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HORIZON STE

Develop indicators and methodology for monitoring success of the execution of the IP

Deliverable 3.2

WP 3: R&I Impact maximization

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ESTELA, European Solar Thermal Electricity Association

Contributing Partners

CIEMAT, Centro de Investigaciones Energeticas, Medioambientales y Tecnologicas

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 Horizon 2020 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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EXECUTIVE SUMMARY

In this Deliverable, indicators and a methodology for monitoring the success of the execution of the Concentrating Solar Power Implementation Plan (CSP IP) are presented. As a public Deliverable, the target audience includes the global scientific R&I community, and Section 1 Introduction contains the necessary background information to make this Deliverable useful to a diverse set of research actors. In Section 2 the procedure to elaborate this Deliverable is presented to 1) allow other research actors including SET-Plan Implementation Working Groups for other IPs to build-on this procedure, and 2) demonstrate strong alignment with HORIZON-STE's Grant Agreement. Sections 3 and 4 contain the resulting methodologies and indicators, respectively. Methodologies are presented to assess 1) the added value of dispatchable and flexible Concentrating Solar Power / Solar Thermal Electricity (CSP/STE) generating units; 2) the specific calls used to support the CSP IP; and 3) the specific Research and Innovation (R&I) Activities defined in the *Initiative for Global Leadership in Concentrated Solar Power - Implementation Plan* published in 2017 and referred to herein as *CSP IP 2017*. Indicators are presented for 1) the SET Plan CSP Targets and 2) the CSP IP development based on CSP IP 2017.

ABBREVIATIONS

CSP IP 2017	CSP Implementation Plan published in 2017
CSP IWG	Concentrating Solar Power Implementation Working Group
CSP/STE	Concentrating Solar Power / Solar Thermal Electricity
EC	European Commission
FOAK	First-Of-A-Kind STE Power Plant
H2020	Horizon 2020
IP	Implementation Plan
IWG	Implementation Working Group
JRC	Joint Research Center
R&I	Research and Innovation
SET-Plan	EU Strategic Energy Technology Plan
STE	Solar Thermal Electricity, which is often referred to as Concentrating Solar Power (CSP) elsewhere
TES	Thermal Energy Storage
TWG	Temporary Working Group

1 Introduction

This report is a Public Deliverable of the HORIZON 2020 project *HORIZON-STE: Implementation of the Initiative for Global Leadership in Solar Thermal Electricity*. While the report is mainly written for the CSP IWG, EC, and SET Plan communities defined below, as a Public Deliverable content is also provided to make the report accessible to and valuable for the larger global scientific community. Specifically, most of the Background content below is aimed at the larger global scientific community.

Background: To keep this report compact and aligned with the objectives described below, only the content from other publications that is critical to understanding the present report is summarized herein, and readers interested in further details are referred to the referenced publications.

The foundation for this report is Europe's Strategic Energy Technology Plan[1] (SET Plan), which is Europe's roadmap to rapidly bring to market low-carbon technologies that accelerate the transition to a climate-neutral energy system that is secure, reliable, and affordable. The SET Plan was refined and reinforced in 2015 when the European Commission (EC) adopted the communication *Towards an Integrated Strategic Energy Technology (SET) Plan: Accelerating the European Energy System Transformation*[2]. As the name implies, the Integrated SET Plan takes a holistic approach to Europe's energy transition, and envisions an energy transition based on the synergistic integration of a diverse set of energy technologies.

Concentrating Solar Power and Solar Thermal Electricity are equivalent terms and herein are abbreviated as CSP/STE. *Dispatchable* and *flexible* CSP/STE generating units are a key part of the Integrated SET Plan as follows. Dispatchable refers to the ability to generate electricity when needed. Flexible refers to the ability to ramp-up or ramp-down electricity generation quickly. The output of dispatchable and flexible CSP/STE generating units can be managed to fill the dynamic gap between electricity supply and demand at grid level. Due to the inherently variable nature of solar resources, dispatchable and flexible CSP/STE implies CSP/STE systems that include utility-scale Thermal Energy Storage (TES). TES is one of the most cost-effective and proven utility-scale energy storage technologies, and can be contrasted with electrical storage technologies such as batteries that are currently more expensive. Due to the relatively high cost of electrical storage technologies, grid-integrated solar photovoltaic (PV) and wind energy systems typically do not include energy storage and consequently are *variable* electricity generators in that their output varies uncontrollably with solar resources (PV) or wind resources (wind energy). In particular, the output from variable PV typically drops-off rapidly in the late afternoon as the sun sets, which is also typically the time when the demand for electricity increases rapidly. As a result, in grids with large levels of PV integration a large gap between demand and low-cost supply can rapidly form in the late afternoon. Filling this gap is critical for grid-stability and typically requires high-cost generating units. The main value of dispatchable and flexible CSP/STE generating units is their ability to fill this gap using renewable energy resources. This value translates into a CSP/STE business model where CSP/STE electricity is sold at premium prices and CSP/STE plants generate additional revenue by providing ancillary grid services. Consequently, the Integrated SET Plan envisions the

