Grant Agreement No. 727348

Project Acronym:

SOCRATCES

Project title:

SOlar Calcium-looping integRAtion for Thermo-Chemical Energy Storage.

DELIVERABLE D8.1

First Innovation Evaluation report

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Project Coordinator:	USE		
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INTRODUCTION

This report is framed in the ***Task 8.5 Innovation management activities*** of WP8. 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.

Why is it important to manage the project innovations properly? Innovations are one of the main factors driven the growth and economic competitiveness of companies and industries. But it has to be carefully decided which are those that have a real potential to be further developed as innovation projects are strong consumers of resources and efforts and their potential benefits occur in most cases in a medium/long-term. This is especially relevant for SMEs where resources (human and economic) are quite limited. Therefore, innovation potential has to be assessed in advance in order to invest in the innovations with the highest expected return.

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.

1. SOCRATCES: OBJECTIVES AND EXPECTED IMPACT

The aim of this section is to provide general information on the SOCRATCES project, its objectives and the expected impacts as foreseen in the DoA.

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	- Prototype demonstration of capacity for energy storage. - Solids and CO2 storage. - Solids conveying and system management. - System tested at TRL5.
	Use of mature inexpensive technologies and materials in solar receiver. Potential for integrating future high temperature developments	- Solar calcination. Integration of already available technology at receiver. - Systems design - CaL attrition control
	T Carbonation (power cycle loop) > 850ºC. High efficiency cycles can be integrated (already commercial as steam) and future ones as SCO2	- Prototype demonstration of high temperature carbonation >850ºC and Striling engine. Integration of already available technology for power block. - Carbonator CO2 closed loop control development
Significant increased technological performance	- Combination of novel (CaL TCES, solar calciner) and commercial technologies (CSP tower plant, fluidized bed reactors,	- Global efficiency: direct integration >46%, indirect integration with high efficiency power block (SCO2)>50%

	pneumatic conveying, gas turbine power cycle). - New conditions for CSP/CaL integration results in high global system efficiency with two possible power block integrations: indirect and direct.	- Reduce prices of receivers by new integration concept on solar-calcination - Tcarbonation>850ºC. High efficiency of power cycle
	Optimized energy storage system. Sensible heat storage plus Thermochemical storage due to $CaCO_3$ endothermic decomposition reaction plus mechanical energy employed for CO_2 compression and extracted from the cycle operation.	- High density energy storage: 3.2 GJ/m3 - Low materials price: <10 €/ton - Highly stable materials: Residual activity >0.5
	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 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 New calcination technology
Contributing to the strengthening the European industrial technology base, thereby creating growth and jobs in Europe	First step to the next generation of SOCRATCES CSP power plants in Europe fully competitive with future fossil fuel plants under market conditions	System tested at TRL5
Increasing the reliability and lifetime while decreasing operation and maintenance costs, hence creating new business opportunities;	- Moderate temperatures at calciner allow using already available receiver technologies - High temperature carbonator in closed CO_2 loop allows the integration of already existing technologies in indirect integration (steam/Stirling) and future ones (SCO2). - Ca-based materials yield limited abrasion compared with other solid particles materials (as SiC)	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	Capacity for long term storage and 24/365 power operation	Operation under **different long term energy storage strategies.**

cost and/or operational costs, hence easing the deployment of renewable energy sources within the energy mix	Optimizing the economic performance under a global approach to all systems (solar field/heat transfer media/ storage/power block)	SOCRATCES costs at commercial scale: Energy Storage <12€/kWh$_{th}$ 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
USE	>6	YES(>2)	Prototype Solar field 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
POLITO	>4	YES (1)	NO	Power block integration/solids conveying/ CO2 storage/ Heat exchangers	>2	-
ZAR	>3	YES (1)	NO	Systems integration/control/ Solids/gas storage/ heat exchangers	>1	-
CERTH	>3	YES (1)	Prototype carbonator reactor	Carbonator design/control	>4	Carbonator reactor
CLX	>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
CSIC	>5	NO	NO	TCES/reactors development/ Solids pneumatic conveying/ CaL attrition / He-Steam calcination	>1	TCES
TTZ	>4	YES (1)	NO	Power block/LCA/ energy integration/ reactors design	>2	Power Unit/ control system/LCA
BIO	NO	NO)	NO	energy integration/ systems management	>1	-
CNR	>3	YES (1)	NO	CaL attrition control /reactors development/ Solids pneumatic conveying	>1	-
VER	>1	NO	NO	SOCRATCES components and global LCC, Risk	>1	LCC, Risk analysis
SPI	NO	NO	NO	SOCRATCES components and global business model	>1	Business Model,
ISI	NO	YES (1)	NO	Control technology/ integration	>1	control system

Partner	Publications	Expected Patents	R&D installations	New Knowledge in	Personnel	Product/ Modules
AUTH	>3	YES (1)	NO	Carbonator design/ CaO sorbents	>2	Carbonator reactor
VM	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.

