



## **Initiative for Global Leadership in Concentrated Solar Power**

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### **Implementation Plan**

November 2017

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## Introduction

### Integrated SET Plan and the ten key priority actions

The Communication *'Towards an Integrated Strategic Energy Technology (SET) Plan: Accelerating the European Energy System Transformation'*<sup>1</sup> was adopted by the European Commission (EC) on 15 September 2015 to reinforce the SET Plan as the technology pillar of the Research, Innovation and Competitiveness Dimension of the Energy Union. The Communication calls for greater prioritization, integration, coordination and ownership by the SET Plan countries and stakeholders and highlights the need to address gaps, duplications and synergies at the European Union (EU) and national level. To this end it defines 10 key priority actions to accelerate the energy system transformation in a cost-effective way, and calls upon the EC, SET Plan countries and stakeholders to co-operate to implement them.

Ambitious targets have been defined under the ten key priority actions of the SET Plan aiming to maintain (or regain in some cases) EU's global leadership on low-carbon technologies with a particular emphasis on driving their costs down and improving their performance. For example, targets have been set for several renewable energy technologies with significant potential for cost reduction and large-scale deployment worldwide. The process for setting the targets has been highly participative engaging the SET Plan countries and a large number of stakeholders from research and industry.

This joint ownership of decisions on prioritization has enhanced the SET Plan's legitimacy regarding strategic discussion on clean energy innovation at European level. Countries start to recognize the targets set as a strategic input to their energy programmes and policies. It is expected that this greater ownership will translate in a higher level of alignment between EU and national efforts, resulting in a higher impact regarding public investments as well as leverage of private investments.

In order to define the approach to reach the targets, Implementation Plans (IP) are under preparation by Temporary Working Groups (TWG), each led by one SET Plan country<sup>2</sup>. The IPs need to describe what needs to be done, how, by whom and when, and how to monitor progress.

The TWG on Concentrated Solar Power was the first one to be launched. It was set up in April-May 2016, building on previous contacts between stakeholders, the EC and a number of SET Plan countries aimed at discussing an ambitious initiative for global leadership of the European CSP industry. The TWG has worked intensively to deliver this IP, which collects the outcomes of its work and its main recommendations.

### Concentrated Solar Power (CSP) technology

By means of thermal energy storage, CSP [also defined as Solar Thermal Electricity (STE)] can make a significant contribution to the transformation of the European energy system by providing an important share of dispatchable renewable electricity. By providing flexibility for grid services, CSP can facilitate the integration of variable output renewables such as photovoltaic (PV) or wind energy, thereby contributing to the reliability of the transmission grid. The best solar resources for CSP are to be found in Southern Europe, which makes this technology complementary to those renewable energy technologies that find their best resources in other regions of Europe.

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<sup>1</sup> C(2015) 6317 final

<sup>2</sup> The TWGs are formed by countries interested in a particular action, stakeholders and the European Commission.

CSP will give a significant contribution to help meet the energy needs of large parts of the world, creating a potentially very important export sector for the European industry and supporting the decarbonisation agenda of the Paris Agreement. According to the forecasts of the International Energy Agency (IEA), CSP could account for up to 11% of the electricity generated worldwide and up to 4% of the electricity generated in Europe by 2050. The market potential worldwide is substantial and this justifies the efforts to maintain the current competitive advantage of the European industry in terms of both installed capacity in Europe and global market share of European companies.

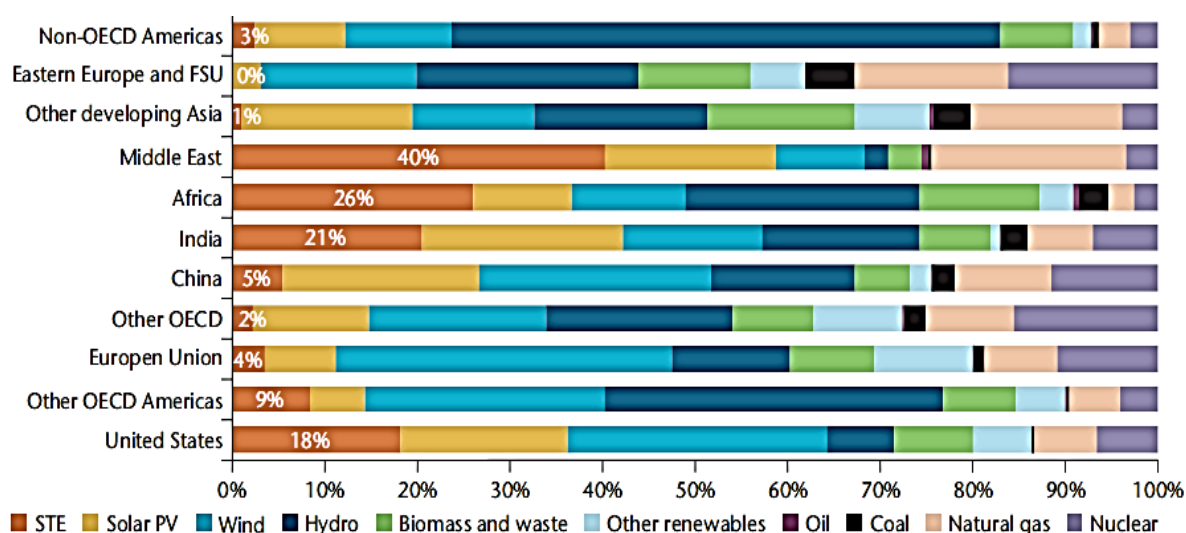


Figure 1 - IEA 2050 Roadmap – Generation mix in %

The European industry is global leader in CSP, with European entities involved in most of the projects developed so far worldwide. Yet, in order to maintain this global leadership, the European industry needs to stay ahead with more advanced, competitive technologies. Other countries are stepping up technology and commercial efforts in this field considerably, all targeting the same world markets as the European industry. In addition, innovation (i.e. new technologies reaching the market) needs to take place in Europe again, to maintain the confidence on European technologies of the international investors and promoters abroad. This is a very distinctive and crucial need of the CSP sector. There is a clear market failure in Europe to bring new CSP technologies to the market (to move new technologies from demonstration to first-of-a-kind commercial scale plants).

A further aspect is that a substantial capacity in conventional power plants will need to be shut down over the next years, especially in Southern Europe, because it reaches the end of its useful lifetime. This can be a turning point for rebalancing the ratio between variable output renewables and dispatchable renewables in the European power system.

CSP innovation needs, therefore, to be reactivated and for this it is necessary to reduce costs via a combination of technology improvements, volumes deployed (learning curve and economies of scale) and risk-financing to support innovation projects. In addition, it is necessary to improve other framework conditions for first-of-a-kind demonstration projects and subsequent market deployment, including the ability to supply dispatchable electricity generated by CSP plants from Southern Europe to Central/Northern Europe, thereby facilitating CSP access to new markets.

### SET Plan strategic targets on CSP

The EC proposed targets for the CSP technology in an Issues Paper published in October 2015. Comments (Input Papers) were received from the European Solar Thermal Electricity Association (ESTELA), the European Association of Gas and Steam Turbine Manufacturers (EUTurbines), the Joint Programme on CSP/STE of the European Energy Research Alliance (EERA) (the three organizations provided a joint set of comments), from the European Platform of Universities in Energy Research & Education (EUA-EPUE) and from the Spanish company IBERDROLA. The SET Plan countries, representatives from the stakeholders and the EC eventually reached an agreement on the targets in January 2016 and committed to the preparation of an Implementation Plan. The targets for CSP are so defined:

#### Agreed Strategic Targets on CSP

1. Short-term: > 40% cost reduction by 2020 (from 2013) translating into
  - Supply price\* < 10 c€/kWh for a radiation of 2050 kWh/m<sup>2</sup>/year (conditions in Southern Europe)
2. Longer-term: develop the next generation of CSP/STE technology
  - New cycles (including supercritical ones) with a first demonstrator by 2020, with the aim to achieve additional cost reductions and opening new business opportunities.

\* The supply price is meant to be the targeted price within Power Purchase Agreements (PPA) with a duration of 25 years

It should be stressed that the CSP target cost for 2020 refers to dispatchable electricity. This is very important to note when comparing it to variable-output power from other renewable energy sources. Therefore, it should be clarified that this target is linked to large plants with storage – large plants because scalability will be crucial to reach the targets. If the cost target is reached, CSP can become competitive in Europe with utility-scale PV and on-shore wind: CSP will offer a higher value thanks to its dispatchability and considering also that no grid and conventional-plant back-up costs are necessary.

### Temporary Working Group to prepare the Implementation Plan to reach the targets

In April 2016 a TWG was set up, led by Spain as Chair and assisted by the EC, to prepare the IP. The TWG is formed by representatives from a number of SET Plan countries, the EC and the stakeholders (both industry and research)<sup>3</sup>. The launch of the TWG was published on the website of the Strategic Energy Technologies Information System (SETIS) and any stakeholder active in the sector was invited to participate<sup>4</sup>.

The Chair proposed to the TWG a number of topics for discussion:

- General matters, objectives, governance, and functioning of the TWG. Members (involvement and transparency).

<sup>3</sup> The TWG on CSP includes representatives of: Spain (Chair), Belgium, Cyprus, France, Germany, Italy, Portugal, Turkey, the European Commission, the European Solar Thermal Electricity Association, the European Association of Gas and Steam Turbine Manufacturers and the Joint Programme on CSP/STE of the European Energy Research Alliance.

<sup>4</sup> <https://setis.ec.europa.eu/implementing-integrated-set-plan/no-1-renewables-ongoing-work>

- Priority technology actions: Actions on the various components of a CSP plant needed to reach the targets.
  - Actions to address both high Technology Readiness Levels (TRLs) for 2020 and new technologies for beyond 2020
  - Informed by the SET Plan Integrated Roadmap
- Demonstration projects at commercial scale with high potential of replication
- Non-technological actions: framework conditions
- Support to internationalization: international cooperation can bring substantial benefits, including in terms of new CSP cycles
- Options for implementation instruments

The outcome of the discussions on these 'building blocks'/topics is addressed in the following chapters. The TWG considers that these 'building blocks'/topics form a unity/'package' of integral actions needed to ensure that the targets are reached. Each topic supports and is supported by the others and well-thought implementation instruments are required.

## Priority technology actions (R&I Activities)

### The process to define the priority technology actions (R&I Activities)

According to the 'building blocks'/topics proposed by the Chair, the TWG had to determine the priority technology actions on the various components of a CSP plant (solar field, reflecting surfaces, receiver, transfer fluid, storage, power block, system integration) needed to reach the targets. Actions should address both high TRLs for 2020 and new technologies – cross-fertilization, breakthroughs – for 2025-30.

Informed by the list of R&I actions on CSP included in the document "Towards an Integrated Roadmap: Research Innovation Challenges and Needs of the EU Energy System" ('Integrated Roadmap')<sup>5</sup>, the EC proposed to the TWG a draft list of priority technology action areas. This list included a portfolio analysis (Figure 2) that weighted all the Integrated Roadmap actions against the two strategic targets on CSP. The list covered the three categories of TRLs of the Integrated Roadmap: (i) Advance Research Programme, (ii) Industrial Research and Demonstration Programme and (iii) Innovative and Market Uptake Programme.

Integrated Roadmap Action Advanced Research Programme	Potential contribution to strategic target 1	Potential contribution to strategic target 2
Action 1: More efficient components – HTF, receivers, reflecting surfaces	5	4
Action 2: Reliability of CSP plants	3	3
Action 3: Hybridization of CSP plants	4	4
Action 4: Storage systems	5	5
Action 5: Water consumption	1	1
Action 6: Weather forecasting	3	3

Integrated Roadmap Action Industrial Research and Demonstration Programme	Potential contribution to strategic target 1	Potential contribution to strategic target 2
Action 1: More efficient components – HTF, receivers, reflecting surfaces	5	4
Action 2: Reliability of CSP plants	3	3
Action 3: Hybridization of CSP plants	4	5
Action 4: Storage systems	5	5
Action 5: Water consumption	1	1

Integrated Roadmap Action Innovative and Market Uptake Programme	Potential contribution to strategic target 1	Potential contribution to strategic target 2
Action 1: Cooperation Mechanisms	5	3
Action 2: European Standards	2	2

Figure 2 - Summary of the portfolio analysis based on the Integrated Roadmap

The TWG confirmed the analysis made by the EC leading to three main priority action areas: (1) storage systems, (2) more efficient components (optical solutions/concentrators, receivers, heat transfer fluids and turbines), and (3) integration and hybridization (priority given to hybridization with renewable resources such as biomass and geothermal).

<sup>5</sup> <https://setis.ec.europa.eu/set-plan-process/integrated-roadmap-and-action-plan>

After completing the analysis of the actions contained in the Integrated Roadmap, the TWG examined some additional technology action areas which were proposed by EUTurbines. These aimed (i) to provide additional flexibility to CSP plants and thus to the energy system, and (ii) to achieve additional, longer-term cost reductions by means of cross-fertilization of technology applications in other areas with a view to develop new CSP cycles (e.g., cycles using supercritical steam). Turbines are a crucial component in CSP plants but so far only few joint R&I efforts have been attempted between the CSP and the turbine manufacturing sector. Both sectors agree that by joining R&I efforts important additional cost reductions and efficiency improvements can result. Independently from types of solar collectors and configurations, CSP poses a number of challenges to turbine design due to differences in temperature and pressure as compared to other turbine applications. The TWG agreed on the merits of including the following two additional priority technology action areas: (4) application of supercritical steam turbines to CSP technology, and (5) development of advanced concepts for improved flexibility and efficiency in CSP applications.

Figure 3 depicts the priority technology areas agreed by the TWG.

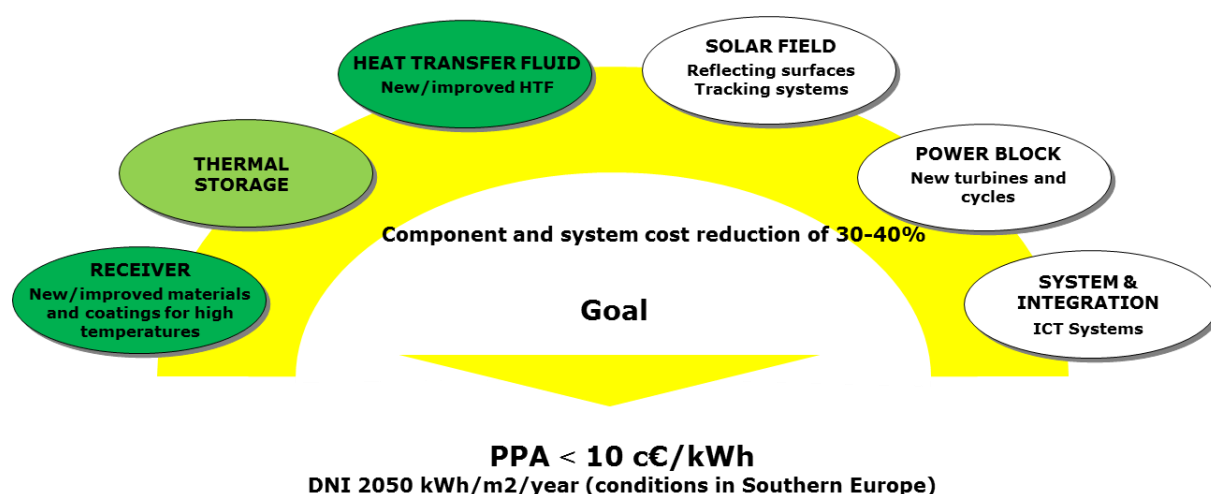


Figure 3 - Main elements of a CSP plant that hold potential for cost reduction



### The R&I Activities

Following the discussions in the TWG, eighteen industrial players and sixteen research centres worked on defining specific R&I Activities to be included in the Implementation Plan. Twelve R&I Activities were eventually identified and ranked according to their potential contribution to achieve the targets.