[1] https://ec.europa.eu/energy/en/topics/technology-and-innovation/strategic-energy-technology-plan

[2] https://ec.europa.eu/energy/sites/ener/files/publication/Complete-A4-setplan.pdf

synergistic integration of low-cost but variable PV and wind energy technologies with higher cost but more valuable dispatchable and flexible CSP/STE technologies.

Europe is currently a global leader in CSP/STE technologies, industrial capacities, and markets. Specifically, between 2008 and 2013 Spain was the global leader in installing new CSP/STE capacity, and as a result Spain presently has the largest installed CSP/STE capacity globally representing approximately 50% of total global installed capacity. Spain's global leadership in installed CSP/STE capacities is synergistic with Europe's global leadership in CSP/STE technologies and industrial capacities. However, the rapid expansion of Spain's CSP/STE capacities ended abruptly in 2013, and subsequently markets for new CSP/STE power plants moved to other countries and regions. Consequently, after 2013 Europe's global leadership position in CSP/STE technologies and industrial capacities became increasingly challenged by other nations.

The CSP/STE dimension of the Integrated SET Plan was framed by two objectives: 1) to maintain and strengthen Europe's global leadership position in CSP/STE technologies and industrial capacities; and 2) to allow Europe to more fully benefit from the unique value of dispatchable and flexible CSP/STE generating units through the installation of new CSP/STE capacities. To support these objectives, in January 2016 representatives from the SET Plan countries, key stakeholders, and the European Commission agreed on the following short and long term CSP Targets:

1. **Short-term CSP Target:** > 40% cost reduction in the supply price for *dispatchable* CSP/STE electricity by 2020 relative to 2013, resulting in a 25-year Power Purchase Agreement (PPA) price < 10 c€/kWh for a Southern European location with 2 050 kWh/m^2 annual Direct Normal Insolation (DNI), such as that found in Spain.
2. **Long-term CSP Target:** Achieve additional cost reductions and open new business opportunities by developing the next generation of CSP/STE technology based on new cycles (including supercritical) with a First of a Kind (FOAK) demonstrator by 2020.

To achieve these two targets, a Temporary Working Group (TWG) was created to elaborate a CSP Implementation Plan under the SET Plan framework. This TWG contained Key Stakeholders representing

- Eight SET-Plan countries: Spain (Chair), Belgium, Cyprus, France, Germany, Italy, Portugal, and Turkey;
- The European Commission (EC);
- European industry including the European Solar Thermal Electricity Association (ESTELA) and the European Association of Gas and Steam Turbine Manufacturers;
- European research stakeholders including from the Joint Programme on CSP of the European Energy Research Alliance (EERA-JP-CSP).

From this TWG, eighteen industrial actors and sixteen research centers defined 12 priority Research and Innovation (R&I) Activities, and then ranked these Activities based on their alignment with the Short and Long term CSP Targets above. The TWG also defined the key requirements of the desired FOAK plant. Details for the TWG's activities and outcomes are provided in the "*Initiative for Global Leadership in Concentrated Solar Power - Implementation Plan*"[3] published in 2017, which is hereafter referred to as *CSP IP 2017* for both brevity and to emphasize its publication year. As detailed in Section 4.2 , CSP IP 2017 contains a detailed

[3] http://www.solar-era.net/files/9315/2706/3908/SET_Plan_CSP_Implmentation_Plan_2017.pdf

description of each of the 12 R&I Activities including indicators to assess the success of each R&I Activity, and is the foundation reference for the present report.

