HORIZON STE

HORIZON-STE: Implementation of the Initiative for Global Leadership in Solar Thermal Electricity

D1.1. "Report on countries' relevance for the Implementation Plan"

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ENEA, Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

DLR, Deutsches Zentrum Fuer Luft - Und Raumfahrt EV

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ABOUT THE PROJECT

HORIZON-STE is a Horizon2020 funded project aiming at supporting the Implementation of the Initiative for Global Leadership in Solar Thermal Electricity (STE), also known as Concentrated Solar Power (CSP), which was launched by the European Commission and adopted within the Strategic Energy Technology Plan (SET Plan) of the European Commission.

Since more than a decade, Europe's Solar Thermal Electricity sector holds a worldwide technology leader until its further development abruptly hindered in Europe. To unlock this situation, the European Commission has launched a dedicated Initiative – Initiative for Global Leadership in Concentrated Solar Power focusing on 2 targets: a cost reduction target and an innovation target, in order to keep STE/CSP’s global technology leadership and rebuild a home market in Europe.

Acting as competence centre of the Implementation Working Group within the Strategic Energy Technology Plan (SET Plan) of the European Commission, the overall goal of HORIZON-STE is to support the execution of the Implementation Plan regarding both STE/CSP Research and Innovation lines as well as First-Of-A-Kind projects that will help steer countries through political, legislative, and institutional shortcomings linked to various national policies concerning solar thermal electricity. Much of the focus centres on improving procurement of manageable RES and increased public funding for STE/CSP research.

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1 EXECUTIVE SUMMARY

The project HORIZON-STE, “Implementation of the Initiative for Global Leadership in Solar Thermal Electricity”, is one of the instruments that the CSP/STE Implementation Working Group has, to achieve the goals and visions of the sector through the execution of the STE/CSP Implementation Plan.

The project will support the execution of the IP considering both, STE/CSP Research and Innovation lines, as well as First-Of-A-Kind projects, that will help steer countries through political, legislative, and institutional shortcomings linked to various national policies concerning solar thermal electricity.

The **deliverable D1.1 “Report on countries’ relevance” is based on the work performed on Task. 1.1:** Update of Implementation Plan, within Work Package 1 “Implementation Plan (IP) initial and yearly status update”. It has the objective to **set the starting point for the project**, analysing the changes that have occurred since the publication of the Implementation Plan and the progress achieved so far. In addition, it will allow to understand which countries are the most relevant to be approached for the interest of the country and from which perspective they should be addressed (Industrial, R&I or jointly).

In order to achieve this, first, a general update of the plan was performed, including a revision of the status of the objectives and a consultation to the countries involved in the IP to understand what their current starting point is. Next, the relevance of selected European countries was assessed based on their stake in the CSP/STE sector, identifying their (actual or potential) participation within 4 basic categories: industry engagement (along the supply chain), potential host for a CSP/STE power plant, potential off-taker country, and/or R&I engagement. Complementing this mapping, additional countries, not currently involved in the IP were reached out to in order to assess their readiness and interest in funding STE/CSP research activities. In the last section, all these results are used to define the right approach for each country, assigning it to a work package depending on its perceived relevance (WP2 for industrial interest, WP3 for fundamentally R&I interest or to both for a joint analysis).

The work performed in this task will allow the consortium to carry on with the following tasks with a clearer perspective and represents a first roadmap to the development of the project. Moreover, the consultations and research described here will continue throughout the project and will allow to update this deliverable on a yearly basis to provide the best possible roadmap for the successful execution of the implementation plan.

2 INTRODUCTION

As expressed in the description of the project, this Coordination and Support Action lies in three main legislative and institutional pillars.

The first pillar is the Regulation on the Governance of the Energy Union and Climate Action ((EU)2018/1999). The second pillar is the Renewable Energy Directive (revised on December 2018, 2018/2001/EU). Lastly, the **third technology-oriented, legislative/institutional pillar is the SET-Plan** of the EU's energy and climate policy, a first step to establish an energy technology policy for Europe. It aims at:

- Accelerating knowledge development, technology transfer and market up-take;
- Maintaining EU industrial leadership on low-carbon energy technologies;
- Fostering science for transforming energy technologies to achieve the 2020 Energy and Climate Change goals;
- Contributing to the worldwide transition to a low carbon economy by 2050;
- Establishing priorities and implementing joint actions via a strengthening dialogue between Member States (MSs) and Associated Countries (ACs), and between MS/ACs and the EC.

The actions towards the a.m. goals of the SET-Plan go back to **European Industrial Initiatives (EIIs)** which would bring together industry, the research community, the Member States and the Commission in risk-sharing, public-private partnerships aimed at the rapid development of key energy technologies at European level. The most recent "**Initiative for Global Leadership in Concentrated Solar Power"**[1] originates in a consultation process launched by the EC at the end of 2015 inviting the European stakeholders in the CSP/STE sector to provide their contribution to an "issues paper on CSP/STE". This contribution is the core of the Initiative and defines two strategic targets:

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

To develop this Initiative, a Temporary Working Group (TWG) was established in 2016 within the SET-Plan structures to prepare a corresponding Implementation Plan (IP) gathering representatives from several SET-Plan countries, the EC and the stakeholders (from both industry and research sectors). The IP includes twelve strategic R&D activities and the implementation of an innovative CSP/STE plant, the so-called First-Of-A-Kind (FOAK) plant. Upon adoption of the Implementation

[1] https://setis.ec.europa.eu/system/files/set_plan_csp_initiative_implementation_plan.pdf

Plan in November 2017, the TWG continued its tasks as "Implementation Working Group" (IWG) focusing from now on the concrete conditions for the implementation of the Initiative**.** During the a.m. process, the CSP/STE sector, represented by ESTELA, was substantially involved. Functionally comparable to an ETIP (European Technology and Innovation Platform), ESTELA extended its consultations to *all* actively involved actors of the sector to ensure a full transparency of the process, taking references from other EU projects, such as STAGE-STE[2].

This report is based on the first task of the Project "HORIZON-STE" (**Task. 1.1: Update of Implementation Plan)** and **i**t has the objective of setting a starting point for the project, analysing changes that have occurred since the publication of the Implementation Plan (including any progress achieved so far). In addition, it will allow to understand which countries should be addressed within the scope of work of this *Coordination and Support Action* and from which perspective (Industrial, R&I or jointly).

Below, Section 3 presents a brief description of the structure of the work performed and Section 4 presents the results obtained from the research performed and consultations made. These results are structured in Sub-tasks and arranged by country.

3 DESCRIPTION OF TASK

This first task was coordinated by ESTELA, with extensive contributions from all the partners from the consortium and was developed during the first two months of work of the project (M1-2), May & June 2019. It involves a total of four main subtasks, three of which were developed in parallel, and a separate sub-task that was developed after the completion of the first 3 as a concluding task.

The four sub-tasks were:

> ***Subtask 1****: Review and update of the execution of the IP, as well as of the countries' engagement, listing and describing ongoing active support initiatives, the evaluation and assessment of such initiatives against full IP outcome and objectives.*
>
> The main purpose of this first sub-task is **to identify what has changed and what has been done so far, from the moment that the Implementation Plan was published until now.** Also, it will shed some light on what initiatives are today in place (or already running projects) that directly or indirectly contribute to the achievement of the objectives of the Plan. It covers only the countries that had a major involvement in the IP.
>
> ***Subtask 2****: Assessment of the relevance of various European countries/regions due to their stake in the CSP/STE sector*
>
> Here, the relevance of selected European countries/regions is assessed based on their stake in the CSP/STE sector. This was done by identifying the type of participation they have along

[2] STAGE-STE website: http://stage-ste.eu

the value chain of the sector and classifying them within **4 basic categories: industry engagement (along the supply chain), potential host for a CSP/STE power plant, potential off-taker country, and/or R&I engagement.**

This selection will be further assessed and reported in the Deliverable 2.1 "Report on stakeholder mapping", which will cover the results of Task 2.1.

Subtask 3*: Request to countries which were not yet considered in the Implementation Plan about their interest and readiness to co-fund R&I projects or activities in the sector.*

In this task, a contact was established with countries such as Belgium (region of Wallonia), Croatia or Switzerland to assess the a.m. aspects. During the development of the project, other countries can be considered and approached to if it is considered relevant. Those new developments will be included in the subsequent updates of this report.

Subtask 4*: Identification of the type of approach to follow for each country and in which WP of the project they will be addressed.*

After analysing the findings obtained in the first three sub-tasks, it was then possible to identify the type of relevance of each country involved along the CSP value chain for the IP and classify them in a table, indicating in which WP it will be addressed.

For instance, if a country is found to be relevant from and industrial or commercial (potential off-taker) point of view, it will be analysed under **Work Package 2.** If any given country is only relevant to the IP from an R&I point of view, it will be analysed further under **Work Package 3**.

However, if any country results to be relevant from the R&I and any other of the criteria mentioned in the sub-task 2, the country will be analysed in both Work Packages and subject to an **"integrated country report"**, coordinated through the Task 2.4, within Work Package 2.

4 RESULTS

4.1 Subtask 1 – Update on the general status of the IP

4.1.1 Objectives of the IP

In January 2016, the SET-Plan countries, representatives from the STE/CSP industry stakeholders and the European Commission, reached an agreement on the targets for the sector and committed to the preparation of an Implementation Plan. The two general objectives that were laid out in the Implementation Plan are shown below:

Agreed Strategic Targets on CSP
Short-term: > 40% cost reduction by 2020 (from 2013) translating into • Supply price < 10 c€/kWh for a radiation of 2050 kWh/m2/year (conditions in Southern Europe) under the assumption that the corresponding Power Purchase Agreements (PPA) have a duration of 25 years and under the assumption of a global market volume of 30 GW.
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.

To date, regarding the short-term target (target #1: cost reduction), it is possible to say the although record-low prices under 10 c€/kWh (for a radiation of 2050 kWh/m2/year) have been achieved before the year 2020, this cannot be considered as a fully achieved objective because the projects that obtained those prices (either as bids or contract attributions) are not within European borders (e.g. Chile, Morocco, UAE). Nevertheless, the original target price was agreed by the industry under the assumption of a global market volume of 30 GW, which is in 2019 far from being the case. Therefore, strong efforts continue to be needed for replicating those successful projects in Europe. Nevertheless, it is also important to mention that the development of such projects has been led/co-led by European developers or counted with European suppliers for the main components (e.g. receivers, heliostats, collector tube, molten salts, etc.). **Therefore, this will continue to be a key objective for the industry.**

As for the longer-term target (target #2: new generation of CSP/STE technology), the industry considers that this target constitutes an objective in the aftermath of a true market relaunch in Europe, where innovative technologies could be introduced progressively along a project pipeline.

The reason is that, under current deployment conditions in Europe, implementing any disruptive innovation (such as new cycles) in a commercial STE plant would essentially push the investment costs higher than what could be immediately offset by the performance gains. This is a consequence of funding institutions requesting a higher premium for not yet implemented technology at wider scale. A possible change of this could be achieved in case an innovation funding instrument would compensate this primary cost increasing effect.

4.1.2 Evolution of the TWG to IWG and its link to this project/action

As described in the IP, in April 2016, a Temporary Working Group was set up to prepare the IP to reach its targets. It was led by Spain as Chair, assisted by the EC and formed by representatives from a number of SET Plan countries, the EC and the stakeholders (both industry and research)[3]. 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.

In 2018, the Temporary Working Group (as all the TWG from the SET-Plan) was turned into "Implementation Working Group", which continues to report to the SET Plan Steering Group. The chair of the TWG, led by Mrs. Inmaculada Figueroa from the Ministry of Economy of Spain, was taken over by Mrs. Marta March of the Ministry of Science, Innovation and Universities of the same country.

In essence, the Implementation working group(s) and the consortia work closely and in a coordinated manner so to support the achievement of the overarching objectives of the Integrated SET-PLAN:

- Identifying actions for research and innovation, based on an assessment of the energy system's needs and on their importance for the energy system transformation and their potential to create growth and jobs in the EU
- Addressing the whole innovation chain, from research to market uptake, and tackles both financing and the regulatory framework
- Adapting the governance structures under the umbrella of the SET Plan to ensure a more effective interaction with EU countries and stakeholders
- Measuring progress via overall Key Performance Indicators (KPIs), such as the level of investment in research and innovation, or cost reductions.

Regarding the specific role of the IWG, the most outstanding features are as follows:

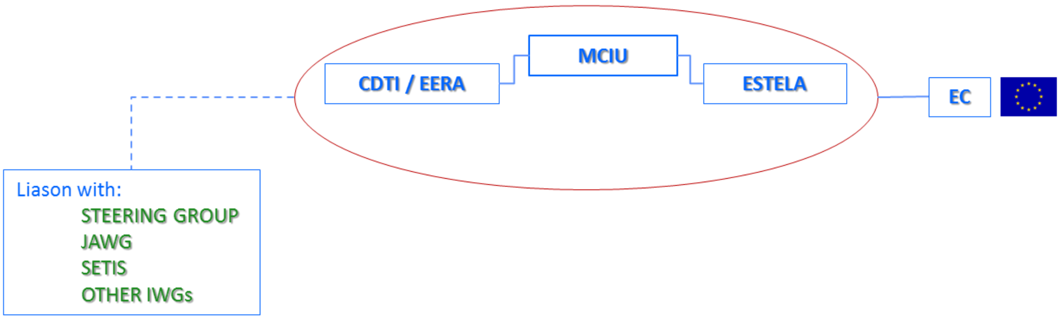
Roles of different actors

- **Chair** (assisted by a number of **Vice-Chairs**):
  - Developing visibility and outreach (be an 'ambassador') of the IWG building visibility and recognition

[3] 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.

- Active support to provide the best updated political contacts to the respective country's public authorities that the IWG will need to interface in order to implement its actions
- Ensuring overall coordination including active task sharing within the group;
- Liaising with SET Plan Country Representatives, European Commission and EERA/ESTELA/ETIPs to help facilitate the execution of the IP and the mobilization of corresponding financial support (e.g. co-funding)
- Facilitate the monitoring and reporting progress in collaboration with SETIS, reporting periodically to the SET Plan Steering Group members on the execution and progress of the IP

Chairmanship: Spain (MCIU)
Assisted by: CDTI (Funding Agency) + ESTELA (Industry) + EERA (Research Organizations) and the European Commission



[4]

Figure 1. Diagram of the organisation of the CSP IWG. Source: Own elaboration.

- **SET Plan Country Representatives**
  - Active support to provide the best updated political contacts to the respective country's public authorities that the IWG will need to interface in order to implement its actions
  - Liaising with national SET Plan Steering Group representatives and Joint Action Working Group members, to jointly find ways to implement common interests
  - Coordinating national public funding and Programs ensuring its alignment with the IP where relevant and appropriate
  - Ensuring visibility and outreach at national level

Moreover, the Implementation Working Group is supported by this Action to facilitate the execution of its duties and the corresponding achievement of the envisioned targets.

[4] MCIU: Ministerio de Ciencia, Innovación y Universidades (ES), CDTI: Centro para el Desarrollo Tecnológico e Industrial (ES)

4.1.3 Demonstration projects at commercial scale

Regarding the building block of *Demonstration projects at commercial scale (where the concept of FOAK was introduced in the IP)*, it was expressed in the same document that the TWG considered 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 was 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 would be necessary in Europe by 2020.

However, **no FOAK project (or even a demonstration project at a smaller commercial scale) has been developed since the publication of the IP till now.**

Nevertheless, different mechanisms and instruments have been mapped out and studied to facilitate the development of such a project (e.g. the use of public funding instruments and frameworks that facilitate the cooperation between regions, as well as mechanisms for cross-border projects). This will be covered in the next point and in detail the deliverable "D1.2 Update of Framework conditions".

Moreover, in section 4.1.5, advancements on demonstration projects at a relevant scale (although not commercial) are included.

4.1.4 Non-technological actions (framework conditions)

As described in the IP, this topic refers to financing, regulatory framework and other that can act as enablers for the successful implementation of the plan and further development of the industry.

These aspects will be covered in the second deliverable of the project, "D1.2 Update of Framework conditions", and will include aspects such as:

Financing

- Co-financing by SET Plan countries and the EC
- Coordination with structural funds
- Risk financing
- Instruments
    - Innovation Fund (derived from the former NER300)
    - Connecting Europe Facilities (Cross border projects)

Energy policy & Regulatory framework

- The completion of the Clean Energy for all legislative Package
- The draft National and Energy Climate Plans put forward by the Member States as required by the Governance Regulation of the Energy Union
- Use of the Cooperation Mechanisms in the re-cast of the Renewable Energy Directive

- Speed-up and facilitation of permitting processes in SET-Plan Countries

Efforts and collaboration between stakeholders to improve the framework conditions

- Collaboration in relevant EU-funded projects
- Results from ESTELA's activities

4.1.5 Update on IP countries represented in the consortium

To begin with, the countries involved in the CSP IP that are represented in the HORIZON-STE consortium were analysed[5]. The corresponding partners (DLR, METU, ENEA and CIEMAT) analysed the following aspects in their national context:

1. Current status of the country's engagement on the execution of the IP
2. Running projects relevant to IP (national, EU and international)
3. Contribution of research facilities to the execution of the Plan (e.g. SFERA III, BOOST-EUSOLARIS, etc.)
4. Implementation instruments
5. National Program relevant to IP (update)
6. Responsibility for program in the country (including contact reference)
7. Evaluation of current initiatives against full IP outcome and objectives
8. Progress of demonstration projects at commercial scale relevant to IP
9. Non-technological actions relevant to IP (framework conditions)
10. Activities related to support to internationalisation
11. Stake of the country in the CSP/STE sector
12. CSP value chain sector relevant for the country

This required desk research and consultations within the corresponding research entities and with governmental institutions, such as ministries and national funding agencies. In addition, the research activities included in the IP can be found in Annex 1.

