sup> [1] Raganati et al., Role of Acoustic Fields in Promoting the Gas-Solid Contact in a Fluidized Bed of Fine Particles, KONA Powder and Particle Journal No. 32 (2015) 23-40  
 [2] Sakellariou et al., Calcium oxide-based materials for thermochemical heat storage in concentrated solar power plants, Solar Energy 122 (2015) 215-230

| WP4- INTEGRATION     |  | INNOVATIONS               |   |              |
|----------------------|--|---------------------------|---|--------------|
| Criteria             | Indicators   | BENCHMARKING <sup>8</sup> | 02_6  | 08_19        |
| Technical Innovation | Efficiency (High/Medium/Low)   | 8-15 % [1,2,3]            | 13-19%  | 18%          |
|                      | Novelty (High/Medium/Low)  | High [6]                  | High. The integration is done with a newly proposed approach [7]                              | High         |
|                      | Implementation cost (High/Medium/Low)                                | 5-15 USD/kW [4,5]         | 12-18 kUSD /kW  | 10-12 USD/kW |
|                      | Ease of implementation (High/Medium/Low)                             | High [6]                  | Medium. An heat exchanger network has to be built in order to optimally recover thermal power | High         |
|                      | Applicability and suitability at a different scale (High/Medium/Low) | High [6]                  | High. The model is scale independent  | High         |
|                      | Sensitiveness to changes in operating conditions (High/Medium/Low)   | Low [6]                   | Low. The model allows taking into account different operating conditions                      | High         |

| WP4- CARBONATOR      |  | INNOVATIONS               |              |       |
|----------------------|--|---------------------------|--------------|-------|
| Criteria             | Indicators   | BENCHMARKING <sup>9</sup> | 08_20        | 08_21 |
| Technical Innovation | Efficiency (High/Medium/Low)   | 40% at 4 m [7]            | ~ 80% at 2 m | N/A   |
|                      | Novelty (High/Medium/Low)  | High [7]                  | High         | Low   |
|                      | Ease of implementation (High/Medium/Low)                               | Low [7]                   | High         | Low   |
|                      | Applicability and suitability at a different scale (High/Medium/Low)   | Medium [7]                | High         | High  |
|                      | Sensitiveness to changes in operating conditions (High/Medium/Low)     | High [7]                  | High         | High  |
|                      | Long term effect and the impact on system complexity (High/Medium/Low) | High [7]                  | Low          | Low   |

<sup>8</sup> [1] Müller-Steinhagen, H. & Trieb, Franz. (2004). Concentrating solar power, - A review of the technology. Ingenia. 18. 43-50.

[2] Ehrhart, B., and D. Gill. "Evaluation of annual efficiencies of high temperature central receiver concentrated solar power plants with thermal energy storage." Energy Procedia 49 (2014): 752-761.

[3] González-Roubaud, Edouard, David Pérez-Osorio, and Cristina Prieto. "Review of commercial thermal energy storage in concentrated solar power plants: Steam vs. molten salts." Renewable and sustainable energy reviews 80 (2017): 133-148."

[4] IRENA, IREA. "Renewable power generation costs in 2014." (2018): 160.

[5] Philibert, C. "Technology roadmap: solar thermal electricity—2014 edition." IEA, Paris, France (2014).

[6] Fischer Tropsch Reactor with Integrated Organic Rankine Cycle," MIT, 2019. [Online]. Available: <http://tlo-dev.mit.edu/technologies/fischer-tropsch-reactor-integrated-organic-rankine-cycle>.

