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Needs vs current status of RI in line with updated CST Implementation Plan

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Outline of the Presentation

- Introduction
- Overview of SFERA-III Consortium & Facilities
- Existing **Facilities** in the field of CST (SFERA-III)
- Existing **Services** in the field of CST (SFERA-III)
- Analysis of RI needs vs IP **2017** (initial version)
- Analysis of RI needs vs IP **2023** (updated version)
- Conclusions

Introduction

- In the framework of the SFERA-III project, a questionnaire form has been sent to all SFERA-III partners to collect detailed up-to-date information about all existing RI facilities and the associated services in the field of CST.

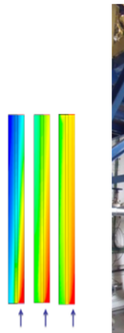
- The main outcome of this work is an exhaustive set of Excel files including the up-to-date inventory of existing RI facilities and associated services in the field of CST among SFERA-III partners.

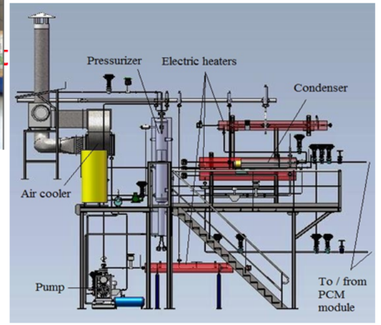
- Anyone can access the detailed information by downloading the public deliverable D3.1 “State of the art of existing RI and Services”:

  https://sfera3.sollab.eu/wp-content/uploads/2021/03/D3.1-SFERA3-state-art-research-infrastructures.pdf

Introduction

facility type	Year of construction	Facility Name	Location (GPS)	Land Area occupied (m²)
Other	2012	LHASSA	*France:* *Latitude N 45°11'48.4"* *Longitude E 5°42'24.6"*	60





Service Name	TNA?
Optimization of the operating procedures	Y
Qualification of Heat Storage using PCM under experimental conditions	Y
Validation of numerical model of thermal storage systems	Y
Validation of the thermo-hydraulic behaviour of storage systems under operating conditions similar to commercial CSP plants,	Y

Facility Type, Year of commissioning, Name of the Facility, Location, Footprint

Available Services, Availability through the Trans-National Access program

Introduction

From small facilities

facility type	Year of construction	Facility Name	Location (GPS)	Land Area occupied (m²)
Other	2017	ATYCOS	*Spain:* *Latitude: N 40.4167º* *Longitude E -3.7032º*	25

The SBMA device (left) and the HDR device (right)