4.1.5.1 Germany

4.1.5.1.1 Current status of the country's engagement on the execution of the IP

Germany has participated actively in the design of the Implementation Plan first by joining the Temporary Working Group (TWG) which set the basis of the plan and then by getting into action in the Implementation Working Group (IWG). Now, with the deployment of Horizon STE, German Stakeholder will shape the next projects with the aim to fulfil the IP goals.

[5] The results of the research made about Italy will be included in the next update of the deliverable.

Germany's strong engagement in the execution of the SET Implementation Plan is demonstrated by the number of projects initiated since its launch. The funding given by the Federal Ministry for Economic Affairs and Energy (BMWi) in relation to the IP is of 12.1 Mio €. Additionally, the Helmholtz Association of German Research Centres (HGF) contributes to these goals currently with a funding of 1.9 Mio € and the participation of German partners in EU projects is funded with 1.4 Mio €.

Also relevant to mention here is the recent commitment of further HGF funding to co-finance the SIMOSA and Si-Power projects, both very relevant to the IP, which were proposed to the H2020 LC-SC3-RES-17-2019 and LC-SC3-2018-RES calls at EC level and which required a co-financing of 3.3 M€. Unfortunately, both projects were not successful in the EC evaluation process.

4.1.5.1.2 Running projects relevant to IP (national, EU and international)

If we consider the timeframe beginning when the SET IP was released (September 2017), the main contribution of Germany to the IP has been on national level, mainly though projects funded by BMWi and one funded by HGF. Starting from January 2018, only one European project in the Framework of H2020 is being executed. The key data of these projects is shown on Table 1 below:

Financing entity: (N)ational or (EU)ropean	Project Name	Acronym	Leading organization (coord)	Years of execution (> January 2018, < June 2019)	Relation to IP research projects	German Industrial Partners	German R&D Partners	Project budget for Germany (€) (*)
N (HGF)	Component tests for molten salt	ProMS	DLR	2018-2021	1,2,5,6,9	-	DLR	1.870.000 €
N (BMWi)	Performance Testing for heliostat fields	Heliodor	DLR	August 2018 - July 2021	*4,5,6*	CSP Services GmbH, sbp Sonne GmbH, KAM-Kraftanlagen München GmbH, Heliokon GmbH	DLR	1.364.281 €
N (BMWi)	Concept study CSP-Reference Plant with Molten Salt "Made in Germany"	CSPRK	DLR	March 2019 - August 2020	5, 6	Steinmüller Engineering GmbH, Tractebel Engineering GmbH, MAN Energy Solutions SE, sbp sonne gmbh	DLR	1.260.415 €
EU	Solving Water Issues for CSP plants	SOLWATT	TSK ELECTRONICA Y ELECTRICIDAD SA (Spain)	May 2018 - April 2022	1,2,3,5,6	-	DLR	1.438.827 €
N (BMWi)	Development and qualification of a three-dimensionally profiled absorber for the open volumetric HiTRec receiver	HitRec3D	Kraftanlagen München	November 2018 - October 2021	4	Kraftanlagen München, Exentis, Continental Emitec	DLR	2.900.000 €
N (BMWi)	High Performance Molten Salt Tower Receiver System	HPMS-II	DLR	October 2018 - September 2021	5	MAN Diesel & Turbo SE, Flexible Industriemesstechnik GmbH Subcontracted: Salzgitter Mannesmann Forschung Associated partners: Endress + Hauser Messtechnik GmbH + CO.KG, Mannesmann Stainless Tubes, HORA - Holter Regelarmaturen GmbH & Co.	DLR and Solar-Institut Jülich der Fachhochschule Aachen.	5.232.684 €
N (BMWi)	Heliostat development with sandwich facets, carrousel tracking and optical closed-loop control	SAHEL	DLR	October 2018 - September 2021	4,5,6	Covestro and SBP	DLR	1.350.051 €
N (BMWi)	Development of components for a solar thermal tower power plant - overall optimization through air wall and optimized heat transfer medium	HelioGLOW	Fraunhofer	September 2018 - August 2021	6	LWT GmbH, NEBUMA GmbH, sbp sonne GmbH	Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.	2.791.455 €
N (BMWi)	Test plant for bulk material and heat	VESUW	FH Aachen, SIJ	May 2019 - July 2022	9	Grenzebach BSH GmbH, Hilger GmbH	Fachhochschule Aachen - Solar-Institut Jülich, Jülich	805.826 €
N (BMWi)	Secondary reflector for solar tower	SolSec	Fraunhofer	May 2019 - April 2021	6	-	DLR, Fraunhofer-Institut für Solare Energiesysteme (ISE)	510.486 €
								17.143.539 €

Table 1. Running projects in Germany relevant to IP (national, EU and international). Source: Elaboration by DLR.

4.1.5.1.3 *Contribution of research facilities to the execution of the Implementation Plan (e.g. SFERA III, BOOST- EUSOLARIS, etc.)*

Regarding research facilities, Germany hosts among others the following specialized infrastructure which may contribute to the IP by offering the required infrastructure for its execution:

- Solar Tower Jülich with focus on receiver and heliostat research, development and demonstration: https://www.dlr.de/sf/en/desktopdefault.aspx/tabid-8560/15527_read-44867/
- High Flux Solar Simulator Synlight, which can be used to research on solar chemical processes: https://www.dlr.de/sf/en/desktopdefault.aspx/tabid-10958/19330_read-44887/
- DLR's Solar Furnace in Cologne, can be used to demonstrate are research on highly concentrated sun light: https://www.dlr.de/sf/en/desktopdefault.aspx/tabid-10953/19318_read-44871/
- The QUARZ Centre which is used to measure and qualify key components of CST technology: https://www.dlr.de/sf/en/desktopdefault.aspx/tabid-10966/19342_read-44924/
- Also at DLR in Cologne the CeraStroE infrastructure is located, where research on new storage materials can be done: https://www.dlr.de/sf/en/desktopdefault.aspx/tabid-10965/19341_read-44922/
  This includes the TESIS facility :https://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10202/334_read-24102/#/gallery/28298
- Fraunhofer Institute for Solar Energy Systems (ISE) offers different laboratories for the research and qualification of CST components and systems, such as the Concentrator Optics Laboratory and Field, CD-Lab for accelerated aging tests, TES-Lab for characterization and simulation of thermal storage materials, and the Water Treatment Laboratory: https://www.ise.fraunhofer.de/en/rd-infrastructure.html

The high quality of the existing facilities will be even improved by means of the European project SFERA-III (grant agreement number 823802 of the H2020-INFRAIA-2018-2020 programme), which is currently underway under the coordination of CIEMAT-PSA. The round robin tests and the joint R+D activities performed by the SFERA-III partners are improving the test protocols and the quality standards of the main European facilities available for components characterization and evaluation.

Work package WP11 is focussing on the detailed design of a virtual facility (e-infrastructure) that will link the European R+D centres devoted to CST technologies. One of the main services to be offered by this e-infrastructure will be the remote access to the European CST research facilities, so that external users could perform experiments remotely using this e-infrastructure. It is expected that this CST e-infrastructure will be managed by EU-SOLARIS once this entity is legally implemented and consolidated. Thus, SFERA III will support all stakeholders related to activities of the IP.

The IP is also supported with the realization the Doctoral Colloquium organized within SFERA-III (WP1) in which all PhD students preparing their thesis in the various European advanced solar energy laboratories involved in the project are brought together. These colloquia will be an opportunity for those PhD students to present the outcomes of their works in the CST field, see what others are doing in the same topic and strengthening the collaboration between these laboratories.

4.1.5.1.4 Implementation instruments

The implementation instruments in Germany are mainly:

- 7th Energy Research Program of the BMWi
- ERA-Net Cofund
- CSP-ERA-Net Cofund
- H2020

4.1.5.1.5 National Funding Programs relevant to IP and entities managing them

BMWi's 7th Energy Research Programme

The Federal Government promotes research and development in the field of forward-looking energy technologies. The Federal Ministry for Economic Affairs and Energy (BMWi) is therefore using the 7th Energy Research Programme[6] to help companies and research establishments to research and develop technologies for the energy supply of tomorrow.

The 7th Energy Research Programme defines the current principles and priorities for Federal Government funding for innovative energy technology. In this context, assistance is aimed primarily at technologies that meet the requirements of the energy transition. As regards the thematic priorities of energy efficiency and renewable energies, the focus is on funding measures for technologies in the fields of wind and solar power generation, a higher proportion of renewables in the heating sector through biomass and geothermal energy, energy-optimised buildings and neighbourhoods, and energy efficiency in the industrial sector. Special emphasis is placed on issues relating to the integration of new technologies into the energy system, the development of the grids, energy storage, and sector coupling.

BMU's International Climate Initiative

The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety developed the program International Climate Initiative (IKI) which finances climate and biodiversity projects in developing and newly industrialising countries, as well as in countries in transition. The Initiative places clear emphasis on climate change mitigation, adaption to the impacts of climate change and the protection of biological diversity. In the mitigation context, IKI supports partner countries in the

[6] For more information on BMWi's 7th Energy Research Programme, see: https://www.bmwi.de/Redaktion/EN/Publikationen/Energie/7th-energy-research-programme-of-the-federal-government.pdf?__blob=publicationFile&v=5

development and implementation of innovative instruments to reduce their greenhouse gas emissions. As such it may be principally also considered as suited for funding activities related to the IP although not explicitly mentioned in the program. The goal is a transformation towards a sustainable and low-emission economy and supply structure. The conceptual focus is on policy advice, capacity building and suitable training measures as well as technology cooperation. The IKI projects are focusing on the increasingly important regional level in their implementation. By the end of 2017, more than 300 projects had been approved in the area of mitigation. Funded projects can be found under https://www.international-climate-initiative.com/en/projects/

Helmholtz Program-oriented Funding

In the case of the Helmholtz Association, funding for research is organized into programs. The Association designs these programs in accordance with the strategic guidelines formulated by the funding partners in dialog with the Helmholtz Association. Program-oriented funding (PoF) seeks to establish a balance between cooperation and competition: Structuring the research according to research programs enables researchers to pool their expertise across centres and disciplines and enhances their cooperation. At the same time, the programs compete for funding. In addition to these research and development activities, Helmholtz provides large-scale scientific equipment and large platforms for scientific communities of users that typically include members from around the world. For more information, see:

https://www.helmholtz.de/fileadmin/user_upload/01_forschung/pof/EN_Factsheet_PoF_as_of_180914.pdf

Responsibility for program in the country

As mentioned above, the main responsible entity in Germany to fund STE research and development is BMWi. The program is coordinated by the Project Management Jülich (PtJ) (https://www.ptj.de/en/project-funding/applied-energy-research), the main contact persons there are:

- Mr. Tarik Schwarzer
  Projektträger Jülich
  Energiesystem: Erneuerbare Energien / Kraftwerkstechnik und CCS, Solarthermische Kraftwerke (ESE 5)
  Forschungszentrum Jülich GmbH, 52425 Jülich
  Tel.: 02461 61-9157
  t.schwarzer@fz-juelich.de

- Dr Sabine Semke
  Energy System: Integration (ESI)
  +49 02461 61-2738
  s.semke@fz-juelich.de

- Dr Frank Stubenrauch
  Energy System: Renewable Energies/Power Plant Technology (ESE)
  +49 02461 61-4744
  f.stubenrauch@fz-juelich.de

- Markus Kratz
  Energy System: End-Use
  +49 02461 61-8644
  m.kratz@fz-juelich.de

4.1.5.1.6 Evaluation of current initiatives against full IP outcome and objectives

Atmospheric volumetric receiver technology for solar tower systems

Germany started funding research on volumetric receivers for towers already back in the 90´s when the commercial project PHOEBUS (30MWe plant) was developed. Although never implemented on commercial scale due to falling fossil fuel prices, the development of the technology was continuously pursued. As alternative to metal mesh absorbers, German companies developed ceramic honeycomb absorber materials. After several R&D projects on national scale, German partners joint the EC project SOLAIR (Advanced solar volumetric air receiver for commercial solar tower power plants (EU funded, GA ID ERK6-CT-1999-00021, 02-2000 – 07-2000)). The objective of this project was to develop and demonstrate a new volumetric air receiver technology based on ceramic volumetric absorber modules, aiming at improved reliability and performance with reduced component costs for solar tower power plants. When finished, the research was again continued on national scale with the projects KOSMOSOL (BMWi, ref. number 03UM0021, 03-2004 – 09-2005) and KOSMOSOL II (BMWi, ref. number 03UM0054) titled “Cost and environmentally efficient energy from modular solar tower power plants”. Their focus was on improving the absorber manufacturing and solving durability problems as well as demonstrating the technology at the 3 MWth scale at *Plataforma Solar de Almeria*. As a result, German industry (Kraftanlagen München GmbH) built the 1 MWe pre-commercial demonstration plant in Jülich consisting of a complete CSP plant with storage, partly funded by BMU (16UM0061).

In the following national funded projects OVABSOL (2008-2011; FKZ 0325078 A-D) and INDUSOL (2011-2014; FKZ 0325330 B), the absorbers were further improved and industrial manufacturing of the absorber ceramics was developed. Co-funded by the country North Rhine Westphalia the project Start-SF (2008-2016; FKZ 323-2010-006) focused on structural improvements of the absorber matrix and on the investigation of the air flow around the absorbers. The project KEST (2012-2015; FKZ 0325443B) developed and tested several concepts for improvement of the yield in tower plants looking at all components of the plant.

In the BMWi funded project VORWAiRTS (BMWi, ref. number 0324093, 2016-09 - 2019-11), starting in 2019, the design of the receiver is modified to a concave shaped structure to improve the air return ratio under wind loads. Also, the heat losses due to radiation from the hot surface are reduced by this design. This work is supported by numerical simulations. For the new construction, a 500kW test receiver will be built and tested under real conditions at the Solar Tower Jülich. Before testing this new receiver design, it is planned to intensively test the current receiver of the Solar Tower Jülich under load in order to have a solid base of measurement data for further development. For a longer-term perspective on implementation, a new receiver design is being developed, with minimal cooling requirements and virtually completely closed air circulation. This design work is supported by detailed FEM (finite element method) and CFD (computational fluid dynamics) simulations to assess the impact of design alternatives on solar performance. For the new HiTRec receiver designs, a technical and economic system analysis is carried out to determine their market potential. The analyses are based on computer-aided simulations of the dynamic and stationary operation of a reference power plant with a new receiver design.

Parabolic Trough with Silicone Oil

German research institutions and industrial key players have been working for over twelve years on different projects to develop, improve, test and demonstrate innovative heat transfer fluids for parabolic trough systems. This path leads to bringing into the market the use of silicon oil on STE plants.

The foundations for HTF analysis, aging and assessment expertise were laid in the BMWi projects Si-HTF (2012-07 – 2015-10, funding reference number 0325453), AReWa (2011-04 – 2013-12, funding reference number 0325288) and AGAVA (2006-10 – 2008-12, funding reference number 03UM0082) developing techniques and procedures for measuring relevant fluid data beyond 400°C, studying the aging kinetics of the conventional HTF in detail (as a reference for HTF related evaluations) and developing sampling methods and analytical procedures for HTF analysis in CSP plants.

The SITEF project (2016-03-01 – 2017-12, funding reference number 0325846, BMWi) was aimed at demonstrating at small scale the functionality and applicability of a first-generation WACKER silicone heat transfer fluid named HELISOL® 5A and associated parabolic-trough solar collector (PTC) components at temperatures up to 425°C. This project was developed making use of the so called PROMETEO test facility at PSA and successfully completed in 2017.

The project SIMON (2017-11 – 2020-10, funding reference number 0324216, BMWi) is closely linked to a successful demonstration of the functionality and applicability of the second-generation WACKER SiHTF named HELISOL® XA and associated PTC components – flexible hoses and receiver tubes- at continuous operation temperatures of 425°C. While the SITEF project's aim was to demonstrate the feasibility of SiHTF for commercial plants, the aim of the SIMON project is to accelerate the market introduction by lowering all identified obstacles.

The next step into the market introduction of silicon oil for parabolic trough plants is the execution of the Si-Power project, which is expected to be funded in the EU H2020 framework as a continuation of previous German and European Solar-ERA.NET projects developed by Si-Power partners that aimed at developing HTF expertise and proof of concepts of individual elements.

Next Generation of central receiver power plants

German researchers and industrial partners have been working on the development of new components in order to improve the performance and reduce the levelized electricity cost of central receiver or solar tower power plants.

The projects described next are examples of this effort in relation to heliostats.

HELIKONTURplus. Cost reduction for solar tower power plants through optimized heliostat contours and adapted tower and field design (BMWi, ref. number 0324053, 07-2016 – 06-2019). *SBP Sonne Gmbh* has developed the 'Stellio', a new type of heliostat with significantly improved price-performance ratio. In order to enable the use in commercial projects, a system demonstration must now follow after a successful prototype test. With a good heliostat alone, it is not yet done: In a holistic optimization 'and only this leads to the minimum cost' the heliostat field and the tower height need to be optimized. This is only possible by knowing current tower cost functions that are determined in the project. Furthermore, in the proposed project, methods and simulation tools are created in order to assess the full cost reduction potential in field design by using heliostats with round or polygonal outer contours; these promise a higher field efficiency through reduced shading and blocking.

MAHWIN. Research into a method for the efficient and safe design of cost-effective heliostats by measuring and modelling dynamic, non-linear wind loads (BMWi, ref. number 0324213, 09-2017 – 09-2019). The central objective of the joint project MAHWIN is the structural optimization of a heliostat system with regard to dynamic wind loads by researching an easily applicable, accurate and thus practicable methodology for the efficient design according to the respective local wind conditions and design execution specifications. Through a better understanding of the dynamic loads and a fast calculation and evaluation of structural variants, the method to be explored should for the first time enable the targeted minimization of wind loads. At the end of an appropriate functional and cost-optimized fine-tuning of the construction, drive technology and production technology a series-ready heliostat concept with outstanding high availability in power plant operation and minimized investment risk by proven stability for each site-specific wind conditions will be available. Finally, this heliostat concept will be tested in a prototypical form within the framework of the research project in order to be available on the market in a timely manner after the end of the project and corresponding further development by the industrial partners.

