Scientific and Technological Alliance for Guaranteeing the European Excellence in Concentrating Solar Thermal Energy

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STAGE-STE milestone 11

MS 11: Definition of European STE facilities suitable for the qualification of the STE components

WP3 – Task 3.4	**Milestone 11 (MS11)**
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DOCUMENT STRUCTURE

Chapter 1 is an introduction. Chapter 2 summarizes the goals of Task 3.4 "*Adaptation of the STE Research Infrastructures according to the new standardized STE components*". Chapter 3 introduces the methodology followed to identify the European Concentrating Solar Thermal (CST) facilities suitable for the qualification of the CST components. Chapter 4 shows the collections of items "census forms" as gathered from the partners involved in this task and it is reported a table of the synthesis of the European CST facilities (extracted from the data collected during the census) that can be employed for the qualification of the various CST components. Chapter 5 provides an analysis of the information collected from the census forms. All items census form filled are reported in Annex 1.

1. Introduction

First of all, it should be emphasized that the STAGE-STE ("*Scientific and Technological Alliance for Guaranteeing the European Excellence in Concentrating Solar Thermal Energy*") project is not only focused on developing of solar technologies to electric power generation, but also all other associated processes, applications and technologies of CSP. For this reason, this report will be not only focus on Solar Thermal Electricity (STE) components but on all Concentrating Solar Thermal (CST) components

The main aim of the STAGE-STE project is to increase the real collaboration among EU research organizations, with a philosophy based on the three following pillars:

- To integrate, within a common structure, all current research capacities, training and knowledge transfer existing at the European level in the field of CST.
- To properly structure and coordinate these capabilities to jointly offer the industry and stakeholders of the sector the best and more complete answer to their needs.
- To get this promote a proper coordination and effective collaboration of different European participant organizations to make it possible previous statements.

In this framework, WP3 ("*Enhancement of STE Research Facilities Cooperation*") is devoted to the coordination activities to enhance the cooperation and use of CST research facilities. This will include the improvement of transnational access and enhancement of current infrastructures as well as the close coordination with other relevant on-going CST initiatives related with research infrastructures, in particular Task 3.4 has the objective to determine the needs for adaptation of the existing research centres' facilities, through a conceptual design, or the needs of new ones, so that the research centres have the appropriate installations (test equipment, laboratory, etc.) for the qualification of the new standardized CST components

The specific components will be standardized will be defined in the framework of the work of WP5 (“*Relationship with Industry & Transfer of Knowledge Activities*”), where they will be identified the definition of guidelines for standardization of CST components.

As a first step of Task 3.4, the research centres, participating in this task, provided a description of their existing installations available for the qualification of the CST components.

The objective of this deliverable is that to assess the potential instrumental existing in the research centres / laboratories of the partners involved in the task, which, in future, could be used to perform standard measurements of CST components.

It should be emphasised, see Fig. 1, that in general, only sometimes the research centres are an active part of the chain metrology.

In this case, inside the research centres there exist a separated department from the other laboratory that work as primary metrology institutes.

More in general in the research centres, they exist more laboratories that employ the standard methodologies or internal procedures to implement a metrological characterization of components or systems.

Only in some cases, the research laboratories are accredited so they are an integral part of the metrological chain, more often they are users.

A European Cooperation for the Accreditation of Laboratories, now known as EA, has been established among the European countries belonging to the EU and EFTA (European Free Trade Association) to establish conditions of mutual trust and mutual recognition among national calibration services.

Among the purposes of the EA there is also to define the rules for the harmonisation of criteria and procedures for the accreditation of testing and calibration laboratories of member countries, basic step to achieve mutual recognition on the basis of equivalence.

To increase confidence and transparency in the metrological activities, the Primary Institutes of various European countries are implementing a quality system, under the directions of EUROMET.

EUROMET brings together the metrological organisations of different countries of the EU and areas EFTA.

Fig 1 – Metrology chain

2. Objective of this report

The main objective of this task is to determine the needs of adaptation of the existing research centres' facilities through a conceptual design or the needs of new ones, so that research centres have the appropriate installations (test equipment, laboratories, etc.) for the qualification of the new standardized CST components.

A specific objective of this task is to prepare a reference document that can be used as:

- a guide describing the existing testing procedures,
- how tests and standards are applied and how they relate to certification, by identifying gaps, inconsistencies and weaknesses along with approaches to addressing/solving problems,
- developing recommendations for improving the system for emerging technologies where standards and testing procedures are still under development.

These results will be used to evaluate the capacities of the existing installations available for the qualification of the CST components or to evaluate the physical variables employed in the design of plants and systems using CST technologies.

In this first phase of the work, the activities have been limited to identify and define, among the partners present in the task, the actual potential of European CST facilities suitable for the qualification of the CST components.