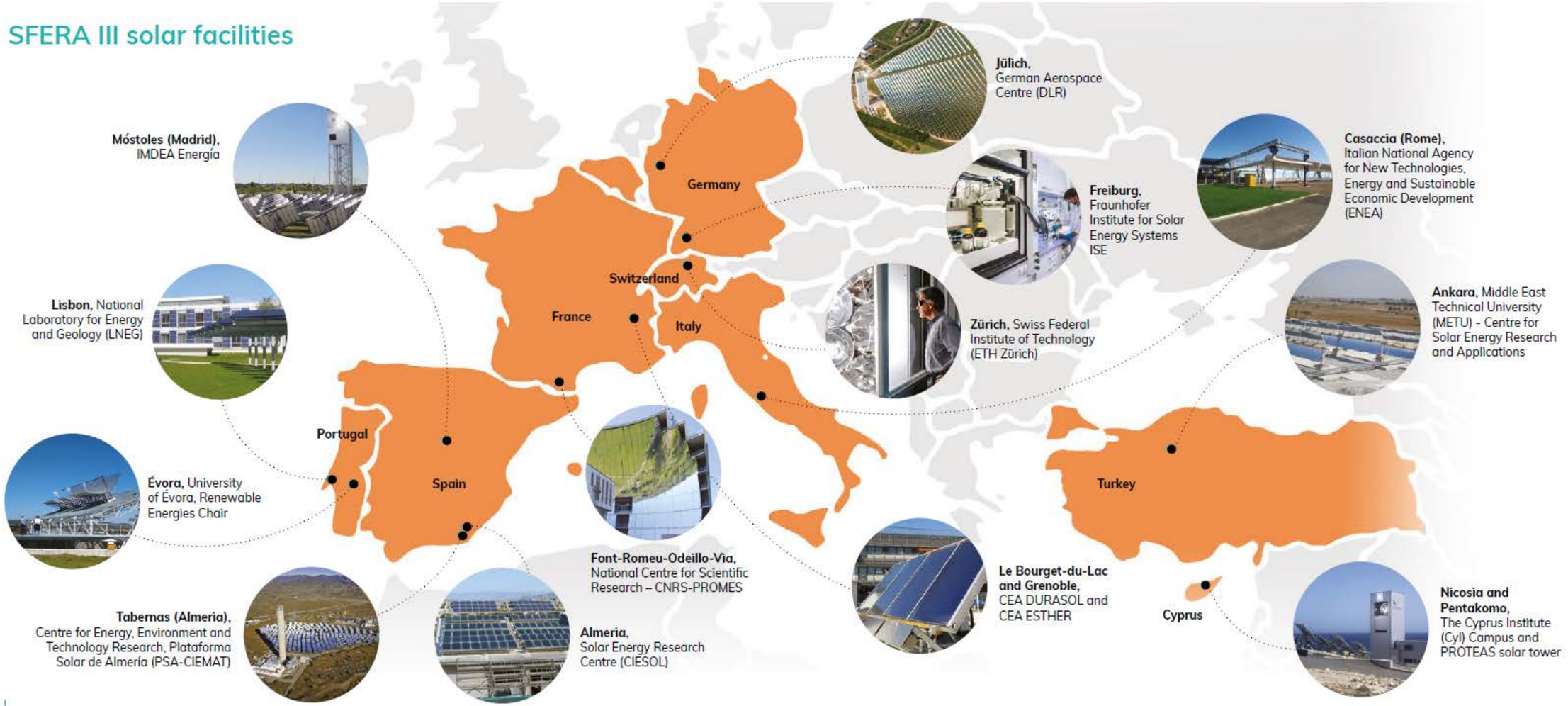
Service Name
Characterization of Materials and Components for TES
Feasibility of Materials for Sensible and Latent Thermal Storage Systems

To large facilities

facility type	Year of construction	Facility Name	Location (GPS)	Land Area occupied (m²)
Central receiver	2008	Solar Tower Jülich	Jülich, Germany	

Service Name
Atmosferic air packed bed test bench for simulation models validation
Deflectometry Measurement of Concentrator's shape
Heliostat control algorithms
Heliostat(s) Performance Qualification
Photogrammetry Measurement of Concentrator's shape
Qualification of Heat Storage using Packed beds under Real Operating Conditions
Qualification of Solar Driven Processes under realistic conditions
Solar Fuels and Thermochemistry
Solar Radiation Measurement and Weather Station
Thermal and Thermodynamic characterization of prototype Reactors for Central Receiver on Tower Technologies under real operating conditions

Overview of SFERA III Consortium & Facilities



Existing Facilities in the field of CST (SFERA- III)

D3.1 “State of the art of existing RI and Services”

https://sfera3.sollab.eu/wp-content/uploads/2021/03/D3.1-SFERA3-state-art-research-infrastructures.pdf

Existing Facilities in the field of CST (SFERA- III)

- Inside SFERA-III consortium, there is a total of **87** existing research **facilities** in the field of CST.

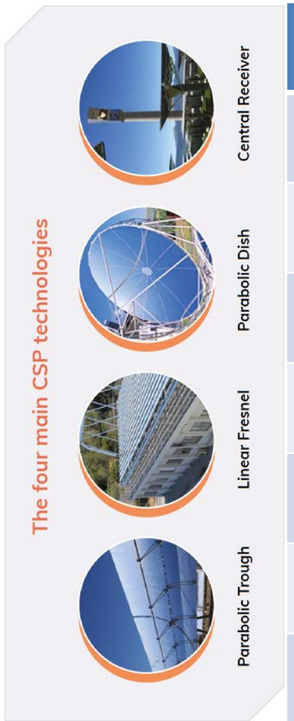
Partner	Total number of facilities
CIEMAT	28
CNRS	5
ENEA	9
DLR	9
CEA	9
UEVORA	4
ETHZ	3
IMDEA	4
CYI	3
Fraunhofer	5
LNEG	6
METU	1
UAL	1

It can be noticed that 38% of the existing R&D CST facilities are located in Spain.

It shows the leading place of Spain in the field of CST and reflect the effectiveness of the market in this European country.