Ranked list of R&I activities	
Ranking	List of R&I Activities to reach the targets
1	Activity 5: Improved central receiver molten salt technology
2	Activity 3: Parabolic trough with silicon oil
3	Activity 6: Next generation of central receiver power plants
4	Activity 1: Advanced linear concentrator Fresnel technology with direct molten salt circulation as heat transfer fluid and for high temperature thermal energy storage
5	Activity 2: Parabolic trough with molten salt
6	Activity 4: Solar tower power plant to commercially scale-up and optimize the core components of the open volumetric air receiver technology
7	Activity 8: Multi-tower central receiver beam down system
8	Activity 9: Thermal energy storage
9	Activity 10: Development of supercritical steam turbines optimised for the specifics of CSP applications
10	Activity 11: Development of advanced concepts for improved flexibility in CSP applications
11	Activity 12: Development and field test of CSP hybrid air Brayton turbine combined cycle sCO <sub>2</sub> systems
12	Activity 7: Pressurized air cycles for high efficiency solar thermal power plants

**Table 1 – The ranked list of R&I Activities**

The R&I Activities are described in Annex I as part of the Implementation Plan. The analysis by the industrial players and research centres on the R&I Activities and on the process to identify them is included as Annex II.

## Demonstration projects at commercial scale

### Context for the demonstration projects at commercial scale

In the CSP sector there is at present a serious market failure in Europe to move new technologies from demonstration to first-of-a-kind commercial-scale plants (FOAKs). As a result the market introduction of new CSP technologies developed in Europe is currently taking place in other continents. However, having innovation taking place and tested in Europe is essential for the European industry to keep sustained global leadership. CSP innovation, now in a stand-still in Europe, needs therefore to be reactivated.

It should be noted that given the important amount of engineering involved in CSP plants, the industry estimates that the first replication of a FOAK (what could be referred to as the 'second of a kind') could achieve additional cost reductions of about 10-20% thanks to the learning curve only – which would diminish the amount of innovative financing support required for subsequent replications. Another crucial element is dispatchability, which is the key asset of CSP. If adequately valued by the market, dispatchability could indeed allow CSP plants owners to have access to more favourable Power Purchase Agreements.

The TWG concluded that FOAKs are a fundamental step to re-activate the deployment of CSP in Europe and that priority should be given to deployment efforts that demonstrate the validity of the cooperation mechanisms set out in the Renewable Energy Directive. This in particular was considered very important by the industry, since the cooperation mechanisms may allow to involve a large number of European countries in this technology, leading to further deployment in Europe.

### Main requirements for demonstration projects at commercial scale

The TWG agreed that the FOAKs should meet the following requirements:

- Demonstrate at commercial scale crucial technology solutions to reach the targets
- Include storage in order to provide fully dispatchable power, and to allow for more flexible generation
- Have a high potential of replication in Europe or other world regions
- Make use of the cooperation mechanisms of the Renewable Energy Directive ( thereby facilitating access to new markets in Europe)
- Combine innovative financial instruments (e.g. loans, loan guarantees) complementing grants and structural funds (together with the equity side by the promoters in project finance)
- Have a business plan which includes an agreement with an off-taker interested in the high value of CSP dispatchable electricity

The TWG considers that a minimum of 3 FOAKs should be implemented in Europe in the coming years, based upon different technology solutions to reach the cost-reduction targets. The objective should not be a one-shot project, but to create a framework/scheme. This is in line with the outcome of the ICF study tendered by DG RTD on financing needs for first-of-a-kind projects on SET Plan technologies, according to which between 5 and 10 new CSP FOAKs will be necessary in Europe by 2020 <sup>6</sup>. In addition, Europe needs

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<sup>6</sup> <https://setis.ec.europa.eu/node/10485>

to keep pace with the ambitious efforts in other world regions (e.g. China) to bring innovative CSP technologies to the market.

The TWG agreed that the choice of the innovative technology solutions proposed in these FOAKs should be up to the promoters – they should not be prescribed by the IP. The promoters will need to reach the cost reduction targets with the innovative technologies they deem most suitable for this purpose.

### **Innovative financing to support demonstration projects at commercial scale**

This issue has been examined by ICF in their study, in which it is estimated that an approximate investment of 0.9 - 3.3 billion EUR would be necessary for the CSP FOAKs.

Considering the high costs of CSP FOAKs, in order to finance such projects it is necessary to achieve a well-coordinated, complex, puzzle-like financial engineering involving many elements relating to very different entities which generally include:

- a project finance scheme (as opposed to corporate finance) involving
  - In the equity side ideally grant support (in addition to the own resources from the promoters)
    - R&I: support (EU, national, regional...) for the innovative part of the project
    - Structural funds support to the infrastructure side of the plant when appropriate
  - In the debt side, ideally involvement of the European Investment Bank using its own instruments, or the European Fund for Strategic Investment (EFSI), or risk-sharing instruments with the EC - this would facilitate, in addition, the participation of other financial entities in the debt-financing of the project
- the agreement with an off-taker interested in the high value of CSP dispatchable electricity

To achieve such a complex engineering it is necessary to ensure a sufficiently high degree of coordination of supporting instruments at the EU, national and regional level, including structural funds, as well as equity and debt public and private financing.

In addition, if the cooperation mechanisms of the Renewable Energy Directive are applied, it is necessary to have in a project at least two Member States ('deployer' and 'off-taker') involved in the discussions.

## Non-technological actions: framework conditions

### Financing

Regarding financing and considering the very high level of ambition in terms of cost-reductions and development of new technologies targeted, it is essential to ensure an optimal coordination and synergies of all funding resources potentially available. For the TWG this includes the following needs:

- Ensure co-financing by SET Plan countries and the EC: including via the alignment of national programs
- Better coordination with structural funds: facilitate the use of structural funds in much better coordination with EU and national grants and financial instruments
- Risk financing

The status of the NER 300 CSP projects was raised by the industry and discussed at length by the TWG. There is a clear need for a sufficiently high degree of coordination and synergies of supporting instruments. Almost none of the six CSP projects which were included in the final list of awardees has reached the financial close yet – and there are indications that some of them will not go ahead. This implies that a total NER 300 'award' amount of approximately 300 million EUR is currently frozen without the possibility to impact positively R&I in Europe in this sector. One of the reasons for this outcome seems to be that the NER300 applicants were left struggling to complete the financial close in market conditions which are unfavourable (the NER 300 awards represent indeed a substantial amount of funding but cover only 20-30% of each plant's cost).

Project Acronym	Country	Technology	Year of award decision	Award amount
HELIOS POWER <sup>7</sup>	Cyprus	Stirling dish	2012	46,6 million EUR
MAXIMUS	Greece	Stirling dish		44,6 million EUR
MINOS <sup>7</sup>	Greece	Solar tower		42,1 million EUR
PTC50-ALVARADO <sup>8</sup>	Spain	Solar tower		70,0 million EUR
EOS GREEN ENERGY <sup>7</sup>	Cyprus	Solar tower	2014	60,2 million EUR
MAZARA SOLAR	Italy	Solar tower		40,0 million EUR

Table 2- The CSP NER 300 projects

For this reason the TWG considered that a much more comprehensive and coordinated approach in terms of financing sources is needed. In addition, the TWG agreed that the IP should call on the EC and the Member States to examine the possibility to channel (at least) the amount of 300 million EUR of NER 300 CSP grants finally not used to support the FOAKs (see previous chapter).

### Regulatory framework

The TWG examined regulatory bottlenecks in EU and national legislation. A transparent and stable regulatory environment guaranteeing investor's confidence on CSP is necessary and the TWG identified the following main actions with respect to the regulatory framework to support the achievement of the CSP targets.

<sup>7</sup> According to recent information, the projects HELIOS POWER, MINOS and EOS GREEN ENERGY have reached the Final Investment Decision or are about to reach it.

<sup>8</sup> The Spanish authorities have confirmed that this project is withdrawn.

- Encourage the use of the cooperation mechanisms in the Renewable Energy Directive

The SET Plan countries are encouraged to investigate their interest to participate in cooperation mechanisms under the Renewable Energy Directive for FOAKs and their willingness to support such projects (included financially) in order to reach the targets. This includes not only SET Plan countries interested in deploying CSP or in developing CSP technologies, but also those countries interested in importing dispatchable renewable electricity generated by CSP plants to achieve their 2020 renewable energy targets.

A first example of use of the cooperation mechanisms is the cooperation mechanism between Germany and Denmark. This mechanism is focused on ground-mounted photovoltaic systems and is based on the principle of reciprocity (i.e. both countries have to give access to their auctions). In the view of the TWG the CSP Initiative should aim to achieve the first dispatchable renewable energy projects based on the cooperation mechanisms.

- Speed up and facilitate permitting process in SET Plan countries (and if appropriate their regions)

Excessively long permitting processes may significantly hinder innovation. It was clarified that two main types of permits are needed for a CSP plant – environmental and administrative authorizations. In addition, grid access can be an issue. SET Plan countries are encouraged to report on cases where their regulatory framework has hindered the development of CSP projects because of permits and grid access.

## Support to internationalisation

International cooperation on CSP can significantly contribute to the achievement of the targets and to maintain global leadership from at least four angles, depending on the effectiveness of the actions taken:

- R&I cooperation based upon excellence in order to accelerate the development of new/breakthrough CSP technologies mainly linked to the second target (new cycles)
- R&I cooperation intended to develop technology suited for specific world regions which would lead to overall cost reductions and would facilitate the subsequent market penetration of European companies
- International cooperation/relations beyond R&I, but closely related to R&I, to support the global competitiveness of the European industry (issues of market access, international trade, development aid supporting the deployment of innovative technologies in other regions, etc.)
- International cooperation objectives stemming from the Paris Agreement, including possibly within the framework of Mission Innovation, and also to support investment in the deployment of innovative clean technologies in developing countries

National representatives in the TWG pointed out that some of the issues described in the points above fall in the remit of other departments within their governments – but they certainly see the rationale for channelling the efforts of various policies in support of low-carbon technologies. The research community is actively engaged in international cooperation in particular in the FP7-funded Integrated Research Programme on CSP (acronym: STAGE-STE) in which countries from all world regions (Australia, Chile, China, India, Libya, Morocco, Saudi Arabia, South Africa) are involved. The industry stresses the important role that development aid funding can have in promoting European technology innovation deployment in other world regions.

The TWG acknowledged the potential benefits stemming from cooperation with countries in the Arabian Peninsula or in North Africa as being regions where European companies can compete with other technology providers. The development of large market shares in the most important world markets is considered a crucial aspect as the perceived mistakes made on photovoltaics (i.e. thinking mainly in terms of the European market) should not be repeated.

The TWG considered that it would be very helpful if R&I international cooperation helps to establish bridges between European stakeholders and planners and policy makers in different world regions regarding the value proposition of (dispatchable) CSP.

## Options for implementation instruments

The previous sections have highlighted the urgent need in the CSP sector to achieve a more focused, comprehensive and coordinated R&I approach to develop and demonstrate the necessary technologies to reach the targets and ensure that the European industry remains global leader. This is particularly the case regarding financing. A much better alignment and coordination of various EU and SET Plan countries' funding instruments, together with risk financing and private investment, is essential in this sector.

In the view of the TWG it is essential to establish a framework to ensure an effective coordination between public funding at EU and national (and preferably regional) level (ideally with a single submission point) and to mobilize private investment with strong leverage effect. Such implementing framework needs in addition to be highly inclusive and transparent.

Three different levels of ambition and potential effectiveness were examined by the TWG in this respect:

1. In a first level, the EC and the SET Plan countries interested in CSP would align the resources of their funding programmes with the strategic targets agreed and would try to better coordinate/synchronize funding, in some cases with some joint actions (e.g., ERA-NETs or other joint actions with variable geometry and not necessarily comprising EU funds). This approach requires the stakeholders to keep navigating between different funding instruments, the timings of which do not always coincide.
2. A second and higher level of potential effectiveness, more ambitious, would entail pooling the public funding resources available from the SET Plan countries interested in CSP and the EU in order to allow for a single submission point.
3. The third and highest level of ambition would aim at pooling the public funding resources of the SET Plan countries interested in CSP and the EC funding together with the stakeholders' private investments, in a public-public-private partnership.

The industry and the research centres strongly prefer a framework in which there is a single submission point. National representatives in the TWG expressed concerns about the level of inclusiveness and transparency in some of the existing public-public-private partnerships as they tend to be dominated by a small number of very large companies from a limited number of countries. The TWG stressed that in case the public-public-private partnership formula is retained it should be articulated in a way to ensure full inclusiveness and transparency - including the inclusiveness of SMEs. Only by setting up a structure which can effectively mobilize the efforts of all interested countries and stakeholders can the CSP targets be reached, and this will require such structure to be highly inclusive. In addition, in the view of the TWG scaling up the InnovFin EDP facility should be considered.

The TWG agreed on inviting the SET Plan countries interested in CSP, the EC and the stakeholders to examine the feasibility of a public-public-private partnership allowing for a single submission point and the pooling of resources to support the CSP Initiative.

## **Contribution of research facilities to the execution of the Plan**

Further development of CSP technologies to 2030 and beyond will require availability of world class R&D infrastructures. The ESFRI project EU-SOLARIS is in current process to tentatively become a European Research Infrastructure Consortium (ERIC) and has an ambition to become a key R&D instrument to meet the objectives of the SET Plan. EU-SOLARIS will offer state-of-the-art R&D infrastructures related to CSP that can be accessed by researchers all over Europe, who are welcome to apply to use the infrastructures. The synergies between EU-SOLARIS and ambitious R&D activities will be essential in the further knowledge development and worldwide deployment of the technology by European companies. In addition, EU-SOLARIS will aim to facilitate projects in the EU Framework Programmes, future European industrial initiatives and education of specialists for the CSP industry.