<sup>9</sup> [7] E. Karasavvas et al, "SOlar Calcium-looping integRation for Thermo-Chemical Energy Storage (SOCRATCES) Deliverable D2.2 Carbonator model," 2019.

| WP4- STIRLING        |  | INNOVATIONS                |  |   |                     |                     |
|----------------------|--|----------------------------|--|---|---------------------|---------------------|
| Criteria             | Indicators   | BENCHMARKING <sup>10</sup> | 02_7   | 02_8  | 08_22               | 08_23               |
| Technical Innovation | Efficiency of the Stirling system<br>(High/Medium/Low)               | 8-18% [8]                  | 10-20 %  | 10-20 %   | Up to 30%           | Up to 35%           |
|                      | Novelty (High/Medium/Low)  | Low [11]                   | High. An approach for the topology improvement is proposed                                       | Medium.   | High                | Low                 |
|                      | Implementation cost of the Stirling system<br>(High/Medium/Low)      | 28,440€ /1kW engine [9]    | 15,000-30,000 € /1kW engine  | 15,000-30,000 € /1kW engine   | 15,000€ /1kW engine | 10,000€ /1kW engine |
|                      | Ease of implementation<br>(High/Medium/Low)                          | High [8]                   | Medium. The design of the heat exchanger must be changed   | Medium  | Low                 | High                |
|                      | Applicability and suitability at a different scale (High/Medium/Low) | Low [10]                   | Medium. The new design can be applied to different system sizes                                  | Medium. In case of smaller size, it is more difficult to find absorption chiller. | Medium              | High                |
|                      | Compatibility in integration<br>(High/Medium/Low)                    | Low [8,10]                 | High. The heat exchanger can be easily included in a new system design                           | High  | High                | High                |
|                      | Sensitivity to changes in operating conditions (High/Medium/Low)     | High [10]                  | Medium. In case of different operating condition, the optimal design could be slightly different | Medium.   | Medium              | Medium              |

<sup>10</sup> [8] M. Eusha and C. Ortiz, "SOlar Calcium-looping integRation for Thermo-Chemical Energy Storage (SOC RATCES) Deliverable D4.3 Stirling Engine Integration," 2019.

[9] G. Lubbers, Quotation for Stirling Engine, Doetinchem: Microgen Engine Corporation, 2019.

[10] E. Guelpa, U. Tesio and V. Verda, "SOlar Calcium-looping integRation for Thermo-Chemical Energy Storage (SOC RATCES) Deliverable D4.1 Power Cycle: Schemes, models and analysis," 2019.

[11] W. Aldayleh and A. Alahmer, "Recovery of Exhaust Waste Heat for ICE Using the Beta Type Stirling Engine," Journal of Energy, 2015.

| WP5- CONTROL         |   | INNOVATIONS   |   |   |   |   |
|----------------------|---|---|---|---|---|---|
| Criteria             | Indicators  | BENCHMARKING <sup>11</sup>  | 01_4  | 03_9  | 04_14   | 13_26   |
| Technical Innovation | Effectiveness<br>(High/Medium/Low)                                      |   |   |   | High. In case of a successful MPC development it is expected that the effectiveness regarding the efficiency of the plant and regarding the scalability would be very high. | In case of a successful development it is expected that the effectiveness regarding the efficiency of the plant and regarding the scalability would be very high.   |
|                      | Efficiency<br>(High/Medium/Low)   |   |   | It is expected that the efficiency of the plant is not increased significantly. The main advantages is that the MI program can be used for different process control task | High. MPC strategies will enhance efficiency of the process as also will optimize the dynamics until a steady state is reached.   | It is expected that the efficiency of the plant is not increased significantly. The main advantages are that the MI program can be used for different process control task  |
|                      | Novelty<br>(High/Medium/Low)  | [1]   | High. The main innovation as there is not a control system developed specifically for these types of installations. | High. The main innovation as there is not a control system developed specifically for these types of installations.   | High. It is the main innovation. It is a novel approach for controlling the carbonator operation.   | High. The synonym AI <sup>12</sup> is used for several kind of method. Special in control technics artificial intelligence like FUZZY logic is used since a long time but specially machine learning is quite new for process control |
|                      | Implementation cost<br>(High/Medium/Low)                                | Medium. Not yet evaluated at this stage for similar installations |   |   | Medium. It is assumed that the implementation cost of a MPC strategy will require additional cost in PM and computers.  | It is assumed that an additional well performed computer for about 1500€ is needed. This cost could be covered within the budget. Further costs are not expected.   |
|                      | Ease of implementation<br>(High/Medium/Low)                             |   | The hardware implementation is quite simple. The human effort (programming) can't be predicted at the actual state. | The hardware implementation is quite simple. The human effort (programming) can't be predicted at the actual state.   | Medium. There is not benchmarked to compare   | The hardware implementation is quite simple. The human effort (programming) can't be predicted at the actual state.   |
|                      | Applicability and suitability at a different scale<br>(High/Medium/Low) |   | High. Applicable at all scale. Once the AI mechanism is set up it can be used for any scale without any changes.    | High. Applicable at all scale. Once the AI mechanism is set up it can be used for any scale without any changes.  | High. MPC strategies can be implemented also at different scales  | High. Applicable at all scale. Once the AI mechanism is set up it can be used for any scale without any changes.  |
|                      | Respond to operational conditions changes                               |   |   |   | High. Very sensitive control strategy   | Reduction of the time of transient processes  |