The current proposal is to develop a multicriteria decision matrix for the quantitative evaluation of the innovation degree/innovation potential of the project INNOVATIONS developed in the different WPs. The work done to prepare the matrix has been structured in the following steps:

2.1. STEP 1: Select the criteria for comparison.

This refers to the criteria to be used for the selection of the innovations. The criteria should take into account several aspects, but the ones considered more relevant are: **engineering specifications** (technical issues) and **customer needs** (economic and market issues).

According to the DoA, the system to be developed should full fill:

- Technical criteria (quantitative)- very much linked to **Task 8.3 and Task 8.4 (both will start at month 21).** Until these tasks begin, the technical criteria have been agreed among the WP leaders. The following table includes the indicators set for the moment:

Criteria	Indicators
Quantitative criteria	
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 (quantitative)- Economic criteria should be in line with the parameters and indicators being used within other tasks within WP8:
  - LCCA (Vertech, **Task 8.2**) such as the costs associated to the life cycle, all the CAPEX (capital-linked expenses) and OPEX (consumption-linked expenses) concerning energy, material, waste, etc.
  - Business plan (SPI, **Task 8.6**) such as those associated to the market demands, legal framework (including standards), etc.

Criteria	Indicators
Quantitative criteria	
Economic innovation	***TCES Investment costs***. Objective defined for SOCRATCES (12€/Kwh_{th}) highly competitive at the moment
	Long term storage / energy. Best performance claimed in projects being developed in 2018: 15 hours/ 1,500 MWh; 10 hours/ 6,000 MWh

	Storage capacity. Objective defined for SOCRATCES (3.2GJ/m3) competitive at the moment
	Levelized cost of energy (LCOE). Depends on the performance of the CSP unit but should be under 73 USD/MWh – best performance in 2018
	O&M costs per kWh. Objective defined for SOCRATCES (53USD/MWh) highly competitive
	Quality of service. Level of importance dependent on the business model to be adopted, as described in Deliverable 8.8

- Environmental criteria (quantitative)- very much linked to **Task 8.1**

Economic and Environmental criteria should be in line with the parameters and indicators being used within other tasks of WP8:

- LCA (TTZ, Task 8.1) such as energy generation/consumption, input & outputs materials and associated environmental releases.
- LCCA (Vertech, Task 8.2) such as the costs associated to the life cycle, all the CAPEX (capital-linked expenses) and OPEX (consumption-linked expenses) concerning energy, material, waste, etc.

Criteria	Indicators
Quantitative criteria	
Environmental innovation	***Cumulative energy demand*** implies the cumulative life cycle energy consumed during product production, use and disposal.
	Depletion potential or amount of key materials consumed, is currently calculated in terms of kg material per kg of the target product. Resources are defined as a fundamental building blocks needed to produce a product (e.g. coal (raw material for electricity manufacturing), oil, gas, sulfur, iron, phosphorus, sand, copper, etc.).
	Emission values are initially calculated separately as water, air, and soil emissions.
	Land Use is an assessment of the environmental impacts on biodiversity through land use and land transformation.
	Toxicity potential should be assessed both for the product and for entire pre-chain chemicals used to manufacture the product.
	Risk potential reflects the danger of accidents in the manufacture, use and recycling of the product. The values used for the individual products are not absolute but only comparative.

- Social criteria (qualitative)

With regards to the Social indicator (qualitative), it has been selected with the inputs from all project partners. For now, only one has been established but with the possibility of increasing the number of indicators throughout the project.

Criteria	Indicators
Qualitative criteria	
Social	***Equity*** (Access to this affordable, viable and sustainable CSP technology regardless of gender, race, age, or any other status)

2.2. STEP2: Select the innovations to be compared.

These would be those innovations resulting from the SOCRATCES WPs. For this, each project partner has identified the innovations that can be extracted from the work carried out in SOCRATCES.