## **Annex I – R&I Activities**

**Main Key Action / Declaration of Intent**

**Key Action 1:** Sustain technological leadership by developing highly performant renewable technologies and their integration in the EU's energy system:

**Key Action 2:** Reduce the cost of key renewable technologies

**Declaration of Intent on CSP/STE****Summary:**

See Annex II

**State of the art:** See R&I Activities

**R&I Activities of the Implementation Plan on CSP:**

- Advanced linear concentrator Fresnel technology with direct molten salt circulation as heat transfer fluid and for high temperature thermal energy storage
- Parabolic trough with molten salt
- Parabolic trough with silicon oil
- Solar tower power plant to commercially scale-up and optimize the core components of the open volumetric air receiver technology
- Improved central receiver molten salt technology
- Next generation of central receiver power plants
- Pressurized air cycles for high efficiency solar thermal power plants
- Multi-tower central receiver beam down system
- Thermal energy storage
- Development of supercritical steam turbines optimised for the specifics of CSP applications
- Development of advanced concepts for improved flexibility in CSP applications
- Development and field test of CSP hybrid air Brayton turbine combined cycle sCO<sub>2</sub> systems

**Non-technological aspects:**

See relevant chapter in the Implementation Plan

**Ongoing R&I activities:**

Name:	Description:	Timeline:	Location/Party:	Budget:
ASE MS Demo Plant	Archimede Solar Energy Platform with 2 MW molten salt parabolic trough solar field	2013-	Italy/Archimede Solar Energy (ASE), SQM, others	6M€ co-funded by the Italian government
Lazo de Sales	Development of new parabolic through collector for using with molten salt. Aperture close to 9 m and using Hitec molten salt. 5 MW.	2009-2016	Spain/ACS COBRA	2M€ CDTI - Spanish government
MSLOOP 2.0	Development of next	2016-	Spain/ACS Cobra,	3.3 M€

	step in the parabolic trough molten salt (Hitec) concept. New operational modes and hybridization with HYSOL concept. Elemental unit of the future “MS solar boiler”.	2018	ASE, SBP, CADE, UCM	Horizon 2020 Fast track to innovation
EMSP and HPS 2 project	Évora molten salt platform	2016-2018	Portugal/University of Évora, DLR, TSK Flagsol, Yara, Steinmüller, eltherm, Eskom	7.5 M€ German Ministry of Economy and Energy
PreFlexMS	Innovative molten salt steam generator	2015-2018	Portugal/PreFlexMS consortium	14.3 M€ Horizon 2020
CAPTure	Competitive Solar Power Towers	2015-2019	Spain/CAPTure consortium	6.5 M€ Horizon 2020
Solar Tower Jülich	Solar Research and Demonstration Plant Jülich	2006-	Germany/DLR, SIJ, KAM	Supported by Kraftanlagen München
STAGE-STE	Integrated Research Programme on CSP	2014-2018	Several locations/STAGE-STE consortium	19,7 M€ FP7 and in-kind contributions
RAISELIFE	New materials for central receivers	2016-2018	Several locations/RAISELIFE consortium	10.5 M€ Horizon 2020
ECOSTOCK II	High temperature sensible heat storage using stabilized mineral wastes and by-products	2015-	France (National project)/ETC (spin-off), CNRS, ADF	2,9 M€ co-funded by the French government
STEM	Solare termo-elettrico Magaldi	2012-	Italy/Magaldi Power	7 M€ co-funded by the Italian Ministry of Research
Greenway CSP	Greenway CSP Mersin Solar Tower Plant	2009-	Turkey	Private funding
EU-SOLARIS	European SOLAR Research Infrastructure for Concentrated Solar Power	2010-	Distributed research infrastructure	4.4 M€ FP7

<b>International cooperation:</b>				
<b>Name:</b>	<b>Description:</b>	<b>Timeline:</b>	<b>Countries involved:</b>	<b>Budget per country:</b>
<b>SolarPACES</b>	<b>IEA's Technology Collaboration Programme on Solar Power and Chemical Energy Systems</b>	<b>1977-</b>	<b>Algeria, Australia, Austria, Brazil, Chile, China, Egypt, European Commission , France, Germany, Greece, Israel, Italy, Mexico, Morocco, Republic of Korea, South Africa, Spain, Switzerland, United Arab Emirates and United States</b>	<b>Total annual budget approximately 0,16 M€</b>
<b>US DOE Sunshot, Air Brayton Combustion</b>	<b>Design, develop and test a 1000 °C air inlet combustion system</b>	<b>2013-2016</b>	<b>United States, Germany</b>	<b>USA = 4M\$ Germany= 0.1M\$</b>
<b>Contacts:</b> <b>Inmaculada Figueroa, Chair, Spain</b>				

## R&amp;I Activity n. 1

<b>Title:</b> Advanced linear concentrator Fresnel technology with direct molten salt circulation as heat transfer fluid and for high temperature thermal energy storage	
<b>Targets:</b> This R&I Activity will help to achieve the target on CSP cost reduction	<b>Monitoring mechanism:</b> Power Purchase Agreements of new CSP plants in Europe
<b>Description:</b> <p>A natural continuity for the very successful development of parabolic technology with oil as heat transfer fluid and molten salts as heat storage fluid is to take linear concentrator technology to the next logical step, that of increased concentration to enable operation at higher temperatures and thus, higher thermodynamic conversion efficiency, together with a much reduced storage size for the same amount of energy stored. This is in favour of highly efficient solar thermal plants with a high capacity factor using large storage capacities.</p> <p>Parabolic troughs can and are being designed for higher concentration values, but there are severe constraints on how far it is possible to go, since individual troughs of large size have severe mechanical wind loads and other size related constraints. However this is an area where Linear Fresnel (LFR) technology has a very good opportunity since, without any changes to the mechanical wind forces on the individual mirrors, by first principles in optics, they can be designed to reach even higher concentration values. When combined with present day evacuated tubes, the LFR collector efficiency curve may decrease with a smaller heat loss coefficient and, at temperatures like 565°C, be expected to reach very competitive instantaneous efficiency values. In this way LFR concentrators, known to suffer more than parabolic troughs from IAM (Incidence Angle Modifier) effects, could possibly reach an annual efficiency in terms of energy delivery much closer to that of parabolic trough systems, with many potential advantages in terms of overall system and O&amp;M costs</p> <p>LFR concentrators have several potential advantages to achieve an inherently lower cost per sqm as for example the use of cheaper flat reflector components, a stationary receiver tube, not requiring any flexible connections, low wind loads resulting in lighter support constructions. Thus a strong and renewed industry's interest on the technology for low cost electricity production is certainly to be expected. However these new collector developments for very high temperature operation have only been proven in small demonstrator loops, or in loops testing individual components. In fact they were not yet given a chance of being demonstrated on a sufficiently large scale for a subsequent entrance on the market.</p> <p>Regardless of which linear concentrator technology is proposed for development (parabolic trough or Fresnel), at these very high temperatures many issues remain to be addressed like: operation of the new concentrators with salts as heat transfer fluid; different and eventually more suitable types of salt; durability of the evacuated tubular receivers at very high temperature; proper integration and operation in view of the thermal energy storage and energy delivery.</p> <p>High concentration has the extra advantage of reducing the number of rows in a concentrator field, with cost impacts on receiver length, receiver volume, pipe length, number of thermal loop components, thermal losses and parasitic losses associated with the loop.</p> <p>In short, before jumping straight from conventional linear concentrating technologies of the past into totally new possibilities like those arising from supercritical CO<sub>2</sub> turbines at even higher temperatures (600°C and higher for supercritical CO<sub>2</sub> turbines), the next new effort to be made should be on much more straightforward and simpler improvements over present day linear concentration technologies, which have been developed by many companies in the last few years without, due to the present crisis on the CSP market, having the chance to reach the bankability milestone. They are much closer already to the higher TRLs required. In fact, the experience gained on molten salts at present day plants in operation and their use at higher temperatures will be quite important (even crucial) for the next and harder step of going past 600°C, using</p>	

possibly more advanced new salts or other fluids.

The reference to 565°C also deserves an explanation. The idea is to be able to use the present day steam turbines operating at 540°C with their high efficiencies, typical of today's thermal power plants, and still stay below the critical 600°C "barrier", requiring special developments and the use of more expensive and/or sophisticated materials, something running contrary to the idea of moving quickly to reliable and cheaper solutions for the market, and able to claim high TRL related experience.

This proposal addresses these issues and proposes the reach of a significant 10 MW plant demonstration stage:

#### 1) Advanced designs

- New optical designs for large acceptance angle and high concentration value
- New cost-optimized commercial designs (higher concentration, improved receiver optics, improved coatings) for high temperature molten salts

#### 2) Plant design

Technical-economical optimization of a 10 MW molten salt power plant with Linear Concentrator Fresnel solar field and 6+(hours) thermal storage

#### TRL:

From TRL 6 to TRL 8

**Total budget required: 30 M€**

#### Expected deliverables:

#### Timeline:

- Testing and evaluating critical plant components (reliability of standard components)
  - o Molten salt pumps and valves
  - o Instrumentation, sensors, and pipe heating
  - o Fixed receiver operation
  - o Full size (length) collector loop (collector, interconnections, drives, instrumentation, emergency concept, control)
- Develop plant engineering, for full operation control in clear skies and variable solar radiation days, start-up and shutdown operation, night time freezing protection, including drain-down gravity assisted strategies. Testing and demonstration of process control concepts (reliability of normal control).
  - o Demonstration of all control processes in the plant by usage of a virtual solar field model that operates via industry-standard interfaces
  - o Demonstration of loop control concept in a full size collector loop
  - o Hardware-in-the-loop simulation of a full solar field
- Selection of best molten salt suitable (existing or new working fluid) regarding technical, economical and risk assessment (reduce the risks related to freezing and chemical decomposition of the salt at high heat), as well as corrosion related impacts
- Demonstration of evacuated tubular receivers with selective coatings to be heat resistant (no out-gassing) and inner pipes to be corrosion resistant.
- Optimization of the (modular) thermal storage, its integration and operational requirements in the system, in order to improve scalability and reduce freezing risks
- Demonstration of molten salt specific operations (availability of emergency operations)
  - o Demonstration of successful and economical commissioning of the salt loop

4 years

<p>(melting of raw material, filling process, commissioning time)</p> <ul style="list-style-type: none"> <li>o Demonstration of drainage process in a representative configuration</li> <li>o Demonstration of freezing and heating process (emergency case)</li> <li>o Work out and demonstrate handling of exceptional operation situations (maintenance of loops, repair of leakages, re-vitalizing frozen parts, exchange of components)</li> </ul> <p>- Technical-economical optimization of the existing solar field. Optimized design of the whole plant, including BOP, in order to reduce the freezing and environmental risks, to improve reliability, but also to propose a scalable and dispatchable plant.</p> <p>- Development of a library for industrial needs and creation of a complete model in order to define process control on normal and emergency cases suitable to avoid freezing, as well as proper maintenance procedures</p> <p>- Integration of forecasting and power grid management and trading as a key input for reliable operation</p>			
<b>Party / Parties:</b>	<b>Implementation instruments:</b>	<b>Indicative financing contribution:</b>	
See Annex III			

## R&amp;I Activity n. 2

<b>Title:</b> Parabolic trough with molten salts	
<b>Targets:</b> This R&I Activity will help to achieve the target on CSP cost reduction	<b>Monitoring mechanism:</b> Power Purchase Agreements of new CSP plants in Europe
<b>Description:</b> Molten salt as heat transfer fluid in parabolic trough systems is an attractive technical option to increase solar-to-electric efficiency, reduce storage costs, enhance co-firing efficiency, simplify control system by separating the solar harvest from electricity production, and improve environmental impact compared to the state of the art oil plants. Technological options for main components like collectors are already demonstrated. For fast commercialisation it is vital to increase the reliability in the whole system by reducing risks originating from molten salt specific operation conditions in main but also sub-ordinate components. The path from today's TRL 6 to TRL 8 requires intensive testing of the components. Compared to tower systems the line focusing systems allow – beside scalability towards larger plant sizes- a break-down of relevant demonstration tasks into smaller units. The action should address all risk-relevant components and include a well-organized project management dedicated to the task of putting together and publishing the knowledge obtained in the various demonstration activities. The overall objective is to bring the technology to a risk level that is acceptable for EPCs and lenders.	
<b>TRL:</b> From TRL 6 to TRL 8	
<b>Total budget required: 11.5 M€</b>	
<b>Expected deliverables:</b>	<b>Timeline:</b>
<ul style="list-style-type: none"> <li>- Testing and evaluating critical plant components (reliability of standard components) <ul style="list-style-type: none"> <li>o Large diameter header systems</li> <li>o Molten salt pumps and valves</li> <li>o Instrumentation, sensors, and pipe heating</li> <li>o Full size (length) collector loop (collector, interconnections, drives, instrumentation, emergency concept, control)</li> </ul> </li> <li>- Testing and demonstration of process control concept (reliability of normal control) <ul style="list-style-type: none"> <li>o Demonstration of all control processes in the plant by usage of a virtual solar field model that operates via industry-standard interfaces.</li> <li>o Demonstrate loop control concept in a full size collector loop</li> <li>o Hardware-in-the-loop simulation of a full solar field</li> </ul> </li> <li>- Demonstration of molten salt specific operations (availability of emergency operations) <ul style="list-style-type: none"> <li>o Demonstration of drainage process in a representative configuration</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>Development of testing procedures: 1 year</li> <li>Verified qualification methods available for critical components: 1.5 years</li> <li>Implementation of testing hardware in loop for further monitoring: 1.5 years</li> <li>Development of virtual solar field model: 2,5 years</li> <li>Demonstrate loop control concept in a full size collector loop or commercial plant: 1.5 years</li> <li>Implementation of drainage hardware demonstration loop or in pre-commercial plant: 1.5 years</li> <li>Demonstration of freezing and heating</li> </ul>



<ul style="list-style-type: none"><li>o Demonstration of freezing and heating process (emergency case)</li><li>o Work out and demonstrate handling of exceptional operation situations (first filling with MS, maintenance of loops, repair of leakages, re-vitalizing frozen parts)</li></ul> <p>- Systematic risk assessment and documentation for molten salt line focusing systems</p> <ul style="list-style-type: none"><li>o identification of risk sources (with EPCs, suppliers, consultants)</li><li>o quantification of risk probability and their impact (e.g. FMECA)</li><li>o compilation of mitigation measures</li></ul>		<p>process: 1.5 years</p> <p>Demonstration of exceptional operation situations: 1.5 years</p> <p>Identification of risk sources: 2 years</p> <p>Quantification of impact and probability: 1 year</p> <p>Develop mitigation measures: 1 year</p>	
Party / Parties:	Implementation instruments:		Indicative financing contribution:
See Annex III			

## R&amp;I Activity n. 3

<b>Title:</b> Parabolic trough with silicon oil		
<b>Targets:</b> This R&I Activity will help to achieve the target on CSP cost reduction	<b>Monitoring mechanism:</b> Power Purchase Agreements of new CSP plants in Europe	
<b>Description:</b> Silicon oil as heat transfer fluid promises higher operating temperatures in the solar field of parabolic trough plants. At the same time these fluids are environmentally harmless in case of leakages compared to the actually used fluids in commercial plants. The operating temperature limit of silicon oil is 430°C which allows more than 30K higher temperatures compared to the state-of-the-art synthetic oil used today. This additional temperature spread between inlet and outlet leads to higher solar field energy enthalpy output and higher system efficiencies at the power block side. Combined with innovative large-scale collectors with high concentration factors and high optical and thermal efficiencies, which are optimized concerning manufacturing and reduced sub component numbers, the use of silicon oil can lead to significant cost reduction of the solar field. The Activity aims at demonstrating all sub-components such as collectors, mirrors, receivers, valves, heat exchanger and steam generator in a pre-commercial scale with 2 complete loops. The accompanying research actions should answer all open questions concerning performance and durability of all involved elements of the system to reach bankability at the end of the project		
<b>TRL:</b> From TRL 6 to TRL 8		
<b>Total budget required:</b> 5-8 M€		
<b>Expected deliverables:</b> - Construction of at least 2 loops of full scale parabolic trough collectors including oil/salt heat exchanger and steam generator - Long term operation to identify durability issues - Assessment of performance of collector and its subcomponents - Analysis of solar flux and heat transfer at receivers to identify maximum film temperatures in fluid - Analysis of heat transfer fluid composition and verification of its durability and chemical stability during commercial plant operation - Optimization of (oil/salt) heat exchanger for increased temperatures up to 430°C, also under transient conditions		<b>Timeline:</b> 3 years
<b>Party / Parties:</b>	<b>Implementation instruments:</b>	<b>Indicative financing contribution:</b>
See Annex III		