CSP IP 2017 was just one of 14 IPs created to support the realization of the SET-Plan. In total these 14 IPs cover all the Energy Union Research & Innovation priority areas, and include IPs for Batteries, Offshore Wind, and PV among others. To manage the execution of each IP, an Implementation Working Group (IWG) was created for each IP containing representatives from relevant SET-Plan countries, the EC, and key European stakeholders.

To realize CSP IP 2017, a diverse set of funding instruments is envisioned including actions funded solely by the European Commission (e.g., HORIZON 2020 and HORIZON Europe), actions funded by regional and national agencies, and joint funding actions such as ERANET calls. Within this context, two aligned European Horizon 2020 (H2020) projects were launched to specifically support the execution of CSP IP 2017:

1. CSP ERANET (csp-eranet.eu), which is charged with developing and executing a series of CSP ERANET calls to support CSP IP 2017;
2. HORIZON-STE (www.horizon-ste.eu), which is charged with providing industrial and scientific input to support the execution of CSP IP 2017 in general and CSP ERANET calls specifically.

The first CSP ERANET call to support CSP IP 2017 was opened on 07 October 2019[4] and specifically targeted 8 of the 12 R&I Actions in CSP IP 2017. While other funding actions may also use CSP IP 2017 as input when defining the aim and scope of a call, these other actions are not expected to be as closely aligned with CSP IP 2017 as this first CSP ERANET call.

Since the Short and Long Term CSP Targets were agreed on in 2016, R&I has led to rapid advances in CSP/STE technologies. According to “Implementing the SET Plan: Progress from the Implementation working groups” [5] published in the Fall 2019, the Short and Long Term CSP Targets need to be revised within the following context. The Short-Term CSP Target was achieved outside of Europe for the Dubai DEWA power plant. However, since no new CSP/STE power plant has been commissioned in Europe since 2013, achievement of this Short-Term CSP Target cannot be claimed for Europe, which has very different boundary conditions from Dubai. Additionally, the SET-Plan Long-Term CSP Target was defined for the year 2020, and therefore this target also needs to be revised. However, the report “Implementing the SET Plan: Progress from the Implementation working groups” does not assess attainment of the indicators associated with the 12 R&I Activities in CSP IP 2017 that the on-going CSP ERANET call is targeting. According to this open CSP ERANET call, funded projects are envisioned to start in October 2020 and the maximum project duration is 36 months, which suggests that the main outcomes from these projects are not expected until 2023. Ultimately the CSP IWG is expected to give input to the Joint Research Center (JRC) of the European Commission (EC), which is responsible for monitoring the success of the CSP IP, and the HORIZON-STE consortium can support the CSP IWG in defining and collecting relevant input for the JRC EC.

Objectives: This report has three objectives ranked from most to least important as follows:

[4] https://csp-eranet.eu/sites/default/files/templates/csp_eranet_d2.1_1st_call_guidelines_final.pdf

[5] https://ec.europa.eu/jrc/en/publication/annual-reports/implementing-set-plan

1. To provide the CSP IWG and JRC a methodology to monitor the success of the CSP IP that is based on quantitative and qualitative indicators, and is sufficiently flexible that it can easily evolve in parallel with the evolution of the CSP IP itself and the funding instruments used to support the CSP IP. A specific focus is to enable the CSP IWG to assess whether 1) costs are being reduced, and/or 2) the TRLs of new technologies that can lead to cost reductions and facilitate scalability are being advanced.
2. To provide sufficient detail on the process used to develop this method that other SET Plan IWGs can easily adapt the method to monitor the success of their IPs.
3. To provide sufficient detail on the process used to develop this method that other Research and Innovation (R&I) actors globally who are interested in developing methodologies to monitor the success of R&I initiatives can benefit from this work.

Target Audiences and Harmonization with H2020 Priorities: Consistent with the Objectives stated above and being an Open-Access Public Deliverable, this report was elaborated to target the following audiences ranked from most to least important as follows. In addition, details for how these audiences support HORIZON-STE objectives specifically and broader SET-Plan and H2020 objectives more generally are provided.

1. CSP IWG and JRC: Well-defined and relevant external primary end-users for this report;
2. EC: The HORIZON-STE consortium must demonstrate effective use of EC funds to produce this report;
3. IWGs for other SET Plan IPs: Increases the European impact of this work by more broadly supporting the realization of the SET-Plan.
4. All R&I actors globally interested in developing methodologies to monitor the success of R&I initiatives: Increases the global scientific impact of EC H2020 investments.