SAHEL. More economical heliostats with sandwich concentrator, carousel tracking and optical closed-loop control (BMWi, ref. number 0324301, 10-2018 – 09-2021). The heliostat 'Stellio' of sbp sonne GmbH is currently the cheapest heliostat available. In order to maintain competitiveness in the medium term, efficiency is to be increased by 5% and costs reduced by 10 to 20% using a patented sandwich mirror panel of high reflectivity and dimensional accuracy. It is necessary to prove sufficient durability and long-term dimensional stability of the sandwich structure. Therefore, Covestro Deutschland AG is to find a suitable hard foam material for the core and to develop and carry out suitable long-term tests together with DLR. In another heliostat variant, the total heliostat costs are to be further reduced by 20% in the long term by using a novel carousel tracking and a closed-loop control. Overall, heliostat field costs of less than 80 EUR/ m² are targeted. A 50 m² concentrator for the Stellio and the new carousel heliostats will be developed, and a heliostat test sample will be built, qualified, tested in the endurance test and modified on the basis of the measurement results.

Improved Central Receiver Molten Salt technology

The projects below describe the latest developments from German stakeholders in the field of molten salt receivers:

HPMS, High Performance Molten Salt Tower Receiver System - Development of a highly efficient receiver system for salt tower power plants (BMWi, ref. number 0325733, 10-2014 – 12-2016).The overarching goal of the HPMS project is to exploit cost-cutting potential in salt tower power plants by developing a highly efficient receiver and by holistically optimizing the solar high-temperature cycle. It thus creates the basis for the next generation of salt tower power plants. For a subsequent project phase, the basic engineering for the test receiver system is created based on the results of the project. Additionally, a roadmap was drawn up and priorities for future R & D activities were set.

HPMS-II, High Performance Molten Salt Tower Receiver System – Phase 2 (BMWi, ref. number 0324327, 10-2018 – 09-2021). During the second phase of the HPMS project, the optimization measures of the external receiver developed in phase 1 are to be implemented Test system to be tested. The aim is to demonstrate a solar sub-receiver system and the associated salt circuit at the Solar Tower in Jülich. Individual components such as salt pumps, valves, insulation and measuring technology are qualified for operation with molten salt. All investigations also aim to validate and extend the simulation models in order to reliably predict the yield of the receiver under different conditions as well as the lifetime of the components and to be able to further develop the receiver through simulation models. As a result, further potential for improvement can be identified and pursued. These improvements are finally incorporated in the development of the basic engineering of a solar high-temperature circuit and receiver for the third phase of the HPMS project. In addition, scientific investigations will be carried out within DLR’s TESIS:com facility in Cologne, this includes the measurement and improvement of the heat transfer between nitrate salts and absorber tubes. In addition, non-intrusive ultrasonic flow measurement and pressure measurement are qualified for operation with nitrate salt melts.

Parabolic trough with molten salts

For more than fifteen years, various studies by independent institutions have determined the economic and technical potential of parabolic trough systems with molten salt as the heat transfer fluid and storage medium. Publications of this technology were mainly done in USA between 2003 and 2008.

Then in 2013 a study written by representatives of leading German component suppliers (Rügamer et al. (2013)[7]), further insights were obtained by varying location, heat transfer media, operating temperatures and collector types. Without going into details, the final result confirmed previous studies: the cost reduction by changing from thermal oil to molten salt is 20% independently of the examined sites. The lowest cost of electricity of 9.9 € cents / kWh was achieved with a liquid salt system.

Germany's first demonstration of a parabolic trough system with molten salt was initiated in the project HPS (funded by BMWi, ref. number 0325208, 2010-04 - 2014-12). Within this project, among other tasks, concepts for commercial power plants were done and the demonstration solar field was designed, including thermodynamic and component evaluations. The construction of the demonstrator in Evora, Portugal, was not completed because the project coordinator, Siemens, left the consortium.

The demonstration of this technology was continued with the project HPS2 (funded by BMWi, ref. number 0324097, 2016-07 - 2019-07). It has de main goal to test and demonstrate the operation, storage and steam generation of a molten salt parabolic trough field. It searches answers to the following questions relevant to the SET-IP:

- Power plant concepts with alternative heat transfer media, in particular salt as a heat transfer medium, with the aim of higher power plant efficiencies
- Measures and components for the energy-related improvement of the systems
- Development of concepts for operation, maintenance and monitoring
- Integrated thermal storage system
- Adaptation of conventional components to the operation modes of solar thermal power plants

<u>Thermal energy storage</u>

Germany has been investigating thermal energy storage since more than 12 years, the following projects are relevant for the SET-IP goals in terms of storage systems and storage media development:

HOTSPOT. High-temperature solids storage in solar tower (BMWi, ref. number 0325048, 2008-08 - 2012-07). The successful market introduction of solar tower power plants with air-cooled receivers depends to a great extent on the availability of high-temperature storage facilities. Suitable types of storage were by the time of the project initiation in an early concept stage. The project aimed to develop and evaluate design concepts for this component, improving cost-efficiency and proximity

[7] Rügamer T, Kamp H, Kuckelkorn T, Schiel W, Weinrebe G, Nava P, Riffelmann KJ, Molten Salt for Parabolic Trough Applications: System Simulation and Scale Effects, SolarPACES 2013

to the market. The work included the construction of a storage test bed and the design of non-pressurized and pressurized storage systems and their subcomponents. Simultaneously, simulation work on critical design aspects was carried out and contributions made to the implementation and techno-economic optimization.

ITES. Development and integration of thermal energy storage in parabolic trough power plants with direct solar steam generation (BMWi, ref. number 03UM0064, 2006-05 - 2012-06). As part of the project, a closed storage system for direct solar steam generation was developed for the first time, in which the storage modules are specially adapted for preheating, evaporation and overheating. Its technical feasibility has been successfully demonstrated with the design, construction, and testing of a 1 MWh phase-change material (PCM) storage with coupled concrete superheater storage in a 100-bar water / steam test loop in nearly 3,000 hours of operation. The storage concept is designed so that it can be flexibly adapted to power plant power and process parameters and can thus be used for the market introduction of the direct evaporation technology in the range of approximately 5 MW, but also for subsequent power plant projects in the range of more than 50 MW.

DE-TOP. Demonstration of solar direct evaporation with thermal storage and optimized steam parameters (BMWi, ref. number 0325164, 2009-10 - 2010-10). In solar direct steam generation, the feed water from the power plant process is vaporized directly in a collector field, superheated and then expanded in a turbine. Previous studies showed that compared to conventional systems, a significant increase in efficiencies while reducing the cost of equipment is possible. The demonstration of direct evaporation in a plant with 2 collector rows and live steam parameters of 500 ° C / 112 bar was intended to prove the process and component stability as well as the realization of further optimization potentials. However, a detailed comparison of the direct steam generation system with an oil system showed that the expected cost reduction potential of this technology with integrated thermal storage cannot be achieved currently.

MS-Store. Liquid salt storage test facility and new fluids (BMU, BMWi, ref. number 0325497, 2012-12 - 2019-03). The focus of the project is the development of a unique salt storage test facility in Germany, which is suitable as a platform for the investigation of storage concepts and liquid salt components up to 560 °C. The size of the plant is dimensioned so that tests can be carried out under realistic operating conditions. Specifically, the following objectives are pursued: Planning and construction of the pilot plant; Synthesis and analysis of new salts to lower the melting point or increase the operating temperature; Investigations to understand the corrosion mechanisms; Investigation of innovative storage systems; Process development for the use of molten salt as heat transfer medium; Techno-economic analysis of the use of liquid salt as a heat transfer medium. The gained large scale test plant design and operation experience will be used during the HALOS project.

Germany is devoted to the continuation of the research and development of storage systems, for instance with the approval of the project MSComp, focused on component tests for molten salt applications (BMWi, ref. number 03EE5005, 2019-07 – 2021-12). The MSComp project aims to provide component manufacturers with a test opportunity to better position their products in the marketplace. First of all, best practice recommendations for test procedures will be developed in order to give manufacturers, as well as customers, better orientation on sensible requirements and test procedures. The developed tests are then examined with the partners involved in the project in their components. This gives the industrial partners an immediate advantage through access to the DLR test facility TESIS (Test Facility for Thermal Energy Storage in Molten Salt) or the proof of operation with molten salt and at the same time leads to the verification of the developed test procedures. In order to further develop the market, it is also intended to publish the basic, but not manufacturer-specific, experience gained from the tests in order to guide other manufacturers in the development of their products.

4.1.5.1.7 Progress of demonstration projects at commercial scale relevant to IP

Two projects are relevant:

- Evora
- STJ (Solar Tower Jülich)

<u>Parabolic trough with molten salts</u>

The project HPS2 (2016-07 – 2020-05), funded by BMWi (funding reference number 0324097), is being realized by an international consortium led by the DLR Institute of Solar Research, to build and operate a solar thermal molten salt parabolic trough test facility in Évora (Portugal). Members of the consortium are the German companies TSK Flagsol Engineering, Eltherm, Yara, and Steinmüller Engineering, Innogy, the Spanish manufacturer of mirrors and receiver Rioglass and the Portuguese University of Évora. As of June 2019, these companies and research institutions will test molten salt as heat transfer fluid under realistic conditions.

The aim of the project is to examine the efficiency and reliability of parabolic trough power plants with molten salt as heat transfer medium. A key advantage of the molten salt is its good resistance at high temperatures. For the thermal oil a temperature of 400 degrees Celsius is the limit. But the salt withstands temperatures above 500 degrees in continuous use. Depending on the salt mixture upper process temperatures of up to 560 degrees are possible.

In an innovatively designed once-through steam generator, the salt transfers its energy to a connected water-steam cycle. The elevated steam parameters compared to state-of-the-art technology allow higher efficiencies of the power plant unit. In addition, the once-through principle allows supercritical steam parameters for commercial application.

Salt can be used in parabolic trough power plants not only as a heat transfer medium, but as the energy storage medium too.

The biggest challenge of using salt is its high melting respectively solidifying temperature between 120 and 240 degrees Celsius. Solidification in the branched pipes of the solar field leads to stand-still and may cause damages. In order to prevent any solidification, an adequate design, an adapted operating concept and appropriate safety equipment is needed.

Solar Tower Jülich

At DLR's Jülich site, some 60 km west of Cologne, the DLR Institute for Solar Research has been operating the solar thermal test facility Jülich since 2011. Covering an area of approximately ten hectares, there are more than 2,000 heliostats, directing the incoming sunrays to the top of the 60-meter-high solar tower. There, the concentrated beams are picked up by a 22 m² solar receiver and converted into heat. The intake air heats up to 700 ° C and generates steam, which drives a turbine. A connected generator converts the mechanical rotational energy generated by the turbine into electrical energy.

The nominal electrical capacity of the system is 1.5 MW. The electricity is fed into the public grid at medium voltage level. A high-temperature heat storage is used to decouple the fluctuating solar radiation from the energy supply and thus enables a smoothed power fed to the grid.

Supported by the federal government and the state of North Rhine-Westphalia, DLR expanded the Jülich site by the end of 2015 with additional test facilities and test facilities. By the end of 2020, a second solar tower with several irradiation levels is to be built next to the existing solar tower.

4.1.5.1.8 Non-technological actions relevant to IP (framework conditions)

In Germany, no new regulatory framework to encourage the use of the cooperation mechanisms in the Renewable Energy Directive can be reported.

4.1.5.1.9 Activities related to support to internationalisation

SolarPACES

SolarPACES is the leading international network of researchers into thermal solar for dispatchable power and solar chemistry technologies. Under the International Energy Agency (IEA) Technology Collaboration Programme (TCP) SolarPACES coordinates international researchers and thermal solar industry experts in conducting research. By providing leadership as the international network of independent experts, its mission is to facilitate technology development, market deployment and energy partnerships for sustainable, reliable, efficient and cost-competitive concentrating solar technologies.

SolarPACES coordinates and advances concentrating solar technology research, by focusing on the next generation of technologies; by providing information and recommendations to policy makers and by organizing international conferences, workshops, reports and task meetings.

For those reasons, SolarPACES unites and keeps CSP stakeholders up to date about the relevant development on the international level. Germany has supported this program since its creation in 1977 and still has a strong representation from the academia, research and industry by providing the chair, secretary and two operating agents. Also, the German industry is represented in the Industry Advisory Panel.

EERA

The European Energy Research Alliance (EERA) is an association of European public research centres and universities active in low-carbon energy research. Bringing together more than 250 organisations and around 50,000 researchers from 30 countries, EERA represents Europe's largest energy research community.

EERA's members work together in currently 17 joint research programmes, the EERA Joint Programmes, which are aligned with the priorities of the SET-Plan. They develop research activities along shared research agendas, cover the whole range of low-carbon energy technologies, integrate the social and economic aspects of the energy transition and address the systemic nature of the transition to a zero-carbon society.

A Joint Programme[8] launched in November 2011 is dedicated to Concentrated Solar Power. The overall objective of this JP is to integrate and coordinate the scientific collaboration among the leading European research institutions in CSP in order to contribute to the achievement of the targets set by the 'Solar Thermal Electricity-European Industrial Initiative (STE-EII):

i. Reduction of generation, operation and maintenance costs
ii. Improvement of operational flexibility and energy 'dispatchability'
iii. Improvement in the environmental and water-use footprint
iv. Advanced concepts and designs

Three of its Sub-Programmes are led by German institutions (DLR and Fraunhofer ISE).

In this context, the most important objectives for the CSP/STE research community, well and efficiently organized within the EERA Joint Programme on CSP, fully aligned with SET-Plan policy targets, are:

i. Supporting the STE industry, in the short term, to achieve significant cost reductions, to increase commercial deployment worldwide and, in the medium term, through the integration of national and European roadmaps.
ii. Clustering of European R&D activities on CSP/STE to develop exploitable breakthrough technologies, novel concepts and innovative configurations enabling improvements in system efficiency and final cost. Significant effort will be devoted to Thermal Energy Storage (TES) as a means to provide low carbon baseload and backup power.
iii. Defining a limited and clear priority of scientific and technological targets/challenges in each current CSP/STE technology (JP-CSP Sub-Programmes) for the effective cost reduction and increase benefits in social and environmental impact.

[8] For more information about EERA Joint Programme CSP visit: https://www.eera-set.eu/wp-content/uploads/JP-CSP_Position-Paper_March-2017.pdf

iv. Increasing the integration of CSP into the energy system through cost-effective solutions supporting the decarbonisation of all main energy sectors, including residential/industrial process heat applications and transport through thermal and chemical storage (thermochemical production of solar fuels, power-to-gas, power-to-liquids).

v. Addressing all previous challenges in the context of aligned European and Member States Research and Innovation objectives to leverage the research potential and optimise integrated resources in the CSP/STE field at European level.

ERA-Net

ERA-NET[9] under Horizon 2020 is a funding instrument designed to support public-public partnerships in their preparation, establishment of networking structures, design and implementation and coordination of joint activities.

ERA-NET under Horizon 2020 merges the former ERA-NET and ERA-NET Plus into a single financial instrument with the central compulsory element of implementing one substantial call with top-up funding from the Commission.

The instruments mainly 'tops-up' funding for single joint calls and transnational actions.

The participation in an ERA-NET allows the country/region to link its research programme to the ones of other Member States/countries and participate in joint activities, in particular the funding of transnational research projects. The implementation of transnational research programmes based on an international peer review evaluation process should contribute to increasing the quality of research, increasing the level of funding for challenges which no Member States can tackle alone and avoiding the duplication of research funding.

Germany supports ERA-Net by providing funds within its 7th Energy Research Program by BMWi. Recently the projects SITEF and SIMON (see above), to develop silicon-oil based parabolic trough systems together with European partners, were nationally co-funded by this program.

4.1.5.1.10 Stake of the country in the CSP/STE sector:

EPC

TSK Flagsol: its business is comprised of the construction of solar fields and turn-key parabolic trough power plants using our own parabolic technology. Moreover, TSK Flagsol offers consultancy services and various products and components of this technology. The business segments of project development, O&M management and equity investments in power plants are closely tied to the plant construction business. As a subsidiary of TSK has access to the expertise in both financing and construction of large industrial plants, especially in the sector of renewable energy.