## R&amp;I Activity n. 4

<b>Title:</b> Solar tower power plant to commercially scale-up and optimize the core components of the open volumetric air receiver technology		
<b>Targets:</b> This R&I Activity will help to achieve the target on CSP cost reduction		<b>Monitoring mechanism:</b> Power Purchase Agreements of new CSP plants in Europe
<b>Description:</b> <p>The large majority of existing CSP plants is based on the parabolic trough technology. Nevertheless, most industry experts agree that solar towers have the potential to reach lower LCOEs, mostly due to the higher reachable process temperatures (i.e. higher overall plant efficiencies). Apart from a higher thermodynamic efficiency, those higher temperatures are especially favourable when large storage capacities are incorporated in order to really benefit from CSP's ability to deliver dispatchable power because when energy is stored at a higher temperature, less storage medium is required for the same capacity.</p> <p>At the moment, the market share of solar towers increases and the average storage sizes of new CSP projects increases, i.e. a low cost thermal storage technology suitable for the high temperatures delivered by solar tower systems will be the key to reaching low LCOEs. Due to the imperfect weather conditions in southern Europe (in comparison to e.g. Chile or South Africa) another key to decreasing the LCOE of CSP in Europe is increasing the average receiver efficiency by improving the receiver's transient and part load behaviour (minimizing the negative effect of clouds by shortening receiver start-up procedures and minimizing own consumption when the receivers is not operational). The open volumetric receiver technology uses an open ceramic honeycomb structure to absorb the concentrated solar radiation from the heliostat field. The absorbed heat is used to heat up ambient air (the plant's heat transfer medium) to 650°C which is then used to both charge the thermal storage and simultaneously produce electricity by means of a conventional water-steam-cycle (similar to those operated in any combined cycle power plant). The technology combines a superior transient receiver behaviour with a very inexpensive high temperature fixed bed thermal storage (investment cost &lt;25€/kWh of heat storage capacity) which is very well suited for the large storage capacities required to dispatch electricity production. Furthermore air is very easy to handle and the thin receiver structure (non-pressurized system) and the very high melting point of the modular ceramic absorbers give the technology very large physical safety margins, a minimized operational risk and allow for plant life expectancies of &gt;40years. Due to this inherent robustness the technology requires very little safety and operational control measures leading to low LCOEs already at comparably small plant sizes (from 50MW). The heat transfer fluid temperature of 650°C allows incorporating a supercritical water-steam cycle.</p> <p>The open volumetric receiver technology needs to be implemented in a plant size of at least 50 MW. A plant like this would incorporate a receiver with a thermal output of 360-400 MW thermal and a thermal storage capacity of at least 1 GWh. The plant would have a surrounding 360° heliostat field and four individual receivers (~80-100 MW thermal each) pointing in four directions. A reasonable intermediate step for the receiver would be one fourth of the 300-400MW thermal receiver with a 90° heliostat (north-)field.</p>		
<b>TRL:</b> From TRL 6 to TRL 8		
<b>Total budget required: 5.5 M€</b>		
<b>Expected deliverables:</b>		<b>Timeline:</b>
<ul style="list-style-type: none"> <li>- Design of scaled-up open volumetric receiver (50-100 MW thermal) and optimization of the receiver design for increased efficiency, improved transient behaviour and a longevity of &gt;40 years.</li> <li>- Design of scaled-up fixed bed thermal energy storage</li> </ul>		2 years

<ul style="list-style-type: none"><li>- Design of cost and performance optimized heliostats by optimizing drive units, mirror reflectivity and optical properties, field layout, cleaning procedures, reliability and durability</li><li>- Detailed overall plant design for an intermediate commercial plant size of approximately 10 MW (50-100 MW thermal) including the up-scaled and optimized components (receiver, thermal energy storage and optimized heliostat field)</li><li>- Optimized plant and operational concepts in order to balance electricity production with other renewables and market the produced electricity in other European markets.</li></ul>			
Party / Parties:	Implementation instruments:	Indicative financing contribution:	
See Annex III			

## R&amp;I Activity n. 5

<b>Title:</b> Improved Central Receiver Molten Salt technology		
<b>Targets:</b> This R&I Activity will help to achieve the target on CSP cost reduction		<b>Monitoring mechanism:</b> Power Purchase Agreements of new CSP plants in Europe
<b>Description:</b> <p>This R&amp;I Activity is concerned with a complete set of items aimed at improving the molten salt central receiver technology currently available, thus achieving a significant cost reduction in a short term because all the proposed activities can be developed within a time period of 3 years after the starting date. The proposed actions would lead to improvements that could be implemented soon in commercial STE plants to increase their competitiveness. Since most of the R&amp;I actions proposed can be implemented in both small and large size plants there is no additional constraint due to the plant size. The actions cover all the main systems of a commercial central receiver plant using molten salt (i.e., the solar field, the storage system, the solar receiver, the control and monitoring systems, the steam generating system and turbine) as well as operation and maintenance issues. Current heliostat and receiver designs can be improved to reduce cost and increase efficiencies. Current costs of these two components are in the range 120-130 €/m<sup>2</sup> (heliostats) and 180-250 k€/MW thermal (molten salt receivers). Improvements concerning the solar flux measurement system and the calibration procedure for the heliostat field have been identified too.</p>		
<b>TRL:</b> From TRL 7 to TRL 9		
<b>Total budget required: 22 M€</b>		
<b>Expected deliverables:</b>		<b>Timeline:</b>
<ul style="list-style-type: none"> <li>- Increase nominal and annual performance of heliostats and heliostat field by 5% (at least) and reduce heliostat cost to &lt; 100€/m<sup>2</sup> by improving the following :               <ul style="list-style-type: none"> <li>- Mirror reflectivity (&gt; 95 %)</li> <li>- Optimized size vs cost (&lt; 100 €/m<sup>2</sup>)</li> <li>- Heliostat field layout</li> <li>- Cleaning requirements and procedures</li> <li>- Slope error ( &lt;3 mrad) and optical quality</li> <li>- Manufacturing, assembly and set-up costs</li> <li>- Procedures for quick and cheap (re)calibration (optics and tracking)</li> <li>- Reliability and durability</li> <li>- More cost-effective drive units</li> <li>- In-deep analysis of the “autonomous” concept for heliostats (at the level of a small group of heliostats for reliability analysis, not a complete solar field)</li> </ul> </li> <li>- For the solar receiver:               <ul style="list-style-type: none"> <li>- Identification and selection of new suitable materials (lower cost and higher performance) for mono-tower receivers and high concentration flow systems                   <ul style="list-style-type: none"> <li>- Reduction of total receiver surface required for a given output in comparison with current solar tower technology</li> <li>- Development or adaptation of existing evaluation models to build and optimize the receiver design</li> </ul> </li> </ul> </li> <li>- For the control               <ul style="list-style-type: none"> <li>- A completely automated procedure must be developed to calibrate the whole</li> </ul> </li> </ul>		3 years

<p>heliostat field in a short time, which should enable re-calibrating heliostats repeatedly to alleviate heliostat requirements and to reduce their costs</p> <ul style="list-style-type: none"> <li>- Development of new tools for the calculation of the flux distribution on the receiver surface, capable of simulating complex receiver geometries and different heliostat layouts</li> <li>- Develop methods to measure (or estimate as accurately as possible) receiver temperature and flux distribution during operation under real working conditions</li> <li>- Determination of atmospheric attenuation on line</li> </ul> <p>- For the storage system:</p> <ul style="list-style-type: none"> <li>- Improvements in heat tracing, and components (e.g., valves, pumps) to reduce parasitic consumption</li> <li>- Improvements of storage tanks designs to reduce capital cost</li> </ul> <p>- For the steam generation and turbine</p> <ul style="list-style-type: none"> <li>- Optimization of steam generator design</li> <li>- Improvement of operational flexibility of the turbine</li> <li>- Improvement of the life of the turbine components and reduction of the maintenance cost</li> </ul> <p>- In terms of operation and maintenance (O&amp;M):</p> <ul style="list-style-type: none"> <li>- Development of predictive maintenance tools, systems and procedures to reduce maintenance costs and increase plant performance</li> </ul>		
<b>Party / Parties:</b>	<b>Implementation instruments:</b>	<b>Indicative financing contribution:</b>
See Annex III		

## R&amp;I Activity n. 6

<b>Title:</b> Next Generation of central receiver power plants		
<b>Targets:</b> This R&I Activity will help to achieve the target on developing the next CSP generation	<b>Monitoring mechanism:</b> New CSP cycles demonstrated	
<b>Description:</b> This R&I Activity aims to contribute to the development of the next generation of CSP plants by achieving additional cost reduction and open new business opportunities. These R&D actions are focused on the central receiver technology with molten salts, since today it is the technology with the greatest short- and mid-term cost reduction potential according to the experience of most relevant industries as it is shown by current market evolution. Since most of the R&D activities proposed can be implemented in both small and large size plants there is no additional constraint due to the plant size. The R&D actions cover all the main systems of a commercial central receiver plant using molten salt (i.e., the Innovative solar field configurations, the storage system, the solar receiver, the control and monitoring systems, new power cycles) as well as advanced operation and maintenance issues. Innovative solar field configurations (i.e. heliostat fields merging different types of heliostat [different sizes and qualities], large heliostat fields with several towers [multi-tower concept]) can increase heliostat field performance in the range ~ 3-4%, and reduce the cost by 30-40 % from current 120-130 €/m2 to 90 €/m2 leading to LCOE reductions in the range of 7-12 %. In addition to this, new advanced cycles (i.e. supercritical steam cycles) could increase power plant efficiency in the range of ~ 2-4%. Additional cost reductions are expected from smart wireless autonomous heliostat developments, improved controls for complex solar field approaches and advanced predictive operation and maintenance protocols for high temperature supercritical steam molten salt concepts.		
<b>TRL:</b> From TRL 6 to TRL 8		
<b>Total budget required: 25 M€</b>		
<b>Expected deliverables:</b>		<b>Timeline:</b>
<b>Heliostats and solar field:</b> <ul style="list-style-type: none"><li>- Innovative solar field configurations should be considered to optimise the plant design: from merging heliostat of different quality and size according to their position in the field, to the detailed analysis of multi-tower approach</li><li>- Development of different low cost heliostat designs according to their specific requirements as a function of their position in the solar field (with a target average of &lt;90€/m2)</li><li>- Smart independent heliostat developments (self-calibrated, self-diagnosis)</li><li>- Wireless and autonomous commercial heliostat field developments</li></ul> <b>Solar receiver:</b> <ul style="list-style-type: none"><li>- Higher temperature solar receiver according to the needs of new power cycles to guarantee reliability and performance at high temperature</li></ul> <b>Heat Transfer Fluids:</b> <ul style="list-style-type: none"><li>- Use of innovative molten salts to allow a wider operation range 160°C – 650°C.</li></ul> <b>Control:</b> <ul style="list-style-type: none"><li>- Development of new control tools to handle and optimize the operation of the innovative solar field configurations according to their degree of complexity (i.e., several kinds of heliostats in the same field, different</li></ul>		5 years

<p>receivers sharing a huge heliostat field, etc.).</p> <ul style="list-style-type: none"><li>- Development of methodologies for on line heliostat field characterization and diagnosis.</li><li>- Increase of accuracy of instrumentation for high temperatures</li></ul> <p>Steam generation and turbine:</p> <ul style="list-style-type: none"><li>- Supercritical turbines</li><li>- Supercritical steam generators</li><li>- Techno-economic optimization of components taking into consideration the working conditions (i.e., pressures and temperatures) and the associated efficiency and cost increases</li></ul> <p>Operation and Maintenance (O&amp;M):</p> <ul style="list-style-type: none"><li>- Monitoring of molten salt degradation status and potential corrosion of molten salt loop and subsystems for high temperatures</li><li>- Low-water or waterless cleaning systems developments</li><li>- New pumping equipment to recover the gravitational energy in the salt circuit of the tower</li><li>- Optimization of O&amp;M procedures to reduce auxiliary energy consumption to prevent the salts from freezing</li></ul>		
<b>Party / Parties:</b>	<b>Implementation instruments:</b>	<b>Indicative financing contribution:</b>
<p>See Annex III</p>		



## R&amp;I Activity n. 7

<b>Title:</b> Pressurized air cycles for high efficiency solar thermal power plants			
<b>Targets:</b> This R&I Activity will help to achieve the target on developing the next CSP generation		<b>Monitoring mechanism:</b> New CSP cycles demonstrated	
<b>Description:</b> Brayton cycles may be driven by a pressurized-air solar receiver, the cycle working either in the solar-only mode at low turbine inlet temperature (TIT) or in the hybrid mode. This concept opens the door to high efficiency combined cycles at large power. The main drawback of the base concept is the low solar fraction because it does not integrate a thermal energy storage. Consequently, the main objective of this R&I activity is to demonstrate the integration of a high temperature thermal energy storage using ceramics in a pressurized air loop heated by a solar receiver. Industrial technologies using ceramics are available but they are working with ambient pressure air.			
<b>TRL:</b> From TRL 5 to TRL 7			
<b>Total budget required:</b> 5M€			
<b>Expected deliverables:</b>		<b>Timeline:</b>	
<ul style="list-style-type: none"><li>- Demonstration of 500 kW thermal solar receiver</li><li>- Demonstration of a ceramic high temperature thermal heat storage with pressurized air as working fluid</li><li>- Integration of pressurized-air solar receiver and storage in a single loop</li></ul>		<ul style="list-style-type: none"><li>2 years</li><li>1.5 years</li><li>1.5 years</li></ul>	
<b>Party / Parties:</b>	<b>Implementation instruments:</b>		<b>Indicative financing contribution:</b>
See Annex III			

## R&amp;I Activity n. 8

<b>Title:</b> Multi-tower central receiver beam down system		
<b>Targets:</b> This R&I Activity will help to achieve the target on developing the next CSP generation	<b>Monitoring mechanism:</b> New CSP cycles demonstrated	
<b>Description:</b> An alternative solution to the classic solar system with the receiver on the top of a tower is the "beam down" solution that simplifies the construction of the receiver as well as the tower with very positive impact on the CSP plant costs. This concept opens the door to the use of other heat transfer fluids and heat storage solution for high efficiency systems even for a medium size plant. The use of different storage materials should demonstrate the integration of a high temperature thermal energy storage using solid materials. The aim of this R&I Activity is the development and demonstration of a new technology capable of improving the flexibility and dispatchability of CSP plants, implementing an advanced concept of storage and heat exchange of solar energy. The modular configuration is concerned with a set of solar generation units and each unity includes the heliostats field, a small tower supporting the secondary mirrors of a beam-down optical system, a receiver - with a heat storage system in a fluidized bed of silica sand - and a steam generator. The units are connected to a generating system. Simplicity, modularity and robustness can result in a strong reduction of CSP installation costs and of operative cost.		
<b>TRL:</b> From TRL 5 to TRL 7-8		
<b>Total budget required:</b> 7-8 M€		
<b>Expected deliverables:</b>		<b>Timeline:</b>
<ul style="list-style-type: none"><li>- Industrial optimization of mirror design and manufacturing with an installed cost of 70-80€/m2</li><li>- Optimization of cavity integrated with storage</li><li>- Industrial optimization operating at very high temperatures (e.g., research in terms of materials)</li><li>- Cost reduction and optimization (O&amp;M) of tracker</li><li>- Study and test of high temperature components (fluidized bed materials, power unit, heat exchanger)</li><li>- Operating control strategies for components, plant with thermal energy storage</li><li>- Operate a 2 MW thermal solar receiver</li></ul>		3 years
<b>Party / Parties:</b>	<b>Implementation instruments:</b>	<b>Indicative financing contribution:</b>
See Annex III		