Existing Facilities in the field of CST (SFERA- III)

- More than **59%** of the referenced facilities are of "**O**ther **T**ype", which refers to laboratories with equipment dedicated to research on a wide range of topics.
  (ex: optical characterisation, thermal characterisation, simulation, thermal storage, water treatment…)



Type	Total number of facilities
Central **R**eceiver	8
Parabolic **T**rough	10
Linear **F**resnel	3
Parabolic **D**ish	4
Solar **F**urnace	7
Solar **S**imulator	4
Other **T**ype	51

Not surprisingly, if we exclude "**O**ther **T**ype", the most represented types of facilities are "**P**arabolic **T**rough", "**C**entral **R**eceiver" and "**S**olar **F**urnace".

"**L**inear **F**resnel" and "**P**arabolic **D**ish" are little represented.

"**S**olar **S**imulator" looks like a popular type of facility for RI in countries with low DNI / solar resources.

Existing Facilities in the field of CST (SFERA- III)

- The **distribution of the type of facilities** is detailed in the following table.

Partner	Central Receiver	Parabolic Trough	Linear Fresnel	Parabolic Dish	Solar Furnace	Solar Simulator	Other Type
CIEMAT	2	5		1	3		17
CNRS	1	1		1	2		
ENEA		2		1			6
DLR	1	1			1	2	4
CEA			2				7
UEVORA		1					3
ETHZ				1		1	1
IMDEA	1					1	2
CYI	2		1				
Fraunhofer							5
LNEG	1				1		4
METU							1
UAL							1
Total	8	10	3	4	7	4	51

Existing Services in the field of CST (SFERA- III)

D3.1 “State of the art of existing RI and Services”

https://sfera3.sollab.eu/wp-content/uploads/2021/03/D3.1-SFERA3-state-art-research-infrastructures.pdf

Existing Services in the field of CST (SFERA- III)

- The existing services have been classified **11** different categories:

Facility Type (7):

- **C**entral **R**eceiver
- **P**arabolic **T**rough
- **L**inear **F**resnel
- **P**arabolic **D**ish
- **S**olar **F**urnace
- **S**olar **S**imulator
- **O**ther **T**ype

Service Categories\ Partner	Solar Resource (DNI) and Meteorological Parameters Assessment	Services on Reflectors and Concentrators	Experimental Services on Absorbers and Receivers	Services on Heat Transfer Fluids	Services on Auxiliary Equipment	Services on Thermal Energy Storage (Media & Systems)	Services on Engines and Power Blocs	Services on Calibration of Key Sensors & Measurements for STE	Services on Solar Chemistry	Services on Materials Testing and Qualification	Services Using Extreme Temperature Conditions in Solar Concentrators
CIEMAT		CR, PT, OT	CR, PT, OT		PT, OT	OT, PD	CR, PD	PD, SF, OT	CR, OT	PD, SF, OT	PD, SF, CR, OT
CNRS	CR, PT, SF, PD	CR, PT, SF, PD	CR, PT, SF, PD	CR, PT, SF, PD	CR, PT, SF, PD	CR, PT, SF, PD	CR, PT, SF, PD	CR, PT, SF, PD	CR, PT, SF, PD	CR, SF, PD	CR, PT, SF, PD
ENEA	PD, PT, OT	PD, PT, OT	PD, PT	OT, PT	PD, PT, OT	PT, OT	OT	PT, OT	OT	OT	
DLR	CR, PD, PT, SF, SS, OT	SS, CR, PT, SF, OT	SS, PT, OT		OT	CR, OT		SF, SS, OT	CR, OT		SS, SF
CEA		OT	OT, LF			OT, LF		LF			
UEVORA	OT	PT, OT	OT	PT	PT	PT, OT					

Service Categories (11):

- Solar Resource (DNI) and Meteorological Parameters Assessment
- Services on Reflectors and Concentrators
- Experimental Services on Absorbers and Receivers
- Services on Heat Transfer Fluids
- Services on Auxiliary Equipment
- Services on Thermal Energy Storage (Media & Systems)
- Services on Engines and Power Blocs
- Services on Calibration of Key Sensors & Measurements for CST
- Services on Solar Chemistry
- Services on Materials Testing and Qualification
- Services Using Extreme Temperature Conditions in Solar Concentrators

Existing Services in the field of CST (SFERA- III)