The other objectives will be achieved when, in WP5, new standardized components will be identified.

Due to the dispersion of the meanings of the acronyms employed in different scientific papers, it is not always easy to identify with exactness the sector of reference and the kind of components. This situation is the consequence of the absence of a standard terminology universally accepted, and corresponds to one of the difficulty met during this work when it has been necessary to define a criterion of classification of the CST technology components.

In the report, it has been proposed to adopt the terminology already adopted by ESTELA and in the FP7 project EU-SOLARIS[1], as follows:

The acronym CST (Concentrating Solar Thermal) is used to refer, in general, to the technologies producing thermal energy with concentrated solar radiation.

The acronym STE (Solar Thermal Electricity) is used, as well as CSP (Concentrating Solar Power), when talking about the electricity produced with concentrating solar thermal systems (e.g., STE plants or STE technologies).

3. Methodology followed

The scope of this first step of the task 3.4 is to evaluate the potential capacities of the existing installations available for the qualification of the CST technologies components (among: CIEMAT-PSA, DLR, CNRS, CYI, LNEG, CTAER, CENER, TECN, UEVORA, IMDEA, TKN, UNIPA, FBK, ENEA and F-ISE).

After that, once the specific components that will be standardized have been defined in the framework of WP5, it will be possible to determine the needs of adaptation of the existing research centres’ facilities through a conceptual design or the needs of new ones, so that the Research Centres can have the appropriate installations (test equipment, laboratories, etc.) for the qualification of the new standardized CST technologies components. CST systems can use different technologies for the concentration of solar radiation. In them, however, it is always possible to identify the following stages:

- collection and concentration of solar radiation,
- conversion of the radiation into thermal energy,
- transport (and possible accumulation) and use of the thermal energy.

The collection and concentration of solar radiation occur with the aid of reflective surfaces, usually optical mirrors with a high degree of reflection, for conveying the solar rays on the

[1] EU-SOLARIS is a FP7 project, which aims to carry out the preparatory work needed for the creation of a large distributed Research Infrastructure (RI) of European character and global reach. The main purpose of this distributed RI is to foster, contribute to and promote the scientific and technological development of CST and Solar Chemistry technologies. (www.eusolaris.eu)

receivers which transfer the energy to the heat transfer fluid which circulates inside them. Before the use in the production process, the thermal energy transported by the fluid can be stored in tanks, using the sensible heat of the fluid itself or by using inert materials with high thermal capacity or various substances exploiting the energy of the phase change or chemical transformation reactions.

As a basis to define the methods of measurement for the characterization of the components used in CST plants have been used the instructions given in the report: “*R12.4 Guidelines for Testing of CSP components*” elaborated in the framework of European project SFERA I (7th Framework Programme).

The report has been drafted according to the differing research focus of the SFERA project partners in the field of CSP technologies. This guideline includes contributions from:

- the German Aerospace Center DLR e.V.: Institute of Solar Research
- the French National Center of Scientific Research (CNRS) : laboratory PROMES (UPR8521)
- the Spanish research centre, Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT)
- The Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA)

The report is divided in two sections:

1) The first section describes different technologies (Parabolic Trough, Tower, Dish and Furnace) available for conversion of solar irradiance to heat/electricity by means of concentration. The focus is on the particular testing needs for the characterization of the components and system involved suitable measurement methods and typical test procedures.
2) In the second section, the most relevant measurement methods are reported in detail. Their measurement principle, sensors/equipment requirements, calibration issues, expected accuracies and recommendations are included.

The format of the census form (see table 1) was elaborated with the support of the partners and taking as reference the suggestions reported in the report R12.4 Guidelines for Testing of CSP components In the census form have been included also the following requests:

- the list of the evaluated features and accuracy that can be assessed for each CST technologies component. For example, for mirrors the most important are reflectance, shape and durability. This is because generally each feature is measured with a specific set-up, or a specific procedure;
- the integration with the existing EU Research Infrastructures (RIs) (e.g. usual round-robin tests or other measurement procedures that involve more laboratories).

Both details are important to identify if there already exists accepted and codified procedures of measurement that are applied by more laboratories.

Table 1: Census Form

Partner	
Institute:	
CST Component [(1)]:	
Measurand:	
Name of the experimental set up:	
for indoor/outdoor qualification of: - Mirrors, Receivers, Mechanics, Piping, Plant, storage, HTF[(2)], HSM[(3)], Other…….	
if commercial - model & manufacturer	
Short description of the experimental set up (max 20 rows):	
Description of the measurement technique / methodology applied:	
List of the evaluated features and accuracy:	
Integration with the existing EU research infrastructure:	

(1) you can find the list of CST components, their parameters and several measurement guidelines at the SFERA websites http://sfera.sollab.eu/index.php?page=joint

(2) HTF Heat transfer Fluid,

(3) HSM Heat Storage Material

4. Collection of census forms

The data extracted from the census forms filled by the WP3 partners have been summarized in the following table. All the census forms filled by the partners are also attached to this report (Annex 1).