[9] For more information about ERA-Net visit: https://ec.europa.eu/programmes/horizon2020/en/h2020-section/era-net, http://ec.europa.eu/research/participants/docs/h2020-funding-guide/cross-cutting-issues/era-net_en.htm

www.flagsol.com

Owners Engineers

Fichtner: offers complete services in all project phases, from prefeasibility studies and evaluation of meteorological data up to commissioning and acceptance of facilities. Clients in this sector are, alongside project developers, investors and banks, also project owners, general contractors and technology suppliers.

https://www.fichtner.de/en/business-sectors/renewable-energies-environment/

Tractebel (previously Lahmeyer): offers traditional engineering solutions for owners and Lenders, and also provides conceptual design studies, Front End Engineering Design (FEED), detailed design for suppliers and contractors within the framework of an EPC and other contractual formulae developed by the business. The 5D to 7D BIM modelling is an integral part of their engineering services.

https://tractebel-engie.com/en/solutions/energy#renewables

Suntrace: Suntrace is an independent expert for the development of solar power projects. Its focus is on solar resource, technical performance, bankability and investment structures.

https://suntrace.de/home.html

Component Manufacturer and Engineering

- **sbp sonne**: is an international engineering office in the field of CSP (Concentrating Solar Power) and well known as experts for the development and design of parabolic trough collectors, point-focusing dish systems, solar tower power plants and heliostats, as well as concentrating photovoltaics.
  https://www.sbp.de/en/solar-energy/
- **Covestro**: it has been participating in the development of materials for heliostat’s sandwich-facet structure.
  https://www.covestro.de/en/products-and-services/overview
- **LWT**: Partner in the project HelioGLOW, related to the development of components for a solar thermal tower power plant - overall optimization through air wall and optimized heat transfer medium.
  https://english.luftwandtechnik.de/products/
- **NEBUMA**: develops special types of high temperature heat storage materials, either pure or hybrid-materials. The temperature range of those storage systems encloses room temperature up to 1.300°C. NEBUMA acts as a materials developer, (technology-) supplier as well as supplier of complete storage systems.
  https://kraftblock.com/
- **Grenzebach**: partner in the project VESUW, offers manufacturing and automation solutions.

https://www.grenzebach.com/home/
- **Hilger**: provider of construction machines. Partner in VESUW project.
https://www.hilger-gmbh.de/maschinenliste.html
- **SeniorFlexonincs**: flexible joints for parabolic trough collectors.
https://www.seniorflexonics.de/produkte/power-generation.html
- **Wacker Chemie**: Silicon heat transfer fluid (partner in SITEF, SIMON)
https://www.wacker.com/cms/en/products/product_groups/silicone_fluids.jsp
- **Enexio Germany**: cooling towers. Partner in MinWaterCSP
https://www.enexio.com/water-technologies/products/
- **Eltherm**: specializing in the field of electrical heat tracing systems. Partner in HPS2 project.
https://eltherm.com/en/the-company/the-company-1/
- **Yara**: new ternary mixture of molten salts based on Calcium-Potassium-Sodium-Nitrate introduced by Yara. Partner in HPS2 project.
https://www.yara.com/chemical-and-environmental-solutions/solar-power-molten-salt/
- **Steinmüller Engineering**: for the solar thermal pilot installation in Évora, Portugal they performed the process design and constructed and supplied the steam generator. In this project practical solutions based on innovative ideas were developed and tested. Partner in HPS2 project.
https://www.steinmueller.com/en/research-development.html
- **Innogy:** Project developer and investor, e.g. partner in Andasol-3. Partner in HPS2 project.
https://iam.innogy.com/ueber-innogy/innogy-innovation-technik/erneuerbare-energien/solarenergie
- **Samson**: component producer, relevant for STE: valves.
https://www.samson.de/en/products-applications/product-selector/valves/
- **Krohne**: Complete portfolio for process instrumentation: Flow, level, temperature, pressure, process analytics. Meters, sensors, systems and accessories. Wide range of measurement technologies.
https://de.krohne.com/en/
- **Kraftanlagen München**: has participated in the development of heliostats and receivers for solar tower systems
https://www.kraftanlagen.com/en/projects/
- **Heliokon**: Develops system solutions for heliostat fields. Partner e.g. in Heliodor project.
http://www.heliokon.com/
- **MAN Energy Solutions**: develops energy storage systems. Partner in CSPRK project.
https://www.man-es.com/energy-storage/products/energy-storage-systems
- **Exentis**: Develops 3D mass customization. Partner in HitRec3D project.
http://www.exentis-group.com/english/

- **Continental Emitec**: he main tasks of Emitec's system engineering are the simulation of catalytic function, flow and vibration analyses, component tests, exhaust system tests and vehicle tests. Partner in HitRec3D project
https://www.emitec.com/en/technology/research-development/
- **FLEXIM**: Flow measurement solutions for demanding power generation applications. Partner in HPMS-II project.
https://www.flexim.com/en/industry-solutions/power-industry-0
- **Endress + Hauser Messtechnik**: Field instrumentation to measure and monitor flow, level, pressure, temperature and analyze liquids. Associated partner in HPMS-II project.
https://www.de.endress.com/en/field-instruments-overview
- **Mannesmann Stainless Tubes**: Manufacturers of seamless stainless steel and nickel based alloy tubes and pipes. Associated partner in HPMS-II project.
https://www.mannesmann-stainless-tubes.com/english/mst-company/profile/profile.html
- **HORA - Holter Regelarmaturen**: Control valves supplier. Associated partner in HPMS-II project
https://www.hora.de/en/home-news/
- **Bilfinger Piping Technologies**: The portfolio covers the entire value chain from consulting, engineering, manufacturing, assembly, maintenance, plant expansion as well as turnarounds and also includes environmental technologies and digital applications. Partner in HPMS project.
https://www.bilfinger.com/en/
- **M+W Germany**: Engineering and procurement of PV components. Partner in HPMS project.
https://www.mwgroup.net/en
- **STEAG Energy Services**: SES evaluates the feasibility of solar thermal projects worldwide and provides support in implementing them. Partner in HPMS project.
https://www.steag-energyservices.com/en/technologies/renewable-energy/
- **SCHOTT**: former supplier for parabolic trough receiver.
https://www.schott.com/uk/english/index.html
- **flucon**: Fluid measurement and analysis. Partner in SIMON project.
https://flucon.de/en/
- **Ruhrpumpen**: pumps supplier. Partner in SIMON project.
http://www.ruhrpumpen.com/products
- **TeAx Technology:** Development and integration of special payloads for UAVs. Partner in HelioPoint.
http://www.teax-tec.de/
- **LeiKon**: IT, energy management, etc. Partner in Dynasalt-2 project.
https://www.leikon.de/
- **Radiant Dyes**: Optica measurement components. Partner in Helibo project.

https://www.radiant-dyes.com/index.php/products

Service

- **CSP Services**: engineering and consulting services for developers, operators and owners of solar thermal power plants applying innovative and specific measurement techniques to assure high performance solar fields.
  http://www.cspservices.de/
- Salzgitter Mannesmann Forschung: Material research and analysis. Partner in HPMS project.
  https://www.salzgitter-mannesmann-forschung.de/de/index.html
- **TÜV NORD:** Standards and certification of systems and equipment. Partner in SIMON project.
  https://www.tuev-nord.de/en/
- **Steinbeis 2i**: Consulting on innovation management, IPR, and knowledge management. Support with applying for EU funding. Search for cooperation partners for research and innovation. Project management. Support with the implementation of research results and transnational technology transfer Partner in MinWaterCSP
  https://www.steinbeis.de/en/network/searching-for-steinbeis-experts/detail.html?tx_z7suprofiles_detail%5Bprofile%5D=2712&cHash=efbbe04b3d84e5c735518511bc1b05b2

4.1.5.1.11 CSP value Chain sector relevant for the country

In Germany, the complete value chain of STE plants is relevant and covered by several stakeholders as shown above. It includes project research, development, engineering, procurement, construction, maintenance and services.

Therefore, it will be addressed by both, WP2 and WP3, where German stakeholders are expected to participate actively.

4.1.5.2 Spain

4.1.5.2.1 Current status of the country's engagement on the execution of the IP

The engagement of Spain on the execution of the IP is very strong. Spain was already strongly involved in the Temporary Working Group (TWG) where the priority R+D topics were decided by a wide representation of European STE/CSP stakeholders. Spain has also been engaged in the Implementation Working Group (IWG) since its launching after the publication of the IP. More precisely, Spain has contributed with 2 Mio € to the common fund currently available to provide financial support under ERANET COFUND administrative framework to the R+D projects related to the priority topics included in the IP. Another evidence of the strong engagement of Spain is their important involvement in the two initiatives that are currently more directly related to the execution of the IP: the ERA-NET-Cofund: "CSP-ERANET", which is coordinated by a Spanish regional entity (the Extremadura Energy Agency,) and the LC-SC3-JA-2-2018 project "HORIZON-STE", which has CIEMAT as a partner.

Spain is also devoting a significant effort for the legal development and implementation of EU-SOLARIS, an ESFRI distributed infrastructure related to the STE/CSP sector that will provide a strong cohesion between the industrial sector and the R+D centres devoted to concentrating solar thermal (CST) technologies. Spain coordinated the preparatory phase of EU-SOLARIS (grant agreement number 312833 of the FP7-Infrastructures-20012-1 programme, INFRA-2012-2.2.1) and it is now coordinating the implementation phase aimed at the legal set up of EU-SOLARIS. To this extent, Spain has coordinated the proposal BOOST-EU-SOLARIS submitted to the call INFRADEV-03-2018-2019, category B, in order to get the E.C. support for the consolidation of EU-SOLARIS after its legal implementation.

It is also worth mentioning the effort that the regional government of Extremadura is devoting to promote a FOAK STE/CSP plant in that region of Spain. This plant would be devoted to produce and sell dispatchable solar electricity produced in Spain to other Member States in Central and Northern Europe, thus making use of the Cooperation mechanism defined by the E.C. to fulfil the targets related to penetration of renewable energies into the European electricity market.

4.1.5.2.2 Running projects relevant to IP (national, EU and international)

Spanish entities are participating in many European projects funded by the H2020 framework programme. However, only four European R+D projects with activities somehow related to the priority activities included in the IP and with participation of Spanish partners started in or after January 2018 and are active in May 2019. The acronyms of these four projects are: POLYPHEM, SOLWATT, SCARABEUS and SOCRATCES. Two out of these four projects are coordinated by a Spanish partner (SOLWATT and SOCRATCES). The total financial EU contribution for Spanish entities participating in these four projects is 8,2 Mio €. Although these four EU projects with Spanish participation are performing actions related to the goals of activities # 6, 7, 9 and 12 of the IP, the activity more often addressed by these projects is #9 (*Thermal energy storage*).

At national level, the lack of a call for year 2018 is the main reason why there is no project started in or after January 2018 and active in May 2019. Therefore, the financial effort devoted by Spain to support R+D projects related to the IP activities is very low. However, it is worth mentioning here the Solar ERANET project SIMON, which started in October 2017 and it is specifically devoted to the Activity #3 of the IP ("Parabolic trough with silicon oil"). The funding given by Spain to SIMON is 105 k€ and this project will end in September 2019. SIMON is developed in collaboration with German partners. The key data of these projects is shown on Table 2 below:

Financing entity: National or (EU)ropean	Project Name	Acronym	Leading organization (name - Country)	Duration	Relation to IP R&I Activities	Spanish Industrial Partners	Spanish R&D Partners	Total Funding for Spanish partners(€)
EU	Small-Scale Solar Thermal Combined Cycle	POLYPHEM	CNRS - France	April 2018-March 2022	7, 9	ARRAELA	CIEMAT	522,024
EU	Solving Water Issues for CSP Plants	SOLWATT	TSK - Spain	May 2018-April 2022	6	TSK, RIOGLASS, FENIKS, BSC, INDETEC	Ciemat, Tekniker	5,488,023
EU	SOlar Calcium-looping integRAtion for Thermo-Chemical Energy Storage	SOCRATCES	Univ. Sevilla - Spain	Jan 2018-Dec. 2020	9	BIOAZUL, VIRTUALMECHANICS	Univ. Sevilla, Univ. Zaragoza, CSIC	1,475,819
EU	Supercritical CARbon dioxide/Alternative fluids Blends for Efficiency Upgrade of Solar power plants	SCARABEUS	POLIMI - Italy	April 2019-March 2023	12	ABENGOA	Univ. Sevilla	731,065
SPAIN								
								8,216,931.00 €

Table 2. Running projects in Spain relevant to IP (national, EU and international). Source: Elaboration by CIEMAT.

4.1.5.2.3 Contribution of research facilities to the execution of the Implementation Plan (e.g. SFERA III, BOOST- EUSOLARIS, etc.)

In Spain there are already excellent research facilities for CST technologies. The most outstanding research centre is the Plataforma Solar de Almeria (www.psa.es), which is formally recognized by the E.C. as a Large European Research facility. At national level, PSA is included in the small group of Unique Scientific and Technical Infrastructures (ICTS) related to Energy, which includes only two other Spanish research organizations. Additionally, to PSA, there are several more facilities in Spain devoted to CST technologies (e.g., IMDEA, CENER, CIC-Energigune, and small facilities in some universities). With the existing facilities Spain can provide a significant support to most of the R+D activities defined in the IP.

The high quality of the existing facilities will be even improved by means of the European project SFERA-III (grant agreement number 823802 of the H2020-INFRAIA-2018-2020 programme), which is currently underway under the coordination of CIEMAT-PSA. The round robin tests and the joint R+D activities performed by the SFERA-III partners are improving the test protocols and the quality standards of the main European facilities available for components characterization and evaluation.

One of the work packages of SFERA-III, the WP11, is especially devoted to the detail design of a virtual facility (e-infrastructure) that will link the European R+D centres devoted to CST technologies. SFERA-III WP11 is coordinated by CIEMAT and the intended e-infrastructure will be a combination of digital technology, computational resources, and communications to support collaborative work and research within the CST sector. One of the main services to be offered by this e-infrastructure will be the remote access to the European CST research facilities, so that external users could perform experiments remotely using this e-infrastructure. Since the main objective of the intended e-infrastructure is to provide global support to the CST sector, its technical requirement and the definition of the list of services and tools that will be offered is being coordinated by CIEMAT taking into consideration the opinion and suggestions of the CST stakeholders. It is expected that this CST e-infrastructure will be managed by EU-SOLARIS once this entity is legally implemented and consolidated. This legal implementation and consolidation are the main objectives of the project proposal BOOST EUSOLARIS prepared under the coordination of CIEMAT and submitted to the call INFRADEV-03-2018-2019, category B, in February 2019.

The comprehensive list of existing Spanish test facilities for CST technologies and the improvements that the projects SFERA-III and EU-SOLARIS will introduce, will have as result an excellent group of Spanish facilities that will provide a strong R+D support to the development of the IP.

4.1.5.2.4 Implementation instruments

The only implementation instrument existing in Spain to provide financial support to the development of the R+D activities of the IP will be the ERA-NET-Cofund: “CSP-ERANET” programme, which will be coordinated by the Extremadura Energy Agency (a Spanish regional entity managed by the regional government of Extremadura). The project proposal to prepare and manage this ERA-NET Cofund program was prepared and submitted in 2018 to the topic H2020-LC-SC3-JA-1-2018.

The proposal was approved by the E.C. and awarded with a grant signed in June 2019. A total budget of 13,8Mio € (included top-up: 4,5Mio€) will be distributed by this programme, which was proposed by 16 partners from 8 European countries (Germany, Spain, Greece, Italy, Israel, Switzerland, Portugal and Turkey). This programme will provide funds to projects related to CSP topics totally aligned with the IP. The first Call issued by this ERA-NET program is expected by the last quarter of 2019.

4.1.5.2.5 National Funding Programs relevant to IP and entities managing them

Additionally, to the ERA-NET program mentioned in the previous section, in Spain there is no national funding program specifically devoted to the activities of the IP. At national level, there are two main public entities in Spain financing R&D projects, CDTI (Centre for Industrial Technological Development) and the State Research Agency, both managed by the Spanish Ministry of Science, Research and Universities. CDTI has different instruments to fund the R&D projects of the Spanish industry. The funding is mainly made of grants + soft loans in an open, not competitive call. There is not a dedicated budget per energy sector but almost no budget limitation either. Spanish entities, other than industry, must participate in the projects as entities subcontracted by the industrial partners.

The State Research Agency also supports R&D projects in Spain mainly through competitive calls for consortia including Spanish companies and research organizations. The goal of this calls is to promote the development of new technologies, and the business application of new ideas and techniques. There are two modalities: “Retos Investigación” (supporting R+D projects developed by one public entity) and “Retos Colaboración” (funding R+D projects developed by industries and R+D centres). There is not a dedicated budget per sector. The funding support is again with grants + soft loans.

In the Spanish R+D programs funded by the central government there is not specific budget nor specific R&D lines for CST technologies. CST activities must compete with the rest of technologies in the competitive calls launched by these programs. There is usually a call every year. However, due to political instabilities there was no call in 2018.

CDTI and the State Research Agency are participating in ERANETs programs as one instrument for cross-national funding. International (EU and associated countries) cooperation projects can be developed also through the Multilateral Programmes (EUREKA, IBEROEKA, Bilateral programmes, EUROSTARS, ...). However, no specific funding for CST activities is available and projects related to different technologies must compete each with others to get funds.

Although ERANET and EUREKA programmes in Spain are useful for the industrial partners because they can get a significant percentage of funding, these programmes are not very appealing for Spanish R+D entities (i.e., Universities, technological centres and public R+D centres) because only their marginal cost can be funded, thus reducing their usefulness to promote CST–related research. Another disadvantage of these programs is the lack of a unified time schedule for the Calls at European and national levels. The duration of the funding period and the funding intensity for R+D entities are additional disadvantages in Spanish ERANET projects because the financing of projects is up to 36 months only and the maximum amount of funding is usually less than 200 k€ per project. So, Spain should strive to make these programmes more appealing for Spanish R+D entities and to define a common time schedule for all the countries. This is a very important issue because if the conditions so far applied by Spain to Spanish entities participating in ERA-NET Cofund programs are not substantially modified for the new ERA-NET COFUND program that will be launched in 2019 to provide funds to projects related to CSP topics totally aligned with the IP, this new ERA-NET program will be of little use for Spanish entities willing to participate in the development of the IP.

Contact persons in Spain for the three funding sources available for R+D projects are:

- State Research Agency: Mrs. Ana Lancha Hernández (e-mail: ana.lancha@aei.gob.es , Phone: +34 916038315)
- CDTI: Mr Gabriel Barthelemy Candela (e-mail: gabriel.barthelemy@cdti.es; Phone: +34 915810707.
- ERANET: Mr. Daniel Ruiz (e-mail: daniel.ruiz@fecyt.es , Phone: +34 916037968)

4.1.5.2.6 Evaluation of current initiatives against full IP outcome and objectives:

The R+D activities performed in Spain related to the IP goals are mainly aimed at reducing the cost and increasing the dispatchability of the solar thermal electricity plants. The main result obtained in Spain so far in these projects and already published is related to the activity #3 of the IP ("*Parabolic trough with silicon oil*"), because in the SIMON project two new generations of silicon oils have been successfully tested at the Plataforma Solar de Almería (PSA) in collaboration with German partners, thus proving the feasibility of silicon oils to be used as heat transfer fluids in line-focus solar systems. A EU project proposal was submitted in 2018 to the H2020 topic LC-SC3-RES-13-2018 to conclude the investigation of these silicon oils with a system prototype demonstration in operational environment (TRL7), but the proposal was rejected by the evaluators adducing a non-fulfilment of the initial TRL specified in the text of the call. Due to this problem, the demonstration in operational environment of silicon oils is still missing and the activity #3 of the IP is still under development.