- The existing services have been classified **11** different categories:

Facility Type (7):

- **C**entral **R**eceiver
- **P**arabolic **T**rough
- **L**inear **F**resnel
- **P**arabolic **D**ish
- **S**olar **F**urnace
- **S**olar **S**imulator
- **O**ther **T**ype

Service Categories\ Partner	Solar Resource (DNI) and Meteorological Parameters Assessment	Services on Reflectors and Concentrators	Experimental Services on Absorbers and Receivers	Services on Heat Transfer Fluids	Services on Auxiliary Equipment	Services on Thermal Energy Storage (Media & Systems)	Services on Engines and Power Blocs	Services on Calibration of Key Sensors & Measurements for STE	Services on Solar Chemistry	Services on Materials Testing and Qualification	Services Using Extreme Temperature Conditions in Solar Concentrators
ETHZ		OT	SS			OT			SS, OT, PD	SS, OT	SS, OT
IMDEA		CR, SS, OT	CR, SS, OT	OT		OT	OT		CR, SS, OT	OT	CR, SS
CYI		CR	CR, LF		CR				CR		
Fraunhofer	OT	OT	OT	OT	OT	OT			OT	OT	
LNEG	OT	OT	OT			OT			OT	OT, SF	SF
METU											OT
UAL	OT	OT				OT			OT	OT	

Service Categories (11):

- Solar Resource (DNI) and Meteorological Parameters Assessment
- Services on Reflectors and Concentrators
- Experimental Services on Absorbers and Receivers
- Services on Heat Transfer Fluids
- Services on Auxiliary Equipment
- Services on Thermal Energy Storage (Media & Systems)
- Services on Engines and Power Blocs
- Services on Calibration of Key Sensors & Measurements for CST
- Services on Solar Chemistry
- Services on Materials Testing and Qualification
- Services Using Extreme Temperature Conditions in Solar Concentrators

Existing Services in the field of CST (SFERA- III)

- Inside SFERA-III consortium, there is a total of **126** existing **services** in the field of CST.

Partner	Total number of services
CIEMAT	74
CNRS	57
ENEA	57
DLR	49
CEA	36
UEVORA	19
ETHZ	17
IMDEA	38
CYI	8
Fraunhofer	25
LNEG	30
METU	3
UAL	11

It can be noticed that alsmost all possible R&D CST services are available in Spain.

Again, it shows the leading place of Spain in the field of CST.

Existing Services in the field of CST (SFERA- III)

- "**O**ther **T**ype" facilities are gathering the most important number of services.
  (including: optical characterisation, thermal characterisation, simulation…)

Type	Total number of services
Central **R**eceiver	52
Parabolic **T**rough	48
Linear **F**resnel	12
Parabolic **D**ish	52
Solar **F**urnace	56
Solar **S**imulator	18
Other **T**ype	97

"Solar Furnace", "Central Receiver" and "Parabolic Dish" facilities are offering more than 50 services each.

Surprisingly, the 4 "Parabolic Dish" facilities are offering more services than the 10 "Parabolic Trough" facilities.

The figures raise questions about the future of the "Linear Fresnel", as only 12 services are available.

Analysis of RI needs vs Implementation Plan

D3.2 “Strategy report on research infrastructure needs”

https://sfera3.sollab.eu/wp-content/uploads/2021/03/D3.1-SFERA3-state-art-research-infrastructures.pdf

Analysis of RI needs vs IP 2017

- In 2016, a Temporary Working Group was formed to prepare the Implementation Plan and one of the topics was dedicated to define “priority technology actions”.
- Following the discussions in the TWG, eighteen industrial players and sixteen research centres worked on defining specific R&I Activities to be included in the IP. **12** R&I “classes” Activities were identified:

R&I Activity number	R&I Activity
1	Linear Concentrator Advanced Fresnel technology
2	Parabolic Troughs with MS
3	Parabolic Troughs with synthetic oil
4	Open Volumetric Receiver
5	Molten Salt Receiver technology - Short-Term approach
6	Molten Salt Receiver technology - Mid-Term approach
7	Pressurized Air Cycles with TES
8	Multitower CR Beam Down System
9	Thermal Energy Storage
10	*EUTurbines I*
11	*EUTurbines II*
12	*EUTurbines III*