## R&amp;I Activity n. 9

<b>Title:</b> Thermal energy storage		
<b>Targets:</b> This R&I Activity will help to achieve the target on developing the next CSP generation	<b>Monitoring mechanism:</b> New CSP cycles demonstrated	
<b>Description:</b> This R&I activity aims to develop storage materials (media) with either affordable cost or outstanding volumetric energy density or higher working temperatures, paying special attention to the reliability of the systems, subsystems associated and storage materials available, including pumps, valves, instrumentation, tank(s) and heat exchanger equipment. The R&I actions proposed are a complete set of items aimed to reduce LCOE. They cover all of the main tasks to reach the desired cost reduction on thermal storage systems (i.e. material development and testing [storage media and subsystems], system and subsystems design, plant scheme performance analysis, detailed cost reduction analysis, subsystems construction and testing, and demonstrator built and tested in a relevant environment).		
<b>TRL:</b> From TRL 4 to TRL 6-7		
<b>Total budget required:</b> 10 M€		
<b>Expected deliverables:</b>  - Development and testing of new storage media with potential to provide efficient, reliable, and economic thermal energy storage in CSP plants, with focus on solutions for the next generation of trough and tower plants  - Identification and selection of storage subsystems materials with suitable characteristics such as compatibility with the storage media, high enough working temperature and affordable cost          - Design and testing of main subsystems and components - Detailed analysis of storage integration in CSP plants (double tank and single tank [thermocline] solutions) - Different plant scheme analyses - Detailed operation and performance analysis (including part load and dynamic analysis) - Detailed cost reduction analysis and impact in LCOE          - Demonstrator at a representative scale		<b>Timeline:</b>  3 years          2 years          2 years
<b>Party / Parties:</b>	<b>Implementation instruments:</b>	<b>Indicative financing contribution:</b>
See Annex III		

## R&amp;I Activity n. 10

<b>Title:</b> Development of supercritical steam turbines optimised for the specifics of CSP applications	
<b>Targets:</b> This R&I Activity will help to achieve the target on developing the next CSP generation	<b>Monitoring mechanism:</b> New CSP cycles demonstrated
<b>Description:</b> <p>The integration of a supercritical steam cycle into CSP applications is a key measure for increasing the cycle efficiency. To overcome limitations resulting from the considered small power range of about 150 MW, high speed geared steam turbines can be applied. Therefore, a detailed assessment of suitable turbine trains for supercritical CSP with respect to technical feasibility, performance, costs and flexibility has to be performed. In parallel, steam turbine technologies such as blades, seals, materials, etc. need to be developed for the specifics of CSP applications.</p> <p><b>Topic 1: Development of an optimised supercritical steam turbine and optimised steam turbine technologies for CSP</b></p> <p>Improved performance (cycle and turbine efficiency) through supercritical steam pressures and high steam temperature in combination with optimized speed.</p> <p>Improved turbine efficiency and operational flexibility as well as cost reduction through the application of latest steam turbine technologies and compact design.</p> <p>Key challenges include:</p> <ul style="list-style-type: none"> <li>• Geared multiple speed turbo-generators (e.g., high pressure and/or intermediate pressure part) due to high (supercritical) pressures and relatively small volumetric flow rates, e.g. high speed high pressure part (or ultra-high pressure part) as separate train</li> <li>• Oxidation resistant and cost effective alloys for small components (scale formation same for given temperature regardless of the component size – i.e. impact to functionality/efficiency larger for smaller machines)</li> <li>• Application of appropriate blading technologies to maximize efficiency and operational flexibility</li> <li>• Application of appropriate sealing technologies at small scale to minimize clearances necessary</li> <li>• Potential application of magnetic bearings and frequency invertors</li> </ul> <p><b>Topic 2: Extend the application of steel to the limits (e.g. 650°C)</b></p> <p>Key challenges include:</p> <ul style="list-style-type: none"> <li>• Application of knowledge from research activities to small scale steam turbine generators - hollow heterogeneous rotor welding and casting of nickel alloys including non-destructive testing methods</li> <li>• Methods for high accuracy of prediction of thermal deformation of steam turbine generators casings during start-up and rapid load changes</li> <li>• Accelerated particle erosion/corrosion protection and deposit formation mitigation measures (impact to flow path integrity, geometry and efficiency) – prediction of behaviour of heat transfer fluid/steam generator tubes</li> <li>• Small scale control valves resistant to long term oxidation, leakage and seizure</li> </ul>	
<b>TRL:</b> Topic 1 Development of a steam turbine optimised for CSP applications	

<b>TRL5: conceptual design</b> <b>TRL6: detailed design</b> <b>TRL7: demonstrator</b> <b>Optimised steam turbine technologies for CSP</b> <b>TRL3: Most promising technologies identified</b> <b>TRL6: Technologies potential demonstrated</b> <b>TRL7: Technologies demonstrated in system prototype</b>		
<b>Topic 2: Extend the application of steel to higher temperatures (e.g. 650°C)</b> <b>TRL3</b>		
<b>Total budget required: 25 M€</b>		
<b>Expected deliverables:</b>	<b>Timeline:</b>	
<b>Topic 1: Development of an optimised supercritical steam turbine and optimised steam turbine technologies for CSP (the two activities are suggested to run in parallel):</b>  <b>Development of a steam turbine optimised for CSP applications</b>  <b>Optimised steam turbine technologies for CSP</b>  <b>Topic 2 Topic 3: Extend the application of steel to higher temperatures (e.g. 650°C)</b>	<b>TRL5: 0.5 year</b> <b>TRL6: 2 year</b> <b>TRL7: 3.5 year</b>  <b>TRL3: 1 year</b> <b>TRL6: 3 years</b> <b>TRL7: 3.5 years</b>  <b>1 year</b>	
<b>Party / Parties:</b>	<b>Implementation instruments:</b>	<b>Indicative financing contribution:</b>
<b>See Annex III</b>		

## R&amp;I Activity n. 11

<b>Title:</b> Development of advanced concepts for improved flexibility in CSP applications		
<b>Targets:</b> This R&I Activity will help to achieve the target on developing the next CSP generation	<b>Monitoring mechanism:</b> New CSP cycles demonstrated	
<b>Description:</b> The operation of CSP plants differs to conventional power plants, where steam supply is in control of the operator. Different CSP cycles (non-reheat, reheat, soft reheat) impose different requirements on the transient operation of steam turbines. Based on defined and CSP specific load regimes, obstacles for flexible operation need to be addressed via design and/or operational concepts.  Topic 1: Improved steam turbine operational concept for CSP With given boundary conditions such as number of starts and load changes, live steam temperatures during start-up, shut down and load changes, measures for improved steam turbine flexibility can be investigated. Key challenges include: <ul style="list-style-type: none"><li>- Improve transient design for thick walled components (compare different turbine designs, improve geometries, reduce thermal stress)</li><li>- Develop enhanced thermal stress limits adjusted to the requirements of CSP projects</li><li>- Optimized live steam temperature concept for transient operation of CSP plants (less live steam temperature variation during operation)</li><li>- Identification of improved components supporting CSP requirements</li></ul> Topic 2: Development of CSP plant analytics The addition of analytics to a CSP operation could provide important improvements to flexibility. The solar conditions could be forecasted and measured, as well as the overall plant and environmental conditions. This data could be analysed, in conjunction with a plant physics-based model, to optimize plant control for flexibility and economics (income and costs). The analytics can do long-term forecast of storage utilization and hybrid balancing. The analytics will initially be demonstrated by simulating the advanced plant and turbomachinery applications. Next, the analytics must be deployed and demonstrated at an operating CSP plant.		
<b>TRL:</b> Topic 1: Improved ST operational concept for CSP – TRL3 Topic 2: Development of CSP plant analytics - Start at TRL 3 and end at TRL 6		
<b>Total budget required: 4 M€</b>		
<b>Expected deliverables:</b> - Concept report of improved steam turbine operational concept for CSP (TRL3)  - Development of CSP plant analytics - Plant analytics system - Plant flexibility gains via analytics		<b>Timeline:</b>  1 year    2 year
<b>Party / Parties:</b>	<b>Implementation instruments:</b>	<b>Indicative financing contribution:</b>
See Annex III		

## R&amp;I Activity n. 12

<b>Title:</b> Development and field test of CSP hybrid air Brayton turbine combined cycle sCO <sub>2</sub> systems		
<b>Targets:</b> This R&I Activity will help to achieve the target on developing the next CSP generation		<b>Monitoring mechanism:</b> New CSP cycles demonstrated
<b>Description:</b> <p>The CSP hybrid air Brayton turbine combined cycle system as described below can achieve single digit LCOE as calculated with the US DOE NREL SAM cost model.</p> <p><b>Topic 1: Design, develop and field test a 1000 °C air receiver</b> The higher air receiver temperature improves the receiver and power block efficiency, which drives down heliostat costs and lowers the LCOE.</p> <p><b>Topic 2: Develop a higher temperature combustion system</b> The higher temperature combustor will be used as a topping cycle for the CSP operation. It can be used to operate the air Brayton turbine and sCO<sub>2</sub> turbine at any time (24/7) and will be fully dispatchable. The air Brayton and sCO<sub>2</sub> combined cycle can achieve a power block efficiency greater than 55%, which drives down heliostat specific costs and minimizes fuel cost when operating solar thermal is not available. The combustor could run off renewable gas sources, like biogas. An important factor of the development of the combustion system is to enhance its flexibility to deal with mixed solar and fossil fuel operation depending on the amount of solar thermal energy.</p> <p><b>Topic 3: Development and test of a sCO<sub>2</sub> bottoming cycle for CSP operation</b> This system is unique to other sCO<sub>2</sub> systems being developed for CSP. This bottoming cycle sCO<sub>2</sub> turbine is much lower risk and much lower cost because it will operate at the air Brayton turbine exhaust temperature, which is less than 600 °C. The primary design and development effort is focused on using existing sub-systems from various companies and integrating into an operating system. The sCO<sub>2</sub> system will be lower cost and more efficient than the current Rankine bottoming cycle system.</p> <p><b>Topic 4: Optimally integrate conventional molten salt storage into the Brayton and sCO<sub>2</sub> plant</b> Thermal storage is a critical element of a CSP plant but state of the art storage media have inherent limitations, e.g. maximum molten salt temperature. With the addition of a Brayton top cycle and a sCO<sub>2</sub> bottom cycle, it will be critical to include storage in the most optimum way. This task will determine the best configuration for the field test, within the constraints of storage technologies.</p>		
<b>TRL:</b> From TRL 3 to TRL 6		
<b>Total budget required: 26 M€</b>		
<b>Expected deliverables:</b>		<b>Timeline:</b>
<ul style="list-style-type: none"> <li>- Develop a high temperature air receiver</li> <li>- Develop a high temperature combustion system</li> <li>- Develop a sCO<sub>2</sub> bottoming cycle system</li> <li>- Optimum thermal storage</li> </ul>		4 years
<b>Party / Parties:</b>	<b>Implementation instruments:</b>	<b>Indicative financing contribution:</b>
See Annex III		

## **Annex II – Input from the industrial and R&D sectors on the R&I Activities**



# Implementation Plan Initiative to the achievement of CSP/STE SET-Plan defined targets

## Input from the Industrial and R&D sectors

### INTRODUCTION

In the context of the recently started process by the European Commission and the Member States within the SET-Plan – the “STE initiative for Europe”-, a Working Group gathering representatives of the European Commission, the Member States the STE industry and research sector was set up to work out specific implementation steps towards these targets, which were:

1. 40% cost reduction by 2020 (from 2013) translating into a [fully dispatchable electricity] supply price<sup>1</sup> < 10 c€/kWh for a radiation of 2050 kWh/m<sup>2</sup>/year (average in Southern Europe) [by large-scale plants with storage].
2. New cycles (including supercritical ones) with a first demonstrator by 2020.

To the achievement of these targets, EU Commission and Member States visualized an Implementation Plan based on two main and independent pillars: the first one would be the FOIK projects and the second one a specific research program to provide the industry additional technological innovations eventually to be used in future commercial or FOIK projects. There would be no formal link between the two pillars.

In order to get inputs to the second pillar, from this Working Group a request was made to the Industrial and R&D sectors to provide specific ideas (proposals) of short-term priority research and innovation actions to reach the CSP/STE targets.

Therefore, to provide the Working Group with the most reasoned and coherent proposals related to research, STE industry and research representatives have agreed to produce for the Working Group, via an informal collaboration, not only the requested research proposals, but also an evaluation of these proposals keeping in mind the commercial and technological relevance that the EC gives to the action lines resulting from this process; thus, a 2-stage evaluation process was initially agreed.

### PROPOSALS EVALUATED

Current assessment exercise has been made over the following proposals, prepared by the sector (organizations indicated in Section 3) and related to the essential targets to be achieved by STE industry and research to relaunch STE in Europe:

1. Advanced Linear Concentrator Fresnel technology with direct molten salt circulation as HTF and for high temperature thermal energy storage

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<sup>1</sup> provided that 30 GW STE plants are installed at that time at world level

2. Parabolic Trough with Molten Salt
3. Parabolic Trough with Silicon Oil
4. Solar Tower Power Plant to commercially scale-up and optimize the core components of the Open Volumetric Air Receiver technology
5. Improved Central Receiver Molten Salt technology
6. Next Generation of Central Receiver power plants
7. Pressurized Air Cycles for high efficiency solar thermal power plants
8. Multi-Tower Central Receiver Beam Down System
9. Thermal Energy Storage
10. Development of innovative concepts for supercritical turbine trains for CSP applications using high speed turbines with optimized speed for each turbine cylinder
11. Development of advanced concepts for improved flexibility in CSP applications
12. Development and Field Test of CSP Hybrid Brayton Turbine Combined Cycle sCO<sub>2</sub> System

These 12 proposals, provided as attachment to this document in separate files, were prepared between July and mid-September 2016 following specific template provided by the European Commission (EC).