<sup>11</sup> There is not any specific control system for this type of installations.

<sup>12</sup> Artificial Intelligence

| WP7                  |  | INNOVATION   |       |
|----------------------|--|--|-------|
| Criteria             | Indicators   | BENCHMARKING [1] <sup>13</sup>                             | 15_30 |
| Technical Innovation | Effectiveness (High/Medium/Low)  | Medium (effective only for large quantities of heliostats) |       |
|                      | Efficiency (High/Medium/Low)   | Low (long travel to standby position)                      |       |
|                      | Novelty (High/Medium/Low)  | Low (typical heliostat control)                            |       |
|                      | Implementation cost (High/Medium/Low)                                  | Low (only programming)                                     |       |
|                      | Ease of implementation (High/Medium/Low)                               | High (remote programming)                                  |       |
|                      | Applicability and suitability at a different scale (High/Medium/Low)   | High (does not change with scale)                          |       |
|                      | Compatibility (High/Medium/Low)  | High (applicable to different receiver types)              |       |
|                      | Sensitiveness to changes in operating conditions (High/Medium/Low)     | Medium (only full on-full off focusing)                    |       |
|                      | Long term effect and the impact on system complexity (High/Medium/Low) | Low (no impact on system complexity)                       |       |

Noticed that the innovation within WP7 has not been evaluated yet because the work has already started.

<sup>13</sup> [1] Osunaa R., Olavarría R., Morilloa R. et al. (2006). PS10, Construction of a 11MW Solar Therman Tower Plant in Seville, Spain

During the following year, after the construction and implementation phase of the prototype, the ideas will be evaluated again following a quantitative criterion as follows:

|             |          |          |          |              |
|-------------|----------|----------|----------|--------------|
| <b>5</b>    | <b>4</b> | <b>3</b> | <b>2</b> | <b>1</b>     |
| <b>Best</b> |          |          |          | <b>Worst</b> |

Likewise, the rest of criteria: Environmental, Economic and Social, will be evaluated the next year based on the outputs of the work from WP8, mainly the deliverables Deliverable 8.3 *First report on Life Cycle Assessment*, Deliverable 8.5 *First report on Life Cycle Cost Analysis* and D8.8 *Market Analysis*.

Furthermore, during the next year, the partners will be requested to accomplish the DG Connect Innovation Questionnaire which has been adapted to an online version by BIOAZUL.