2 Procedure to Elaborate Deliverable

A description of the process to develop this methodology is included to provide important context to facilitate effective and appropriate application of the resulting methodology, and allow other R&I actors across a diverse set of fields to more easily adapt and build-on this work for their own needs, thereby increasing the impact of this work. Additionally, the methodology reported herein strongly reflects the process used to develop this methodology, and a different process may have yielded a different methodology.

This report was elaborated as part of the contractual obligations for the H2020 HORIZON-STE project, and therefore the resulting methodology reflects the project's Grant Agreement (GA) with details as follows. HORIZON-STE is coordinated by the European Solar Thermal Electricity Association (ESTELA), which represents the interests of the European STE industry. In addition to ESTELA, HORIZON-STE contains the scientific partners DLR (Germany), CIEMAT-PSA (Spain), ENEA (Italy), and METU (Turkey), which represent the European STE scientific community in general, and the interests of the four countries (Germany, Italy, Spain, and Turkey) who committed long-term funding to support a series of ERANET calls to support the STE IP. The primary contributions of these four Scientific partners is to Work Package 3 (WP3) *R&I Impact Maximisation* lead by DLR. Within WP3, this report was specifically elaborated through Task 3.4 (T3.4) *Evaluation of implementation* lead by METU with participation of the other 3 scientific partners. As stated in the GA, the starting point for the elaboration of this report were the report title (*Develop indicators and methodology for monitoring success of the execution of the IP*) and the following content in the T3.4 description:

> *Procedures will be suggested in order to monitor the success of the R&I projects such as performance indicators and expected quantifiable results. This will also be done in cooperation with the IWG in order to consider their priorities towards reaching the IP goals.*

Within this GA context, this Deliverable was elaborated as follows:

- The HORIZON-STE scientific partners lead by METU developed an outline for the method and report through an iterative procedure.
- Feedback on this outline was solicited from the following key stakeholders: 1) the HORIZON-STE project coordinator ESTELA; 2) the coordinator for the aligned H2020 CSP ERANET project; 3) the coordinator for the CSP IWG; and 4) TÜBİTAK, which is the Turkish scientific funding agency participating in the H2020 CSP ERANET project. Note METU and TÜBİTAK regularly communicate to coordinate the execution of the HORIZON-STE and CSP ERANET projects, and therefore soliciting comments from TÜBİTAK was an easy and low-cost way to increase the diversity of inputs to this report. However, METU does not have similar open communication channels with the other scientific funding agencies in the CSP ERANET call, and soliciting quality input from these other scientific funding agencies would likely require significant effort and therefore was not deemed cost-effective.
- ESTELA presented the broad framework for this Deliverable at the CSP IWG meeting in Brussels on 13 January 2020, and the audience approved of the current direction.
- Based on comments from the key stakeholders, the HORIZON-STE scientific partners lead by METU elaborated the final form of this report.

3 Suggested Methodology to monitor success of the execution of the IP

As a starting point, the scientific partners of HORIZON-STE are recommending to the CSP IWG and the EC JRC the following methodology to monitor the success of the execution of the IP, with the expectation that the IWG and EC JRC will refine and update this methodology based on their expert judgment that includes an up-to-date assessment of current conditions and a realistic assessment of the ability to gather the required information.

3.1 Develop Appropriate Indicators to Assess CSP/STE's Added-Value

As described in Section 1, the main added-value of CSP/STE is as a dispatchable and flexible electricity generator, where dispatchable and flexible implies CSP/STE power plants with Thermal Energy Storage (TES). Historically electricity generating technologies were primarily assessed and compared economically based on their Levelized Cost of Electricity (LCOE), with the technologies with the lowest LCOE being preferred.

However and building on the ideas in Section 1, while PV can have a very low LCOE during the day and therefore is often considered a preferred technology, the large penetration of PV into a grid can result in the need for very high-cost dispatchable and flexible electricity generating units to fill the gap between demand and supply that can rapidly form in the late afternoon. In response and consistent with the holistic approach of the *Integrated* SET-Plan, methods to assess the economic performance of electric generating units are evolving to better quantify the added-value dispatchable and flexible generating technologies to the grid. To date, well-accepted indicators to assess the added-value of dispatchable and flexible electricity generation that are comparable to the presently universal LCOE indicator do not exist. Therefore, to accurately assess CSP/STE's value to the grid, the scientific partners of HORIZON-STE are recommending that relevant Experts develop indicators and define associated objective targets to assess

1. Dispatchability: Dispatchability for CSP/STE generating units tends to be strongly correlated to the TES characteristics, and as an example relevant indicators may quantify hours of TES, energy stored (e.g. MWh), and/or maximum discharge rate (e.g. MW).
2. Flexibility: One quantitative indicator for flexibility is ramp rate (e.g. MW/s).