4.1.5.2.7 Progress of demonstration projects at commercial scale relevant to IP

Concerning Spain, the progress of demonstration projects at commercial scale relevant to IP is very little. Due to the problem explained in the previous section with the project proposal submitted in collaboration with DLR in 2018 to the H2020 topic LC-SC3-RES-13-2018, the demonstration of silicon oils acting as heat transfer fluid in a solar system working in operational environment is still pending. CIEMAT-PSA and DLR have decided to submit another proposal in 2019 to the topic H2020-LC-SC3-RES-35-2020 ("*Reduce the cost and increase performance and reliability of CSP plants*") to achieve a TRL 7 using silicon oil in parabolic trough collectors under real solar conditions.

Although most of the R+D projects currently underway with activities somehow related to the IP include in their work plan the construction and testing of small prototypes, due to the size of the prototypes such projects can´t be considered as demonstration projects at commercial scale.

4.1.5.2.8 Non-technological actions relevant to IP (framework conditions)

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

Spain is coordinating the H2020 project MUSTEC **(Market uptake of Solar Thermal Electricity** through Cooperation), which is aimed at promoting the use of the cooperation mechanism to favour the exchange of renewable electricity within the European Union, thus promoting the commercial deployment of STE/CSP plants in Europe. MUSTEC has three main action lines: a) learning from STE/CSP past project case studies and experiences, b) identifying specific STE/CSP cooperation opportunities, and c) propose the required policies to enable these projects in Europe

Financing

Spain is participating in a very active way in the Implementation Working Group and it is also contributing to the common fund that will be managed by the new Solar ERA-NET COFUND program, which will be coordinated by the Extremadura Energy Agency, a Spanish regional entity linked to the regional government of Extremadura.

The Spanish representative at the Energy Group of H2020 is also devoting a great effort to include, with the support of the national representatives of Germany, France, Portugal, Cyprus, Greece and Turkey, in the H2020 Work Program topics related to the CST technologies in general and to the IP activities in particular. One of the results of this joint effort has been the inclusion of a new topic in the H2020 work programmed for 2020 with the name H2020-LC-SC3-RES-35-2020 “Reduce the cost and increase performance and reliability of CSP plants”, and the inclusion of CST technologies in other horizontal topics that were initially aimed at PV and wind only.

National Renewable Energies Program

The Spanish Government sent to Brussels in February 2019 the draft of the new Integrated National Plan for Energy and Climate (PNIEC), in which there is a firm support to renewable energies in the period from 2021 to 2030. Concerning STE/CSP plants, the PNIEC foresees 5 GWe of additional STE/CSP plants in the period from 2021 to 2030, thus reaching a total installed capacity of 7,3 GW in 2030. This declaration of the Spanish Government will clearly help to develop CST technologies in the coming years.

4.1.5.2.9 Activities related to support to internationalisation

Participation in the Implementation Working Group (IWG) is somehow an activity of the Spanish Government to provide support to internationalisation. At the level of the Spanish R+D centres, an initiative leaded by CIEMAT-PSA was submitted to the 2018 national call for “Research Networks” to get funds to support a Spanish strategic network composed of eight Spanish research entities

(CIEMAT, University Carlos III of Madrid, IMDEA, TEKNIKER, CENER, CIC Energigune, University of Seville and the Polytechnic University of Cataluña). The main goal of this strategic network is to coordinate and support the participation of the participating entities in international initiatives related to concentrating solar thermal technologies (i.e. JP CSP of EERA, SolarPACES, EU-SOLARIS and the CSP IP of the SET Plan). In addition, ongoing collaboration, activities and contact of all previous organizations with some key international organizations (from Morocco, Chile, China, etc.) could be used to foster and promote the internationalisation of some IWG initiatives.

4.1.5.2.10 Stake of the country in the CSP/STE sector

Spain is at present the country with not only more STE/CSP plants in operation but also with the highest installed power. This leadership is due to the 50 STE plants in routine operation since 2013 with a total installed power of 2,3 GWe. In R+D activities Spain is also at a high level in the World ranking, with the largest public R+D centre devoted to CST technologies (the Plataforma Solar de Almería) and many good smaller experimental facilities available in other Spanish R+D centres and universities.

However, no commercial plant has been installed in Spain since December 2013 because the favourable conditions defined by the Government in the Royal Decree RD-661 of May, 2007, for electricity produced with renewable energies (not only for STE but also for other technologies like PV and wind) were drastically modified in the subsequent years, thus making STE/CSP plants no longer interesting for investors. The lack of commercial projects in Spain pushed the Spanish companies to look for opportunities in other countries, thus becoming involved in may project promoted in foreign countries (Morocco, USA and South Africa, mainly).

In February 2019 the Spanish government sent to the E.C. the “National Energy and Climate Plan (PNIEC, in Spanish) 2021-2030”, which proposes the installation of 5 GWe of STE/CSP plants during the period 2021-2030. This means that a total installed power of 7,3 GWe would be in operation at the end of 2030. The PNIEC is now being analysed by the E.C., together with the energy plans submitted by the other Member States. If the Spanish PNIEC is approved by the E.C. and there is a commitment from the government to achieve the goals defined in the national plan for renewable electricity, the Spanish CST sector will experience a great favourable impulse. In addition, Spanish R+D centres are highly committed with the development of the CST technologies to make them more profitable and competitive with conventional technologies used for power generation. This situation guarantees a good scientific support to the industrial sector in any effort to develop these technologies.

4.1.5.2.11 CSP value Chain sector relevant for the country

Considering the key components used in STE/CSP plants, most of them can be manufactured in Spain (e.g., solar reflectors, steel structures, electronics, receiver tubes, heat exchangers, storage vessels, piping, thermal insulation, etc.). About 85% of the total CAPEX of a STE/CSP plant can go to Spanish suppliers of components. The main equipment that can´t be manufactured in Spain is the turbo-generator and some auxiliaries for the power block.

Concerning engineering and industrial know-how about STE/CSP plant, Spain has a high number of companies with a great experience in this field, mainly due to their participation in the development of the 50 commercial plants currently in operation in Spain and in many other projects implemented in other countries. Most of the STE/CSP plants implemented in other countries (e.g., Morocco, USA, United Arab Emirates, South Africa, etc.) had the participation of Spanish companies, like SENER, COBRA, Empresarios Agrupados, ACCIONA, ABENGOA, TSK and many others. What follows is a short list of Spanish companies that have been involved in the development of commercial STE/CSP plants (the complete list is much larger):

- Hydraulic systems: FERJOVI, RODICAR
- Solar reflectors: RIOGLASS
- Receiver tubes: RIOGLAS
- Steel structures and components: IMETAL, Jesús Castro, HIASA, GOZON, Talleres Vicente Merino, Talleres Verot, LUALVA
- Galvanization: Galvanizados Avilés
- Electronics: ISASTUR, MASERMIC
- Engineering & EPC contractors: TSK, SENER, ACCIONA, COBRA, SENCENER, COSERMO, IMASA
- Water treatment plants: IMAGUA
- Construction & Assembly: Duro Felguera, COBRA
- Power block maintenance: PTSI
- Heavy duty mechanism and machinery: GAM, ALVEMACO
- Valves, instrumentation and fittings: ASTURFLUID, FLOWSERVE, SAMSON
- Civil Works, fences and buildings: MOLDUCEA, BRUN
- Welding: Talleres Marte
- Pumping equipment: HIDROMATIC
- Painting, coatings and surface treatment: SEM, APLITECSA
- Thermal insulation: SUAVAL
- Insurance: MPM

It is therefore evident that Spain is at a very good position within the STE/CSP value chain, because the industrial relevance is very well complemented with excellent Spanish R+D infrastructures, as explained in previous sections. However, due to the incorporation of companies from other countries, China and United Arab Emirates mainly, the involvement of Spanish companies in international commercial projects is decreasing.

Taking into consideration the good industrial background and the excellent R+D CST facilities existing in Spain, together with the promising goals defined for STE in the “National Energy and Climate Plan 2021-2030”, it seems advisable to address this country in both WP2 and WP3 in order to take advantage of synergies among the industrial sector, the public administration and the R+D centres and thus make the most of the available resources to develop the IP.

4.1.5.3 Turkey

As elaborated in this profile of Turkey, Turkey's CSP sector in general and support for the IP specifically is nascent, which is defined as "just coming into existence and beginning to display signs of future potential."[10] Additionally, due to Turkey being an EU candidate country rather than an EU member state, many of the regulations governing EU countries discussed in profiles of EU member states are not relevant to Turkey. Within this context and with an aim to best reflect Turkey's relevance to the IP, both Turkey's current status with respect to the IP and aligned activities that can be leveraged to support attainment of the IP are presented in this profile.

4.1.5.3.1 Current status of the country's engagement on the execution of the IP:

Turkey main activities to specifically support the execution of the IP are structured around its participation in the ongoing Horizon 2020 Projects *CSP ERANET* and *HORIZON-STE*, and the preparation of open national calls in 2020 that include CSP and are discussed in item 4.1.5.3.5 below. Also, and as detailed in the following items, Turkey has many additional CSP initiatives that can be leveraged to support attainment of the IP.

4.1.5.3.2 Running projects relevant to IP (national, EU and international)

As of May 2019, Turkey does not have any running projects relevant to the IP that started on or after January 2018. To paint a more complete picture of the situation in Turkey, it should be noted that a national project with budget of approximately 600 000 € to develop and pilot a high-temperature Thermal Energy Storage (TES) system that supports IP R&I Activity 9 was accepted in April 2018. This project was led by the industrial partner Greenway CSP and included Middle East Technical University's Centre for Solar Energy Research and Applications (METU-GÜNAM), Istanbul Technical University's Energy Institute, and the Turkish-German University. Due to managerial problems within Greenway CSP, this project was never started. Furthermore, and as detailed in items 10 and 11, Turkey is participating in several CSP projects that could be leveraged to support attainment of the IP.

4.1.5.3.3 Contribution of research facilities to the execution of the Plan (e.g. SFERA III, BOOST-EUSOLARIS, etc.)

The Centre for Solar Energy Research and Applications at Middle East Technical University (METU-GÜNAM) has a 3-lamp 5.6 kW high-flux solar simulator with 4 MW/m^2 concentration that is offered for open-access through SFERA-III and is currently developing a test facility for studying particle-based CSP technologies. METU-GÜNAM also has a wide range of basic facilities for material characterization and testing, and METU's Central Laboratory is one of the largest in Turkey focused on providing scientific testing services to outside customers.

[10] https://en.oxforddictionaries.com/definition/nascent

4.1.5.3.4 *Implementation instruments*

The Turkish partners participating in the CSP ERANET programme will be supported by Turkey's main scientific funding agency TÜBİTAK (The Scientific and Technological Research Council of Turkey) using the new 1071 instrument.

1071 Programme - Support Programme for Increasing Capacity to Benefit from International Research Funds and Participation in International R&D Cooperation: The purpose of the programme is to support research and innovation activities of Turkish higher education institutions, their institutes, research hospitals, public R&D centres, and private companies established in Turkey. Personnel, travel, equipment/tool/software, consultancy and service procurement, and consumables can be covered in accordance with the call rules. There is no inherent budget limit of the 1071 Programme and the budget limit is determined per call.

Historically Turkish partners participating in ERANET calls were supported by the TÜBİTAK 1001 and 1003 instruments detailed in Item 5.

4.1.5.3.5 *National Funding Programs relevant to IP and entities managing them*

While Turkey does not have a National Program relevant to the IP specifically or CSP more generally, Turkey is participating in the ongoing Horizon 2020 *CSP ERANET* and *HORIZON-STE* projects to execute the IP. Additionally, TÜBİTAK is preparing national calls for 2020 targeting highly efficient solar energy technologies that will include (but not be limited to) CSP technologies. Additional CSP activities aligned with the IP are discussed in items 8-12.

Turkey has a range of national funding programmes that can be used to support the IP as detailed below. Note as an EU candidate country rather than an EU member state, Turkey has its own currency, which is the Turkish Lira (TRY). The TRY exchange rate is variable, and in response to these variations TÜBİTAK periodically adjusts project budget limits, with recently the project budget limit for TÜBİTAK 1001 projects being doubled from 360 000 TRY to 720 000 TRY. While the budget numbers presented here are accurate at the time this deliverable was written, interested parties should consult the relevant TÜBİTAK webpages for current budget information.

TÜBİTAK's 1001 Scientific and Technological Research Projects Funding Program is the primary funding mechanism for research at lower Technology Readiness Levels (TRLs) and is open to universities, public research institutes, industry and Small and Medium Enterprises (SMEs). 1001 calls are typically opened 1-2 times per year and are completely open to all research topics. There is no inherent budget limit for this mechanism, but a budget limit is set for each call. Currently this budget limit is typically 720 000 TRY (~ 100 000 €) for equipment, consumables, travel, and student scholarships. An additional budget is given to cover overhead costs and personnel costs in addition to student scholarships such as for faculty members at universities. For more information in Turkish, see http://www.tubitak.gov.tr/tr/destekler/akademik/ulusal-destek-programlari/icerik-1001-bilimsel-ve-teknolojik-arastirma-projelerini-destekleme-pr.

TÜBİTAK's 1003 Primary Subjects R&D Funding Program generally addresses higher TRLs than the TÜBİTAK 1001 program. In contrast to the 1001 program, 1003 calls are only opened in specific areas. Projects are classified as Small, Medium, or Large with the following characteristics. Small projects last up to 24 months and have budgets up to 750 00 TRY (~100 000 €). Medium projects last up to 36 months and have budgets between 750 001 and 1 500 000 TRY (~ 100 000 – 200 000 €). Large projects also last up to 36 months but have budgets between 1 500 001 and 3 750 000 TRY (~200 000 – 350 000 €). Not included in these budget limits are overhead costs and personnel costs in addition to student scholarships such as for faculty members at universities. For more information in Turkish, see https://www.tubitak.gov.tr/tr/destekler/akademik/ulusal-destek-programlari/icerik-1003-oncelikli-alanlar-ar-ge-projeleri-destekleme-programi.

1509 - TÜBİTAK International Industrial R&D Projects Grant Programme funds market focused R&D Projects between European countries using cooperation webs such as EUREKA with an objective to increase cooperation between Europe wide firms, universities and research institutions. The Programme is open to all the R&D topics including CSP. The call is open to SMEs and large companies settled in Turkey. Eligible costs include personnel, travel, equipment/tool/software, R&D services from domestic RTOs, consultancy/other services, material costs. The program funds applied research and experimental development (i.e. higher TRL activities). There is no budget limit for this Programme, but a limit is determined per call. Note the 1509 Programme has not been used recently and therefore an up-to-date webpage does not exist. For more information in English, see http://www.tubitak.gov.tr/en/funds/industry/international-support-programmes/content-1509-tubitak-international-industrial-rd-projects-grant-programme.

1511 - Research & Technology Development and Innovation Program with Priority Fields supports and coordinates 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, which includes Solar Energy. 1511 is similar to the 1003 Programme except that an industrial organization/SME must be included. The budget limit is specified according individual calls. For more information in Turkish, see http://www.tubitak.gov.tr/tr/destekler/sanayi/ulusal-destek-programlari/icerik-1511-tubitak-oncelikli-alanlar-arastirma-teknoloji-gelistirme-ve-yenilik-p-d-p.

Responsibility for the program in the country

İlknur Yılmaz and Çağrı Yıldırım of TÜBİTAK are the H2020 National Contact Points (NCPs) for energy in general and the CSP ERANET project specifically (https://h2020.org.tr/en/contact-info). Additionally, Kaan Karaöz and Salih Hacıalioğlu are the National Contact Points for ERANET calls and their contact information will be provided in the forthcoming CSP ERANET calls.

4.1.5.3.6 Evaluation of current initiatives against full IP outcome and objectives

As stated in the introduction of this profile, Turkish initiatives to support the full IP outcomes and objectives are characterized as nascent, which is consistent with the Turkish CSP sector in general also being characterized as nascent. In particular, the EU H2020 HIFLEX and GeoSmart projects presented in item 10 that support the IP are both starting after May 2019 and therefore are not included in item 2. Furthermore, most of the aligned CSP activities detailed in items 10 and 11 that can be leveraged to support the IP are also starting in 2019 or 2020.

4.1.5.3.7 Progress of demonstration projects at commercial scale relevant to IP

A demonstration 5 MW_{th} / 1 MW_e demonstration central receiver power plant was built by Greenway CSP in Mersin, Turkey (shown in Figure 2 below), along the southeast Mediterranean coast of Turkey. The field consists of 510 heliostats based on a proprietary design and includes many innovative features including wireless heliostat field communication, precise solar position calculation, automated heliostat tracking correction, accurate reflection angle calculation, and positioning of heliostats autonomously in dual axis for optimum exposure to solar rays with reduced manufacturing and assembly costs. The receiver uses natural circulation Direct Steam Generation (DSG) at 550 °C and 55 bars with four evaporators and one superheater. To reduce capital costs and target higher feed-in-tariffs enabled by high local content as detailed in item 9, the majority of the components were either developed & produced in-house, or sourced from domestic manufacturers, and therefore the technology and components embedded in this demonstration project are largely of Turkish origin.

Figure 2. Greenway CSP's 5 MW_{th} / 1 MW_e DSG Demonstration Project in Mersin, Turkey.