## ORGANIZATIONS INVOLVED IN THE PROCESS

The evaluation of these proposals was made in the two stages described into the following section (Industrial Risk –STEP1-, Technological Relevance –STEP2). Later on, an assessment of the TRL level of each proposal was asked to all participants. In the whole process the following organizations ACTIVELY participated:

### INDUSTRIAL Organizations

- ESTELA
- EUTURBINES<sup>2</sup>
- SENER
- ABENGOA
- ARCHIMEDE SOLAR ENERGY
- ACS-COBRA
- SUNCNIM
- ENI
- RIOGLASS
- ALMECO
- EMPRESARIOS AGRUPADOS
- KRAFTANLAGEN
- SCHLAICH BERGERMANN  
PARTNER - SBP SONNE
- TSK DEVELOPER
- TSK-FLAGSOL (EPC)

### RTD Organizations

- UNIVERSITY OF EVORA
- DLR
- ENEA
- FRAUNHOFER
- CNRS
- CIEMAT
- IMDEA
- CEA
- CYI
- TECNALIA
- CENER
- IK4-TEKNIKER
- FBK
- UNIVERSITY DI FIRENZE
- LNEG

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<sup>2</sup> The involvement of EUTurbines has been limited to sharing proposals 10, 11, 12 with this group. The proposals were prepared by EUTurbines independently from this process and directly provided to the Commission as well. EUTurbines has not participated in the evaluation process.

- MAGALDI
  - ACCIONA
  - INNOGY
  - SQM
  - ACWA POWER
- METU

These organizations are representing a large amount of CSP/STE sector in Europe. STEP1 was analyzed by the Industrial Developers<sup>3</sup> and STEP2 by all organizations.

## USED METHODOLOGY

### Step 1: Assessment of the Industrial Risk

Provided that they decide to participate in this exercise, the Industrial Developers were invited to perform a first evaluation step of each R&D proposal: first assessing the degree of relevance of several aspects that constitute the industrial risk for our sector, and then evaluating each proposal regarding these aspects, i.e. ranking them according to the probability of having each respective aspect impacting the commercial/industrial implementation of the subject of the proposal.

More specifically (as also explained in the corresponding Excel sheet), contributors were requested to follow the guidelines below:

1. In the first table of the worksheet (Question 1), the degree of relevance of each aspect independently of the projects themselves should be selected (the answers will be automatically duplicated as reference for each project proposal).
2. In Question 2, the risk of occurrence should be ticked (i.e. the opinion regarding the probability that a given aspect becomes an obstacle to the commercial/industrial implementation of each proposal).

The aspects regarding to the industrial risk that were assessed were the following:

- **Technological risk:** incremental designs vs new designs, validated industrial equipment, conventional vs specific equipment, synergies with components used in other commercial technologies, commercial equipment scale-up, materials, process plant complexity, integration of subsystems, standard accepted code design and operational safety.
- **Supplier chain available,** complete and secure, especially for those critical key components. Components/suppliers scarcity. Ability to enforce appropriate product guarantee.
- **Construction and plant commissioning times.** Operation of the plant complexity.
- **Operational and maintenance costs** of the plant based on components lifetime, degradation and recovery time after failure.
- **Nominal annual performance target risk,** operation flexibility, start-up, transient and shutdown times.

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<sup>3</sup> Industrial Developers are companies having carried out, or signed an EPC Contract of a commercial STE plant, or having contributed to the funding of at least one of these plants.

- **Financial/Market risk.** Bankability. Lack of confidence of private sector investment. Insurance. Lack of confidence in equipment manufacturers given their sometimes short track records

In case a voting entity does not feel competent to assess the industrial risk of a given proposal it should leave the corresponding proposal x table blank.

The evaluation results of this step (a total “score”) was later distributed to both the participating industrial developers and the R&D Centres. In case of strong disagreement, a joint analysis should be performed with the purpose of reaching a consensus. At least **one Industrial Developer** shall support in writing any proposal that will have passed this step. Just one answer (Excel file) per company would be accepted.

## **Step 2: Evaluation of Technological Relevance**

After the first Step, all proposals were also evaluated by **industrial organizations and R&D Centres** according to general criteria that were also agreed and defined by the following criteria:

<b>Cost reduction:</b>	Evaluate the cost reduction potential implementing the concept in the short term
<b>Innovation:</b>	Evaluate the innovation potential that enable cost reduction in the longer term
<b>Dispatchability:</b>	Evaluate the impact of the approach on the dispatchability and storage cost
<b>Market penetration:</b>	Evaluate 'time horizon for expected marketable effects' Short is high score
<b>Scalability:</b>	Evaluate the time frame and investments needed to scale the technology up to competitive market size

The excel file ‘STEP 2 GENERAL CRITERIA EVALUATION’ was created with the following sheets:

### **Sheet ‘CRITERIA’**

- **Aim:** This sheet ranks the importance of each criterion.
- **Procedure:** The evaluator will fill only **the yellow cells** of the table – the other cells will update correspondingly. The filling will be done **horizontally** confronting the row criteria with each of the column criteria.
- The values to be entered are to be chosen among:

Number to enter in the table in the purple boxes	Definition
2	It is extremely less important or preferred.
4	It is significantly less important or preferred.
6	The criterion being considered is equally important or equally preferred when judged against the criterion you are comparing it to.
8	The criterion being considered is significantly more

	important or more preferred.
10	The criterion is extremely more important or more preferred.

Result: The percentage column in blue provides the ranking of importance for each criterion.

#### Sheet 'PROPOSALS CONFRONTATION'

- Aim: Provide a ranking on the relevance of each project proposal with regards to the criteria
- Procedure: A table confronting a proposal with the other proposals is made for each of the criteria. Such table is duplicated as many times as the number of criteria. In each of the tables, the evaluator will fill only **the yellow cells** of the table – the other cells will update correspondingly. The filling should be done **horizontally** confronting the Proposal 1 with each of the column Proposals (proposal 2, 3 etc) with respect to the respective criterion.
- The values to be entered are chosen among 2, 4, 6, 8, 10, following the same definition as above but applied this time to the 'proposal' instead of the 'criterion'. This operation is repeated as many times as the number of criteria.
- The final evaluation is performed automatically in the last sheet. It weights the results according to the criteria weight issued in the sheet 'CRITERIA'.
- Result:
  - *The percentage row in green provides the relevance of each proposal with regards to the agreed criteria.*
  - *The percentage column in blue provides the relevance of each proposal with regards to the other proposals.*

As general background information, the methodology used in STEP 2 is the same than the one described in <http://www.processexcellencenetwork.com/lean-six-sigma-business-transformation/articles/process-excellence-methodologies-using-prioritizat> but using a linear scale (2-4-6-8-10), as agreed in telco meetings.

### **Step 3: TRL assessment**

A STEP 3 was finally added, to translate the TRL levels in the final assessment. Also, one single answer per organization was requested.

## **TIMING**

The evaluation process of the 12 proposals was split into the two described steps with the followed initial timetable:

## STEP 1 -- EVALUATION OF INDUSTRIAL RISK

WHO	DEADLINE	WHAT
ESTELA	20/9	Distribute list of involved companies
WG members	23/9	Send to Marcel Bial (MB, ESTELA coordinator) and Julian Blanco (JB, PSA coordinator) contacts of not mentioned potentially interested “industrial developers” companies
ESTELA	23/9	Invitation to industry to participate in evaluation STEP 1: <ul style="list-style-type: none"> <li>• Explanation text and instructions (incl. procedure timing)</li> <li>• Evaluation tool (Excel sheet)</li> <li>• Deadline 30. September)</li> <li>• 12 Proposals to evaluate</li> </ul>
Industrial developers	30/09 0:00h	Send to MB and JB their evaluation sheet
ESTELA	8/10	Distribute to ALL (industrial dev. + R&D centres) the resulting evaluation of the industrial risk (ranking)
All	15/10	Time for Q&A, corrections, <b>consensus finding</b>
ESTELA	17/10	Conclusion of step 1 – communicate preliminary result to EC

## STEP 2 -- EVALUATION OF TECHNOLOGICAL RELEVANCE

WHO	DEADLINE	WHAT
ESTELA	18/10 extended to 21/10	Invitation to ALL (industrial developers, companies and R&D centers) to participate in evaluation STEP 2: <ul style="list-style-type: none"> <li>• Explanation text and instructions</li> <li>• Evaluation tool (Excel sheet)</li> <li>• Deadline (20. October)</li> <li>• Ranked proposals remaining to evaluate (max. 12)</li> </ul>
ALL	28/10 0:00h	Respondents to send to MB and JB their evaluation sheet
ESTELA	02/11	Distribute to ALL the resulting evaluation of the general criteria (ranking)
ALL	14/11	Final TelCo among working group
All	15/11	Provide information on TRL level for each of the 12 Proposals to include this parameter in the final ranking.
ESTELA / PSA	18/11	Send final results + methodology to EC

## ORGANIZED MEETINGS

During this process, the following meetings were organized:

1. Telco meeting (18<sup>th</sup> June, 2016)
2. Villigen (Switzerland), in the context of an STAGE-STE meeting
3. Telco meeting (28<sup>th</sup> July 2016)
4. Telco meeting (20<sup>th</sup> September, 016)
5. Telco meeting (4<sup>th</sup> November, 2016)
6. Telco meeting (14<sup>th</sup> November, 2016)

## CONCLUSIONS

Final results of this exercise are presented into the following table and the following analysis can be done:

1. Results are presented here only for the proposals with very high expected final TRL (8 to 9) with the premise that the industry urgently needs innovations to be introduced into new plants in the short term and, therefore, only technologies close to the market are addressed in this exercise (it is considered that interesting but long-term developments should also be the object of regular R&D financing).
2. The Step 1 results show that two proposals are perceived as quite safe (#5 and #3), four proposals are considered to still have a certain level of industrial risk (#1, #6, #4 and #2) and one proposal (#8) relatively risky.
3. As concerns the Step 2, the proposals #5 and #6 are classified as quite relevant, followed by a second group of proposals (#2, #1 and #4) considered of intermediate relevance and a couple of proposals (#3 and #8) with a minor relevance.
4. An exercise calculating the simple average value of the scores in Step 1 and Step 2, is presented. Given the proximity of the individual values, different resulting final rankings would be obtained if weights were to be used in the averaging process.
5. According to the calculation exercise outcome, the proposal with the highest final score is the number #5 (Improved Central Receiver Molten Salt technology), with a clear distance to the next group formed by proposals #3 and #6. A third group with minor differences of score can be appreciated at proposals #1, #2 and #4. Finally, the proposal #8 has the lowest ranking (among this list) with the additional difference of having an initial TRL lower than the rest of proposal.

	RESULT STEP1		RESULT STEP 2		RELATIVE SCORING [(points,i)/(points,max)]				TRL level	
	Points	Rank	Points	Rank	STEP1	STEP2	AVG	Rank	Initial	Final
Proposal 5: Improved Central Receiver Molten Salt tech.	129,17	2	9,88	1	0,96	1,00	0,98	1	7	9
Proposal 3: Parabolic Trough with Silicon Oil	134,58	1	7,82	6	1,00	0,79	0,90	2	6	8
Proposal 6: Next Generation of Central Receiver power plants	102,50	4	9,73	2	0,76	0,98	0,87	3	6	8
Proposal 1: Advanced Linear Fresnel technology	105,83	3	8,60	3	0,79	0,87	0,83	4	6	8
Proposal 2 : Parabolic Trough with Molten Salt	97,92	6	8,53	44	0,73	0,86	0,80	5	6	8
Proposal 4: Open Volumetric Air Receiver	100,00	5	8,18	5	0,74	0,83	0,79	6	6	8
Proposal 8: Multi-Tower Beam Down System	75,00	7	7,16	7	0,56	0,72	0,64	7	5	7 to 8

Among the other proposals not indicated here, it should be mentioned that the highest score corresponds to the proposal #9 (Thermal Energy Storage). This proposal would rank on third position on absolute terms but its initial and final expected TRL (4 and 6 to 7, respectively) would imply that the respective technology would not be ready for imminent commercial plants.

It should be kept in mind that the proposals provided by EUTurbines may fit into the longer term perspective, having a lower initial and final expected TRL compared to other proposals. While proposals #10 and #11 have a high score in terms of industrial risk, the TRL levels have an impact on the overall score of this exercise.

However, funding of medium/long term actions is also needed to ensure the European leadership in the long-term.



## **Annex III – Financing tools and instruments**

Activity	Countries interested	Priority Level to country	National Financing Tools and instruments eventually suitable to be used		National Entities potentially interested to develop it (indicative non-exhaustive list)	Ongoing directly related R&I Activities
#1. Advanced Linear Fresnel technology	Portugal	1	<ul style="list-style-type: none"> <li>- Regional Funds (CCDRA).</li> <li>- Contributions from national CSP companies</li> <li>- In-kind contribution from research organizations</li> </ul>		<ul style="list-style-type: none"> <li>- Research centres: INIESC (Uni. Evora + LNEG), IST (Universidade de Lisboa), INESC (Lisboa), INEGI (Porto).</li> <li>- Companies: EDP, EFACEC, ProCME, Tecneira, Integrum Energia (Sonae group), ISQ, CREDITE</li> <li>- Energy Agencies: Areanatejo</li> </ul>	-
	France	1	<ul style="list-style-type: none"> <li>- European Regional Development Funds (already used)</li> <li>- Investment for the Future (already used)</li> <li>- National Agency for Research (ANR)</li> <li>- National Agency for the Environment and Energy Management (ADEME)</li> </ul>		<ul style="list-style-type: none"> <li>- Companies: SUNCNIM, ALSOLEN, SMPE, ENOGIA</li> <li>- Research centres: CEA</li> </ul>	- Projects : LLO (SUNCNIM), ALSOLEN SUP, ALSOLEN MT
	Italy	1	<ul style="list-style-type: none"> <li>- Regional funds; National funds</li> <li>- Contributions from national companies</li> <li>- In-kind contribution from research organizations</li> <li>- EU-funded projects</li> </ul>		-	<ul style="list-style-type: none"> <li>- Research centres</li> <li>- Universities</li> <li>- Companies</li> </ul>
#2. Parabolic Trough with Molten Salt	Portugal	2	Suitable Call: LC-CS3-RES-13-2018. Budget to be available per project: EUR 15-20 million	<ul style="list-style-type: none"> <li>- Regional Funds (CCDRA).</li> <li>- Contributions from national CSP companies</li> <li>- In-kind contribution from research organizations</li> </ul>	<ul style="list-style-type: none"> <li>- Research centres: INIESC (Uni. Evora + LNEG), IST (Universidade de Lisboa), INESC (Lisboa), INEGI (Porto).</li> <li>- Companies: EDP, EFACEC, ProCME, Tecneira, Integrum Energia (Sonae group), ISQ, CREDITE</li> <li>- Energy Agencies: Areanatejo</li> </ul>	-
	Germany	2		- Energy Research Framework Programme: Topic High Temperature Solar Thermal Technologies (annual budget of about 10	- DLR: with large scale research facilities on CSP and molten salt technology	- HPS2: Molten salt in parabolic trough