3.2 Analysis of Specific Calls

The table presented below is a suggested methodology to assess outcomes from a specific call. For illustrative purposes, the CSP ERANET 2019 call is used as an example, and the CSP IWG and EC JRC are expected to use their expert judgement when adapting this method to other funding instruments. All reported numbers are taken from the CSP ERANET 2019 call's *Guidelines for Proposers* [6]. Blank cells indicate values that are not defined in the call and that should be determined as part of the method to monitor the success of the CSP IP. Supporting details for the columns are given after the table.

[6] https://csp-eranet.eu/calls/guidelines-for-proposers

	Call Information					Successful Proposals						Stranded Proposals	
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j) Budget Spent	(k)	(l)	(m)
	Committed Budget Defined in Call (€)	Additional Contribution (€)	Total Budget: = a + b (€)	Max. Contribution To One Project (€)	Min. No. of Projects to Fully Use Budget: = c / d -	No. Projects Supported -	IP R&I Activities Supported -	Min. Project Budget (€)	Max. Project Budget (€)	(€)	= j / c x 100% (%)	Number -	Budget (€)
National / Regional Funding Agency													
Germany PtJ	3,000,000												
Germany ETN	500,000												
Greece	1,000,000			250,000									
Israel	600,000												
Italy	600,000			250,000									
Portugal	100,000												
Spain AEI	500,000			350,000									
Spain CDTI	1,500,000												
Spain JUNTAEX	50,000			50,000									
Switzerland	200,000												
Turkey	700,000			None									
Total	**8,750,000**												
EC Contribution													
Call Total													

Call Information: The data in these columns are the budgetary boundary conditions for the call as follows.

(a) **Committed Budget Defined in the Call:** These numbers were taken from the CSP ERANET 2019 call's *Guidelines for Proposers*.

(b) **Additional Contribution:** In some cases, countries may elect to provide support that is in addition to that reported in the *Guidelines for Proposers*.

(c) **Total Budget:** The total budget committed to the call = (a) + (b).

(d) **Maximum Contribution to One Project:** One potential weakness of the CSP ERANET 2019 call identified by the scientific partners of HORIZON-STE is that the budgetary boundary conditions imposed by the ERANET funding instrument can make it difficult to impossible to achieve project budgets that are sufficiently large to successfully execute innovation actions (i.e. higher TRL level actions), which in turn impacts the success of the execution of the IP. Specifically, within the *Guidelines for Proposers*, Greece, Italy, Spain CDTI and Spain JUNTAEX defined a maximum budget per proposal that is less than their committed budget, and these budget limitations then impact maximum project budgets. Hence this column is included to define upper limits to project budgets within the following constraints. First, at least Turkey has budgetary limitations for a proposal defined in supporting national documents that are not defined in the *Guidelines for Proposers*, which indicates that the budgetary limits in the *Guidelines for Proposers* may not be complete. Second, Greece, Italy, and Spain AEI define a larger maximum budget if the funded institution is coordinating the project, which adds further complexity to trying to accurately assess maximum project budgets. For simplicity, in the table above only budget limits presented in the *Guidelines* *for Proposers* are included and these correspond to the maximum contribution assuming that the funded institution is coordinator. These simplifications are seen as being appropriate for this assessment as the increase in accuracy after properly accounting for all the budgetary boundary conditions for all 11 funding agencies and the EC Is likely to be small relative to the deviation of actual project budgets from the maximum project budgeted defined in the table above due to the likelihood that the winning consortia would only draw funds from a limited number of these 11 funding agencies.

(e) **Minimum Number of Projects to Fully Use the Budget = c/d.** Similar to column (d), this calculation is intended to provide a simple and macroscopic assessment of the minimum number of projects that can be funded. The accuracy of this calculation obviously reflects the simplifications discussed for row (d), and this accuracy is considered acceptable, especially considering the calculation will almost certainly result in a fractional value while in reality only a whole number is possible (i.e. a fraction of a proposal cannot be funded).