4.1.5.3.8 Non-technological actions relevant to IP (framework conditions)

As detailed in item 11, while Turkey has some of the largest solar electric (CSP + PV) market potentials in ERA due to its large physical size, large solar resources, large population, and growing demand for energy, the growth of Turkish industries and markets for solar electricity has historically lagged those of many Western European countries, including those with more limited solar resources such as Germany. In recent years Turkey has been initiating targeted actions to catalyse growth in CSP and PV domestic industrial capacities and markets. These initiatives have been particularly effective for PV, and now Turkey has rapidly growing PV industrial capacities and the largest PV market in Europe. Turkey is also working to catalyse growth in Turkish CSP industries and markets, including by establishing Feed-in-Tariffs (FiTs) for CSP as part of the National Renewable Energy Action Plan for Turkey published in December 2014. These FiTs are presented in the table below and are valid through 2020. New FiTs for CSP will be announced before the end of 2020. As per Table 3 below, the base FiT for CSP is 13.3 USD Cent/kWh, and the CSP FiT can increase up to

22.5 USD Cent/kWh with increases in local content. Additional details about this CSP FiT can be found in the National Renewable Energy Action Plan for Turkey[11].

Feed-in-tariff and Local Equipment Bonus Prices for Solar CSP	
Locally manufactured component	**Bonus (USD cent/kWh)**
Solar CSP	13.3
Radiation collector tube	2.4
Reflective surface	0.6
Sun tracking system	0.6
Mechanical components of heat energy storage system	1.3
Mechanical components of heat energy storage system	2.4
Stirling engine	1.3
Panel integration and production of structural solar mechanics	0.6

Table 3. Feed-in-Tariffs for Turkey from the National Renewable Energy Action Plan for Turkey

Many of the barriers to growing the CSP sector in Turkey are non-technological, and in response METU-GÜNAM has been making a concerted effort to integrate the METU Science and Technological Policy Research Centre (METU-TEKPOL) into Turkish CSP activities. METU-TEKPOL has extensive experience developing and executing Science, Technology and Innovation projects and has strong policy networks at national, EU, and global levels. METU-GÜNAM and METU-TEKPOL are currently collaborating on several EU proposals and projects.

4.1.5.3.9 Activities related to support to internationalisation

Turkey's CSP research activities have a strong European dimension due to Turkey contributing to the development of the pan-European CSP Research Infrastructure EU-SOLARIS since 2012. Turkey will be a founding member of the EU-SOLARIS European Research Infrastructure Consortium (ERIC) when it is constituted in the fall 2019. Significantly, EU-SOLARIS ERIC is the first ERIC that Turkey has committed to joining, which reflects Turkey's strong commitment to catalysing growth in Turkey's CSP sector. Turkey's involvement in EU-SOLARIS and the 5 MW_{th} demonstration power plant described in item 8 in particular have resulted in Turkey being involved in several EU CSP projects. While many of these projects do not directly support the IP, they do provide a strong foundation for European collaboration that can be leveraged to support the IP. The complete list of EU projects in which Turkey is participating is presented in the table below, and for completeness includes the

[11] https://www.eigm.gov.tr/File/?path=ROOT%2F4%2FDocuments%2FEnerji%20Politikas%C4%B1%2FNational_Renewable_Energy_Action_For_Turkey.pdf

BOOST EU-SOLARIS proposal that is currently under review. Furthermore, it should be noted that the core technologies being developed for the GeoSmart project are geothermal, Zorlu Energy (602 219 €) and Kadir Has University (109 375 €) are primarily contributing to the development of these technologies, while METU-GÜNAM’s (193 333 €) is primarily contributing to the evaluation of opportunities to hybridize geothermal power plants with CSP and/or biomass to increase the flexibility of geothermal power plants, and which will in turn increase the flexibility of CSP power plants. Finally, METU-GÜNAM is an Associated Participant in the European Energy Research Area-Joint Programme-CSP (EERA-JP-CSP).

Project Name	Acronym	Leading organization	Duration	Partners (R&D; I = Industrial; F = Funding Agency)	Comments	Turkish Budget (€)
Building an Open Science COmmunity around Concentrating Solar Thermal Research Infrastructures at EU-SOLARIS	BOOST EU-SOLARIS	CIEMAT-PSA (Spain)	Under Review	METU-GÜNAM (R&D)	Objective is to strengthen METU-GÜNAM's CSP Capacities. With CIEMAT-PSA (Spain) and DLR (Germany).	438,750
Solar Twinning to Create Solar Research Twins	SolarTwins	METU-GÜNAM (Turkey)	Jan. 2020 - Dec. 2022	METU-GÜNAM (R&D)	Objective is to strengthen METU-GÜNAM's CSP Capacities. With CIEMAT-PSA (Spain) and DLR (Germany).	399,621
High Storage Density Solar Power Plant for Flexible Energy Systems	HIFLEX	Processi Innovativi Srl (Italy)	Sept. 2019 - Aug. 2023	Tekfen Engr. (I)	Tekfen contributes design, construction and installation of heliostats	3,700,000
Technologies for geothermal to enhance competitiveness in smart and flexible operation	GeoSmart	Twi Limited (UK)	June 2019 - May 2023	Zorlu Energy (I); METU-GÜNAM (R&D); Kadir Has U. (R&D)	METU-GÜNAM contributes to hybridization of geothermal with CSP	904,926
Joint programming actions to foster innovative CSP solutions	CSP ERANET	Agencia Extremena de la Energia (Spain)	June 2019 - May 2024	TÜBİTAK (F)	The objective is to implement joint calls to support the CSP SET Plan objectives	404,588
Implementation of the Initiative for Global Leadership in Solar Thermal Electricity	HORIZON-STE	ESTELA (EU)	Apr. 2019 - Mar. 2022	METU-GÜNAM (R&D)	The objective is to support the CSP IP for the EU SET-Plan	64,581
Solar Facilities for the European Research Area - Third Phase	SFERA-III	CIEMAT-PSA (Spain)	Jan. 2019 - Dec. 2022	METU-GÜNAM (R&D)	The objective is to build-on and extend the activities of SFERA and SFERA II.	84,687
Advanced materials solutions for next generation high efficiency concentrated solar power (CSP) tower systems	NEXTOWER	ENEA (Italy)	Jan. 2017 - Dec.2020	Tekfen Engr. (i)	The objective is to introduce a set of innovative materials to boost the performance of atmospheric air-based CSP systems	145,250
PhD on Innovation Pathways for TES	INPATH-TES	U. De Lleida (Spain)	May 2015 - Apr. 2018	U. of Cukurova (R&D); Arcelik A.S (I);	The objective is to develop a joint PhD programme on Thermal Energy Storage (TES) between universities & research centres	236,371
						6,378,774

Table 4. Summary of EU CSP Projects Turkey is contributing to that have started since 2014. Source: METU.

4.1.5.3.10 Stake of the country in the CSP/STE sector

Additional details supporting the characterization of Turkey's CSP sector as being nascent are as follows. Currently Turkey does not have any commercial CSP power plants. However, Turkey's CSP markets have large potentials due to Turkey's large population (~ 80 M, or about equal to Germany's), large land mass (~780 000 km^2, or ~1.5x that of Spain), and large solar resources (annual DNI > 2000 kWh m^{-2} in some regions) as shown in the solar resource map below (Figure 3).

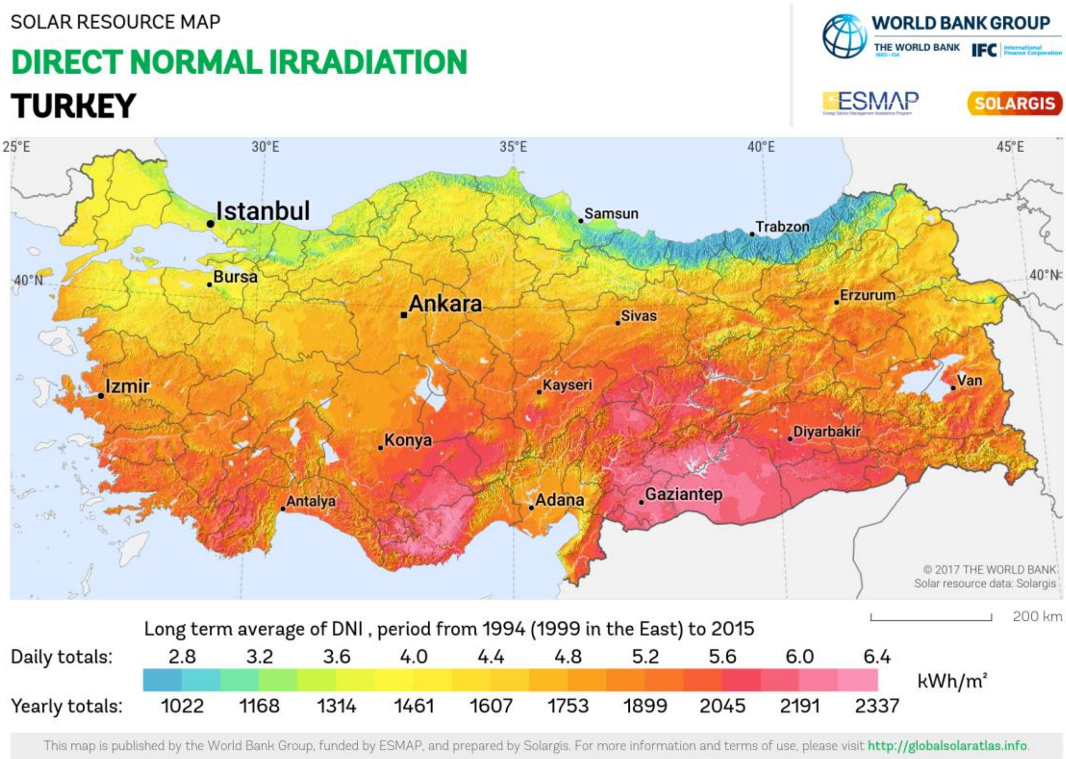


Figure 3. DNI of Turkey. Source: World Bank Group, Global Solar Atlas, https://globalsolaratlas.info/

Furthermore, as an emerging economy with a growing population, Turkey's electricity demand is also increasing, which is necessitating new power plants. And finally, Turkey has limited conventional energy resources and therefore is interested in increasing its energy security through the greater use of domestic renewable energy resources. Therefore, Turkey's CSP markets can be described as currently non-existent but having large growth potentials.

Additionally, and as detailed in item 12, although Turkey does not currently have any industries with significant commercial activities in the CSP value chain, it has large industrial potentials in this area.

Greenway CSP historically was (and Tefken Engineering currently is) the main industrial CSP actor in Turkey, and METU-GÜNAM is the main research actor. Greenway CSP was headquartered at Istanbul Technical University (ITU) and collaborated extensively with ITU's Energy Institute. Relevant national activities involving Greenway CSP and METU-GÜNAM that have started since 2014 are as follows:

ODTÜ-GÜNAM: To strengthen Turkey's R&I capacities, Turkey is beginning to spin-out university-based research centres that are high-performing and of strategic national importance from universities to create national research centres. METU-GÜNAM has been selected to be one of the first research centres to go through this spin-out process, and in the Fall 2019 METU-GÜNAM will become the national solar energy research centre ODTÜ-GÜNAM. ODTÜ-GÜNAM's mission explicitly includes 1) catalysing, coordinating, and leading Turkish CSP R&I activities and 2) strengthening Turkey's synergistic integration into EU CSP activities. Of particular significance, ODTÜ-GÜNAM will be Turkey's national node (and therefore Turkey's scientific representative) for EU-SOLARIS ERIC. A proposal to TÜBİTAK is currently under review to define a 5-year budget to create and operate ODTÜ-GÜNAM that includes financial commitments to strengthen and operate ODTÜ-GÜNAM's CSP R&I capacities.

HOYTI (Heliostat Optical Surface Analysis & Restoration, 2016-2018): A TÜBİTAK project awarded to GREENWAY CSP and ITU to develop image process application using photometry for heliostat surface optical analysis and field calibration using edge detection technology.

GÜNAM-II (Formation of Global Excellence Centre and Interface with Industry, 2nd Phase, 2015-2018). Funding was supplied by the Turkish Ministry of Development to expand GÜNAM's photovoltaic (PV) research infrastructure and establish Turkey's first dedicated CSP research laboratory.

The other CSP activities and associated capacities in Turkey can mostly be described as unaligned and often the result of bottom-up activities initiated by individuals. Presenting a complete and detailed picture of these other CSP activities and capacities in Turkey is difficult due to their distributed and fragmented nature, the lack of a single source where information on these activities and capacities are compiled, and the fact that associated individuals often do not respond to requests for information. However, a partial picture of these other activities is as follows. At Boğaziçi University, Hakan Erturk is active in nanofluids and spectrally-selective coatings for CSP applications, and Hasan Bedir is active in power cycles driven by solar thermal, geothermal, and waste heat. At Ege University's Solar Energy Institute, Seçkin Erden has performed research on parabolic trough collectors. And finally, the group at Harran's University's Southeast Anatolian Renewable Energy and Energy Efficiency Centre (GAP YENEV) has performed research on Fresnel collectors. As noted above, part of ODTÜ-GÜNAM's explicit mission is to leverage, align, and exploit these fragmented capacities to support the IP.

4.1.5.3.11 CSP value Chain sector relevant for the country

As noted above, Turkey does not presently have any industries with significant commercial activities in the CSP value chain, but it does have large potentials to contribute to this value chain. Turkey's economy is approximately the 19th largest in the world and has a large industrial base including in the glass, power plant, construction and manufacturing sectors. While the company Greenway CSP that built the 5 MW_{th} demonstration power plant described in item 8 is no longer active, many of the technologies embedded in this demonstration plant are protected by trade secrets that have recently been absorbed by Tekfen Engineering. To enable the technologies resulting from this demonstration power plant to be commercialized in Turkey and to benefit from the highest FiTs possible through the use of high-domestic content (see item 9), most of the components for this demonstration CSP plant are domestic technologies, which indicates the potential for Turkish industry to supply core CSP technologies. Additionally, Turkey has many companies involved domestically and internationally in constructing and operating power plants using conventional and geothermal energy sources, including Zorlu Energy which is involved in the EU GeoSmart project introduced in item 4.1.5.3.10.

Turkey has committed funds to participate in the CSP ERANET calls and therefore will be active in the WP3 R&I activities. Additionally, Turkey will be exploring opportunities to participate in the WP2 activities to re-launch the STE industry in Europe. As described above, Turkey is also planning national calls in 2020 to support CSP research. Therefore, it seems reasonable to approach Turkey on both WP2 & WP3.

4.1.6 Update on IP countries not represented in the consortium

In order to understand the current situation of the sector in the countries that collaborated in the IP but that are not represented in the consortium of Horizon-STE, support was requested to the Chair of the CSP-IWG in order to identify the most adequate people to reach out to and to obtain their contact details. In addition, the knowledge from the R&I partners of the consortium and their network outreach in the sector was an important factor in the selection of the people to contact. They were selected for their knowledge of the R&I activities in the sector and their perceived willingness to contribute to the task. It is worth pointing out that the participants (or at least the people whose contacts are included in the participants list of the IWG) not necessarily have the most updated information, or it would take more time for them to then reach out to national experts than collecting the information through other collaboration networks.

For these countries, the identified people will be consulted in the following months and asked to provide the same information that was researched for the countries represented in the consortium, covered in section 4.1.5. The results will be included in the following update of this deliverable. Table 5 below summarizes the contact people identified:

Country	Contact person	*Institution*	*Email address*
Portugal	**Joao Cardoso**	**LNEG - Laboratório Nacional de Energia e Geologia**	**joao.cardoso@lneg.pt**
Cyprus	**Manuel Blanco**	**The Cyprus Institute**	**m.blanco@cyi.ac.cy**
France	**Alain Dollet**	**CNRS-PROMES**	**alain.dollet@promes.cnrs.fr**

Table 5. Contact people for Portugal, Cyprus and France.

4.2 Subtask 2 – Assessment of the relevance of various European countries due to their stake in STE/ CSP sector

In this task, the aim was to identify the relevance of certain Member States based on their stake in the CSP/STE sector and to classify it by the type of participation they have along the value chain of the sector, classifying them within 4 basic categories: industry engagement (along the supply chain), potential host for a CSP/STE power plant, potential off-taker country, and/or R&I engagement. Countries can also fall into more than one category.

In addition to the (updated) panorama provided by the results of sub-task 1, a "cross-check" was made with the knowledge obtained from the activities of ESTELA, from its own experience and from its collaborations in other projects, as well as from publicly available documents from the European Commission and other relevant organisations.

Industrial engagement

As per a mapping of the sector done by ESTELA (also published in the most recent version of the sector's directory made by ESTELA), which considered various entities beyond the borders of the association's membership base, it is possible to identify the type of involvement of each country in the sector (to the best of the association's knowledge):

	Member State	DE	DK	CZ	ES	FR	NL	IT	PT	BE
Activitity	Developer	✓			✓	✓		✓		
	Civil works				✓			✓	✓	
	Solar field	✓			✓	✓				✓
	Tower				✓			✓	✓	
	Receiver	✓	✓		✓		✓			
	Storage	✓			✓					✓
	Control	✓	✓		✓	✓	✓	✓	✓	
	Piping/Valves	✓			✓	✓		✓	✓	✓
	Steam generation	✓	✓		✓		✓	✓		
	Turbine	✓		✓				✓		
	Cooling system				✓			✓	✓	
	Electrical system	✓	✓	✓	✓	✓	✓	✓	✓	
	Auxiliary system				✓			✓	✓	
	Assembling				✓			✓	✓	
	Research	✓			✓	✓		✓	✓	

Table 6. Mapping of activities within the STE/CSP sector per country. Source: Own elaboration (ESTELA).