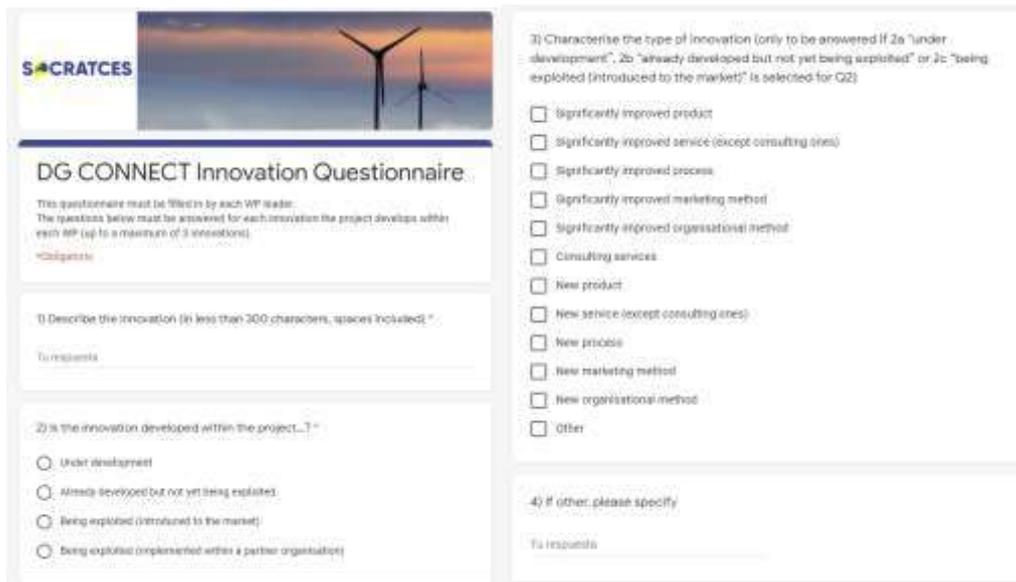


Figure 1: Screenshots online Innovation Questionnaire

The aim is to obtain consolidated results about the raised innovations after the development and implementation of the prototype. The online questionnaire allows us to get the information more comprehensive in a visual way, as the follows examples.

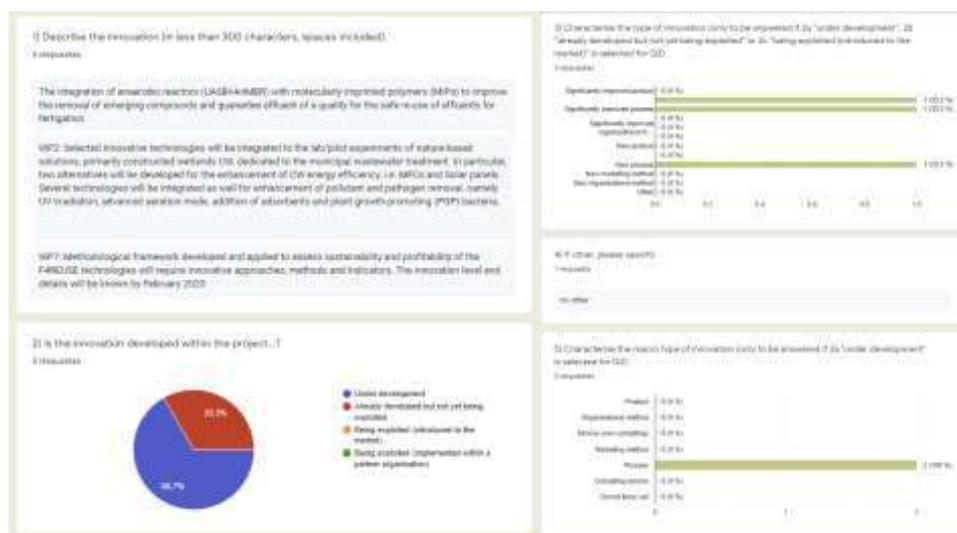


Figure 2: Screenshots results of an online Innovation Questionnaire

## CONCLUSION

After 24 months of work the SOCRATCES consortium is really excited about the possibilities to further research, development and exploitation of the results to our work. The research made during the first two years brings us to assume the design and implementation plan for the prototype and its test phase.

At this stage the **33 innovations** described by the partners has been evaluated according to specific references and technical indicators with high potential for most of them. The next implementation and test phase of SOCRATCES could help the consortium to identify each of them which could reach the market in a short time and which could be used as innovation ideas for further research. In all cases the consortium is very excited about the huge possibilities that the project brings to the centres and companies involved in the work.

Finally, the project has asked for the Dissemination and Exploitation Booster services to support these activities and it is waiting for the resolution, the requested services included:

- identifying and creating the portfolio of R&I project results.
- helping projects from the portfolio to design and execute a portfolio dissemination plan.
- assisting projects to improve their existing exploitation strategy.

Moreover, for the selected innovations a deeper risk analysis and resource allocation needed could be performed for the project SMEs and industries to take a decision on how to continue once the project is over.