Analysis of RI needs vs IP 2017

- From these 12 R&I Activities “classes”, the needed research activities have been identified (**21**):

R&I Activity number	Activity to be performed, related to IP R&I activities	CIEMAT	CNRS	ENEA	DLR	CEA	UEVORA	ETH	IMDEA	CYI	F-ISE	LNEG	METU	UAL
1, 2	Testing Molten Salt Pumps, Valves, Sensors, Connections… Temperature up to 565°C.	Y	NO	Y	Y	NO	Y	-	NO	YES	YES	NO	-	-
1, 2	Testing of Molten Salt suitable for use in LFR or PTC plants (Durability, Stability). Temperature up to 565°C.	NO	NO	Y	Y	NO	YES	-	NO	NO	YES	Y	-	-
1, 2	Testing of Receivers for use in LFR or PTC plants. Temperature up to 565°C.	NO	Y	YES	Y	NO	YES	-	NO	NO	YES	YES	-	-
1, 2	Testing Specific Operations with MS as HTF (Normal, Maintenance, Emergency). Temperature up to 565°C.	NO	NO	Y	Y	NO	YES	-	NO	Y	NO	NO	-	-
3	Testing of Silicone Oil suitable for use in PTC plants (Durability, Stability). Temperature up to 450°C.	YES	Y	NO	YES	YES	Y	-	NO	NO	YES	NO	-	-
3	Testing of Oil/MS HeX under transient conditions. Temperature up to 450°C.	NO	Y	NO	NO	NO	Y	-	NO	NO	YES	NO	-	-
5	Testing and improving Heliostats cleaning procedures and requirements.	YES	YES	NO	YES	NO	NO	-	YES	YES	YES	YES	-	-
5	Testing Heliostats for reflectivity > 95%.	YES	NO	NO	YES	NO	NO	-	YES	YES	YES	Y	-	-
5	Testing Heliostats for slope error < 3 mrad.	YES	NO	NO	YES	NO	NO	-	YES	NO	YES	Y	-	-
5	Testing and improving Heliostats (re)calibration procedures.	YES	YES	NO	YES	NO	NO	-	Y	YES	YES	Y	-	-
5	Testing of flux measurement / distribution on CRs surface. Flux densities up to 1 MW/m².	YES	YES	Y	Y	NO	NO	-	Y	Y	YES	Y	-	-
5	Testing of temperature measurement / distribution on CRs surface. Temperature > 650°C.	NO	YES	NO	YES	NO	NO	-	Y	NO	YES	Y	-	-

Analysis of RI needs vs IP 2017

- From these 12 R&I Activities “classes”, the needed research activities have been identified (**21**):

R&I Activity number	Activity to be performed, related to IP R&I activities	CIEMAT	CNRS	ENEA	DLR	CEA	UEVORA	ETH	IMDEA	CYI	F-ISE	LNEG	METU	UAL
6	Testing of Receivers for use in CR plants. Temperature > 650°C.	NO	YES	NO	YES	NO	YES	-	NO	NO	NO	YES	-	-
6	Testing of working fluids or MS suitable for use in CR plants (Durability, Stability). Temperature > 650°C.	NO	YES	Y	Y	NO	YES	-	NO	NO	Y	Y	-	-
6	Testing and improving Heliostats on-site characterization and diagnosis.	YES	YES	NO	YES	NO	NO	-	Y	YES	YES	Y	-	-
6	Testing device to monitor molten salt degradation and prevent MS loop corrosion.	NO	YES	YES	YES	NO	YES	-	NO	Y	NO	NO	-	-
7	Testing of ceramic HT thermal heat storage with pressurized air as HTF. Temperature >700°C.	Y	YES	NO	YES	NO	NO	-	NO	NO	NO	NO	-	-
7	Testing of Receivers for use in CR plants with pressurized air as HTF. Temperature > 700°C.	Y	YES	NO	YES	NO	NO	-	Y	NO	NO	YES	-	-
8	Testing of beam down receiver with integrated HT thermal energy storage. Temperature up to 1000°C.	NO	YES	NO	NO	NO	NO	-	Y	NO	NO	NO	-	-
9	Testing of storage media / materials suitable for CSP (Durability, Stability). Temperature > 650°C.	YES	YES	Y	YES	NO	NO	-	YES	NO	YES	Y	-	-
9	Testing of MS/sCO2 HeX under transient conditions (Durability, Stability). Temperature > 650°C.	NO	Y	NO	NO	NO	NO	-	NO	NO	NO	NO	-	-