Potencial host for a STE/CSP power plant

As it is known in the sector and also expressed in publications like “Selection of representative and strategic CSP/STE projects potentially suitable for cooperation”[12], prepared as a deliverable of the EU-funded project MUSTEC (which CIEMAT coordinates and where ESTELA also collaborates), southern European countries are the best suited for hosting a power plant due to their high DNI.

Potencial off-taker country

As the potential for building a powerplant whose production would be consumed in the same country (e.g. Spain, Portugal, Italy, Greece or Cyprus) is rather limited (even if 5 new GW of capacity are announced in the Spanish NECP), the interest and readiness of central/northern European countries for procuring manageable RES from the host countries (either including physical transfers or statistically) will be assessed. A starting point for this analysis is the current progress and announced trajectories for the share of RES in gross final energy consumption and in the share for the production of electricity in the Member States for 2020. It is worth mentioning that interest in the procurement of STE would rise if industrial participation from national companies could be considered in the project for cooperation.

This will be investigated during WP2 of the project. It is expect (and yet to be confirmed or corrected), that STE could be of special interest to those MS falling behind in their 2020 (and without a clear pathway for 2030), that have an open attitude towards potential cooperation project, that are not restricted by limited interconnection capacities (or where an interconnection would make no sense at all) and that are in a sound financial position to explore its viability. In addition, the NECP plans will be analysed in order to complement the selection of countries to investigate further. Figures 4 and 5 below show examples of recent figures for each MS.

[12] Souza A. (2018): Selection of representative and strategic STE projects potentially suitable for cooperation. Deliverable 5.1, MUSTEC project, ESTELA, Brussels.

Share of electricity from renewable sources in gross electricity consumption, 2004-2017

(%)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
EU-28	14.3	14.8	15.4	16.1	17.0	19.0	19.7	21.7	23.5	25.3	27.4	28.8	29.6	30.7
Belgium	1.7	2.4	3.1	3.6	4.6	6.2	7.1	9.1	11.3	12.5	13.4	15.5	15.8	17.2
Bulgaria	9.1	9.3	9.3	9.4	10.0	11.3	12.7	12.9	16.1	18.9	18.9	19.1	19.2	19.1
Czechia	3.7	3.8	4.1	4.6	5.2	6.4	7.5	10.6	11.7	12.8	13.9	14.1	13.6	13.7
Denmark	23.8	24.6	24.0	25.0	25.9	28.3	32.7	35.9	38.7	43.1	48.5	51.4	53.9	60.4
Germany	9.4	10.5	11.8	13.6	15.0	17.3	18.2	20.9	23.6	25.3	28.1	30.8	32.2	34.4
Estonia	0.5	1.0	1.3	1.3	1.9	5.8	10.2	12.1	15.4	12.7	13.8	14.9	15.2	17.0
Ireland	6.0	7.2	8.5	9.7	10.8	14.0	15.6	18.3	19.8	21.3	23.5	25.5	26.8	30.1
Greece	7.8	8.2	8.9	9.3	9.6	11.0	12.3	13.8	16.4	21.2	21.9	22.1	22.7	24.5
Spain	19.0	19.1	20.0	21.7	23.7	27.8	29.8	31.6	33.5	36.7	37.8	37.0	36.6	36.3
France	13.8	13.7	14.1	14.3	14.4	15.1	14.8	16.2	16.5	16.9	18.4	18.8	19.2	19.9
Croatia	35.0	35.4	35.0	34.0	33.8	35.9	37.5	37.6	38.7	42.1	45.2	45.4	46.6	46.4
Italy	16.1	16.3	15.9	16.0	16.6	18.8	20.1	23.5	27.4	31.3	33.4	33.5	34.0	34.1
Cyprus	0.0	0.0	0.0	0.1	0.3	0.6	1.4	3.4	4.9	6.6	7.4	8.4	8.6	8.9
Latvia	46.0	43.0	40.4	38.6	38.7	41.9	42.1	44.7	44.9	48.7	51.0	52.2	51.3	54.4
Lithuania	3.6	3.8	4.0	4.7	4.9	5.9	7.4	9.0	10.9	13.1	13.7	15.5	16.9	18.3
Luxembourg	2.8	3.2	3.2	3.3	3.6	4.1	3.8	4.1	4.7	5.3	6.0	6.2	6.7	8.1
Hungary	2.2	4.4	3.5	4.2	5.3	7.0	7.1	6.4	6.1	6.6	7.3	7.3	7.3	7.5
Malta	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.1	1.6	3.3	4.3	5.7	6.6
Netherlands	4.4	6.3	6.5	6.0	7.5	9.1	9.6	9.7	10.4	9.9	9.9	11.0	12.5	13.8
Austria	61.6	61.9	62.8	64.7	65.0	67.8	65.6	66.0	66.5	68.0	70.1	70.6	73.3	72.2
Poland	2.2	2.7	3.0	3.5	4.4	5.8	6.6	8.2	10.7	10.7	12.4	13.4	13.4	13.1
Portugal	27.4	27.7	29.3	32.3	34.1	37.6	40.6	45.8	47.5	49.1	52.1	52.6	54.0	54.2
Romania	25.0	26.9	28.1	28.1	28.1	30.9	30.4	31.1	33.6	37.5	41.7	43.2	42.7	41.6
Slovenia	29.3	28.7	28.2	27.7	30.0	33.8	32.2	31.0	31.6	33.1	33.9	32.7	32.1	32.4
Slovakia	15.4	15.7	16.6	16.5	17.0	17.8	17.8	19.3	20.1	20.8	22.9	22.7	22.5	21.3
Finland	26.7	26.9	26.4	25.5	27.3	27.3	27.7	29.4	29.5	30.9	31.4	32.5	32.9	35.2
Sweden	51.2	50.9	51.8	53.2	53.6	58.3	56.0	59.9	60.0	61.8	63.2	65.8	64.9	65.9
United Kingdom	3.5	4.1	4.5	4.8	5.5	6.7	7.5	8.9	10.8	13.8	17.8	22.3	24.6	28.1
Montenegro	:	39.1	37.7	37.6	38.3	46.6	45.7	41.6	42.8	49.1	51.4	49.6	51.0	50.1
North Macedonia	14.5	14.0	14.0	13.7	13.8	15.5	15.8	14.8	16.7	18.2	19.3	21.7	24.1	24.8
Albania	70.0	76.1	74.2	79.6	73.3	70.7	74.6	66.1	72.4	62.7	71.0	79.2	86.0	90.7
Serbia	18.5	22.4	23.6	24.8	25.9	28.3	28.2	27.5	28.5	28.0	30.3	28.9	29.2	28.7
Turkey	27.9	26.4	24.7	23.2	22.8	24.7	25.3	25.1	27.1	30.0	30.5	33.2	34.8	35.1
Kosovo (¹)	1.2	1.3	1.6	1.6	1.4	1.5	1.7	1.6	1.6	1.7	1.9	1.8	3.7	3.2

(¹) This designation is without prejudice to positions on status, and is in line with UNSCR 1244/1999 and the ICJ Opinion on the Kosovo declaration of independence.

Source: SHARES_summary_results in http://ec.europa.eu/eurostat/web/energy/data/shares

Figure 4. Share of electricity from renewable sources in gross electricity consumption 2004-2017. Source: Eurostat.

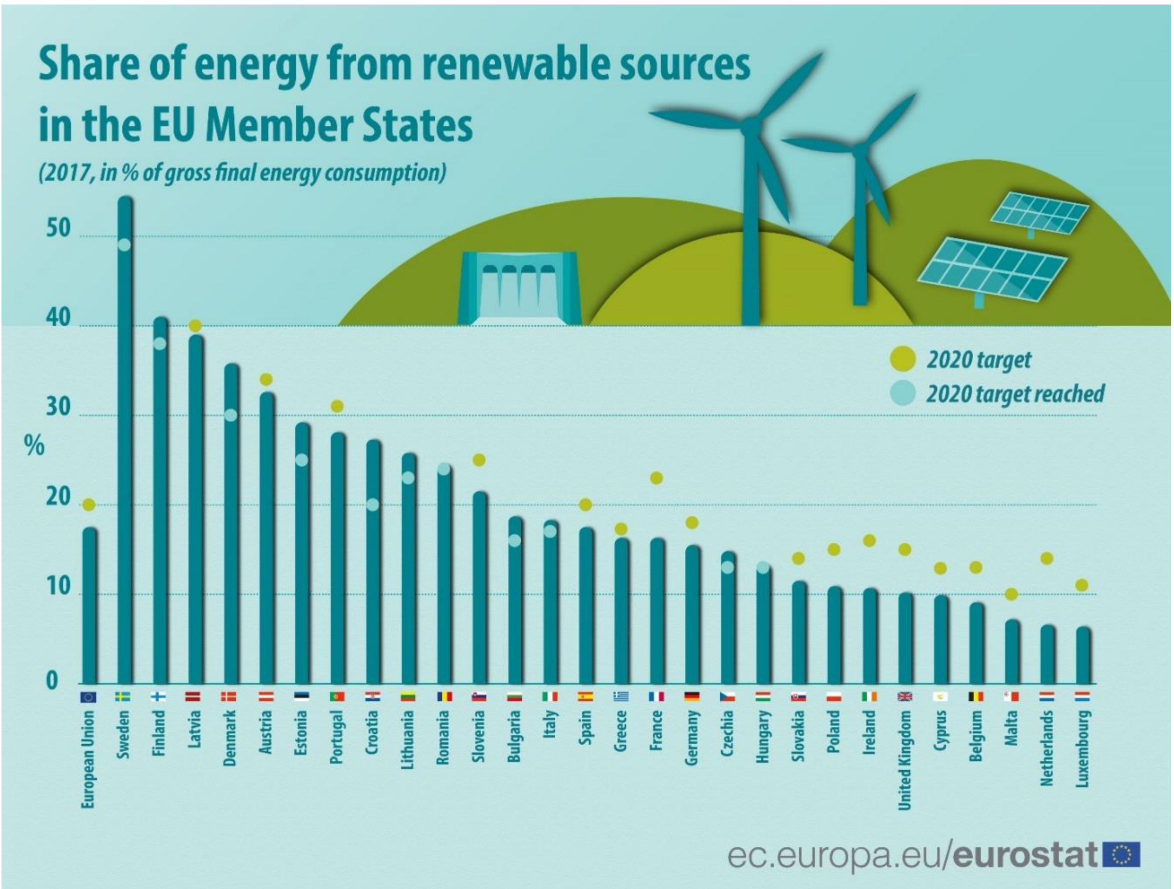


Figure 5. Share of energy from renewable sources in the EU Member States. Source: Eurostat.

Countries such as Netherlands, Belgium or Luxembourg (who has successfully engaged already in two statistical transfer cooperation projects) stand out as first potential countries to address from an *off-taker perspective.* However, this analysis will continue throughout the following months and a more detailed selection will be shown in Deliverable 2.1 “Report on stakeholder mapping”.

Table 7 below summarises the mapping of relevance per country made under the a.m. criteria:

Country	Type of involvement			
	Industrial Engagement	Potential Off-taker	Potential Host Country	R&I activities
Germany	✓	✓		✓
Spain	✓	✓	✓	✓
Turkey	✓	✓	✓	✓
Italy	✓	✓	✓	✓
Portugal	✓	✓	✓	✓
Cyprus		✓	✓	✓
France	✓	TBC*	TBC*	✓
Greece			✓	✓
Belgium	✓	✓		TBC
Switzerland				TBC
Croatia		TBC		TBC
Netherlands	TBC	✓		
Luxemburg		✓		
Denmark	✓	✓		
Czech Republic	TBC			

*Table 7. Relevance to the implementation of the IP of each country based on their type of involvement in the STE sector. Source: Own elaboration. *TBCD - To be confirmed.*

4.3 Subtask 3 – Reach out to Additional Countries

Under sub-task 3, an inquiry was made to countries which were not yet considered in the IP (or to an important extent) about their readiness to co-fund R&I projects or activities in the sector. These countries were: **Greece, Switzerland, Belgium and Croatia.**

Again, with the help of the Chair of the IWG (but not exclusively), contact persons were identify in an attempt to obtain the same information (naturally expecting less content than in countries participating in the IP). In some cases, the representative of the country to the SET-Plan SG was the starting point. A brief summary of each country is presented below:

4.3.1 Greece

In Greece, Mr. George Karagiannakis (gkarag@cperi.certh.gr), from the Centre for Research & Technology Hellas (CERTH) was identified due to his closeness to the sector and his participation CSP R&I projects. The consultation for Greece will be done in parallel to the ones for France, Portugal and Cyprus and the results will be included in the next update of the deliverable.

4.3.2 Belgium (Wallonia Region)

Due partly to the fact that the company CMI (today John Cockerill), which has been awarded with important contracts in recent projects (such as the receiver for the DEWA-IV phase plant) is based in the region of Wallonia, contact was established/re-taken with the representative of the Region of Wallonia to the IWG for assessing the interest and readiness of Belgium to support industrial and research activities related to the sector.

Although no concrete response was received at the time of submission of the deliverable, one of the contact persons identified, Mr. Alain Stephenne (alain.stephenne@spw.wallonie.be) from the Department of Energy and Sustainable Building of the Public Service of Wallonia, replied in a positive way and promised to come back with more information in the near future. Follow up will be given in the following months. Responses are still missing from the company John Cockerill to assess their views on the topic.

4.3.3 Switzerland

In Switzerland, Mr. Stefan Oberholzer, the representative of the country to the SET-Plan SG, was contacted via email with the same inquiry as the other contact persons. However, no answer was received. Follow up will be given over the following months.

4.3.4 Republic of Croatia

In the same way as for the previous countries, the respective representative, Ms. Martina Velnić Župić, Head of Unit for Energy Strategy, Statistic and Planning at Ministry of Environment and Energy, was contacted also via email. Croatia was selected as a potentially interesting country due to the mention of CSP (at least for heat purposes) in their National Energy and Climate Plan. In her response, she indicated the following:

- There is no current engagement of the country in the Solar Thermal Electricity (CSP) sector or related running projects.
- The national program/framework that (would) provide funding to the sector STE are considered and under development (early stage).
- The role and possibility of EU funding to the STE sector would be essential and welcomed.

The consortium will further evaluate possibilities for developing the interest of the country in the sector and explore concrete ways for collaboration during the project, if possible.

4.4 Subtask 4 – Identification of the type of approach for each country and in which WP of the project they will be addressed.

Based on the results of the first three subtasks, a first classification of the countries can be done considering the WP in which where they will be studied.

Taking into consideration the good industrial background and the excellent R+D CST facilities existing in Spain, together with the promising goals defined for STE in the "National Energy and Climate Plan 2021-2030", it seems advisable to address this country in both WP2 and WP3 in order to take advantage of synergies among the industrial sector, the public administration and the R+D centres and thus make the most of the available resources to develop the IP. Similarly, due to its strong research and industrial involvement, Germany will also be analysed in both WPs. In addition, since Turkey has committed funds to participate in the CSP ERANET calls (therefore being active in the WP3 R&I activities) and will also be exploring opportunities to participate in the re-launch the STE industry in Europe (also planning national calls in 2020 to support CSP research), it seems reasonable to approach Turkey on both WP2 & WP3.

Although the most updated landscape for Italy is not presented in this (will be included in the first update), it also has relevant research and industrial participations, which is why the country was invited to participate as a project member in the consortium. Therefore, it will also be approached with a dual perspective as the a.m. countries.

Table 8 (below) presents a summary of this classification. In the category industrial focus, the three aspects evaluated under subtask 4.2 concerning industrial/commercial involvement are considered: industrial engagement in the supply chain, potential off-taker country, potential host country. This initial classification will be revised during the first months of the project and updated by M12 so to include/exclude countries in the work agendas of each WP if necessary (and possible).

As for the rest of the countries, further research needs to be done to define the degree of interest and the most suitable approach to follow in case they result to be attractive. This will also be reflected in the first update of the deliverable.

Country	Industrial focus	R&I focus	Work package
Germany	✓	✓	WP2 & WP3
Spain	✓	✓	WP2 & WP3
Turkey	✓	✓	WP2 & WP3
Italy	✓	✓	WP2 & WP3
Portugal	✓	✓	WP2 & WP3
Cyprus	TBC	✓	WP2 & WP3 – TBC
France	✓	✓	WP2 & WP3 – TBC
Greece	✓	✓	WP2 & WP3 – TBC
Belgium	✓	TBC	WP2 – TBC
Switzerland	TBC	TBC	TBC
Croatia	TBC	TBC	WP2 & WP3
Netherlands	✓		WP2
Luxemburg	✓		WP2
Denmark	✓		WP2
Czech Republic	TBC	TBC	WP2 – TBC

Table 8. Identification of the approach for each country as per the results of subtasks 1-3.

In this way, a first list of countries to analyse during the first year of the project has been identified, with its corresponding work approach. Also, next steps for the development of the project have been identified: 1) coordinate the most adequate work agenda between WP2 and WP3 leaders; 2) continue the research and consultations to refine the classification of the selected countries; 3) start in-depth stakeholder mapping exercises for each country selected and 4) proceed with the scheduled visits, analysis, reports and events for the countries selected, as per the planning developed in point 1.

5 APPENDIX

5.1 Annex 1 – List of the priority research activities included in the CSP Implementation Plan

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_2 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

International cooperation:

Name:	Description:	Timeline:	Countries involved:	Budget per country:
SolarPACES	IEA's Technology Collaboration Programme on Solar Power and Chemical Energy Systems	1977-	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	Total annual budget approximately 0,16 M€
US DOE Sunshot, Air Brayton Combustion	Design, develop and test a 1000 °C air inlet combustion system	2013-2016	United States, Germany	USA = 4M$ Germany= 0.1M$

Contacts:
Inmaculada Figueroa, Chair, Spain

R&I Activity n. 1

Title: Advanced linear concentrator Fresnel technology with direct molten salt circulation as heat transfer fluid and for high temperature thermal energy storage	
Targets: This R&I Activity will help to achieve the target on CSP cost reduction	**Monitoring mechanism**: Power Purchase Agreements of new CSP plants in Europe

Description:

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.