Activity	Countries interested	Priority Level to country	National Financing Tools and instruments eventually suitable to be used		National Entities potentially interested to develop it (indicative non-exhaustive list)	Ongoing directly related R&I Activities
				Mio€/a: applicable to German industry or research partners) at a level of 35-50% cost sharing - Helmholtz Program on Renewables; Topic Concentrating Solar Power: Research on advance heat transfer fluids 1.5 Mio€/a funding is linked to research in DLR.	- TSK Flagsol (engineering molten salt and silicon oil systems) - YARA Industrial GmbH (salt manufacturer) - Eltherm production GmbH (trace heating) - Wacker Chemie (Silicon Oil producer) - TÜV Nord (Inspection, safety aspects of high temperature materials) - Bilfinger (Salt receiver engineering) - Eckrohkessel (molten salt steam generator) - M&W (Engineering / Turnkey molten salt trough) - BASF Molten Slat producer - Senior Flexionix (REPA producer)	
	Italy	1		- Regional funds; National funds - Contributions from national companies - In-kind contribution from research organizations - EU-funded projects	-	- Research centres - Universities - Companies
#3. Parabolic Trough with Silicon Oil	Spain	3	Suitable Call: LC-CS3-RES-13-2018. Budget to be available per project: EUR 15-20 million	- Support from CDTI to technological development and industrial innovation - Support/grants from MEIC to research activities - Contributions from national CSP companies - In-kind contribution from research organizations	- Research centres: CIEMAT, CENER, IMDEA, TECNALIA, TEKNIKER, UNIV. SEVILLA. - Companies: ABENGOA, SENER, COBRA, ACCIONA	- Project SITEF: "Silicone fluid Test facility". SolarERANET project Ref. Spain: PCIN-2014-083. - SIMON: "Silicone Fluid Maintenance and Operation". Solar ERANET project Ref. Spain not yet received

Activity	Countries interested	Priority Level to country	National Financing Tools and instruments eventually suitable to be used		National Entities potentially interested to develop it (indicative non-exhaustive list)	Ongoing directly related R&I Activities
	Cyprus	2		<ul style="list-style-type: none"> <li>- Possible grants from Research Promotion Foundation under the RESTART calls (<a href="https://iris.research.org.cy/#/index">https://iris.research.org.cy/#/index</a>) and other structural funds.</li> </ul>	<ul style="list-style-type: none"> <li>- Members of the National Task Force: Research Promotion Foundation, Directorate General for European Programmes Cooperation and Development, Advanced Energy Laboratory, Energy Service (Ministry of Energy, Commerce, Industry and Tourism), University of Cyprus, Cyprus University of Technology, Electricity Authority of Cyprus, Cyprus Employers and Industrialists' Federation (OEB), Cyprus Chamber of Commerce and Industry (CCCI)</li> </ul>	<ul style="list-style-type: none"> <li>- Cyl work at its Thermal Energy Storage Laboratory (TESLAB) and PROTEAS CSP-DSW facility as well as CFD modelling.</li> <li>- Projects: CySTEM (H2020 ERA Chair), NESTER (H2020 TWINNING)</li> </ul>
	Germany	1		<ul style="list-style-type: none"> <li>- Energy Research Framework Programme: Topic High Temperature Solar Thermal Technologies (annual budget of about 10 Mio€/a: applicable to German industry or research partners) at a level of 35-50% cost sharing</li> <li>- Helmholtz Program on Renewables; Topic Concentrating Solar Power: Research on advance heat transfer fluids 1.5 Mio€/a funding is linked to research in DLR.</li> </ul>	<ul style="list-style-type: none"> <li>- DLR: large scale research facilities on CSP and molten salt technology</li> <li>- TSK Flagsol (engineering molten salt and silicon oil systems)</li> <li>- YARA Industrial GmbH (salt manufacturer)</li> <li>- Eltherm production GmbH (trace heating)</li> <li>- Wacker Chemie (Silicon Oil producer)</li> <li>- TÜV Nord (Inspection, safety aspects of high temperature materials)</li> <li>- Bilfinger (Salt receiver engineering)</li> <li>- Eckrohkessel (molten salt steam generator)</li> <li>- M&amp;W (Engineering / Turnkey molten salt trough)</li> <li>- BASF Molten Salt producer</li> <li>- Senior Flexionix (REPA producer)</li> </ul>	<ul style="list-style-type: none"> <li>- SITEF: Silicone test facility</li> </ul>

Activity	Countries interested	Priority Level to country	National Financing Tools and instruments eventually suitable to be used	National Entities potentially interested to develop it (indicative non-exhaustive list)	Ongoing directly related R&I Activities
#4. Open Volumetric Air Receiver	Turkey	4	<p>TÜBİTAK is the main body for RDI funding in Turkey having two programmes which could be used for international project funding (participation subject to decision of Science Board).</p> <ul style="list-style-type: none"> <li>- 1509 - TÜBİTAK International Industrial R&amp;D Projects Grant Programme. Objective: to create market focused R&amp;D Projects between EU countries and to increase cooperation between Europe wide firms, universities and research institutions, by using cooperation tools such as EUREKA. Eligible applicants: SMEs and large companies settled in Turkey.</li> </ul> <p>Eligible costs: Personnel, travel, equipment/ tool/software, R&amp;D services from domestic RTOs, consultancy/other services, material costs. Type of research funded: Applied research, experimental development. There is no budget limit of the Programme but limit is determined per call.</p> <ul style="list-style-type: none"> <li>- 1001 - Scientific and Technological Research Projects Funding Program. Purpose: to support research in Turkey for generating new information, interpreting scientific findings, or solving technological problems on a scientific basis. Eligible applicants: university, public research institutes, industry and SMEs settled in Turkey. Eligible costs: Personnel, consumables, subcontracts, equipment, travel, documentation. Type of research funded: Basic, Applied research, experimental development. There is no budget limit of the Programme but limit is determined per call.</li> </ul> <p>TÜBİTAK has also call oriented programmes which are:</p> <ul style="list-style-type: none"> <li>- 1003 - R&amp;D Funding Program supporting and coordinating national result oriented R&amp;D projects (traceable targets on scientific and technological fields within the National Science, Technology and Innovation Strategy).</li> </ul>	<ul style="list-style-type: none"> <li>- Middle East Technical University</li> <li>- İstanbul Technical University</li> <li>- Greenway Solar</li> </ul>	<ul style="list-style-type: none"> <li>- Call targeting CSP technologies has been published recently. The focus of this call would be parabolic through, Fresnel, parabolic dish and heliostat technologies. There is no budget limit for the call. However, the budget limit for large-scale projects is 2.5 Million TRY, for medium-scale 1 Million TRY and for small-scale 500.000 TRY.</li> </ul>

Activity	Countries interested	Priority Level to country	National Financing Tools and instruments eventually suitable to be used	National Entities potentially interested to develop it (indicative non-exhaustive list)	Ongoing directly related R&I Activities
			1511 - Research & Technology Development and Innovation Program with Priority Fields support and coordinate result-oriented, observable, national R&D and Innovation projects that are well-matched with the priority fields determined within the scope of the National Science Technology and Innovation Strategy.		
	Belgium	3	- ...	- ...	- ...
#5. Improved Central Receiver Molten Salt technology	Spain	1	<ul style="list-style-type: none"> <li>- Support from CDTI to technological development and industrial innovation</li> <li>- Support/grants from MEIC to research activities</li> <li>- Contributions from national CSP companies</li> <li>- In-kind contribution from research organizations</li> </ul>	<ul style="list-style-type: none"> <li>- Research centres: CIEMAT, CENER, IMDEA, TECNALIA, TEKNIKER, UNIV. SEVILLA.</li> <li>- Companies: ABENGOA, SENER, COBRA, ACCIONA</li> </ul>	<ul style="list-style-type: none"> <li>- Project sFeCTO: "Sistema de mEdida de Flujo concEntrado en Centrales de Torre Online". Proyecto FEDER INTERCONNECTA 2016</li> <li>- Project GRIDSOL "Smart Renewable Hubs for Flexible Generation: Solar Grid Stability". European H2020 project with G.A.: 727362</li> </ul>
	Cyprus	1	<ul style="list-style-type: none"> <li>- Possible grants from Research Promotion Foundation under the RESTART calls (<a href="https://iris.research.org.cy/#/index">https://iris.research.org.cy/#/index</a>) and other structural funds.</li> </ul>	<ul style="list-style-type: none"> <li>- Members of the National Task Force: Research Promotion Foundation, Directorate General for European Programmes Cooperation and Development, Advanced Energy Laboratory, Energy Service (Ministry of Energy, Commerce, Industry and Tourism), University of Cyprus, Cyprus University of Technology, Electricity Authority of Cyprus, Cyprus Employers and Industrialists' Federation (OEB), Cyprus Chamber of Commerce and Industry (CCCI)</li> </ul>	<ul style="list-style-type: none"> <li>- Cyl work at its Thermal Energy Storage Laboratory (TESLAB) and PROTEAS CSP-DSW facility as well as CFD modelling.</li> <li>- Projects: CySTEM (H2020 ERA Chair), NESTER (H2020 TWINNING)</li> </ul>
	Germany	1	- Energy Research Framework Programme: Topic High	- DLR: with large scale research	- HPMS: Advanced molten

Activity	Countries interested	Priority Level to country	National Financing Tools and instruments eventually suitable to be used	National Entities potentially interested to develop it (indicative non-exhaustive list)	Ongoing directly related R&I Activities
			<p>Temperature Solar Thermal Technologies (annual budget of about 10 Mio€/a: applicable to German industry or research partners) at a level of 35-50% cost sharing</p> <ul style="list-style-type: none"> <li>- Helmholtz Program on Renewables; Topic Concentrating Solar Power: Research on advance heat transfer fluids 1.5 Mio€/a funding is linked to research in DLR.</li> </ul>	<p>facilities on CSP and molten salt technology</p> <ul style="list-style-type: none"> <li>- TSK Flagsol (engineering molten salt and silicon oil systems)</li> <li>- YARA Industrial GmbH (salt manufacturer)</li> <li>- Eltherm production GmbH (trace heating)</li> <li>- Wacker Chemie (Silicon Oil producer)</li> <li>- TÜV Nord (Inspection, safety aspects of high temperature materials)</li> <li>- Bilfinger (Salt receiver engineering)</li> <li>- Eckrohkessel (molten salt steam generator)</li> <li>- M&amp;W (Engineering / Turnkey molten salt trough)</li> <li>- BASF Molten Slat producer</li> <li>- Senior Flexionix (REPA producer)</li> </ul>	salt tower receiver system
	Turkey	1	<p>TÜBİTAK is the main body for RDI funding in Turkey having two programmes which could be used for international project funding (participation subject to decision of Science Board).</p> <ul style="list-style-type: none"> <li>- 1509 - TÜBİTAK International Industrial R&amp;D Projects Grant Programme. Objective: to create market focused R&amp;D Projects between EU countries and to increase cooperation between Europe wide firms, universities and research institutions, by using cooperation tools such as EUREKA. Eligible applicants: SMEs and large companies settled in Turkey.</li> </ul> <p>Eligible costs: Personnel, travel, equipment/ tool/software, R&amp;D services from domestic RTOs, consultancy/other</p>	<ul style="list-style-type: none"> <li>- Middle East Technical University</li> <li>- İstanbul Technical University</li> <li>- Greenway Solar</li> <li>-</li> </ul>	<ul style="list-style-type: none"> <li>- Call targeting CSP technologies has been published recently. The focus of this call would be parabolic through, Fresnel, parabolic dish and heliostat technologies. There is no budget limit for the call. However, the budget limit for large-scale projects is 2.5 Million TRY, for medium-scale 1 Million TRY and for small-scale 500.000 TRY.</li> </ul>

Activity	Countries interested	Priority Level to country	National Financing Tools and instruments eventually suitable to be used	National Entities potentially interested to develop it (indicative non-exhaustive list)	Ongoing directly related R&I Activities
			<p>services, material costs. Type of research funded: Applied research, experimental development. There is no budget limit of the Programme but limit is determined per call.</p> <p>- 1001 - Scientific and Technological Research Projects Funding Program. Purpose: to support research in Turkey for generating new information, interpreting scientific findings, or solving technological problems on a scientific basis. Eligible applicants: university, public research institutes, industry and SMEs settled in Turkey. Eligible costs: Personnel, consumables, subcontracts, equipment, travel, documentation. Type of research funded: Basic, Applied research, experimental development. There is no budget limit of the Programme but limit is determined per call.</p> <p>TÜBİTAK has also call oriented programmes which are:</p> <p>- 1003 - R&amp;D Funding Program supporting and coordinating national result oriented R&amp;D projects (traceable targets on scientific and technological fields within the National Science, Technology and Innovation Strategy).</p> <p>- 1511 - Research &amp; Technology Development and Innovation Program with Priority Fields support and coordinate result-oriented, observable, national R&amp;D and Innovation projects that are well-matched with the priority fields determined within the scope of the National Science Technology and Innovation Strategy.</p>		
	Belgium	1	<p>- Support from Wallonia, General Directorate for Economy, Employment and Research</p> <p>- Support from cluster MECATECH</p> <p>- Contributions from national CSP companies</p> <p>- In-kind contribution from research organizations</p>	<p>- Research centres:</p> <ul style="list-style-type: none"> <li>o CRM (metallurgy) <a href="http://www.crmgroup.be/">http://www.crmgroup.be/</a></li> <li>o BCRC (ceramic) <a href="http://www.bcrc.be">http://www.bcrc.be</a></li> <li>o Materia Nova (materials) <a href="http://www.materianova.be/">http://www.materianova.be/</a></li> </ul> <p>- Companies: CMI</p>	<p>- Project Absol: Development of new absorber coating</p> <p>- Project SolarFocus: development of High temperatura solar absorbing coating</p> <p>- Project SOLAR PERFORM:</p>



Activity	Countries interested	Priority Level to country	National Financing Tools and instruments eventually suitable to be used	National Entities potentially interested to develop it (indicative non-exhaustive list)	Ongoing directly related R&I Activities
				- Universities: Liège University, CSL	Development of an Accurate lifetime prediction model for the Molten Salt Solar Receiver
#6. Next Generation of Central Receiver power plants	Spain	2	<ul style="list-style-type: none"> <li>- Support from CDTI to technological development and industrial innovation</li> <li>- Support/grants from MEIC to research activities</li> <li>- Contributions from national CSP companies</li> <li>- In-kind contribution from research organizations</li> </ul>	<ul style="list-style-type: none"> <li>- Research centres: CIEMAT, CENER, IMDEA, TECNALIA, TEKNIKER, UNIV. SEVILLA.</li> <li>- Companies: ABENGOA, SENER, COBRA, ACCIONA</li> </ul>	- Project “Loop Heat Pipe technology for Solar-Dynamic Energy Conversion”, funded by the European Space Agency
	Cyprus	3	<ul style="list-style-type: none"> <li>- Possible grants from Research Promotion Foundation under the RESTART calls (<a href="https://iris.research.org.cy/#/index">https://iris.research.org.cy/#/index</a>) and other structural funds.</li> </ul>	Members of the National Task Force: <ul style="list-style-type: none"> <li>- Research Promotion Foundation,</li> <li>- Directorate General for European Programmes Cooperation and Development,</li> <li>- Advanced Energy Laboratory,</li> <li>- Energy Service (Ministry of Energy, Commerce, Industry and Tourism),</li> <li>- University of Cyprus,</li> <li>- Cyprus University of Technology,</li> <li>- Electricity Authority of Cyprus,</li> <li>- Cyprus Employers and Industrialists' Federation (OEB),</li> <li>- Cyprus Chamber of Commerce and Industry (CCCI)</li> </ul>	<ul style="list-style-type: none"> <li>- Cyl work at PROTEAS CSP-DSW facility as well as system modelling efforts</li> <li>- Projects: CySTEM (H2020 ERA Chair), NESTER (H2020 TWINNING)</li> </ul>
	France	1	<ul style="list-style-type: none"> <li>- European Regional Development Funds (already used)</li> <li>- Investment for the Future (already used)</li> <li>- National Agency for Research (ANR)</li> <li>- National Agency for the Environment and Energy Management (ADEME)</li> </ul>	<ul style="list-style-type: none"> <li>- Companies: EDF, ENGIE, CMI</li> <li>- Research centres: CEA, CNRS</li> <li>- Occitanie Regional authorities</li> </ul>	- H2020 Next-CSP project “High Temperature concentrated solar thermal power plant with particle receiver and direct thermal storage” (2016-2020)