Successful Proposals: These columns describe the characteristics of funded projects deemed relevant to assessing the success of the IP as follows.

(f) **Number of projects supported:** In particular, column (f) may be contrasted with column (e).

(g) **IP R&I Activities Supported:** In this column the numbers corresponding to the R&I Activities Supported are entered.

(h) **Minimum Project Budget:** The minimum contributions to a successful proposal.

(i) **Maximum Project Budget:** The maximum contributions to a successful proposal.

(j) and (k) **Budget Spent:** The total contributions from funding agencies in both Euros and as a percent of the total budget committed to the call.

Stranded Proposals: A stranded proposal is defined herein as a proposal where at least one relevant funding agency had sufficient funds to support the proposal but at least one other relevant funding agency did not, and therefore the proposal was not funded.

(l) **Number:** Number of stranded proposals.

(k) **Budget:** Total budgets for stranded proposals.

3.3 R&I Activity Analysis

In the table below a methodology is suggested to monitor the success of the execution of the IP based on support for each R&I Activity defined in CSP IP 2017. As defined by the column titles, for each project this method summarizes information related to budget, funding instrument, countries involved, start and end dates, and number of industrial and research partners. This table is assumed to be sufficiently self-explanatory that no further discussion is required.

	Total	Funding	Countries	Duration		No. Partners	
	Budget (€)	Instrument	Involved	Start	End	Industrial	Research
R&I Activity No. 1							
Project 1							
Project 2							
….							
R&I Activity No. 2							
…..							
R&I Activity No. 12							

4 INDICATORS

The indicators and targets presented below are defined herein within the context detailed in Section 1. The indicators and target objectives in this section are intended as initial inputs to key stakeholders evaluating the success of the IP, including the IWG and EC JRC, additional stakeholders identified through a survey performed by HORIZON-STE in the fall 2019 to support the implementation of the 1st CSP ERANET call, and associate members of ESTELA. These Key Stakeholders are expected to use expert judgement to assess and as necessary revise these indicators to reflect the current landscape and SET Plan vision. In particular, the final indicators should enable the assessment of the IP on two main dimensions: 1) reducing costs; and 2) advancing the TRLs of new technologies that can lead to cost reductions and facilitate scalability.

4.1 CSP Targets for SET Plan

As detailed in Section 1, in January 2016 representatives from the SET Plan countries, key stakeholders, and the European Commission agreed on Short and Long Term CSP Targets. However, in the Fall 2019 the EC JRC noted that these SET Plan CSP Targets need to be revised. Importantly, these Short and Long Term CSP Targets defined in 2016 represent a consensus view from a diverse set of European CSP/STE Key Stakeholders from the research, industrial, and regional, national and European funding agencies communities spanning 8 countries, and revising these consensus Short and Long Term CSP Targets is outside the scope of the current work. Any evaluation of the success of the IP should be based on up-to-date CSP Targets, and therefore will first require revision of these Short and Long Term CSP Targets. For example, the expert judgement of the scientific partners of HORIZON-STE is that the Long Term CSP Target should be revised from narrowly addressing new cycles to more broadly addressing any new plant concept that can reduce costs.

4.2 Technical indicators to monitor the CSP IP development

CSP IP 2017 contains many quantitative and qualitative indicators to assess success of the 12 R&I Activities, and Technical Indicators and Target Objectives for each of these 12 R&I Activities are presented below. Herein two types of Technical Indicators and Target Objectives are defined as follows. The first type are quantitative indicators describing properties or characteristic that are easy to measure or define quantitatively such as temperature, capacity (electrical or thermal), unit cost, etc. These quantitative indicators are explicitly taken from CSP IP 2017. In most cases a Target Objective is also given in CSP IP 2017 for each quantitative indicator, and in this case a Target Objective for the quantitative indicator is also given. However, in some instances an appropriate Target Objective is not obvious in CSP IP 2017, and in these cases the Target Objective is defined as "TBD" (to be determined), indicating that the relevant stakeholders need to define these Target Objectives. The second type are qualitative indicators describing the technical level or scalability of a component, system, or plant. Technical Level is assessed on a scale from 0 to 3 as follows: 0 = still not designed; 1 = detailed design; 2 = implemented; and 3 = evaluated. The qualitative indicators describing technical level presented below were defined based on the expert judgement of the HORIZON-STE scientific partners based on CSP IP 2017. In all instances the target objective for these qualitative indicators is 3 (evaluated). Scalability is a cross-cutting qualitative indicator describing the ease with which a technology can be scaled-up to commercial sizes. Scalability is not explicitly included as an indicator for any of the 12 R&I Activities below, and the scientific partners of HORIZON-STE are recommending that relevant experts define and implement appropriate Indicators and Target Objectives to assess scalability. As noted in the list below, well-defined technical indicators were not found in the descriptions of R&I Activities 10-12 in CSP IP 2017. Therefore, no technical indicators are listed for these R&I Activities herein and these need to be defined along with target objectives by relevant stakeholders.