PARTNER	COUNTRY	ITEM NUMBER	Type/ Standard applied	CST Technology COMPONENT	MEASURAND
CENER	ES	Cener_1	Own design	Receiver tube	• On-site inspection of the surface temperature of tubes
CENER	ES	Cener_2	Commercial	Receiver tube	• Indoor non-destructive optical characterization • Indoor qualification: thermal loss power of single receiver tube • Indoor destructive optical characterization (absortance of the absorber tube and transmittance of the glass tube)
CENER	ES	Cener_3	Commercial	Mirrors	• Solar reflectance • Durability
CENER	ES	Cener_4	Commercial Own design	Mirror facet	• Impact resistance test • Geometric characterization
CENER	ES	Cener_5	Own design	Receiver material	• Thermal shocks
CENER	ES	Cener_6	Own design	Parabolic Trough	On site characterization for: • Peak optical efficiency • Thermal losses • Incidence angle modifier

PARTNER	COUNTRY	ITEM NUMBER	Type/ Standard applied	CST Technology COMPONENT	MEASURAND
CENER	ES	Cener_7	Commercial instruments	Central Receiver System, Dish	• On site High solar radiation flux Surface temperature.
CENER	ES	Cener_8	Commercial	Solar Radiation Measurement Station	• On-site measurement audit
CENER	ES	Cener_9	Own design	Heliostat	• Optical characterization • Geometry characterization • Tracking Accuracy
CENER	ES	Cener_10	Commercial	HTF	• HTF Purity and traces analysis by GC/MS-FID Chromatography
CENER	ES	Cener_11	Laboratory accredited ISO 9806:2013/ EN 12975-1	Solar Thermal Collectors	• Thermal Performance
CENER	ES	Cener_12	Laboratory accredited EN 12976-2/ ISO 9459-2 / ISO 9459-5	Solar systems for the production of sanitary hot water	• Thermal Performance
CENER	ES	Cener_13	Laboratory accredited ISO EN 12977-3	Solar thermal store	• Thermal Performance

PARTNER	COUNTRY	ITEM NUMBER	Type/ Standard applied	CST Technology COMPONENT	MEASURAND
CENER	ES	Cener_14	Commercial	Solar Resource	• Measurement of DNI, GHI and DHI • Measurement of global horizontal downward infrared irradiance with a pyrgeometer • Measurement of spectral direct normal irradiance and spectral sky radiance with a sun photometer, (part of the AERONET measurement network) • Wind speed and direction
CENER	ES	Cener_15	Laboratory accredited ISO 9847 / ISO 9060	Solar Resource	• Calibration of pyranometer • Calibration of pyrheliometer
IMDEA	ES	IMDEA_1	Own design	HSM for thermal sensible Energy storage and Thermochemical Energy Storage	• Temperatures of reaction, • Oxygen concentration • pressure drop, • Fluidization capacity • Cycling performance • Attrition resistance of the material.
IMDEA	ES	IMDEA_2	Own design	Receivers	• Thermal/optical efficiency, • Materials durability/ stability, • High temperature • Radiation flux density • Gas composition analysis
FBK	IT	FBK_1	Own plant design	Small-scale parabolic Trough	• Optical Efficiency solar collector • Thermal Efficiency pipe receiver
FBK	IT	FBK_2	Own plant design	Parabolic Trough Collector using thermal oil	• Optical and thermal efficiency of receiver • DNI on Horizontal plane

PARTNER	COUNTRY	ITEM NUMBER	Type/ Standard applied	CST Technology COMPONENT	MEASURAND
FBK	IT	FBK_3	Own plant design	Distribution unit for thermal oil	• Thermal efficiency of piping • Working condition (pressure, mass flow and temperature)
FBK	IT	FBK_4	Own plant design	m-CHP using a Stirling engine coupled with the distribution unit	• Thermodynamic and kinetic performances of the Stirling engine
CNRS	FR	CNRS_1	Own design	Solar receiver for heliostats system	• Optical Efficiency; • Thermal Efficiency;
TECNALIA	ES	TEC_1	Commercial	HTF, HSM	• Melting point, • Heat Capacity, • Enthalpy
IK4-TEKNIKER	ES	TKN_1	Commercial	HTF	• Composition thermal oil
IK4-TEKNIKER	ES	TKN_2	Commercial	HTF	• Physical properties of thermal oil • Chemical properties of thermal oil
IK4-TEKNIKER	ES	TKN_	Commercial/Standard ASTM D 6743	HTF	• Heat transfer fluids thermal oil • Thermal stability thermal oil
IK4-TEKNIKER	ES	TKN_4	Commercial	HSM	• Composition MS
IK4-TEKNIKER	ES	TKN_5	Commercial/ ASTMD 3417 ASTMD 3418 ASTM E1269	HSM	• Thermal properties MS