Activity	Countries interested	Priority Level to country	National Financing Tools and instruments eventually suitable to be used	National Entities potentially interested to develop it (indicative non-exhaustive list)	Ongoing directly related R&I Activities
	Turkey	3	<p>TÜBİTAK is the main body for RDI funding in Turkey having two programmes which could be used for international project funding (participation subject to decision of Science Board).</p> <ul style="list-style-type: none"> <li>- 1509 - TÜBİTAK International Industrial R&amp;D Projects Grant Programme. Objective: to create market focused R&amp;D Projects between EU countries and to increase cooperation between Europe wide firms, universities and research institutions, by using cooperation tools such as EUREKA. Eligible applicants: SMEs and large companies settled in Turkey.</li> </ul> <p>Eligible costs: Personnel, travel, equipment/ tool/software, R&amp;D services from domestic RTOs, consultancy/other services, material costs. Type of research funded: Applied research, experimental development. There is no budget limit of the Programme but limit is determined per call.</p> <ul style="list-style-type: none"> <li>- 1001 - Scientific and Technological Research Projects Funding Program. Purpose: to support research in Turkey for generating new information, interpreting scientific findings, or solving technological problems on a scientific basis. Eligible applicants: university, public research institutes, industry and SMEs settled in Turkey. Eligible costs: Personnel, consumables, subcontracts, equipment, travel, documentation. Type of research funded: Basic, Applied research, experimental development. There is no budget limit of the Programme but limit is determined per call.</li> </ul> <p>TÜBİTAK has also call oriented programmes which are:</p> <ul style="list-style-type: none"> <li>- 1003 - R&amp;D Funding Program supporting and coordinating national result oriented R&amp;D projects (traceable targets on scientific and technological fields within the National Science, Technology and Innovation Strategy).</li> </ul>	<ul style="list-style-type: none"> <li>- Middle East Technical University</li> <li>- İstanbul Technical University</li> <li>- Greenway Solar</li> </ul>	<ul style="list-style-type: none"> <li>- Call targeting CSP technologies has been published recently. The focus of this call would be parabolic through, Fresnel, parabolic dish and heliostat technologies. There is no budget limit for the call. However, the budget limit for large-scale projects is 2.5 Million TRY, for medium-scale 1 Million TRY and for small-scale 500.000 TRY.</li> </ul>

Activity	Countries interested	Priority Level to country	National Financing Tools and instruments eventually suitable to be used	National Entities potentially interested to develop it (indicative non-exhaustive list)	Ongoing directly related R&I Activities
			- 1511 - Research & Technology Development and Innovation Program with Priority Fields support and coordinate result-oriented, observable, national R&D and Innovation projects that are well-matched with the priority fields determined within the scope of the National Science Technology and Innovation Strategy.		
	Belgium	2	<ul style="list-style-type: none"> <li>- Support from Wallonia, General Directorate for Economy, Employment and Research</li> <li>- Support from cluster MECATECH</li> <li>- Contributions from national CSP companies</li> <li>- In-kind contribution from research organizations</li> </ul>	<ul style="list-style-type: none"> <li>- Research centres: <ul style="list-style-type: none"> <li>o CRM (metallurgy)<a href="http://www.crmgroup.be/">http://www.crmgroup.be/</a></li> <li>o BCRC (ceramic)<a href="http://www.bcrc.be/">http://www.bcrc.be/</a></li> <li>o Materia Nova (materials)<a href="http://www.materianova.be">http://www.materianova.be</a></li> </ul> </li> <li>- Companies: CMI</li> <li>- Universities: Liège University, CSL</li> </ul>	<ul style="list-style-type: none"> <li>- Project SolarFocus: development of High temperatura solar absorbing coating</li> <li>- Project SOLAR PERFORM: Development of an Accurate lifetime prediction model for the Molten Salt Solar Receiver</li> <li>- Project SOLAR GNEXT: Development of the next generation solar receiver</li> </ul>
#7. Pressurized Air Receiver with Storage	France	4	<ul style="list-style-type: none"> <li>- National Agency for Research (ANR)</li> <li>- National Agency for the Environment and Energy Management (ADEME)</li> <li>- LCE-07-2016-2017</li> </ul>	<ul style="list-style-type: none"> <li>- Research centres: CEA, CNRS</li> <li>- Companies: CMI</li> </ul>	<ul style="list-style-type: none"> <li>- Investment for the Future (Laboratory of Excellence SOLSTICE)</li> <li>- POLYPHEM proposal submitted to LCE-07-2016-2017 call</li> </ul>
#8. Multi-Tower Beam Down System	Portugal	4	<ul style="list-style-type: none"> <li>- In-kind contribution from research organizations</li> </ul>	<ul style="list-style-type: none"> <li>- Research centres: INIESC (Uni. Evora + LNEG), IST (Universidade de Lisboa), INESC (Lisboa), INEGI (Porto).</li> <li>- Companies: EDP, EFACEC, ProCME, Tecneira, Integrum Energia (Sonae group), ISQ, CREDITE</li> </ul>	-

Activity	Countries interested	Priority Level to country	National Financing Tools and instruments eventually suitable to be used	National Entities potentially interested to develop it (indicative non-exhaustive list)	Ongoing directly related R&I Activities
				- Energy Agencies: Areanatejo	
	Cyprus	4	- Possible grants from Research Promotion Foundation under the RESTART calls ( <a href="https://iris.research.org.cy/#/index">https://iris.research.org.cy/#/index</a> ) and other structural funds.	Members of the National Task Force: Research Promotion Foundation, Directorate General for European Programmes Cooperation and Development, Advanced Energy Laboratory, Energy Service (Ministry of Energy, Commerce, Industry and Tourism), University of Cyprus, Cyprus University of Technology, Electricity Authority of Cyprus, Cyprus Employers and Industrialists' Federation (OEB), Cyprus Chamber of Commerce and Industry (CCCI)	- Projects: CySTEM (H2020 ERA Chair), NESTER (H2020 TWINNING)
	Italy	1	- Regional funds - National funds - Contributions from national companies - In-kind contribution from research organizations - EU-funded projects		- Research centres - Universities - Companies
#9. Advanced TES (Thermal Energy Storage)	Spain	4	<div>Suitable Call: LC-CS3-RES-17-2019. Budget to be available per project: EUR 12-15 million</div> <ul style="list-style-type: none"> <li>- Support from CDTI to technological development and industrial innovation</li> <li>- Support/grants from MEIC to research activities</li> <li>- Contributions from national CSP companies</li> <li>- In-kind contribution from research organizations</li> </ul>	<ul style="list-style-type: none"> <li>- Research centres: CIEMAT, CENER, IMDEA, TECNALIA, TEKNIKER, UNIV. SEVILLA.</li> <li>- Companies: ABENGOA, SENER, COBRA, ACCIONA</li> </ul>	<ul style="list-style-type: none"> <li>- Project HTSTORAGE: "Desarrollo de sistemas de almacenamiento térmico avanzado de alta temperatura y bajo coste en la Comunidad Foral de Navarra". Financed by the Navarra Regional Government (Spain)</li> <li>- Project ALCCONES "Storage and conversion of concentrated solar power".</li> </ul>

Activity	Countries interested	Priority Level to country	National Financing Tools and instruments eventually suitable to be used		National Entities potentially interested to develop it (indicative non-exhaustive list)	Ongoing directly related R&I Activities
						<p>Project financed by Madrid Regional Government (Spain) Ref. S2013/MAE-2985</p> <ul style="list-style-type: none"> <li>- Project NEXTOWER “Advanced materials solutions for next generation high efficiency concentrated solar power (CSP) tower systems“. H2020-NMBP project with GA: #721045</li> <li>- Project REELCOOP “Research Cooperation in Renewable Energy Technologies for Electricity Generation“. European FPT project, GA: 608466)</li> <li>- Project WASCOP “Water Saving for Solar Concentrated Power. European H2020 project, GA 654479)</li> <li>- Project DETECSOL “Nuevos desarrollos para una tecnología termosolar mas eficiente“. Spanish national project (Ref. ENE2014-56079-R)</li> <li>- Project INSHIP “Integrating National Research Agendas on Solar Heat for Industrial Processes“. European</li> </ul>

Activity	Countries interested	Priority Level to country	National Financing Tools and instruments eventually suitable to be used		National Entities potentially interested to develop it (indicative non-exhaustive list)	Ongoing directly related R&I Activities
						<p>H2020 ECRIA Project , G.A.: 731287</p> <ul style="list-style-type: none"> <li>- Project TERMOSTOK “Advanced storage systems for dispatchable renewable energy”. Spanish national project. Ref.:RTC-2016-5002-3</li> <li>- Project NEXT-CSP “High Temperature concentrated solar thermal power plan with particle receiver and direct thermal storage”. European H2020 project. G.A.: 727762</li> <li>- Project “Desarrollo de actividades de investigación fundamental estratégica en almacenamiento de energía electroquímica y térmica”. Regional project financed by the SPRI Program of the Basque Government (Spain)</li> <li>- Project “Captación de calor residual de sólidos para su reutilización eficiente y competitiva”. Regional project financed by the Basque Government (Spain)</li> <li>- Project SUSPIRE “Sustainable Production of storage technologies”.</li> </ul>

Activity	Countries interested	Priority Level to country	National Financing Tools and instruments eventually suitable to be used		National Entities potentially interested to develop it (indicative non-exhaustive list)	Ongoing directly related R&I Activities
						European H2020 project with G.A.: 680169
	Portugal	3		<ul style="list-style-type: none"> <li>- Regional Funds (CCDRA).</li> <li>- Contributions from national CSP companies</li> <li>- In-kind contribution from research organizations</li> </ul>	<ul style="list-style-type: none"> <li>- Research centres: INIESC (Uni. Evora + LNEG), IST (Universidade de Lisboa), INESC (Lisboa), INEGI (Porto).</li> <li>- Companies: EDP, EFACEC, ProCME, Tecneira, Integrum Energia (Sonae group), ISQ, CREDITE</li> <li>- Energy Agencies: Areanatejo</li> </ul>	<ul style="list-style-type: none"> <li>- “NewSOL - New StOrage Latent and sensible concept for high efficient CSP Plants” (H2020 - 720985)</li> </ul>
	France	1		<ul style="list-style-type: none"> <li>- Investment for the Future (already used)</li> <li>- National Agency for Research (ANR)</li> <li>- National Agency for the Environment and Energy Management (ADEME)</li> </ul>	<ul style="list-style-type: none"> <li>- Companies: ADF, Ecotech-Ceram, ACM, ALSOLEN</li> <li>- Research centres: CEA, CNRS</li> <li>- Occitanie Regional authorities</li> </ul>	<ul style="list-style-type: none"> <li>- Investment for the Future (Laboratory of Excellence SOLSTICE)</li> <li>- “Opticline – Optimisation of high temperature thermal energy storage using thermocline” National project funded by the National Agency for research” starting in 2017</li> <li>- ALSOLEN SUP, INPOWER (PCM storage at HT),</li> <li>- H2020 WASCOP</li> </ul>
	Turkey	2		<p>TÜBİTAK is the main body for RDI funding in Turkey having two programmes which could be used for international project funding (participation subject to decision of Science Board).</p> <ul style="list-style-type: none"> <li>- 1509 - TÜBİTAK International Industrial R&amp;D Projects Grant Programme. Objective: to create market focused R&amp;D Projects between</li> </ul>	<ul style="list-style-type: none"> <li>- Middle East Technical University</li> <li>- İstanbul Technical University</li> <li>- Greenway Solar</li> <li>-</li> </ul>	<ul style="list-style-type: none"> <li>- Call targeting CSP technologies has been published recently. The focus of this call would be parabolic through, Fresnel, parabolic dish and heliostat technologies. There is no budget limit for the call.</li> </ul>

Activity	Countries interested	Priority Level to country	National Financing Tools and instruments eventually suitable to be used		National Entities potentially interested to develop it (indicative non-exhaustive list)	Ongoing directly related R&I Activities
				<p>EU countries and to increase cooperation between Europe wide firms, universities and research institutions, by using cooperation tools such as EUREKA. Eligible applicants: SMEs and large companies settled in Turkey. Eligible costs: Personnel, travel, equipment/ tool/software, R&amp;D services from domestic RTOs, consultancy/other services, material costs. Type of research funded: Applied research, experimental development. There is no budget limit of the Programme but limit is determined per call.</p> <p>- 1001 - Scientific and Technological Research Projects Funding Program. Purpose: to support research in Turkey for generating new information, interpreting scientific findings, or solving technological problems on a scientific basis. Eligible applicants: university, public research institutes, industry and SMEs settled in Turkey. Eligible costs: Personnel, consumables, subcontracts, equipment, travel, documentation. Type of research funded: Basic, Applied research, experimental development. There is no budget limit of the Programme but limit is determined per call. TÜBİTAK has also call oriented programmes which are:</p> <p>- 1003 - R&amp;D Funding Program supporting and coordinating national result oriented R&amp;D projects (traceable targets on scientific and technological fields within the National Science, Technology and Innovation Strategy).</p>		<p>However, the budget limit for large-scale projects is 2.5 Million TRY, for medium-scale 1 Million TRY and for small-scale 500.000 TRY.</p>



Activity	Countries interested	Priority Level to country	National Financing Tools and instruments eventually suitable to be used		National Entities potentially interested to develop it (indicative non-exhaustive list)	Ongoing directly related R&I Activities
				- 1511 - Research & Technology Development and Innovation Program with Priority Fields support and coordinate result-oriented, observable, national R&D and Innovation projects that are well-matched with the priority fields determined within the scope of the National Science Technology and Innovation Strategy.		
	Italy	1		- Regional funds - National funds - Contributions from national companies - In-kind contribution from research organizations - EU-funded projects		- Research centres - Universities - Companies
#10. Supercritical Steam Cycle 600°			Suitable Call: H2020-LCE-7-2017: New cycles & innovative power blocks for CSP plants	-		-
				-		-
				-		-
#11. Flex. Steam Turbine				-		-
				-		-
				-		-
#12. High Temp Brayton Sc. CO2				-		-
				-		-
				-		-
				-		-

**NOTES:**

1. Financial resources are still under definition
2. Priority level to country: 1 is the highest priority level

3. Other EC coming calls suitable to provide additional potential support to the previous 12 project/topics:
- LC-SC3-RES-11-2018: Developing solutions to reduce the cost and increase performance of renewable technologies. CSP: Novel components and configurations for linear focusing and point focusing technologies need to be developed and tested. Budget available per project: EUR 2 to 5 million.
  - LC-SC3-JA-2-2018: Support to the realisation of the Implementation Plans of the SET Plan. Budget available per project: EUR 1 million