Analysis of RI needs vs IP 2017

- All the needed research activities can be addressed without any need for a new dedicated infrastructure.
- Except for "Testing of MS/sCO2 HeX under transient conditions (Durability, Stability) – T > 650°C" for which an upgrade of CNRS facilities is necessary.
- In the case of "Testing Specific Operations with MS as HTF (Normal, Maintenance, Emergency) - Up to 565°C", "Testing of Oil/MS HeX under transient conditions - Up to 450°C" and "Testing of beam down receiver with integrated HT thermal energy storage - Up to 1000°C", only one infrastructure is able to realise the needed research activity at the moment.
- There is a lot of infrastructure that can be upgraded to address the needed research activities. For some of these infrastructure, the modifications are already planned and funded; for some others, the modifications have to be funded either by a national or a European project.

Analysis of RI needs vs IP 2023

- In the new revision of the Implementation Plan issued early **2023**, the R&I Activities have been updated in order to "introduce lower TRL key actions with the capacity to improve efficiency, sustainability and reliability as well as cost reduction", and "add other important applications such as **solar heat for industrial processes** and **solar fuel**". The list now includes **18** R&I activities "classes" organised into **7** activity areas:

R&I Activity number	R&I Activity
1. Line-focus solar power plants technology	Activity 1.1: Component development, process innovation and cost optimization for molten salts systems Activity 1.2: Solar collector fields with silicone oil as HTF
2. Central Receiver power plants technology	Activity 2.1: Improvement and optimization of current central receiver molten-salt technology Activity 2.2: Innovative concepts, materials and components for central receiver molten-salt technology Activity 2.3: Solar tower with particle receiver technology
3. Reliable and cost-effective heat transfer medium and high-temp. thermal storage systems	Activity 3.1: Single molten salt thermocline Activity 3.2: Next generation of Thermal Energy Storage technologies
4. Turbo-machinery developed for specific conditions of solar thermal power plants	Activity 4.1: Development of expansion turbine technologies for advanced CSP power blocks Activity 4.2: Development of turbo-machinery for supercritical CO2 cycles
5. Medium-and high temp. systems for industrial solar heat applications	Activity 5.1: Medium temperature systems for industrial solar heat applications Activity 5.2: High temperature solar treatment of minerals and metals
6. Thermochemical production of solar fuels and hydrogen	Activity 6.1: Liquid synthetic fuels from solar redox cycles Activity 6.2: Solar fuels from carbon neutral feedstock Activity 6.3: Solar particle receivers/reactors for solar fuels production
7. Cross-cutting issues	Activity 7.1: Digitalization of CST plants for a more efficient monitoring, operation and maintenance Activity 7.2: Innovative coatings for CST mirrors Activity 7.3: Reliable CST, PV and other renewables integration Activity 7.4: Promoting the utilization of CST with thermal storage to facilitate variable RE penetration in the electrical system

Analysis of RI needs vs IP 2023

- Revised or additional research activities identified in the Implementation Plan **2023** (**35**):

R&I Activity number	Activity to be performed, related to IP R&I activities
1.2	Analysis of hydrogen formation and degradation products of Silicone Oils used as HTF for temperature up to 450°C.
1.2	Testing of SiHTF /MS and SiHTF /Steam HeX under transient conditions (Durability, Stability). Temperature up to 450°C.
2.1	Testing (characterization and ageing) CRs surface with absorptance > 97% and degradation rates < 0.5ppt/year.
2.1	Testing of flux measurement / distribution on CRs surface. Flux densities > 1 MW/m².
2.1	Testing of temperature measurement / distribution on CRs surface. Temperature up to 750°C.
2.1	Development and testing of alloys or coatings to prevent the existence of chromium at the material's surface.
2.1	Development and testing of equipment for the electrochemical removal of chromium from the molten salt.
2.1	Testing of O&M procedures and control strategies for emergency situations in order to avoid large damage of CRs.
2.1	Testing of O&M procedures and control strategies for safe and fast pre-heating and change between partial- and full-load operation of CRs.
2.1	Assessment of stability, compatibility and corrosivity of NEW molten salts used for CRs at temperature up to 750°C.
3.1, 3.2	Testing of charging and discharging strategies of single tank MS and filler thermocline storages and next generation TES technologies.
3.1, 3.2	Testing compatibility and ageing of materials for single tank MS and filler thermocline storages and next generation TES technologies.
4.1	Development and testing of advanced sealing technologies for expansion turbine of new CSP power blocks. Temperature up to 650°C.
4.1	Development and testing of oxidation resistant alloys for expansion turbine of new CSP power blocks. Temperature up to 650°C.
4.1, 4.2	Development and optimization of advanced CSP cycles and power blocks using supercritical steam or supercritical CO2 as working fluid.
5.1	Development and testing of cheaper CST collectors for SHIP applications in the mid-temperature range.
5.1	Development and testing of highly autonomous CST fields for SHIP applications in the mid-temperature range.
5.1	Development and standardization of components for the installation of CST fields on rooftops.
5.2	Development and testing of a pre-pilot demonstrator of a reactor for the solar treatment of minerals and metals. Scale >100 kW.