For brevity and clarity, The *Initiative for Global Leadership in Concentrated Solar Power - Implementation Plan*[7] is hereafter referred to as *STE IP 2017* to emphasize its publication year of 2017. STE IP 2017 is a consensus document produced by a working group containing key stakeholders from the European STE scientific and industrial communities. Although some quantitative target objectives were given in CSP IP 2017 for some items of the 12 R&I Activities defined in that document, target objectives should be defined by the CSP/STE sector for the rest of the items in order to have a complete list, which would facilitate the evaluation and monitoring of the progress achieved for each item. The tables below contain some quantitative targets that are not explicitly defined in CSP IP 2017 and therefore should be agreed upon by the CSP/STE sector to guarantee their validity..

R&I Activity n. 1: Advanced Linear Fresnel Concentrator technology with direct molten salts circulation as Heat Transfer Fluid (HTF) and for high temperature thermal energy storage	
Indicator Definition	**Target Objective**

[7] http://www.solar-era.net/files/9315/2706/3908/SET_Plan_CSP_Implmentation_Plan_2017.pdf

1.1 Maximum working temperature of receiver tubes commercially available for linear Fresnel concentrators.	565ºC (610ºC steel temperature)
1.2 Maximum optical concentration of linear Fresnel concentrators commercially available.	≥ 70
1.3 Size of the first demonstration plant using linear Fresnel concentrators with molten salts acting as working fluid.	≥ 10 MWe demonstration plant
1.4 Technical level (0-3) of a first demonstration plant (≥ 10 MWe) using linear Fresnel concentrators with molten salts acting as working fluid.	3 (plant evaluated)

R&I Activity n. 2: Advanced Parabolic trough technology with direct molten salts circulation as HTF and for high temperature thermal energy storage	
Indicator Definition	**Target Objective**
2.1 Maximum working temperature of receiver tubes commercially available for parabolic trough collectors.	565ºC (610ºC steel temperature)
2.2 Maximum optical concentration of parabolic trough collectors commercially available.	≥ 70
2.3 Size of the first demonstration plant using parabolic trough collectors with molten salts acting as working fluid.	≥ 10 MWe demonstration plant
2.4 Technical level (0-3) of a first demonstration plant (≥ 10 MWe) using parabolic trough collectors with molten salts acting as working fluid.	3 (plant evaluated)

R&I Activity n. 3: Parabolic trough technology with silicone oil	
Indicator Definition	**Target Objective**
3.1 Technical level (0-3) of a 2-loop demonstration plant with all key components associated to parabolic troughs with silicone oil.	3 (plant evaluated)
3.2 Maximum working temperature of silicone oil commercially available at affordable price.	450ºC
3.3 Technical level (0-3) of an optimized steam generator for silicone oil.	3 (equipment evaluated)
3.4 Technical level (0-3) of an optimized oil/molten salt heat exchanger for silicone oil	3 (equipment evaluated)

R&I Activity n. 4: Open volumetric receiver technology	
Indicator Definition	**Target Objective**
4.1 Technical level (0-3) of a large size receiver prototype (≥ 50 MW_{th})	3 (receiver evaluated)

4.2 Technical level (0-3) of a cost-effective fixed-bed thermal storage for T≥800ºC and easily scalable.	3 (system evaluated)
4.3 Technical level (0-3) of a demonstration plant ≥ 50 MW_{th}	3 (system evaluated)