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 565ºC, 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&M costs

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.

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.

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.

In short, before jumping straight from conventional linear concentrating technologies of the past into totally new possibilities like those arising from supercritical CO_2 turbines at even higher temperatures (600ºC and higher for supercritical CO_2 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 600ºC, using

<table>
<tr><td colspan="2">possibly more advanced new salts or other fluids.
The reference to 565ºC also deserves an explanation. The idea is to be able to use the present day steam turbines operating at 540ºC with their high efficiencies, typical of today's thermal power plants, and still stay below the critical 600ºC "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</td></tr>
<tr><td colspan="2">TRL:
From TRL 6 to TRL 8</td></tr>
<tr><td colspan="2">Total budget required: 30 M€</td></tr>
<tr><td>Expected deliverables:</td><td>Timeline:</td></tr>
<tr><td>- 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</td><td>4 years</td></tr>
</table>

(melting of raw material, filling process, commissioning time) o Demonstration of drainage process in a representative configuration o Demonstration of freezing and heating process (emergency case) o Work out and demonstrate handling of exceptional operation situations (maintenance of loops, repair of leakages, re-vitalizing frozen parts, exchange of components) - 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. - 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 - Integration of forecasting and power grid management and trading as a key input for reliable operation			
Party / Parties:	**Implementation instruments:**	**Indicative financing contribution:**	
See Annex III			

R&I Activity n. 2

Title: Parabolic trough with molten salts	
Targets: This R&I Activity will help to achieve the target on CSP cost reduction	**Monitoring mechanism**: Power Purchase Agreements of new CSP plants in Europe
Description: 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.	
TRL: From TRL 6 to TRL 8	
Total budget required: 11.5 M€	
Expected deliverables:	**Timeline:**
- Testing and evaluating critical plant components (reliability of standard components) o Large diameter header systems o Molten salt pumps and valves o Instrumentation, sensors, and pipe heating o Full size (length) collector loop (collector, interconnections, drives, instrumentation, emergency concept, control) - Testing and demonstration of process control concept (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 Demonstrate loop control concept in a full size collector loop o Hardware-in-the-loop simulation of a full solar field - Demonstration of molten salt specific operations (availability of emergency operations) o Demonstration of drainage process in a representative configuration	Development of testing procedures: 1 year Verified qualification methods available for critical components: 1.5 years Implementation of testing hardware in loop for further monitoring: 1.5 years Development of virtual solar field model: 2,5 years Demonstrate loop control concept in a full size collector loop or commercial plant: 1.5 years Implementation of drainage hardware demonstration loop or in pre-commercial plant: 1.5 years Demonstration of freezing and heating

o Demonstration of freezing and heating process (emergency case) o Work out and demonstrate handling of exceptional operation situations (first filling with MS, maintenance of loops, repair of leakages, re-vitalizing frozen parts) - Systematic risk assessment and documentation for molten salt line focusing systems o identification of risk sources (with EPCs, suppliers, consultants) o quantification of risk probability and their impact (e.g. FMECA) o compilation of mitigation measures	process: 1.5 years Demonstration of exceptional operation situations: 1.5 years Identification of risk sources: 2 years Quantification of impact and probability: 1 year Develop mitigation measures: 1 year

Party / Parties:	**Implementation instruments:**	**Indicative financing contribution:**
	See Annex III	

R&I Activity n. 3

<table>
<tr><td colspan="3">Title:
Parabolic trough with silicon oil</td></tr>
<tr><td>Targets:
This R&I Activity will help to achieve the target on CSP cost reduction</td><td colspan="2">Monitoring mechanism:
Power Purchase Agreements of new CSP plants in Europe</td></tr>
<tr><td colspan="3">Description:
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</td></tr>
<tr><td colspan="3">TRL:
From TRL 6 to TRL 8</td></tr>
<tr><td colspan="3">Total budget required: 5-8 M€</td></tr>
<tr><td colspan="2">Expected deliverables:</td><td>Timeline:</td></tr>
<tr><td colspan="2">- 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</td><td>3 years</td></tr>
<tr><td>Party / Parties:</td><td>Implementation instruments:</td><td>Indicative financing contribution:</td></tr>
<tr><td colspan="3" align="center">See Annex III</td></tr>
</table>

R&I Activity n. 4

Title: Solar tower power plant to commercially scale-up and optimize the core components of the open volumetric air receiver technology		
Targets: This R&I Activity will help to achieve the target on CSP cost reduction	**Monitoring mechanism**: Power Purchase Agreements of new CSP plants in Europe	
Description: 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. 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 <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 >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. 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.		
TRL: From TRL 6 to TRL 8		
Total budget required: 5.5 M€		
Expected deliverables:		**Timeline:**
- 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 >40 years. - Design of scaled-up fixed bed thermal energy storage		2 years

- Design of cost and performance optimized heliostats by optimizing drive units, mirror reflectivity and optical properties, field layout, cleaning procedures, reliability and durability - 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) - Optimized plant and operational concepts in order to balance electricity production with other renewables and market the produced electricity in other European markets.		
Party / Parties:	**Implementation instruments:**	**Indicative financing contribution:**
See Annex III		

R&I Activity n. 5

<table>
<tr><td colspan="2">Title:
Improved Central Receiver Molten Salt technology</td></tr>
<tr><td>Targets:
This R&I Activity will help to achieve the target on CSP cost reduction</td><td>Monitoring mechanism:
Power Purchase Agreements of new CSP plants in Europe</td></tr>
<tr><td colspan="2">Description:
This R&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&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 €/m2 (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.</td></tr>
<tr><td colspan="2">TRL:
From TRL 7 to TRL 9</td></tr>
<tr><td colspan="2">Total budget required: 22 M€</td></tr>
<tr><td>Expected deliverables:</td><td>Timeline:</td></tr>
<tr><td>- Increase nominal and annual performance of heliostats and heliostat field by 5% (at least) and reduce heliostat cost to < 100€/m2 by improving the following :
- Mirror reflectivity (> 95 %)
- Optimized size vs cost (< 100 €/m2)
- Heliostat field layout
- Cleaning requirements and procedures
- Slope error (<3 mrad) and optical quality
- Manufacturing, assembly and set-up costs
- Procedures for quick and cheap (re)calibration (optics and tracking)
- Reliability and durability
- More cost-effective drive units
- 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)

- For the solar receiver:
- Identification and selection of new suitable materials (lower cost and higher performance) for mono-tower receivers and high concentration flow systems
- Reduction of total receiver surface required for a given output in comparison with current solar tower technology
- Development or adaptation of existing evaluation models to build and optimize the receiver design

- For the control
- A completely automated procedure must be developed to calibrate the whole</td><td>3 years</td></tr>
</table>

heliostat field in a short time, which should enable re-calibrating heliostats repeatedly to alleviate heliostat requirements and to reduce their costs - 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 - Develop methods to measure (or estimate as accurately as possible) receiver temperature and flux distribution during operation under real working conditions - Determination of atmospheric attenuation on line - For the storage system: - Improvements in heat tracing, and components (e.g., valves, pumps) to reduce parasitic consumption - Improvements of storage tanks designs to reduce capital cost - For the steam generation and turbine - Optimization of steam generator design - Improvement of operational flexibility of the turbine - Improvement of the life of the turbine components and reduction of the maintenance cost - In terms of operation and maintenance (O&M): - Development of predictive maintenance tools, systems and procedures to reduce maintenance costs and increase plant performance	

Party / Parties:	**Implementation instruments:**	**Indicative financing contribution:**
	See Annex III	

R&I Activity n. 6

<table>
<tr><td colspan="3">Title:
Next Generation of central receiver power plants</td></tr>
<tr><td>Targets:
This R&I Activity will help to achieve the target on developing the next CSP generation</td><td colspan="2">Monitoring mechanism:
New CSP cycles demonstrated</td></tr>
<tr><td colspan="3">Description:
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.</td></tr>
<tr><td colspan="3">TRL:
From TRL 6 to TRL 8</td></tr>
<tr><td colspan="3">Total budget required: 25 M€</td></tr>
<tr><td colspan="2">Expected deliverables:</td><td>Timeline:</td></tr>
<tr><td colspan="2">Heliostats and solar field:
- 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
- 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 <90€/m2)
- Smart independent heliostat developments (self-calibrated, self-diagnosis)
- Wireless and autonomous commercial heliostat field developments
Solar receiver:
- Higher temperature solar receiver according to the needs of new power cycles to guarantee reliability and performance at high temperature
Heat Transfer Fluids:
- Use of innovative molten salts to allow a wider operation range 160ºC – 650ºC.
Control:
- 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</td><td>5 years</td></tr>
</table>

<table>
<tr><td colspan="3">receivers sharing a huge heliostat field, etc.).
- Development of methodologies for on line heliostat field characterization and diagnosis.
- Increase of accuracy of instrumentation for high temperatures
Steam generation and turbine:
- Supercritical turbines
- Supercritical steam generators
- Techno-economic optimization of components taking into consideration the working conditions (i.e., pressures and temperatures) and the associated efficiency and cost increases
Operation and Maintenance (O&M):
- Monitoring of molten salt degradation status and potential corrosion of molten salt loop and subsystems for high temperatures
- Low-water or waterless cleaning systems developments
- New pumping equipment to recover the gravitational energy in the salt circuit of the tower
- Optimization of O&M procedures to reduce auxiliary energy consumption to prevent the salts from freezing</td><td></td></tr>
<tr><td>Party / Parties:</td><td>Implementation instruments:</td><td colspan="2">Indicative financing contribution:</td></tr>
<tr><td colspan="4">See Annex III</td></tr>
</table>

R&I Activity n. 7

<table>
<tr><td colspan="3">Title:
Pressurized air cycles for high efficiency solar thermal power plants</td></tr>
<tr><td>Targets:
This R&I Activity will help to achieve the target on developing the next CSP generation</td><td colspan="2">Monitoring mechanism:
New CSP cycles demonstrated</td></tr>
<tr><td colspan="3">Description:
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.</td></tr>
<tr><td colspan="3">TRL:
From TRL 5 to TRL 7</td></tr>
<tr><td colspan="3">Total budget required: 5M€</td></tr>
<tr><td colspan="2">Expected deliverables:</td><td>Timeline:</td></tr>
<tr><td colspan="2">- Demonstration of 500 kW thermal solar receiver
- Demonstration of a ceramic high temperature thermal heat storage with pressurized air as working fluid
- Integration of pressurized-air solar receiver and storage in a single loop</td><td>2 years
1.5 years

1.5 years</td></tr>
<tr><td>Party / Parties:</td><td>Implementation instruments:</td><td>Indicative financing contribution:</td></tr>
<tr><td colspan="3">See Annex III</td></tr>
</table>

R&I Activity n. 8

<table>
<tr><td colspan="3">Title:
Multi-tower central receiver beam down system</td></tr>
<tr><td>Targets:
This R&I Activity will help to achieve the target on developing the next CSP generation</td><td colspan="2">Monitoring mechanism:
New CSP cycles demonstrated</td></tr>
<tr><td colspan="3">Description:
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.</td></tr>
<tr><td colspan="3">TRL:
From TRL 5 to TRL 7-8</td></tr>
<tr><td colspan="3">Total budget required: 7-8 M€</td></tr>
<tr><td colspan="2">Expected deliverables:</td><td>Timeline:</td></tr>
<tr><td colspan="2">- Industrial optimization of mirror design and manufacturing with an installed cost of 70-80€/m2
- Optimization of cavity integrated with storage
- Industrial optimization operating at very high temperatures (e.g., research in terms of materials)
- Cost reduction and optimization (O&M) of tracker
- Study and test of high temperature components (fluidized bed materials, power unit, heat exchanger)
- Operating control strategies for components, plant with thermal energy storage
- Operate a 2 MW thermal solar receiver</td><td>3 years</td></tr>
<tr><td>Party / Parties:</td><td>Implementation instruments:</td><td>Indicative financing contribution:</td></tr>
<tr><td colspan="3" align="center">See Annex III</td></tr>
</table>

R&I Activity n. 9

Title: Thermal energy storage		
Targets: This R&I Activity will help to achieve the target on developing the next CSP generation	**Monitoring mechanism**: New CSP cycles demonstrated	
Description: 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).		
TRL: From TRL 4 to TRL 6-7		
Total budget required: 10 M€		
Expected deliverables:		**Timeline:**
- 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		3 years
- 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		2 years
- Demonstrator at a representative scale		2 years
Party / Parties:	**Implementation instruments:**	**Indicative financing contribution:**
See Annex III		

R&I Activity n. 10

Title: Development of supercritical steam turbines optimised for the specifics of CSP applications	
Targets: This R&I Activity will help to achieve the target on developing the next CSP generation	**Monitoring mechanism**: New CSP cycles demonstrated

Description:

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.

Topic 1: Development of an optimised supercritical steam turbine and optimised steam turbine technologies for CSP

Improved performance (cycle and turbine efficiency) through supercritical steam pressures and high steam temperature in combination with optimized speed.

Improved turbine efficiency and operational flexibility as well as cost reduction through the application of latest steam turbine technologies and compact design.

Key challenges include:

- 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
- 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)
- Application of appropriate blading technologies to maximize efficiency and operational flexibility
- Application of appropriate sealing technologies at small scale to minimize clearances necessary
- Potential application of magnetic bearings and frequency invertors

Topic 2: Extend the application of steel to the limits (e.g. 650°C)

Key challenges include:

- 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
- Methods for high accuracy of prediction of thermal deformation of steam turbine generators casings during start-up and rapid load changes
- 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
- Small scale control valves resistant to long term oxidation, leakage and seizure

TRL:

Topic 1

Development of a steam turbine optimised for CSP applications

<table>
<tr><td colspan="3">TRL5: conceptual design
TRL6: detailed design
TRL7: demonstrator
Optimised steam turbine technologies for CSP
TRL3: Most promising technologies identified
TRL6: Technologies potential demonstrated
TRL7: Technologies demonstrated in system prototype

Topic 2: Extend the application of steel to higher temperatures (e.g. 650°C)
TRL3</td></tr>
<tr><td colspan="3">Total budget required: 25 M€</td></tr>
<tr><td colspan="2">Expected deliverables:</td><td>Timeline:</td></tr>
<tr><td colspan="2">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):

Development of a steam turbine optimised for CSP applications

Optimised steam turbine technologies for CSP

Topic 2 Topic 3: Extend the application of steel to higher temperatures (e.g. 650°C)</td><td>

TRL5: 0.5 year
TRL6: 2 year
TRL7: 3.5 year

TRL3: 1 year
TRL6: 3 years
TRL7: 3.5 years

1 year</td></tr>
<tr><td>Party / Parties:</td><td>Implementation instruments:</td><td>Indicative financing contribution:</td></tr>
<tr><td colspan="3">See Annex III</td></tr>
</table>

R&I Activity n. 11

<table>
<tr><td colspan="3">Title:
Development of advanced concepts for improved flexibility in CSP applications</td></tr>
<tr><td>Targets:
This R&I Activity will help to achieve the target on developing the next CSP generation</td><td colspan="2">Monitoring mechanism:
New CSP cycles demonstrated</td></tr>
<tr><td colspan="3">Description:
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:
- Improve transient design for thick walled components (compare different turbine designs, improve geometries, reduce thermal stress)
- Develop enhanced thermal stress limits adjusted to the requirements of CSP projects
- Optimized live steam temperature concept for transient operation of CSP plants (less live steam temperature variation during operation)
- Identification of improved components supporting CSP requirements

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.</td></tr>
<tr><td colspan="3">TRL:
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</td></tr>
<tr><td colspan="3">Total budget required: 4 M€</td></tr>
<tr><td colspan="2">Expected deliverables:</td><td>Timeline:</td></tr>
<tr><td colspan="2">- Concept report of improved steam turbine operational concept for CSP (TRL3)

- Development of CSP plant analytics
- Plant analytics system
- Plant flexibility gains via analytics</td><td>1 year

2 year</td></tr>
<tr><td>Party / Parties:</td><td>Implementation instruments:</td><td>Indicative financing contribution:</td></tr>
<tr><td colspan="3">See Annex III</td></tr>
</table>

R&I Activity n. 12

<table>
<tr><td colspan="3">Title:
Development and field test of CSP hybrid air Brayton turbine combined cycle sCO_2 systems</td></tr>
<tr><td>Targets:
This R&I Activity will help to achieve the target on developing the next CSP generation</td><td colspan="2">Monitoring mechanism:
New CSP cycles demonstrated</td></tr>
<tr><td colspan="3">Description:
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.

Topic 1: Design, develop and field test a 1000 °C air receiver
The higher air receiver temperature improves the receiver and power block efficiency, which drives down heliostat costs and lowers the LCOE.

Topic 2: Develop a higher temperature combustion system
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_2 turbine at any time (24/7) and will be fully dispatchable. The air Brayton and sCO_2 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.

Topic 3: Development and test of a sCO_2 bottoming cycle for CSP operation
This system is unique to other sCO_2 systems being developed for CSP. This bottoming cycle sCO_2 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_2 system will be lower cost and more efficient than the current Rankine bottoming cycle system.

Topic 4: Optimally integrate conventional molten salt storage into the Brayton and sCO_2 plant
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_2 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.</td></tr>
<tr><td colspan="3">TRL:
From TRL 3 to TRL 6</td></tr>
<tr><td colspan="3">Total budget required: 26 M€</td></tr>
<tr><td colspan="2">Expected deliverables:</td><td>Timeline:</td></tr>
<tr><td colspan="2">- Develop a high temperature air receiver
- Develop a high temperature combustion system
- Develop a sCO_2 bottoming cycle system
- Optimum thermal storage</td><td>4 years</td></tr>
<tr><td>Party / Parties:</td><td>Implementation instruments:</td><td>Indicative financing contribution:</td></tr>
<tr><td colspan="3">See Annex III</td></tr>
</table>