At the beginning of the project, an initial exercise was made to define the possible Key Exploitable Results (KERs) and 22 KERs were identified by the consortium and included within deliverable 1.3.

After a first year of technical work and with the use of the questionnaire developed by the **DG CONNECT Innovation Questionnaire** (ANNEX I), the partners were requested to identify the main innovations as outcomes of their work. In a first approach, project partners have identified **28 innovation** with exploitation potential. The innovations identified are not listed on this report 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.

The questionnaires have been used to characterize these innovations and to assess the maturity of innovations developed within the project. The partners will trace the innovation's evolution during the project duration. The aim will be to define if finally, all these innovations can become key exploitable results (KERs) with real market potential.

2.3. STEP3: Score the selected innovations.

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

It is important to point out that the indicators are likely to vary throughout the work within the project, as the developments are more advanced. Main objective is to fulfil the real market demands. A key point in the review of these indicators will be the work done within the other tasks of WP8.

It is expected that during the first year a first screening of the innovations already detected will be made using a simple matrix; only quantitative criteria will be scored (technical, economic and environmental indicators). In case of equal scores, qualitative criteria can be use (social). Once the score is done, it will be possible to make the selection and give priority to some project innovations.

Possible example of a score matrix:

		Selected Innovations				
Criteria		Idea 1	Idea 2	Idea 3	Idea 4	Idea …
Technical Innovation	Indicator 1					
	Indicator 2					
Economic Innovation	Indicator 3					
	Indicator 4					
	Indicator 5					
Environmental Innovation	Indicator 6					
	Indicator 7					
Social	Indicator 8					

Rank quantitative indicators:

5	**4**	**3**	**2**	**1**
Best				**Worst**

After this first ranking, a more complex model will be used for the SOCRATCES innovations assessment. According to several authors [1][2][3], the following key aspects will be taken into account for the selection of the most appropriate model:

1. **Realism:** related to the real demands of the market and the situation of the company/industry (strategy, available resources, risks, etc.)
2. **Capability:** ability to analyse different types of decision variables and to deal with the several factors (multiple time periods, interest rate changes, etc.)
3. **Flexibility**: reaction capacity to changes within the company and due to external changes (market, legislation).
4. **Use:** Clear, easily understood by all organizational members and rapidly executed.
5. **Cost**: the costs (if any) for the model implementation should be inferior to the potential benefits.

In all cases, it is necessary that the innovation assessment is being performed by a team of decisions makers. At project level, it means that partners working at technical, economic, market, legislation, IPR, levels among others, should work together in order to gather the relevant knowledge and experience, and ensure transparency in the decision-making process.

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

[1] Souder, E. W. A Scoring Methodology for Assessing the Suitability of Management Science Models. Management Science, 18(10), 1972.
[2] Meredith, J. R.; Mantel Jr., S. J. Project Management: A managerial Approach. John Wiley & Sons, Inc., 2009.
[3] Pinto, J. K. Project Management: Achieving Competitive Advantage, Chapter Project Selection and Portfolio Management, pages 70–105. Prentice Hall, 2010.

CONCLUSION

At this early stage of the project, the numbers of innovations identified by project partners is huge and promising. Therefore, it is necessary to assess which ones are those that get higher score according to the defined indicators. For this assessment, technical partners should provide results and evidences based on the work and developments achieved by each technical WP. In addition, results of the LCA (Task 8.1), LCCA (Task 8.2) and Business plan (Task 8.6) will feed the matrix with regards to environmental, economic and market criteria respectively. As already mentioned, main goal is to prioritize such those that fulfil current and bear future market demands, being at the same time aligned to the legal framework (including standards).

A workshop on IP issues will be scheduled in the second year of the project for the partners to better understand the exploitation potential of the project results, the different ways of their protection according to the result nature, the exploitation claims, the ownership and co-ownership, etc. If possible, the project will ask for the BOOSTER Common exploitation services in the future to support these activities.

It has been requested to the coordinator to change the deliverable dissemination level from Public to Confidential in order to include in the deliverable updates detailed information on the innovations selected by the project consortium and their assessment.

ANNEX I

SOCRATCES PROJECT 727348

DG CONNECT Innovation Questionnaire

Note: the questions below are to be answered for **each** innovation the project develops.