Analysis of RI needs vs IP 2023

- Revised or additional research activities identified in the Implementation Plan **2023** (**35**):

R&I Activity number	Activity to be performed, related to IP R&I activities
6.1	Development and testing of smart control procedures for the operation of solar fuel reactors
6.1	Development and testing of 3-dimensional structuring of the redox materials for solar redox cycles
6.1	Development and testing of hybrid thermo-electrochemical energy integration schemes for solar redox cycles
6.1	Development and testing of reactors for solar redox cycles capable to operate under a vacuum
6.1, 6.2, 6.3	Long term on-sun operation of reactors prototype at relevant scale. Scale > 50 kW.
6.1, 6.2, 6.3	Characterisation and ageing of materials suitable for use in solar fuel reactors (building, reaction or bedding materials).
7.1	Development and testing of CST components with cost-effective integration of sensors for self-diagnostic and –calibration.
7.1	Development and testing of sensors for on-line measurement of concentrated solar flux and temperature on CST receivers.
7.1	Development and testing of sensors for field diagnosis of CST plants (leakage detection, mirror and glass cover breakage, H2 permeation…).
7.1	Development and testing of AI for techniques for early fault diagnosis and preventive maintenance of CST plants.
7.1	Development and testing of advanced cleaning systems and anti-soiling treatments for mirrors used in CST technologies.
7.1	Development and testing of sensors for automatic and continuous monitoring of HTF degradation in CST plants.
7.1	Development and testing of optimal energy management strategies and control for the flexible generation of energy from hybrid CST systems.
7.1	Development and testing of smart energy meters for thermal storage systems used in CST plants.
7.2	Development and testing (characterization and ageing) of new coatings for mirrors used on flexible substrates in innovative CST technologies.
7.3, 7.4	Development of tools and methodologies for an optimal techno-economic and environmental design of CST and Hybrid CST plants.

Analysis of RI needs vs IP 2023

- All the needed research activities can be addressed without any need for a new dedicated infrastructure.

- With the new targets included in the updated IP in terms of maximum temperatures and heat flux, some services will need an upgrade.

- In the case of "Development and testing of advanced sealing technologies for expansion turbine of new CSP power blocks", "Development and testing of oxidation resistant alloys for expansion turbine of new CSP power blocks. Temperature up to 650ºC", and "Development and optimization of advanced CSP cycles and power blocks using supercritical steam or supercritical CO2 as working fluid", only one infrastructure is able to realise the needed research activity at the moment.

Conclusions

It is clear that **all research activities identified** as crucial to finally reach the strategic targets in the field of CST **can be realised thanks to existing infrastructures**.

In some cases, an upgrade of infrastructure is needed to fully address the specific research activity.

In general, **there are several RIs** capable of handling each of the needed research activities, **except in the case of 7 very specific services**.

Then, the most important need would eventually be to **increase the number of infrastructures able to provide these very specific services**.

Conclusions

In order to carry out the research activities identified in the IP, **RTOs need new funded projects that make use of the existing facilities and services**.

In some particular cases, **part of the budget for these projects could be used to improve the quality or scope of the services**.

Particular attention should be paid to research activities related to the "Development of turbomachinery adapted to the specific conditions of solar thermal power plants", which cannot be covered only by the laboratories involved in the CST field.

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Thank You

For Your Attention

SFERA-III

Final Event

December 13, 2023 | Madrid, Spain

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