R&I Activity n. 5: Improved molten-salt tower technology	
Indicator Definition	**Target Objective**
5.1 Specific heliostat cost (3 mrad).	<100 €/m^2
5.2 Mirror specular solar reflectance	>95%
5.3 Heliostat slope error.	< 3mrad
5.4 Technical level (0-3) of an automatic recalibration system of heliostat field	3 (system evaluated)
5.5 Technical level (0-3) of an autonomous heliostat prototype.	3 (prototype evaluated)
5.6 Technical level (0-3) of a receiver prototype for outlet fluid temperature of 575ºC and average solar flux of 1 MW/m^2.	3 (receiver evaluated)
5.7 Technical level (0-3) of a solar flux measurement device for large central receivers (i.e., ≥ 150 MW_{th})	3 (system evaluated)
5.8 Technical level (0-3) of accurate temperature measurement system/method for large central receivers (i.e., ≥ 150 MW_{th})	3 (system/method evaluated)
5.9 Technical level (0-3) of a measurement system for atmospheric attenuation.	3 (system evaluated)
5.10 More reliable heat tracing systems.	Failure rate < one per year and MWe of installed power
5.11 Validation (number of years) of new durable & reliable hot storage tank designs	TBD
5.12 More durable steam generator design.	Percentage of spare tubes inside ≤ 10%
5.13 New steam turbines for 150bar/550ºC, with improved operational flexibility (number of start-up/shut-down cycles, minimum/maximum operating load allowed)	TBD

R&I Activity n. 6: Next generation of central-receiver plants	
Indicator Definition	**Target Objective**
6.1 Heliostat field performance (due to innovative field lay-out or multi-tower approach).	TBD
6.2 Specific heliostat field cost without reducing its performance.	90/m^2
6.3 Technical level (0-3) of heliostats with different qualities and optical parameters for different places within the heliostat field	3 (heliostats evaluated)

6.4 Technical level (0-3) of advanced power cycles (supercritical water or sCO2 cycles).	3 (system evaluated)
6.5 Innovative working fluids at affordable cost for higher temperatures.	T ≥ 700ºC
6.6 Technical level (0-3) of autonomous (wireless) heliostats	3 (heliostat evaluated)
6.7 Technical level (0-3) of self-calibrating heliostats.	3 (heliostat evaluated)
6.8 Technical level (0-3) of pumping equipment to recover the gravitational energy in the working fluid circuit	3 (system evaluated)

R&I Activity n. 7: Pressurized air cycles for high efficiency solar thermal power plants	
Indicator Definition	**Target Objective**
7.1 Technical level (0-3) of efficient solar receiver prototype for ≥ 10 MW_{th} and T > 700ºC.	3 (receiver evaluated)
7.2 Development status of efficient and affordable thermal energy storage (TES) system for pressurized air at T > 700ºC.	3 (system evaluated)
7.3 Technical level (0-3) of a demonstration plant (solar receiver+TES) for ≥ 10 MW_{th}	3 (plant evaluated)

R&I Activity n. 8: Multi-tower central receiver beam-down system	
Indicator Definition	**Target Objective**
8.1 Installed cost of the beam-down mirrors.	< 80 €/m^2
8.2 Technical level (0-3) of a 2 MW_{th} prototype of an integrated solar receiver (not necessarily cavity receiver) and high temperature thermal energy storage	3 (prototype evaluated)
8.3 Technical level (0-3) of fluidized bed of silica sand.	3 (prototype evaluated)
8.4 Technical level (0-3) of a cavity solar receiver with integrated high-temperature thermal energy storage	3 (system evaluated)

R&I Activity n. 9: Thermal energy storage (TES)	
Indicator Definition	**Target Objective**
9.1 New storage media with either higher temperatures than current molten salts or lower cost.	T > 575ºC Cost < 1€/kg
9.2 New storage tank raw materials with less corrosion and reliability issues	TBD

9.3 Technical level (0-3) of innovative TES integration concepts (both, thermocline and 2-tank systems)	3 (prototypes evaluated)

R&I Activity n. 10: Development of supercritical steam turbines optimized for the specifics of CSP applications	
Indicator Definition	**Target Objective**
Input is required from key stakeholders to define relevant technical indicators and target objectives for this R&I Activity.	

R&I Activity n. 11: Development of advanced concepts for improved flexibility in CSP applications	
Indicator Definition	**Target Objective**
Input is required from key stakeholders to define relevant technical indicators and target objectives for this R&I Activity.	

R&I Activity n. 12: Development and field test of CSP hybrid air Brayton turbine combined cycle sCO2 systems.	
Indicator Definition	**Target Objective**
Input is required from key stakeholders to define relevant technical indicators and target objectives for this R&I Activity.	