PARTNER	COUNTRY	ITEM NUMBER	Type/ Standard applied	CST Technology COMPONENT	MEASURAND
F- ISE	DE	FISE_1	Commercial / SolarPACES round robin on mirror shape measurement 2014.	Mirrors (parabolic trough, Fresnel, Heliostats, dishes)	• Mirror shape • Gradient distribution of mirror area • Curvature over mirror area • Derived parameters
DLR	DE	DLR_1	Own design	Parabolic Trough Receiver	• Thermal Loss Power / Thermal performance
DLR	DE	DLR_2	Own design	Parabolic Trough Receiver	• Optical Efficiency (relative to reference receiver)
DLR	DE	DLR_3	Own design	Parabolic Trough Receiver	• Accelerated Ageing of bellows • Bellow fatigue test
DLR	DE	DLR_4	Own design	Parabolic Trough Receiver	• Accelerated Ageing of absorber coating • Overheating test • Thermal cycling test
DLR	DE	DLR_5	Own design, also commercial available, SolarPACES round robin on mirror shape measurement 2014	Mirrors (parabolic trough, Fresnel, Heliostats, dishes)	• Mirror shape accuracy • Slope deviation over mirror area • Focal deviation over mirror area • Mean slope and focal deviation
DLR	DE	DLR_6	Array of commercial instruments	Mirrors	• Solar weighted specular reflectance
DLR	DE	DLR_7	Own design	Parabolic Trough Receiver (in-field)	• Heat Loss • Emittance • Vacuum Quality

PARTNER	COUNTRY	ITEM NUMBER	Type/ Standard applied	CST Technology COMPONENT	MEASURAND
DLR	DE	DLR_8	Commercial	Parabolic Trough Receiver and Tubing (in-field)	• Glass temperature • Insulation temperature
DLR	DE	DLR_9	Own design	HTF (in field & laboratory)	• Heat capacity
DLR	DE	DLR_10	Own design	Parabolic Trough Module/Collector or Loop	• Performance: optical and thermal efficiency • Mass Flow Rate
DLR	DE	DLR_11	Own design	Central Receiver System, Dish	• Solar Flux Density Measurement • Solar Input Power
DLR	DE	DLR_12	Own design, Commercial	Central Receiver, Dish Receiver	• Optical efficiency of receiver
DLR	DE	DLR_13	Own design, Commercial	Heliostat	• Tracking Accuracy • Shape • Gravitational shape Deformation
DLR/PSA	DE	DLR_14 (PSA_4)	Own design	Volumetric receivers	• Thermal performance • Ageing
DLR/PSA	DE	DLR_15 (PSA_5)	Own design	Dish Receivers	• Thermal accelerated ageing of raw materials
DLR/PSA	DE	DLR_16 (PSA_11)	Array of commercial instruments	Concentrator, reflectors	• Optical Characterization • Durability
DLR/PSA	DE	DLR_17 (PSA_12)	Array of commercial instruments	Mirror facets	• Optical quality of concentrators • Durability • Solar reflectance

PARTNER	COUNTRY	ITEM NUMBER	Type/ Standard applied	CST Technology COMPONENT	MEASURAND
DLR	DE	DLR_18	Own design, Commercial	Solar Resource	• Measurement of DNI, GHI and DHI with both thermal sensors and RSIs • Measurement of global horizontal downward infrared irradiance with a pyrometer • Measurement of spectral direct normal irradiance and spectral sky radiance with a sun photometer, which is part of the AERONET measurement network • Wind speed and direction at 10m • Temperature and humidity profile at 2 m • Barometer • Visibility • SAM • Ceilometer • Lidar • All sky cameras • Shadow-cameras

PARTNER	COUNTRY	ITEM NUMBER	Type/ Standard applied	CST Technology COMPONENT	MEASURAND
CTAER	ES	CT_1	Own design	Receiver (Parabolic Trough)	• Absorbance • Emissivity • Receiver Efficiency • Thermal Shock Resistance • Poisson ratio • Young Modulus • Yield strength • Ultimate Tensile Strength • Exchange Area • Thermal Inertia.
CTAER	ES	CT_1	Own design	HTF (Parabolic Trough)	• Maximum Operating Temperature • Thermal Conductivity • Specific Heat Capacity • Heat Transfer Coefficient • Heat Capacity • Thermal Diffusivity
CTAER	ES	CT_2	Commercial	Concentrators/Facet (Heliostat, Parabolic Trough and Disk)	• Geometric accuracy • Stability • Stiffness • Tracking accuracy • Effective solar reflectance • Shape accuracy • Nominal intercept factor • Nominal shooting error

PARTNER	COUNTRY	ITEM NUMBER	Type/ Standard applied	CST Technology COMPONENT	MEASURAND
CTAER	ES	CT_3	Own design	Central Receivers	• Absorbance, Receiver Efficiency • Thermal Inertia • Maximum Operating Temperature • Thermal Shock • Thermal Conductivity • Poisson ratio • Young Modulus • Yield strength • Ultimate Tensile Strength • Absorbance • Reflectance • Emissivity • Heat Transfer Coefficient • Exchange Area
UEVORA	PT	UEVO_1	Own design / Application ISO9806 procedures	Line-focus concentrator modules based on different technological concepts	• Optical characterization parameters of line-focus concentrators • Thermal characterization parameters of line-focus concentrators
UEVORA	PT	UEVO_2	Own design / Application ISO9806 procedures	Parabolic Trough Loop using Molten Salts	• Instantaneous efficiency
UNIPA	IT	EN PA_1	Own design	Solar fuel chemical reactor	• Experimental plant under construction to evaluate the characteristics of chemical reactor for solar fuel
CYI	CY	CYI_1	Own design	Heliostat-receiver	• Little tower solar Experimental plant under construction

PARTNER	COUNTRY	ITEM NUMBER	Type/ Standard applied	CST Technology COMPONENT	MEASURAND
ENEA	IT	EN_1	Commercial	HTF/HSM	• Phase diagrams • Phase change heats • Heat capacity
ENEA	IT	EN_2	Own design	HTF/HSM	• Thermal stability
ENEA	IT	EN_3	Commercial	HTF/HSM	• Viscosity
ENEA	IT	EN_4	Commercial	HTF/HSM	• Decomposition of molten salts mixtures
ENEA	IT	EN_5	Commercial	Mirrors	• Point coordinates of the position in space (x,y,z)
ENEA	IT	EN_6	Own design	Mirrors	• Near-specular reflectance
ENEA	IT	EN_7	Own design	Mirrors facet	• Optical quality of concentrators
ENEA	IT	EN_8	Own design	Parabolic trough collectors	• Intercept factor map
ENEA	IT	EN_9	Own design	Mirrors	• Shape
ENEA	IT	EN_10	Own design	Receiver pipes	• Indoor qualification: thermal loss power of a single receiver tube
ENEA	IT	EN_11	Own design	Parabolic-trough collectors (PTC) with molten salt as HTF (Up to 530°C)	• Thermal Efficiency in real condition • Optimization of the operating procedures with molten salt
ENEA	IT	EN_11	Own design	Pipe receiver with molten salt as HTF fluid	• Thermal Efficiency in real condition

PARTNER	COUNTRY	ITEM NUMBER	Type/ Standard applied	CST Technology COMPONENT	MEASURAND
ENEA	IT	EN_11	Own design	Molten salt components	• Durability • Thermal loss • Temperature profile • Drop pressure, with flow of MS • Optimization of the operating procedures with molten salt
ENEA	IT	EN_11	Own design	Thermal storage with molten salt as HSM	• Thermal loss, temperature • Thermal stratification • Optimization of the operating procedures with molten salt
ENEA	IT	EN_11	Own design	Coil SG for MS	• Temperature • Pressure • Global heat exchange coefficients
ENEA	IT	EN_12	Own design	Material	• Dynamic corrosion
ENEA	IT	EN_13	Laboratory accredited ISO 9806:2013 EN 12975-2	Solar Thermal Collectors (up to 300 ºC)	• Thermal Performance
ENEA	IT	EN_14	Laboratory accredited ISO EN 12976-2 ISO 9459-2	Solar systems for the production of sanitary hot water	• Thermal Performance

PARTNER	COUNTRY	ITEM NUMBER	Type/ Standard applied	CST Technology COMPONENT	MEASURAND
ENEA	IT	EN_14	Own design, Commercial	Solar Resource	• Measurement of DNI, GHI and DHI with both thermal sensors and RSIs • Measurement of global horizontal downward infrared irradiance with a pyrometer • Measurement of spectral direct normal irradiance and spectral sky radiance with a sun photometer, • Wind speed and direction at 10m • Temperature and humidity profile at 2 m • Barometer
LNEG	PT	LNEG_1	Own design/ Laboratory accredited ISO 9806:2013	Solar Thermal Collectors (up to 100 ºC)	• Thermal Performance
LNEG	PT	LNEG_2	Commercial	Not applied	• DNI
LNEG	PT	LNEG_3	Commercial	Mirrors	• Reflectance spectrum in the solar spectrum (250-2500 nm).
LNEG	PT	LNEG_4	Certified laboratory	Bio fuel	• Chemical characterization of biomass • Thermo physical complete characterization of biomass
LNEG	PT	LNEG_5	Array commercial instrument	Mirrors Material for CSP plant	• Durability of Materials
LNEG	PT	LNEG_6	Array commercial instrument	bio fuel	• Syngas and tars chemical composition

PARTNER	COUNTRY	ITEM NUMBER	Type/ Standard applied	CST Technology COMPONENT	MEASURAND
CIEMAT/PSA	ES	PSA_1	Commercial instrumentations	Linear Receiver	• Solar absorptance, • Thermal emittance • Solar transmittance • Surface contact angle • Accelerated aging • Abrasion resistance
CIEMAT/PSA	ES	PSA_2	Own design	Solar reactors for Central Receiver systems	• Solar reactors performance in real operating condition
CIEMAT/PSA	ES	PSA_3	Own design	Materials for thermo chemical water splitting	• Cycling performance
CIEMAT/PSA	ES	PSA_4	Own design	Volumetric receivers	• Thermal performance • Ageing
CIEMAT/PSA	ES	PSA_5	Own design	Dish Receivers	• Thermal accelerated ageing of raw materials
CIEMAT/PSA	ES	PSA_6	Own design	Small parabolic-trough collectors with water as HTF	• Efficiency in real operating conditions • Peak optical-geometrical efficiency
CIEMAT/PSA	ES	PSA_7	Array of commercial instruments	Materials for CSP components	• Hardness • Rugosity • Uniformity and surface finish, • Depth of treated surface of materials. • Characterization of materials in clean room temperature to 1750 ºC in different atmospheres

PARTNER	COUNTRY	ITEM NUMBER	Type/ Standard applied	CST Technology COMPONENT	MEASURAND
CIEMAT/PSA	ES	PSA_8	Own design	Any component for parabolic trough solar fields with Direct Steam Generation	• Cycling performance • Thermo-hydraulic performance of two-phase of water/steam in horizontal line with non-homogeneous heat flux • Performance for parabolic-trough collector solar fields with direct steam • Performance for line-focus collector solar fields with direct steam • Ageing components with direct steam • optimization of the operating procedures with direct steam
CIEMAT/PSA	ES	PSA_9	Own design	Molten salt components	• Durability • Thermal loss • Ageing in real operative condition • Temperature profile • Drop pressure, with flow of MS
CIEMAT/PSA	ES	PSA_10	Own design	Molten salt components	• Durability • Thermal loss • Ageing in real operative condition • Temperature profile • Drop pressure, with flow of MS • Optimization of the operating procedures with molten salt
CIEMAT/PSA	ES	PSA_11	Array of commercial instruments	Concentrator, reflectors	• Optical Characterization • Durability

PARTNER	COUNTRY	ITEM NUMBER	Type/ Standard applied	CST Technology COMPONENT	MEASURAND
CIEMAT/PSA	ES	PSA_12	Array of commercial instruments	Mirror facets	• Optical quality of concentrators • Durability • Solar reflectance
CIEMAT/PSA	ES	PSA_13	Array of commercial instruments	Solar receivers	• High solar radiation flux • Surface temperature.
CIEMAT/PSA	ES	PSA_14	Own design	Solar Furnaces	• Temperature and thermal flux distribution on absorbers and tested samples • Temperature and flow of air in volumetric receivers • Temperature and flow of gas produced in solar reactors • Temperature of materials processed in reactors
CIEMAT/PSA	ES	CIEMAT_1	Laboratory with commercial equipment	Structural Material for CST plant component	• Corrosion static test • Microscopy surface characteriation material • Mechanical characterisation of structural alloys
CIEMAT/PSA	ES	PSA_16	Own design	Linear Fresnel modules, mirrors and receivers for linear Fresnel collectors	• Optical efficiency (including incidence angle modifier). • Ageing components with direct steam • optimization of the operating
CIEMAT/PSA	ES	PSA_17	Own design	Large parabolic-trough collectors (PTC) and receiver pipes with Oil as HTF (Up to 400 °C)	• Peak optical efficiency • Incidence angle modifier. • Heat losses
CIEMAT/PSA	ES	PSA_18	Own design	Parabolic-trough collectors (PTC), receiver tubes with pressurized gas as HTF	• Performance for parabolic-trough collector solar fields using compressed gas as HTF • Ageing components using compressed gas as HTF • Pressure losses in solar receivers using compressed gas as HTF

PARTNER	COUNTRY	ITEM NUMBER	Type/ Standard applied	CST Technology COMPONENT	MEASURAND
CIEMAT/PSA	ES	PSA_19	Own design	Receiver pipes	• Outdoor qualification : optical performance • Indoor qualification: thermal loss power of single receiver tubes
CIEMAT/PSA	ES	PSA_20	Own design	Linear Fresnel collector (LFC) modules and receiver tubes for LFC	• Outdoor qualification of: Optical efficiency (including incidence angle modifier) • Heat losses.

5. Conclusions

The census carried out is a good starting point to make some assessments about the possibilities that have laboratories / research respondents to integrate with the international system of standardized measurements of components for CST technologies.

On the basis of the data collected, it is possible to assert that all the data collected shows that the laboratories / research centres surveyed have a good experimental equipment to feature:

- Heat Transfer Fluid;
- Heat Storage Material;
- Structural Material for CSP plant component;
- Optical characteristics, (included the durability) of the materials used in the construction of reflective systems (mirrors);
- Receiver pipes.

The equipment used consists of commercial tools, or instrumental equipment of its own design, that employ commercial tools. For some measurements, the standardized procedure used for performing the measurement is also indicated. In any case, from the analysis of the census forms, it is not clear whether the same laboratories have an internal organization for the execution of measurements that follows the laboratories certified.

DLR, F-ISE, CENER (shape of the mirrors) and IK4-TEKNIKER (HTF and HSM) have underlined that their laboratories apply programme of Round Robin tests, which corresponds to programmes used to compare results of test methods with other laboratories. In particular, F-ISE is inserted in a programme F-ISE the round robin tests within workgroups SolarPACES, while IK4-TEKNIKER applies the standards set by the American Society for Testing and Materials (ASTM) for the execution of the round robin tests.

Solar collectors at low/medium temperature (<300 °C)

With regard to the measurement of the performance of the solar collectors at low / medium temperature, during the census, three laboratories accredited (Approved laboratories follow the dictates of the EN ISO 17025 / EN ISO / IEC 17025 / ISO-Guide 43-1) have been identified. All laboratories follow the ISO 9806 standard. In particular:

- ENEA is able to test solar collectors to a temperature of up to 300 °C;
- FBK is able to test solar collectors to a temperature of up to 300°C;
- LNEG is able to test solar collectors to a temperature of up to 100 C;
- CENER is accredited laboratory to test solar collectors to a temperature of up to 100 C according to ISO 9806:2013. CENER could also determine the thermal performance of medium temperature small parabolic trough collectors testing separately the components.
- UEVORA indicates the presence of an accredited laboratory without giving specifications in detail;

CIEMAT-PSA can also evaluate the performance of parabolic trough collector at low/medium temperatures. However, their facilities are not accredited for certification by ISO standards.

The standard ISO 9806:2013 specifies test methods for assessing the durability, reliability and safety for fluid heating collectors. It also includes test methods for the thermal performance characterization of fluid heating collectors, namely steady-state and quasi-dynamic thermal performance of glazed and unglazed liquid heating solar collectors and steady-state thermal performance of glazed and unglazed air heating solar collectors (open to ambient as well as closed loop) [6].

The theme of the collectors to medium / low temperature requires a greater deepening to evaluate the potential of the market and the capacity to answer at the requests of the industrial sector. In particular will be necessary define survey methodology jointly with the coordinator of WP5 (CEA - Commissariat à l'énergie atomique et aux énergies alternatives).

Solar collectors at high temperature (>300 °C)

ENEA is the only partner able to characterize the performance of outdoor parabolic solar collectors that use molten salt as HTF. In this case, the qualification takes place according to internal procedures.

PSA-CIEMAT is the only one able to supply facilities for the characterization of parabolic solar collectors for high temperatures that use pressurized gases, steam or oil as the HTF. PSA-CIEMAT has a facility useful to characterize the Fresnel collectors (with water/steam as HTF). For each kind of the characterization test, PSA-CIEMAT employs internal procedures.

FBK is able to test solar collectors at a small size reaching up to 350°C, using thermal oils as HTF.

CTAER and DLR are able to test and evaluate the performance of Parabolic Trough Module/Collector.

CENER is able to evaluate on site the thermal performance of Parabolic Trough module/collectors. CENER could also determine the thermal performance of Parabolic Trough collectors testing separately the components.

CST components for molten salt industrial loop

With regard to the ability to test components only ENEA and PSA-CIEMAT have facilities able to fulfill this task. Both partners employ not procedures standardized for the characterization of components, but methodologies elaborated inside the laboratory.

Components for thermal energy storage system subservient to CST

Only ENEA has indicated the ability to characterize heat storage at molten salts and heat coil steam generators.

Volumetric receiver

DLR is the only one able to provide facilities capable of test volumetric receiver. For this activity has implanted own facility

Parabolic Trough Receiver

DLR has different facilities to test the different features of parabolic trough receivers. They are able to test both the optical and the thermal characteristics. The test can be performed both in laboratory that in field and include also the aspects Accelerated Ageing of bellows. For the different measures, DLR employs array of commercial instruments or own design facility.

ENEA is able to test the thermal performance of parabolic trough receiver in laboratory trough an own facility.

CENER has different facilities to evaluate optical and thermal features of parabolic trough receivers. They have a non-destructive test bench for measuring optical characteristics.

Solar resource.

DLR and ENEA own some array of commercial instrumentation able to measure the solar resource in the field.

CENER owns a solar radiometric station part of Baseline Surface Radiation network (BSRN)

CENER Solar Thermal Testing Laboratory is accredited for pyranometers calibrations based on the International Standard ISO 9847 and for pyrheliometers calibration based on ISO9059.

CENER audits Solar Radiation Measurement Stations in field, by comparison of the radiation measurement with CENER portable station, traceable to World Radiation Center (PMOD-WRC, Davos-Suiza) World Radiometric Reference (WRR)).

General considerations

The sample of the census form is not homogeneous in its compilation and in many cases we have the impression that they have been filled by describing experimental systems born of research needs and not normed for the characterization of components.

- Part of the reasons of the dispersion of the data is to be attributed to the high number of components that are used in CST systems and to the different technologies that are under examination in the sector of the CST technologies. For the future in coordination with the works of WP5 will be necessary to define in greater detail the classification of CST technologies components, in fact in general we can told that the label of CST technologies components employed in the census form, it is not so easy: e.g. both mirror that solar collector are classified as component. For this reason we can deduce that among the first tasks that should be examined in the WP5, they should be defined the criteria to define what we mean by CST technologies component. Other tasks of WP5, they will be solved the following issues:
- To choose in the list of parameters proposed in SFERA-I the parameters that have to be employed or not: e.g. the parameters associated to the raw material of the receivers (thermal

conductivity, thermal expansion, etc.) should not be considered as parameters to assess, because these parameters only depend on the raw material, not by manufacture of the receiver;

- To define a complete list of components and their associated parameters that must be evaluated, because the actual list is much larger than that proposed in SFERA-I. For heliostats, the list of parameters prepared by DLR in WP14 of SFERA-II to be evaluated is already much larger than the complete list prepared in SFERA-I for all the components (1);
- Subdivision of CST components in similar categories;
- Indication on the type of instruments to be used for each component category before identified;
- Identification of the standard procedures for the characterization of CSP components already existing;
- Definition of possible standard procedures for the characterization of CSP components not yet existing;
- Identification of the families of CSP components where the practice of round robin test is functional for the development of commonly recognized methods for their characterization;
- Definition of the minimum characteristics that must have the laboratories to take part at the programmes of Round Robin tests;
- Acceptance or less of existing standards for the implementation of round robin tests.

6. List of abbreviations

CPC	Compound Parabolic Concentrator (for Solar Collectors And Solar Cells)
CSP	Concentrated Solar Power
CST	Concentrating Solar Thermal
DHI	Diffuse Horizontal Irradiance
DNI	Direct Normal Irradiance
DoW	Description of Work
DSG	Direct Steam Generation
EA	European Cooperation for the Accreditation of Laboratories
EC	European Commission
FP7	Seventh Framework Programme
GHI	Global Horizontal Irradiance
GRR	Ground Reflected Radiation
HTF	Heat transfer fluid
HSM	Heat storage material
LFR	Linear Fresnel Reflector
MS	Molten Salt
PTC	Parabolic-Trough Collectors
RI	Research Infrastructure
SAM	Sun and Aureole Measurement
SG	Steam Generator
STE	Solar Thermal Electricity
WP(s)	Work Package(s)

7. References

[1] http://www.iso.org/iso/home/standards_development.htm

[2] RENEWABLES 2014, Global Status Report, Renewable Energy Policy Network for the 21st Century (REN21), 2014

[3] Technology Roadmap, Concentrating Solar Power, International Energy Agency, 2010

[4] Metrology – in short 3 rd edition July, 2008 EURAMET

[5] http://sfera.sollab.eu/downloads/JRA/WP12/Deliverable_R12.4_Guidelines_for_Testing_CSP.pdf

[6] http://www.iso.org/iso/catalogue_detail.htm?csnumber=59879

[7] An Overview of CSP in Europe, North Africa and the Middle East October, 2008 CSP Today

8. Annex 1

Census forms

9. Annex 2

List of existing installations available for the qualification of the CST components, classified by component.