1) Describe the innovation (in less than 300 characters, spaces included):

2) Is the innovation developed within the project…:

- (•) a) Under development
- ( ) b) Already developed but not yet being exploited
- ( ) c) being exploited (Introduced to the market)
- ( ) d) being exploited (Implemented within a partner organisation)

3) Characterise the type of innovation (only to be answered if 2a, 2b, or 2c is selected)

- ( ) Significantly improved product
- ( ) Significantly improved service (except consulting ones)
- ( ) Significantly improved process
- ( ) Significantly improved marketing method
- ( ) Significantly improved organisational method
- ( ) Consulting services
- ( ) New product
- ( ) New service (except consulting ones)
- ( ) New process
- ( ) New marketing method
- ( ) New organisational method
- ( ) Other

4) If other, please specify: _____

5) Characterise the macro type of innovation (only to be answered if "under development" is selected for Q2):

- ○ Product
- ○ Organisational method
- ○ Service (non-consulting)
- ○ Marketing method
- ○ Process
- ○ Consulting service
- ◉ Do not know yet

6. Will the innovation be introduced to the market or deployed within a partner:

- ○ (a) Introduced new to the market (commercial exploitation)
- ○ (b) Deployed within a partner (internal exploitation: Changes in organisation, new internal processes implemented, etc.)
- ○ (c) No exploitation planned

7. If no exploitation planned, please explain why no exploitation is planned (answer only if 6(c) is selected)

8. Is there a clear owner of the innovation in the consortium or multiple owners?

- ○ A clear owner
- ○ Multiple owners

9. Indicate who is the "owner" of the innovation:

10. Indicate the step(s) already done (or are foreseen) in the project in order to bring the innovation to (or closer to) the market

	Done	Planned in project	Not Planned	Desirable
1. Technology transfer	☐	☐	☐	☐
2. Engagement by Industrial research team of one of their company's business units in project activities	☐	☐	☐	☐
3. Pilot	☐	☐	☐	x

4. Capital investment (VC, Angel, other)	☐	☐	☐	x
5. Investment from public authority (national, regional)	☐	☐	x	☐
6. Business plan	☐	☐	☐	☐
7. Prototyping	☐	☐	☐	☐
8. Market study	☐	☐	☐	☐
9. Demonstration or Testing activities	☐	☐	☐	☐
10. Feasibility study	☐	☐	☐	☐
11. Launch a start-up or spin-off	☐	☐	☐	☐
12. Other	☐	☐	☐	☐

11. If other, please specify:

12. Indicate which participant(s) is/are the key organisation(s) in the project <u>delivering</u> this innovation. For each of these identify under the next question their needs to fulfil their market potential:

13. Indicate their needs to fulfil their market potential

	Investor readiness training	Investor introductions	Biz plan development	Expanding to more markets	Legal advice (IPR or other)	Mentoring	Partnership with other company (technology or other)	Incubation	Startup accelerator
Org 1	☐	☐	☐	☐	☐	☐	☐	☐	☐
Org 2	☐	☐	☐	☐	☐	☐	☐	☐	☐
Org 3	☐	☐	☐	☐	☐	☐	☐	☐	☐
Org 4	☐	☐	☐	☐	☐	☐	☐	☐	☐
Org 5	☐	☐	☐	☐	☐	☐	☐	☐	☐

14. When do you expect that such innovation could be commercialised? (answer only if 6(a) is selected)

- ○ Less than one year
- ○ Between 1 and 3 years
- ○ Between 3 and 5 years
- ○ More than 5 years

○ Do not know

15. Have any of the project partners…

(only to be answered if "Done" or "Planned in Project" is chosen for 10.5 "Investment from public authority")

☐ already applied for support from private investors?

☐ already applied for investment from public authorities?

☐ been planning to start discussions with private and public investors?

16. Which partners are in discussion with investors (or are planning such discussions)?

17. How does the consortium engage end-users?

○ End user organisation in the consortium

○ An end user organisation outside of the consortium is consulted

○ No end user organisation in the consortium or consulted

18. Are there in the consortium internal IPR issues that could compromise the ability of a project partner to exploit new products/solutions/services, internally or in the market place?

○ yes

○ No

19. Which are the external bottlenecks that compromise the ability of project partners to exploit new products, solutions or services, internally or in the market place?

☐ IPR

☐ Standards

☐ Regulation

☐ Financing

☐ Workforce's skills

☐ Trade issues (between MS, globally)

☐ Others

20. Indicate how many patents have been applied for by the project: