SFERA-III

Solar Facilities for the European Research Area

Description of facilities participating to the TA programme

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Executive Summary

The core of the SFERA-III project is the Trans-national Access (TA) to Research Infrastructures (RI). SFERA-III provides European and non-European researchers from academia, business, industry and public services the opportunity to carry out their own research projects through the TA programme to the SFERA-III consortium's RIs – free-of-charge, supported by the European Commission, thus adding new and valuable knowledge to their research. This SFERA-III TA programme provides access to 47 distributed installations that are located in 9 countries. Project applications, proposing the utilisation of the SFERA-III consortium's RIs, will be selected by a selection oanel through a transparent process based on defined merit criteria. The free-of-charge access will include transport, accommodation, RI access and access assistance - to be agreed on and specified between the parties.

The objective of this document is to provide those Users Groups who are thinking of applying for access one of the RIs offered under this TA programme and benefiting from this opportunity supported by the European Commission (H2020) a detail description of the offered Research Infrastructures, of the corresponding services offered by these research infrastructures, and a description of the support offered to the User Groups. An updated version of the document might be necessary during the execution phase of the TA programme as further aspects are brought to light by the TA providers, potential applicants and granted users.

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1. Introduction

The SFERA-III project addresses advanced science challenges and integrated research activities in the field of Concentrating Solar Thermal (CST) by integrating key European research infrastructures into an ambitious wide project aiming at offering to the R&D community a new level of high-quality services. This project aims at coordinating efforts of the main European research institution operating a unique set of RIs to promote innovative researches, to improve services offered by concentrating solar RIs and to train researchers and engineers on the CST technologies. Both academia and industry users are targeted.

The SFERA-III Research Infrastructure, which integrates 13 research infrastructures (11 European advanced solar laboratories and 2 research infrastructures located in two neighbouring countries, i.e. Turkey and Switzerland), supports the technology development and the roll out of CST solutions by the joint development of testing methods and validation procedures. This SFERA-III TA programme provides access to a total of 47 distributed installations that are located in 9 countries (see Figure 1).

Figure 1. **Overview of the SFERA-III consortium members**.

The SFERA-III RI aims at placing the RI at disposal of researchers, engineers and developers, from both academia and industry, in a 4-year access programme supported by the European Commission (H2020).

SFERA-III offers to eligible external users free of charge Trans-national Access (TA) to its research infrastructures along with logistical, technological and scientific support. The TA scheme includes also free travel and accommodation for the access stays, as well as subsistence allowances associated to the granted Access.

In Table 1 a summary of the services offered by the SFERA-III RI is provided. A more detailed description of these services can be found in section 2 of this document. As can be seen in this table, the services offered under this TA scheme cover a wide range. In total there are more than 100 services offered under this TA scheme.

Table 1. **Summary of the services offered by the SFERA-III consortium members.**

1. SOLAR RESOURCE (DNI) AND METEOROLOGICAL PARAMETERS ASSESSMENT
2. SERVICES ON REFLECTORS AND CONCENTRATORS
2.1. Experimental Services on Reflectors
2.2. Available Services on Concentrator's Experimental Characterization
3. EXPERIMENTAL SERVICES ON ABSORBERS AND RECEIVERS
3.1. Experimental Services on Absorbers
3.2. Experimental Services on Linear Focus Receivers
3.3. Experimental Services on Anti-Reflective Materials
3.4. Experimental Services on Point Focus Receivers
4. SERVICES ON HEAT TRANSFER FLUIDS
5. SERVICES ON AUXILIARY EQUIPMENT
6. SERVICES ON THERMAL ENERGY STORAGE (MEDIA & SYSTEMS)
7. SERVICES ON ENGINES AND POWER BLOCS
7.1. Solarized Stirling Engines
7.2. Other Services on Engines and Power Blocks for CSP
8. SERVICES ON CALIBRATION OF KEY SENSORS & MEASUREMENTS FOR STE
9. SERVICES ON SOLAR CHEMISTRY
9.1. Water Treatment, Disinfection and Desalination
9.2. High Temperature Solar Chemistry
9.3. Solar Hydrogen

Table 1. **Summary of the services offered by the SFERA-III consortium members.**

10. SERVICES ON MATERIALS TESTING AND QUALIFICATION
11. SERVICES USING EXTREME TEMPERATURE CONDITIONS IN SOLAR CONCENTRATORS

This information is available to all potential users of the SFERA-III RI at https://sfera3.sollab.eu/.

2. Description of the Research Infrastructures offered under the SFERA-III TA programme

2.1. Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT)

2.1.1. Research Infrastructure

Name of the infrastructure:	Plataforma Solar de Almeria
Location:	Tabernas (Almería), Spain
Web site address:	www.psa.es

2.1.2. Description of the infrastructure

The Plataforma Solar de Almeria (PSA) is recognised as a Major European Scientific Installation by the European Commission and is also the largest and most complete R&D centre in the world dedicated to Solar Thermal Concentrating Systems, Solar Desalination and Photochemistry. It is a privileged place for the development, evaluation, demonstration, and transfer of solar concentrating technologies, both for thermal applications and for chemical processes. It offers researchers a location with insolation and climate characteristics similar to those of the developing countries of the equatorial belt with the advantages of owning the largest scientific facilities among European countries. Research activity at PSA has been structured around four R&D Units:

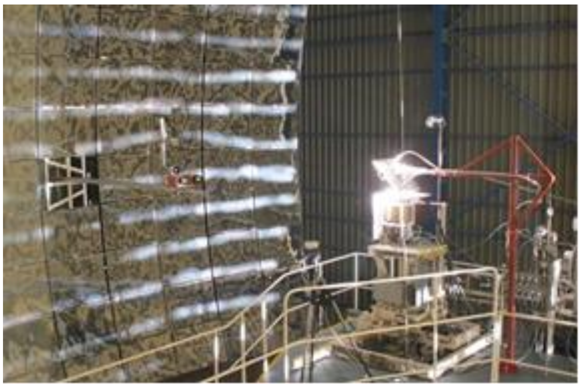
- Solar Concentrating Systems Unit. This unit is devoted to promote and contribute to the development of solar concentrating systems, both for power generation and for industrial processes requiring solar concentration, whether for medium/high temperatures or high photon fluxes.

- Thermal Storage and Solar Fuels Unit. Its objective is to look for different solutions to make concentrating solar thermal a dispatchable energy supply, either by thermal storage systems and/or solar fuels as hydrogen.
- Solar Desalination Unit. Its objective is new scientific and technological knowledge development in the field of brackish and sea water solar desalination.
- Water Solar Treatment Unit. Exploring the chemical possibilities of solar energy for promoting photochemical processes, mainly in water for treatment and purification applications but also for chemical synthesis and production of photofuels.

The PSA consists of solar concentrating and solar water treatment facilities that are unique in the world due to their variety and size. In the SFERA-III Project we offer access to the following installations:

PSA Solar Furnace (SOLFU)

The PSA Solar furnace installation houses three solar furnaces: two horizontal axis solar furnaces SF60 and SF40 and a vertical axis solar furnace SF5. It is the installation with the highest concentration of the PSA, with peak concentrations range from 3000 to 7000 kW/m^2. The SF60 (the 60 kW power solar furnace) consists essentially of a 130 m^2 flat heliostat and a 100 m^2 surface reflection parabolic concentrator, slats shutter or attenuator, and test table. This SF60 has a peak concentration of 3000 kW/m^2. The SF40 (the 40 kW power solar furnace) consists of a flat heliostat with 100 m^2 reflecting surface, a Eurodish parabolic concentrator with 56.5 m^2 projecting area, slats shutter or attenuator, and test table with three axis movement, and has a peak concentration of 7000 kW/m^2. The vertical axis solar furnace (SF5) reaches concentrations over 6000 kW/m^2 and operates in a vertical axis, i.e. parabolic concentrator and heliostat are vertically aligned on the optical axis of the paraboloid. Basically consists of a concentrator mirror, placed upside-down with the reflecting surface facing the floor, on a 18 m height metallic tower; in the center of the base of the tower there is a flat heliostat, whose center of rotation is aligned with the optical axis of the concentrator. At the top of the tower, in the test room, and 2 m below the vertex of the concentrator, there is a test table. Finally, under the test table and at floor level of the test room, a louver attenuator is placed, located between heliostat and concentrator. The main advantage of the SF5 is that the focus is arranged in a horizontal plane, so that the samples may be treated on a horizontal surface, just placing them directly in the focus, without a holder, avoiding problems of loss of material by gravity in those tests in which the treatment requires surface melting of the specimens.



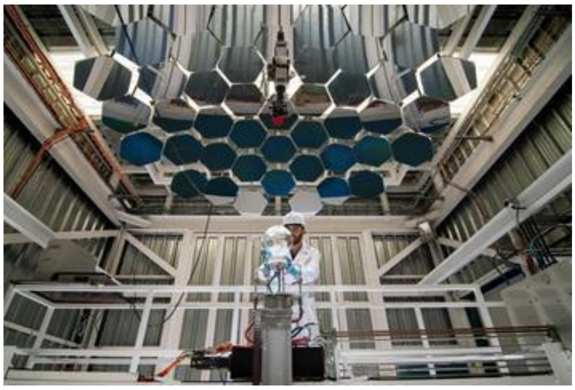


Figure 2. **Interior view of the PSA SF60 Solar Furnace in operation (left) and Interior view of the PSA SF5 Solar Furnace (right)**.

Molten Salt Test Loop for Thermal Energy Systems (MOSA)

The Molten Salt Test Loop for Thermal Energy Systems is a replica of a thermal energy storage (TES) system with molten salts and a two-tank configuration. With 40t of molten salts plant, this installation consists basically of two tanks, -one vertical, for hot molten salts, and another horizontal, for cold molten salts-, a thermal oil loop that can be used for heating the salt up to 380°C and cooling it to 290°C, and two flanged sections, where different components for this type of loops (e.g. valves, flow meters, heat trace, pumps…) can be tested.

Figure 3. **MOlten SAlt test loop for Thermal Energy Systems (MOSA).**

Central Receiver System (CRS)

The Central Receiver System is an outdoor installation specially conditioned for scaling and qualifying systems prior to commercial demonstration. The heliostat field is composed of 92 units, all completely autonomous and powered by photovoltaic energy, with centralized control communicated by radio. Under typical conditions of 950 W/m^2, total field capacity is 2.5 MWth and peak flux is 2.5 MW/m^2. 99% of the power is collected in a 2.5-m-diameter circumference and 90% in a 1.8-m circumference. The 43-m-high metal tower has three test platforms, all test levels with access to pressurized air (1.5m^3/min at 7-8 bar), pure nitrogen supplied by two batteries of 23 standard-bottles (50dm3/225bar) each, steam generators with capacity of 20 and 60kg/h of steam, cooling water with a capacity of up to 700 kW, demineralized water (ASTM type 2) from a 8m^3 buffer tank for use in steam generators or directly in the process, and the data network infrastructure consisting of Ethernet cable and optical fibre.

Figure 4. **Central Receiver System (CRS) tower (left) and front view of the CRS tower test bench (right)**.

A hybrid heat flux measurement system to measure the incident solar power that is concentrated by the heliostat field is located at the CRS tower. This method comprises two measurement systems, one direct and the other indirect. The direct measurement system consists of several heat flux sensors with a 6.32 mm front-face diameter and a response time in microseconds. These micro sensors are placed on a moving bar which is mounted in front of the reactor window. The indirect measurement system works optically with a calibrated CCD camera that uses a water-cooled heat flux sensor as a reference for converting grey-scale levels into heat flux values.

SolWater

SolWater is the biggest European installation dedicated to solar water treatment and disinfection at pilot plant scale. It is composed by several photo-reactors based on Compound Parabolic Collectors (CPC) technology combined or not with other conventional and advanced technologies for achieving the scientific and development goals of wastewater (urban and industrial) treatment/disinfection and reuse in different applications (crops irrigation, industrial processes, etc.). Available solar pilot plants are built by modules which can be connected in series. Each module consists of a number of photo-reactors placed on the focus of an anodized aluminum mirror with CPC shape to optimize solar photons collection in the photo-reactor tube. The modules are place on a platform titled at 37° from the horizontal to maximize the global solar collection of photons through the year. In addition, the pilot plants may be equipped with added systems for different purposes, for example: sedimentation tanks (for catalyst recovery), heating and cooling systems for temperature control during the experiments, coupling with other treatment technologies like bio-treatment, ozonation, etc. A 2 m^2 CPC collector with 10 borosilicate glass tubes (50 mm diameter), illuminated volume of 25 L and a total volume of 40 L is connected to four electrocells for experimental research on electro-photo-Fenton processes for decontamination and disinfection of water. There are also several CPC prototypes for applications of water disinfection. One of these systems consists of two 50 mm outer diameter borosilicate-glass tubes installed in the reflector focus and mounted on a fixed platform tilted 37°. The illuminated collector surface area is 0.42 m^2. The total volume of the system is 14 L and the illuminated volume is 4.7 L. Photo-reactor for solar disinfection 'FITOSOL' consists of two components, a CPC solar reactor (4.5 m^2 of collector surface, 45 L of irradiated volume, and 60 L total) and a pilot post-treatment plant for photocatalyst recovery (100L). The system is equipped with pH and dissolved oxygen online sensors, connected to a controller for automatic data acquisition. In 2016, a new pilot plant with two modules of 2 m^2-collectors with different mirror shape (CPC and U mirror type) has been installed. It is composed by a feeding polypropylene tank of 192 L of total volume and a preparation tank of 92.5 L, connected by gravity to the CPC and U type photoreactors. The last presents 1.98 m^2 of irradiated surface with a recommended operating volume of 53 L. The whole pilot plant is equipped and automatically controlled by a UVA solar sensor. In addition, the pilot plant is equipped with a solar water heating panel which permits to increase the temperature of water prior to discharge it in the photoreactors.

WetOx

WetOx is a new installation based on combinations of high temperature and pressure, various proportions of oxygen and nitrogen, the use of oxidants and different catalysts, for the application of highly powerful oxidant conditions for the treatment of complex wastewaters. The innovative part of this installation lays in its combination with solar energy. The high versatility of this system opens a wide spectrum of applications. The WetOx pilot plant consists of a stainless steel reactor with a total volume of 1000 mL, a magnetic stirrer, a breakup disk, liquid reagents injector prepared to operate under 200 bar and a maximum temperature of 300 °C, thermo-probe, pressure sensor (until 250 bar) and a cooling-heating jacket , all made of stainless steel. The Wet Air Oxidation pilot plant includes an automatic system of control and data acquisition of diverse parameters such as pressure, temperature, reagents dosses and mixture.

Figure 5. **CPC in the Solar Water (SolWat) pilot plant (left) and Wet Air Oxidation (WetOx) pilot plant (right)**.

HyWATOx

The HyWATOx installation is connected to a CPC photo-reactor for the simultaneous removal of organic contaminants contained in aqueous solutions. This is the first photo-reactor at pilot plant scale in Europe devoted to the application of this technology for the generation of solar hydrogen. The pilot plant consists on a stainless steel tank with a total volume of 22 L, fitted with gas and liquid inlet and outlet and a sampling port. Two parallel mass flow controllers are used to control the desired N_2 gas flow into the reactor headspace during the filling step.

Figure 6. **Solar pilot plant for photocatalytic generation of hydrogen (left) and CPC photo-reactor (right)**.

DESAL

The DESAL installation consists of several test-beds and bench-scale units for the experimental assessment of different desalination technologies: **a) Solar Multi-Effect Distillation installation (SOL-14)**: it is composed of a 14-effect vertically-stacked forward-feed MED unit. Working in low-temperature mode (LT-MED at 70°C) the unit has a nominal fresh water production of 72 m^3/day for a thermal consumption of 200 kW. For low-temperature operation the MED plant is powered by the AQUASOL-II solar field

Figure 7. **Solar Multi-Effect Distillation installation (SOL-14)**

(large-aperture flat-plate) **b) Double-Effect Absorption Heat Pump – MED Plant & NEP CCP Solar Field (DEAHP-MED):** A Double-Effect Absorption Heat Pump (DEAHP) can be coupled to the last effect of the MED unit for low-temperature thermal energy recovery and gives the possibility of working in ABS-MED mode. The DEAHP is able to work in hybrid mode (solar/gas) and has a nominal thermal consumption of 100 kW at180°C. For solar operation a 230-m^2 of small aperture parabolic trough solar collectors is connected to a steam generator that powers the DEAHP. The solar field is composed of 8 collectors (NEP Solar Polytrough 1200) arranged in four parallel rows with two collectors in series within each row. This solar field has a nominal capacity of 125 kW$_{th}$ (at 200°C) **c) Test-bed for solar thermal desalination applications (AQUASOL-II)**: The AQUASOL-II solar field is a large-aperture high-efficiency flat plate solar field composed of 60 collectors (Wagner Solar LBM 10HTF) with a total aperture area of 606 m^2 and a total thermal power output of 323 kW$_{th}$ under nominal conditions (efficiency of 59% for 900 W/m^2 global irradiance and 75°C as average collector temperature). It consists of 4 loops with 14 large-aperture flat plate collectors each (two rows connected in series per loop with 7 collectors in parallel per row), and one additional smaller loop with 4 collectors connected in parallel, all of them titled 35° south orientation. The

flexibility of the solar field allows the operation of each loop independently, through their own valves and pumping system, each loop being connected to an individual heat exchanger where a user can connect its own thermal desalination mode for testing purposes under real climatic conditions. **d) Test-bed for solar membrane distillation applications at pilot-scale (PILOT-MD)**: It is composed of two solar fields of flat-plate collectors available: one of 20 m^2 with two parallel rows of five collectors in series (Solaris CP1 Nova, by Solaris, Spain), and another of 40 m^2 with four large-aperture collectors in parallel (LBM 10HTF, by Wagner Solar, Spain). The test-beds allow for a stationary heat supply using the thermal heat storage or for direct supply of solar energy without buffering. The installation is fully automated and monitored (temperatures and flows) and allows for heat flow regulation. The maximum thermal power is 7 kW$_{th}$ in one case and 14 kW$_{th}$ in the other, and hot water can be supplied with temperature up to about 90°C. The installation currently operates with Membrane Distillation modules and has a wide range of different commercial and pre-commercial units from several manufacturers. **e) Bench-Scale Units for MD & FO Applications (LAB-MEM)**: The *bench-scale unit for testing*

<u>*membranes on isobaric MD*</u> consists of a test-bed with a small plate and frame module that can be used for evaluating direct-contact, air-gap or permeate-gap membrane distillation. The module is made of polypropylene and designed so that the membrane can be replaced very easily. The module has a condensation plate on the cold side to operate on air-gap configuration, but it can be closed at the bottom to operate on permeate-gap keeping the distillate inside the gap or spared to operate on direct-contact mode. The effective membrane surface is 250 cm^2. The installation has two separate hydraulic circuits, one on the hot side and another on the cold side. On the hot side, there is a tank of 80 L equipped with an electric heater (3 kW) controlled by a thermostat (90°C maximum), and circulation is made from the storage and the feed side of the module by a centrifugal pump. On the cold side there is a chiller (800 W at 20°C) controlled by temperature and water is circulated between a cold storage of 80 L and the module. The circuit is heat insulated and fully monitored for temperature, flow rate and pressure sensors, connected to a SCADA system. The <u>*bench-scale unit for flat sheet membrane distillation testing*</u> is a high precision laboratory grade research equipment designed for testing fundamental and feasibility test trials on membrane distillation. It possesses the following unique features that are essential for representative and scalable results: 1) Cell format with representative flow distribution. The cell size is sufficient for flow distribution and regime to be applicable to full scale MD technology. 2) Adjustable MD channel configuration to all channel variants (PGMD, AGMD, DCMD, VMD, VAGMD). 3) Temperature precision of 0.5°C. 4) Driving force temperature difference controllable. 5) Fully automated control system and large range of possible parameter settings by touch screen PLC. 6) Practical A4 format for membrane and condenser foil materials. The <u>*bench-scale unit for 2-stage forward osmosis and pressure-retarded osmosis*</u> consists of a test-bed with two small plate and frame modules of forward osmosis (FO) which can be connected in series or in parallel. There is, therefore, one pump for the draw solution and two for the feed solution, each with variable flow and flow-rate measurements. The hydraulic circuit has been modified so that the modules can be operated in pressure retarded osmosis (PRO) mode. For that purpose, steel pipes and a high-pressure pump (3 L/min; up to 17 bar) are installed in the draw side, and cells with operational pressure up to 15 bar are used. The cells have each a total effective membrane area of 100 cm^2, and hydraulic channels in zig-zag 4 mm wide and 2 mm deep. The system uses one container for the draw solution and two for the feed solutions, each placed on a

balance in order to measure changes in the mass flow rates of the draw solution and the feed solution of each cell. The containers have an automatic dosing system to keep the salinities constant. The system has two conductivity meters for low salinity and one for high salinity, as well as pressure gauges in each line and temperature readings.

Figure 8. **Internal (left) and external (right) views of the Membrane Distillation experimental test bed within the PSA low-temperature solar thermal desalination facility.**

2.1.3. Services offered by the infrastructure

- The **SOLFU** installation is very suitable for **Surface Treatments of Material**, since metallic and ceramic samples can be treated at very high temperatures with great accuracy. The treatments can be carried out in air, vacuum or in controlled atmosphere conditions, inside different vacuum chambers available. Some of the thermal treatments that can be carried out are: quenching, sintering, nitrurization, carburization, foaming, coatings, sintering of nanostructured materials, etc. The SOLFU installation is also very suitable for **Volumetric Absorbers Tests**, since these absorbers can be tested at high temperatures, with very good control of both, temperatures and air flow, in particular in the high flux focus of the PSA SF60 solar furnace. Various configurations are ready for the porous absorber materials to be tested. Finally, the SOLFU installation is suitable for **Accelerated Aging – Durability Tests**, since metallic and ceramic samples can be treated at very high temperatures, and cycles can be performed very precisely. The tests can be carried out in air, vacuum or in controlled atmosphere conditions. Several tests campaigns have been carried out in the last years on this topic.

- **MOSA** is hosting visitor who wants to **Characterize Components and**

Equipment for molten salts loops, i.e. to test small hydraulic components and equipment, such as valves and pressure transducers to be placed in molten solar salt loops in order to verify their feasibility. Since MOSA is a replica of a thermal energy storage system with molten salts and two-tank configuration, it can be used to **Validate any Simulation Model** used to predict the behaviour of such type of thermal storage systems. Additionally in the labs associated to MOSA it is possible to study the **Feasibility of Materials for Sensible and Latent Thermal Storage Systems**, i.e. validation of a storage material for a certain application by testing it under different temperature conditions and environments according to an accelerated ageing test plan at the devices of the thermal storage laboratory. Such study allows predicting and ensuring the long-term performance of the storage material under service condition. It can be applied to materials for either sensible or latent storage systems.

- The **CRS** tower allows **Thermal and Thermodynamic characterization of prototype Reactors for Central Receiver on Tower Technologies under real operating conditions**: Selection of the operating parameters depending on the required power, flux (from 50 kW/m^2 to 2500 kW/m^2) and mechanical boundary conditions for the prototype testing. On the other hand, this CRS tower can be used for the **Qualification of Solar Driven Processes**: Test design and evaluation of the endothermal processes under pilot scale operating conditions, and the **Qualification of Solar Hydrogen Production Process under realistic conditions**, which involves: Preliminary simulation of the system using ray-tracing approach (commercial software). Design/ Set up of test bench. Test operation, Data collection, Data processing end evaluation reporting. Furthermore, the installation is equipped with a large quantity of auxiliary devices that allow the execution of a wide range of tests in the field of solar thermal chemistry.

- **SolWater** is the biggest European installation dedicated to **Solar photocatalytic treatment and disinfection of urban and industrial wastewaters** at pilot plant scale.

- **WetOx** is a new installation based on combinations of high temperature and pressure, various proportions of oxygen and nitrogen, the use of oxidants and different catalysts, for the application of highly powerful oxidant conditions for the

treatment of complex wastewaters. The innovative part of this installation lays in its combination with solar energy.

- The **HyWATOx** installation is connected to a CPC photo-reactor for the simultaneous removal of organic contaminants contained in aqueous solutions and the generation of solar hydrogen. The high versatility of this system opens a wide spectrum of applications for the **simultaneous solar hydrogen production and wastewater treatment**.
- The **DESAL** installation offers the following services: a) **SOL-14** installation allows to carry out **experimental model (stationary and dynamic) validation of MED processes**. First effect of the MED plant works with hot water instead of saturated steam, which allows to establish different temperature levels for the top brine temperature (TBT) as well as the final condenser temperature. The installation also permits to perform research in new materials for the heat exchange surfaces required in the MED process. The connection between solar field, thermal storage and MED plant is regulated through a fully-controllable system of valves which also lets to carry out research tasks in automatic control. b) **DEAHP-MED** installation offers full flexibility for operation of a coupled MED-DEAHP system at different temperatures, allowing **simulation model validation and research in control algorithms** for the different existing flow regulation devices. The DEAHP can be powered by solar thermal energy coming from a 230-m^2 small-aperture parabolic trough solar field (NEPSOLAR 1200) or from a propane gas-boiler (saturated steam at 180°C, 10 bar abs. c) **AQUASOL-II** solar field flexibility offers to the research community the possibility of coupling it with any low-temperature thermal desalination system (60-90°C) for **testing purposes under real climatic conditions**. The AQUASOL-II installation also offers the service of **automatic control development and testing for static collector solar fields and dynamic modelling**. d) **PILOT-MD** is designed for **evaluating solar thermal membrane distillation (MD) prototypes at pilot scale**. The researchers can assess the performance of their own MD modules, model validation of the existing MD modules at PSA and research in automatic control of solar MD processes. e) **LAB-MEM**: The PSA desalination laboratory is equipped with three bench-scale units for the **testing of membrane distillation (MD) process** that allow to the researchers to test different types of membranes adjusting the MD channel

configuration to all channel variants (air-gap, permeate-gap, direct-contact) as well as testing them at atmospheric pressure or working with vacuum. Temperature precision of 0.5°C and driving force temperature difference controllable make these bench-scale unit a very valuable tool for model validation and experimental assessment of the membrane behaviour under different conditions of the saline solution. The bench-scale unit with 2-stage **forward osmosis (FO)** and **pressure-retarded osmosis (PRO)** is equipped with two small plate and frame modules of FO which can be connected in series or in parallel. The hydraulic circuit can be modified so that the modules can be operated in PRO mode. With this installation the researchers are able to carry out **assessment of new FO membranes, and model development of this kind of technology** due to the full control of temperatures and flows within the experimental installation.

2.1.4. Contact Details for Research Infrastructure

<table>
<tr><td colspan="2">Plataforma Solar de Almería
Address: Ctra. de Senés km 4.5, E-04200 Tabernas, Almería (SPAIN)
Website: www.psa.es</td></tr>
<tr><td>Ricardo Sánchez
Tel.: +34 950 387 800
E-mail: ricardo.sanchez@psa.es</td><td></td></tr>
</table>

2.2. Centre National de la Recherche Scientifique (CNRS)

2.2.1. Research Infrastructure

Name of the infrastructure:	Procédés, Matériaux et Énergie Solaire
Location:	*Odeillo, France:* 12 solar furnaces of various sizes and high concentration (1 to 1000 kWth) + parabolic trough solar plant with thermocline and ORC (150 kWth) + 1 dish with Stirling engine (52 kWth) + Solar Energy Materials characterization equipment *Targassonne, France:* Themis solar tower plant (5000 kWth)
Web site address:	www.promes.cnrs.fr

2.2.2. Description of the infrastructure

The Procédés, Matériaux et Énergie Solaire (PROMES) is a Research Unit of the National Centre for Scientific Research, depending on the Institute for Engineering and Systems Sciences (INSIS-CNRS); it is also linked by an agreement to the University of Perpignan (UPVD). The laboratory is located in three sites: Odeillo-Font Romeu (Solar furnaces owned by CNRS), Targasonne (central receiver solar facility in Thémis site owned by the 'Pyrénées Orientales' Council/CD66) and Perpignan (near the University at the Technosud business zone.). The staff of PROMES is about 150 employees, working in 8 research groups and 7 technical or administrative departments. The main research fields are 'materials under extreme conditions' and 'conversion, storage and transport of solar energy'. PROMES is leading or is involved in several European projects; it is also currently leading 2 important national projects: the 'laboratory of excellence' SOLSTICE (Solar Energy: Science, Technology and Innovation for Energy Conversion) and the 'equipment of excellence' SOCRATE (Concentrated solar energy, advanced researches and energy technologies). Since 2016, the solar facilities of PROMES in Odeillo and Targasonne have been identified by the French Ministry of higher education research and Innovation as the National Solar Thermal Research Infrastructure for Concentrated Solar Power under the acronym FR-SOLARIS.

- Access is offered to 12 high concentration solar furnaces, whose thermal power ranges from 1 to 1000 kW. Maximum solar concentration is as high as 16000 suns (16 MW/m^2) for the **MSSFs**, and 10000 suns for the **MWSF**, which is exceptional and allows temperature reaching nearly 4000°C. The maximum power available at the focal point (spot diameter as large as 80 cm) of the big solar furnace MWSF is 1 MW, which allows world unique high temperature pilot-scale experiments. All the solar furnaces are equipped to accurately modulate power and flux density over wide ranges and very high dynamic control. This allows to perform repeatable heating cycles, including with fast controlled temperature variations (> 1000°C/s). Numerous setups are available for tests under air, vacuum or controlled atmosphere, most with complex instrumentation such as in situ-characterization of chemical composition.

- The pilot trough parabolic plant (**MicroSol'R**) has 2 orientations of the collectors (E-W and N-S) for testing of collector tubes with thermal oil. It is equipped with two kinds of thermal storage systems including a thermocline, a loop for steam generation and an ORC turbine to produce electricity. This research infrastructure has high flexibility of its 3 heat loops with extensive instrumentation (temperature, flow, pressure), allowing for e.g. the test of new materials for solar absorption, tests of materials for thermal energy storage, or tests of thermodynamic converters and assessing their efficiency.
- The 5MW **Themis** solar tower plant is one of the rare facilities of this size available for research and development purposes up to the prototype scale. It is particularly suitable for research on high temperature solar plants (800-1400°C), allowing the test of next generation solar processes as well as innovative cycles. Its availability has been extended by creating a second stage suitable for pilot size experiments (power up to 500 kWth).

A large spectrum of research areas is supported, either at high temperature (up to 4000°C) and/or high flux (up to 16 MW/m^2), from fundamental researches to industrial developments, such as: electricity production, thermochemistry (e.g. solar fuels), physics (e.g. radiation heat transfer & fluid flow), solar metallurgy and high temperature materials synthesis or characterization (e.g. aerospace, automotive, solar receivers, nuclear reactors…), photophysics (e.g. high concentration PV, thermoionic conversion…), biology (e.g. bioreactors, water treatment…), industrial heat, etc.

2.2.3. Services offered by the infrastructure

The CNRS-PROMES (FR-SOLARIS) infrastructure allows to carry out **any research**

or development activity under low to high solar radiation (up to 16 MW/m²) and low to high temperatures (up to 4000°C), thanks to its facilities and the existing setups: various chambers, automated robots and extensive instrumentation, both in-situ or in laboratory for specialized rare material properties characterisations. The facilities are supported by a dedicated team of experienced specialists notably in processes, instrumentation, material science, control.

The services offered include but are not limited to:

- Solar energy harvesting process testing and qualification, such as:
  - Electricity production processes development and qualification, such as:
    - Pressurized air processes (as previously in PEGASE, POLYPHEM, SICSOL…) at the MWSF or at the THEMIS facility (which includes a 1 MWe turbine)
    - Oil based process, at ambient pressure up to 350°C at the MicroSol'R facility
    - Particles HTF based processes as previously in NextCSP, SolPART, CSP2 projects…
    - Or any other HTF as required by the project.
    - Concentrated PV cells qualification and ageing.
    - Solar thermoionic receivers qualification.
  - Heat storage qualification: materials qualification, chemical compatibility, control strategies. For example:
    - Thermocline heat storage with easily changeable filler materials at MicroSol'R facility: 2hrs @ 150 kWth in oil at 320°C.
    - Double tanks heat storage with oil at MicroSol'R facility.
    - Metallic phase change materials for solar tower receivers (MSSF, MWSF and THEMIS facilities).
    - Or any other heat storage as required by the project.
  - Solar fuels production such as but not limited to:
    - Hhydrogen production: for example the direct thermolysis of water beyond

3500°C with the horizontal axis MSSF.

- Hydrocarbons production: biomass solar heat treatment with or without water vapour, to form charcoal, natural gas, liquid hydrocarbons such as tar, petrol, oil… Such projects and collaborations have been hosted at the MSSF and at the MWSF.
- ,M metallic fuels such as Zn, Mg or Ce s metallic cycles. MSSF and MWSF have been used to reduce those oxides and store solar energy which can be used in fuel cells or to produce hydrogen for example. See for example the Solar2zinc project.

- Any industrial heat processes testing such as:
  - Receiver development and qualification
  - Heat storage development and qualification
  - Chemistry conversion to solar energy such as $CaCo_3$ reduction for concrete production (SolPART project at the MWSF)
  - Coatings for solar receivers (trough and towers) development and qualification
  - Control strategies development and qualification

- Material science for CSP, aerospace, automotive sectors… For example:
  - Synthesis of nanomaterials at MSSF such as:
    - Carbon based nanotubes and fullurenes, including graphene
    - Oxide based such as ZnO for electronic components such as for condensators and LEDs
    - Other such as nanotube WS2 for low friction agent
  - Coatings deposition on metals or on ceramics at MSSF such as:
    - Heat barriers such as ZnO and YO_2 on metals such as turbine blades or on ceramics such as space probe shields (as previously for ESA and NASA)
    - Low friction and/or enhance hardness metallic coatings for automotive

engines

- ☐ Ceramic synthesis at MSSF such as:
  - Solar sintering of newly proposed materials such as for medical applications (bone replacement, dental repairs…)
  - Evaluation of heat treatment process on the produced materials properties: heating and cooling rates, plateaux lengths…
- ☐ properties: heating and cooling rates, plateaux lengths…
- ☐ Glasses synthesis at MSSF such as:
  - Vitrification of waste materials for safety issue such as flying ashes or nuclear wastes
  - Production of lowcost heat storage materials from waste materials (coal plants, waste plants…), sands…
- ☐ Accelerated ageing of solar receivers with the SAAF setup at the MSSF.
- ☐ High flux material exposition at MSSF and MWSF, such as:
  - Space or aerospace heat shield qualification such as re-entry shield on Earth, Mars or Venus, or solar heat shields for probes around Earth or around the Sun, as for the NASA, ESA, CNES…
  - Nuclear sector material testing such as corium pool walls studies and qualification of materials for ITER walls
  - Thermal shocks such as for space components or nuclear bomb simulation
  - High temperature mechanical characterisation, including using ultrasonic acoustic instrumentation (IMPACT setup at the MSSF)
- ☐ Synthesis of new materials such as metallic foams
- ☐ Characterisation of materials at high temperature: emissivity measurements for solar receivers, aerospace shields such as for NASA, and ESA space probes, …

■ Any other experiment or prototype requiring high temperature fast and clean, and/or high radiative flux.

These activities are carried out from lab-scale (MSSF) to industrial prototype scale (MWSF, MicroSol'R, THEMIS) thanks to the wide range of available facilities within the RI since 1949, with the support of skilled experienced technicians, engineers and scientists.

2.2.4. Contact Details for Research Infrastructure

Procédés, Matériaux et Énergie Solaire Address: 7 rue du Four Solaire, 66120 Font Romeu Odeillo Via, France Website: www.promes.cnrs.fr	
Emmanuel Guillot Tel.: +33 4 68 30 77 56 E-mail: Emmanuel.guillot@promes.cnrs.fr	

2.3. Agenzia Nazionale per le Nuove Tecnologie, L'energia e lo Sviluppo Economico Sostenibile (ENEA)

ENEA
Italian National Agency for New Technologies, Energy and Sustainable Economic Development

2.3.1. Research Infrastructure

Name of the infrastructure:	ENEA Thermodynamic Solar Laboratories
Location:	Casaccia (Rome), Italy
Web site address:	www.enea.it

2.3.2. Description of the infrastructure

The ENEA Thermodynamic Solar Laboratories (ST-ITES) includes the most part of the activities performed in ENEA concerning Concentrating Solar Energy. Its activity (as SOLTERM Project) has started in year 2000 and since that time it gained a specific experience in several fields of CST technologies particularly in Parabolic Trough system operating at high temperature with MS (Molten Salts) as HTF (Heat Transfer Fluid), and has recently expanded its research interests also in Dish systems. The ST-ITES is one of the largest public research centres in Europe. The centre extends over an area of around 90 hectares, with 188 buildings (offices, laboratories, facilities and service infrastructures). ST-ITES regularly hosts more than 1400 employees. Besides ENEA personnel, Casaccia hosts every day 300-400 people, Italians and foreigners, coming from universities, research organizations and industries.

- The **P.C.S.** (**P**rova **C**ollettori **S**olari, i.e. Test of Solar Collectors) facility operates with MS up to 550°C for field testing, in actual size, of PTCs and other components, including HEXs (Heat Exchangers) coupling MS with steam or air. The **PCS** facility is the main testing loop built by UTRINN-STD and it is unique in the world. It consists in two lines of PTCs operating at high temperature and uses, as HTF, a binary mixture of molten salt (60% $NaNO_3$ and 40% KNO_3) operating up to 10 bar, 550°C and 6.5 kg/s. It consist of a close loop totally instrumented (flow rate, pressures, temperatures, etc.) a molten salt storage (7 m^3 of useful volume). The PCS plant has been involved in several European projects (MATS, SFERA, SFERA-II, STAGE-STE, ORC-PLUS, RESLAG, InPOWER, ARCHETYPE) and other international collaboration with the companies of the sector. Actually the **PCS** facility is devoted to:
  - ☐ characterization of the receiver tubes in outdoor tests
  - ☐ characterization of the molten salt circuit components in real operating environment;
  - ☐ training for management of CSP molten salt circuit.;
  - ☐ characterization of different types of thermocline TES systems

From 2019 the PCS experimental loop will be integrated with two additional circuits:

- RESLAG circuit that is a system dedicated at analysis of the performance of a TES system based on backed bed with MS as HTF and , this will be first facility in Europe at this scale (The first installation will be available for SFERA III Project from September 2019).

- ORC-PLUS circuit that is a system dedicated at analysis of the performance of a thermocline TES system that employs low melting molten salt as Heat Storage Material and oil as Heat Transfer fluid

- The **OMSoP** solar dish facility will be made available for the characterization of solar receivers to be coupled with the dish technology for the distributed electricity production. The peculiarity of this system is the integration of the dish technology with micro-gas turbines (MGTs) to produce electricity from solar source in a small scale capacity range (5-10 kWe). The introduction of a MGT in place of the more conventional Stirling engine, was aimed at increasing the system lifetime and improving its operability in relation to solar energy short time fluctuations.

Figure 9. **Prova Collettori Solari (PCS) facility (left) OMSoP solar dish facility (right)**.

- The **Thermophysical Characterization Laboratory** (TFC-LAB) consists of a proper set of equipment and devices able to obtain a complete experimental characterization of MS mixture and of each feasible HTF/HSM for CST applications; An experimental set-up to investigate the chemical stability was assessed during the last SFERA-II Project and is present at the DTE/STT/ITES ENEA thermophysical characterization laboratory. The equipment allows the determination of the produced gases and the liquid chemical composition, and permits to work in isothermal conditions and to control the reaction atmosphere. The TFC labs include instrumentations specifically dedicated to the characterization of thermal fluids. There is no other lab-scale facility in Europe like this one, uniquely designed and dedicated to thermal fluid chemical stability.

The TFC-LAB has been involved in several European projects (MATS, SFERA-II, STAGE-STE, ORC-PLUS, RESLAG, Hycycles, Sol2Hy2) regarding the investigation of thermal fluids and the development of solar fuels.

- The **ENEA Solar Collector Optics laboratory** (ESOL) is deeply involved in the international effort to outline guidelines for CST components. ESOL is devoted to the optical characterization of materials, components and systems for CST applications At this purpose several innovative instruments have been proposed along the last years. The most relevant are:

  - Solar Mirror Qualification set-up: it is an innovative instrument specifically conceived for measuring solar near-specular reflectance versus incidence and acceptance angle.
  - VISprofileLF: shape measuring of reflective panels (facets) for linear Fresnel CST plants. Differently to the others instruments, VISprofileLF is based on an original digital version of deflectometry, which ensures better reliability and accuracy.
  - VISprofilePT: idem, but for parabolic trough panels and by means VIS approach.
  - VISfield: in-field direct measurement of the intercept factor of parabolic trough modules by means of the
  - An upgraded version of VISprofilePT of ESOL which will be made available in January 2019.
  - ENEA patented VIS methodology (shape evaluation and ray tracing are not needed!). Optical coating characterization: spectrophotometric measurements, modelling and features evaluations.

Figure 10. **Thermophysical Characterization Laboratory, TFC-LAB (left) and ENEA Solar Collector Optics laboratory, ESOL (right)**.

2.3.3. Services offered by the infrastructure

- The **PCS** plant is equipped to auxiliary experimental loop to test *Components and Systems for molten salt solar plant* as : Molten Salt Thermal Energy Storage, Coil Steam Generators , New generation of Receiver Tubes and Linear Solar PTC, System Engineering and Management specialized to Heat Transfer Fluid as molten salt, Numerical Analysis/Simulation Codes, measure of thermal loss for molten salt pipe heated with electric cable heater or with joule direct system with or without molten salt circulation. The tests are performed by operators according to the tests matrix, and they control the plant process by means of a Digital Control System (DCS). The DCS system plant allows to look in real time all the data related to the tests, and to store it in a proper file. Its main purpose is the testing, in actual operating conditions, of all the components (and operating procedures) of a molten salt solar field and namely: parabolic solar collector (including supporting structure, mirrors, tracking and driving systems and heat collecting elements), components of molten salt loop (circulating pumps, sensors, valves, preheating systems) and operation and maintenance procedures (control loops, draining and filling procedures, etc.). Inside of the PCS facility was present a special testing loop that permit to do characterization tests of discharge and charge of a thermocline TES system, that uses low melting molten salt as heat storage media (HSM) and thermal oil as energy vector. In the new experimental mock up devoted at packed bed + MS will be possible to perform test of thermocline system during the charge and discharge operation of the TES System.

- The **OMSoP** solar dish facility is a unique installation, recently completed (July 2017), to validate advanced technical solutions for coupling the solar dish technology with the MGTs, enabling the production of small scale, reliable and easy to maintain units for either on or off-grid applications. The replacement of the Stirling engine, which is the most common technology coupled with the solar dish systems, with a micro-gas turbine is the distinctive feature of the project. The use of MGT with the concentrated solar source for distributed electricity production in remote areas is a new perspective. This technology provides highly efficient and reliable components, capable of standing high temperature levels (800-900°C) and unstable operative conditions, and provides an integrated solution for the MGT and the solar dish maximizing the overall plant efficiency, depending on the meteorological conditions.

- The **TFC-LAB** has in general a key role in the national and European project where ENEA is involved and that are concerned with the innovation and characterization of thermal fluids. Several reports, posters and peer reviewed publications have been produced by the DTE/STT/ITES laboratory ENEA staff, also in collaboration with other Italian and European researchers. As a rule, the laboratory provides information about the thermophysical features of thermal fluids (both for heat storage (HSM) and transfer (HTF)), especially molten salts, their compatibility with fillers and CST components, and their chemical stability. In particular, the latter topic is currently of considerable interest, given the necessity to determine the upper temperature limit of thermal fluids before their use in real conditions for CST plants. Actually, the degradation reactions can be very slow and lead to the production of gases, besides the changes in the melt composition. To date few data are agreed upon regarding the chemical stability of molten salts, and there is a clear interest from the concerned scientific community and the materials manufacturers to obtain information about this feature.

- The **ESOL** is endowed of several on the top original instruments making it a unique place to conduct advanced experiments. Guests will be assisted by the ENEA stuff for the best usage of instruments and methods of the laboratory, many of which are greatly influencing the drafting of the international guidelines in the optical sector.

2.3.4. Contact Details for Research Infrastructure

<table>
<tr><td colspan="2">ENEA Thermodynamic Solar Laboratories
Address: Via Anguillarese 301 -00123 Rome, Italy
Website: www.enea.it</td></tr>
<tr><td>Walter Gaggioli
Tel.: +39 0630 486 212
E-mail: walter.gaggioli@enea.it</td><td></td></tr>
</table>

2.4. Deutsches Zentrum für Luft- und Raumfahrt EV (DLR)

2.4.1. Research Infrastructure

Name of the infrastructure:	Deutsches Zentrum für Luft- und Raumfahrt
Location:	Jülich, Germany
Web site address:	www.dlr.de

2.4.2. Description of the infrastructure

The Solar institute of the German Aerospace Center (DLR) is one of the leading research facilities in the world. In Jülich it offers a large variety of services for research, such as:

- Experimental platform at the Solar Tower Jülich (STJ) for testing of full-scale receivers or solar reactors under real conditions
- **Synlight**, the worldwide largest solar simulator with radiation power up to 300kW and three independent test chambers
- Two further major research facilities (solar furnace and a smaller solar simulator) in Cologne, only 50 km away from Jülich
- Excellent accessibility of the facilities including storage space, spacious testing rooms and fully equipped workshops
- Over 30 well-trained specialists and scientists, who can offer assistance to research groups in the field of solar energy, solar process or chemical engineering.
- Various local craftsman's workshops and specialised traders located close to the facility, which enables fast and cost effective repairs or reconstructions of test rigs

2.4.3. Services offered by the infrastructure

Since the **Synlight** installation is quite new (less than a year of operation) only few results has been achieved so far. During testing of full-scale solar-thermal reactors temperatures over 1000°C were reached. At the moment further qualification works are running, in order to determine the highest reachable temperatures (over 3000°C expected) and the heat flux profiles.

The five main areas of research supported by the infrastructure are:

- Testing of components for concentrated solar thermal plants
- Testing of solar-chemical reactors
- Testing of high-temperature resistant materials or components
- Rapid material ageing and resistance testing (UV, heat), also for simulation of radiation conditions in space
- Calibration of optical measuring devices

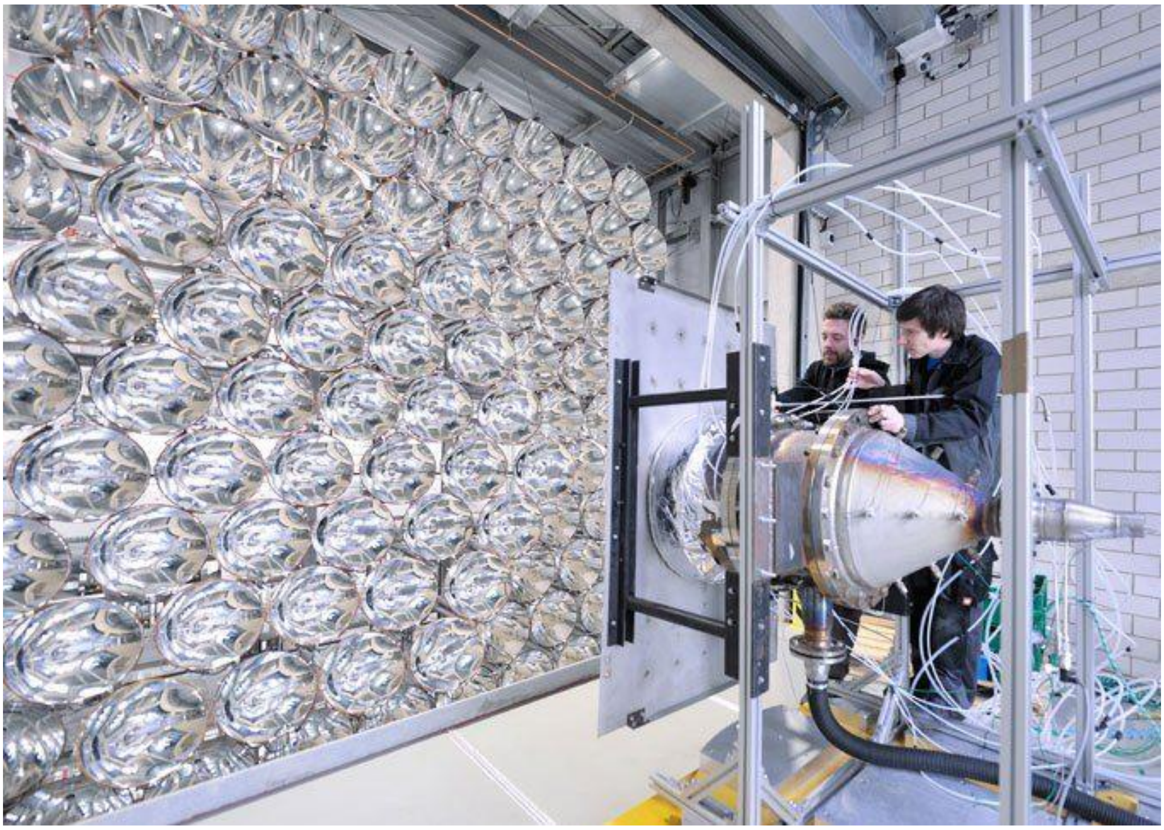


Figure 11. **Interior view of the High Flux Solar Simulator Synlight**.

2.4.4. Contact Details for Research Infrastructure

DLR- Institute of Solar Research Address: Rudolf-Schulten-Str. 11, 52428 Jülich Website: www.dlr.de/sf/en/	
Dmitrij Laaber Tel.: +49 (0) 2203 601 2831 E-mail: dmitrij.laaber@dlr.de	

2.5. Commissariat à l'énergie atomique et aux énergies alternatives (CEA)

2.5.1. Research Infrastructure

Name of the infrastructure:	DURASOL
Location:	Le Bourget-du-Lac, France
Web site address:	http://liten.cea.fr

2.5.2. Description of the infrastructure

DURASOL infrastructure is located at French National Institute for Solar Energy (INES) and consists of: On one side, equipment for indoor ageing tests reproduce the environmental conditions for accelerated testing, such as climatic chambers, UV weather-ometer, mechanical test bench, potential induced degradation chambers… On the other side, outdoor experimental benches monitor the aging of solar technologies under real operating conditions with continuous monitoring. Finally, there is also a number of characterisation equipment to analyse the degradation of materials and to adapt the processes for solar systems development versus durability issues.

The **DURASOL** infrastructure comprises three installations located in the same centre:

- **Optical Characterisation of Materials (Opti-Lab)**: Absorbance & emittance at ambiance temperature and high temperature. Spectral emittance in temperature up to 1000°C. Emittance at 80°C. Optical microscopy observation. Hemispherical reflectance, specular reflectance, directional reflectance. Colorimetry of paints. FTIR spectra. Optical microscopy observation.

- **Optical Characterisation of Systems, (Shape)**: Reflector qualification: Optical performance evaluation, flux mapping, tracking accuracy evaluation. Absorber qualification: Thermal performance evaluation. Accelerated ageing: Flux up to 60 suns.

- **Accelerated Ageing Under Controlled Conditions (Indoor)**: A unique ensemble of equipment: Mechanical Load Test bench for PV Modules, Damp Heat Chamber, Dark and Illuminated Lock-In Thermography, Dynamic Mechanical and Thermal Analyser (DMTA), Hazemeter, High Accelerated Stress Test (HAST) Chamber, Industrial Manufacturing Line for PV Module Prototyping, Insulation Resistance Tester, Module-scale Impact and Vibration Test bench, Multi-angle Colorimeter, Portable Digital Microscope, Potential Induced Degradation Test Bench, Real-time and in-situ thermal measurement system, Small-scale climatic chambers for parameter screening, Solar Simulator for PV Modules, Spectrophotometre IR Emissivite Haute Temperature, Spectrophotometre UV Visible ARTA, Suntest XXL +, Surge Voltage Tester, Thermal and Optical test chamber for large PV modules, Weatherometer LMPV-WOM.

The areas of research normally supported by the infrastructure are related to PV/ST/CST systems:

- Opti-Lab: optical characterisation of materials,
- Shape: optical characterisation of systems,
- Indoor: accelerated ageing under controlled conditions.

The infrastructure could also be open to any area of research interested in shape measurement and accelerated ageing of material subjected to solar flux.

2.5.3. Services offered by the infrastructure

The services offered by the infrastructure within the framework of the SFERA-III Project are:

- Advanced lab equipment for accelerated ageing under controlled conditions,
- Optical characterisation from materials to systems,
- Absorbance, emittance at ambiance temperature and high temperature, and
- Spectral emittance in temperature.

2.5.4. Contact Details for Research Infrastructure

DURASOL Address: 50 avenue du Lac Léman, 73375 Le Bourget-du-Lac Website: www.ines-solaire.org	
Valery Vuillerme Tel.: +33 479 792 126 E-mail: valery.vuillerme@cea.fr	

2.5.5. Research Infrastructure

Name of the infrastructure:	ESTHER
Location:	Grenoble, France
Web site address:	www.liten.cea.fr

2.5.6. Description of the infrastructure

The **ESTHER** infrastructure belongs to the experimental platform of CEA's Grenoble center dedicated to thermal applications. It comprises thermal storage and heat exchangers testing facilities, a PCM corrosion test bench, and storage media characterisation devices (Thermal-diffusivity, conductivity, calorimetry, ovens). Two main facilities located in the same building will be included in SFERA-III Trans-national Access programme:

- **Dual media thermocline facility (STONE)**: This sensible thermocline heat storage involves a tank filled with solid materials (rock and sand) that are gradually heated or cooled by an oil loop. This prototype-scale (3 m^3) thermocline tank has been built and successfully operated at CEA Grenoble since 2010, demonstrating highly controllable and predictable operation at different oil velocities and fine understanding of the hydraulic and thermal behaviours of the storage tank.

Figure 12. **STONE: A dual media thermocline storage prototype + Oil loop**.

- **Latent Heat Storage with PCM (LHASSA)**: The LHASSA facility is a high pressure water-steam closed loop designed to test latent storage modules under operating conditions similar to those of commercial DSG STE plants (145 bar, 350 °C) with a flow rate of 35 g/s. Electric heaters simulate the STE solar field while a condenser and an air cooler condense and subcool the fluid flow at the storage outlet. A pressurizer is used to maintain the required pressure level in the loop and acts as an expansion vessel. Two PCM storage modules (3 m^3 and 1 m^3) have been installed on this loop and tested successfully. These modules contain sodium nitrate as PCM, compatible with water's evaporation temperature of 300°C.

Figure 13. **LHASSA: A PCM storage prototype + HP Steam loop**.

The area of research normally supported by the infrastructure is thermal energy storage for CST applications. The infrastructure could also be opened to research on thermal energy storage for other applications for industry or other thermal power production systems. Participation in SFERA-III will increase the visibility of these unique facilities initially dedicated to private partners and undoubtedly increase the opportunities for international cooperation.

2.5.7. Services offered by the infrastructure

The services offered by the infrastructure within the framework of the SFERA-III

Project are:

- Validation of the thermo-hydraulic behaviour of storage systems under operating conditions similar to commercial STE plants,
- Performance and durability assessment of thermal storages,
- Optimization of the operating procedures,
- Validation of numerical model of thermal storage systems.

The STONE facility already showed highly controllable and predictable operations, allowing fine understanding of the hydraulic and thermal behaviours of the thermocline tank in controlled operating conditions. Results from numerical models were already successfully compared with the experimental data, proving that they can be used for performance predictions and for the definition of operating strategies of commercial STE plants. In 2016, STONE hosted academics from CIEMAT's Thermal Storage Group for 3 weeks. One outcome has been a paper presented during SolarPACES 2017

The LHASSA facility was already used to validate the thermo-hydraulic behaviour of PCM storage tanks under operating conditions similar to commercial DSG STE plants, with measured storage performances meeting the specifications, optimized operating procedures, and obtaining good agreement with simulation results given by dynamic models developed at CEA.

2.5.8. Contact Details for Research Infrastructure

<table>
<tr><td colspan="2">ESTHER
Address: 17 rue des Martyrs, 38054 GRENOBLE Cedex 9
Website: www.liten.cea.fr</td></tr>
<tr><td>Valery Vuillerme
Tel.: +33 479 792 126
E-mail: valery.vuillerme@cea.fr</td><td></td></tr>
</table>

2.6. Universidade de Evora (UEVORA)

2.6.1. Research Infrastructure

Name of the infrastructure:	Universiade de Évora, Renewable Energies Chair
Location:	Évora, Portugal
Web site address:	www.catedraer.uevora.pt

2.6.2. Description of the infrastructure

The Renewable Energies Chair was created in November 2010 and its Chairman is Prof. Manuel Collares Pereira. Focus its activity on Concentrating Solar Power, developing and testing new technologies to capture and convert solar radiation into heat (for environment heating and cooling, industrial processes, desalination, production of synthetic fuels, etc.) and electricity by photovoltaic or thermal means.

The infrastructure is involved in different solar concentrator developments. Some topics include: Development of stationary or quasi-stationary Compound Parabolic Concentrator for medium temperature applications and for solar thermal electricity, R&D in solar concentrated driven systems modelling (e.g. for combined heat and power production end industrial process heat), Solar Thermal energy storage (solid storage and molten salts storage), Materials related research and processes in particular dust control deposition in mirrors and covers, Direct normal radiation measurement and statistics. Particularly important is the 2-axis platform (PECS, dimensions: 18*13m^2) with two circuits, one operating with thermal oil up to 400°C and the other with pressurized water, unique in current World context. Additionally a facility with Molten Salts for collectors fields testing at temperatures up to 565°C, which is expected to be fully operational still during 2017. It is also relevant to mention the close cooperation with LNEG – National Laboratory for Energy and Geology, with whom it has constituted the National Research Infrastructure in Solar Energy Concentration – INIESC.

The infrastructure is composed by the following installations:

- **CER** - The Renewable Energies Chair centre (CER) can provide services on analysis/certification of solar thermal concentrators, thermal storage, PV and batteries systems, Materials related research and processes in particular dust control deposition in mirrors and covers, Direct Normal Radiation measurements and statistics.

- **INIESC** - INIESC stands for National Research Infrastructure in Solar Energy Concentration. It belongs to ESFRI infrastructures roadmap and it has two nodes, UEVORA and LNEG. The offer of TA to a node is the responsibility of each of the institutions. The research/services topics within INIESC are: i) Solar concentrators for thermal conversion of solar radiation, ii) Standardized methods and experimental testing of solar concentrators, iii) Solar Energy Storage, iv) Solar fuels, v) Applications and system demonstration, vi) Solar materials and components.

- **DNI-N** - The DNI-N is a network of solar stations measuring global, direct and diffuse solar radiation and its statistics. It is composed 12 stations mainly distributed in the southern of Portugal. It can provide data related to solar radiation.

- **PECS** - The PECS is a two-axis platform (test bench dimensions: 18*13m^2) with an oil loop to test concentrator collectors and promote collector development, as well as certification purposes. There are two circuits, one operating with thermal oil up to 400°C and the other with pressurized water.

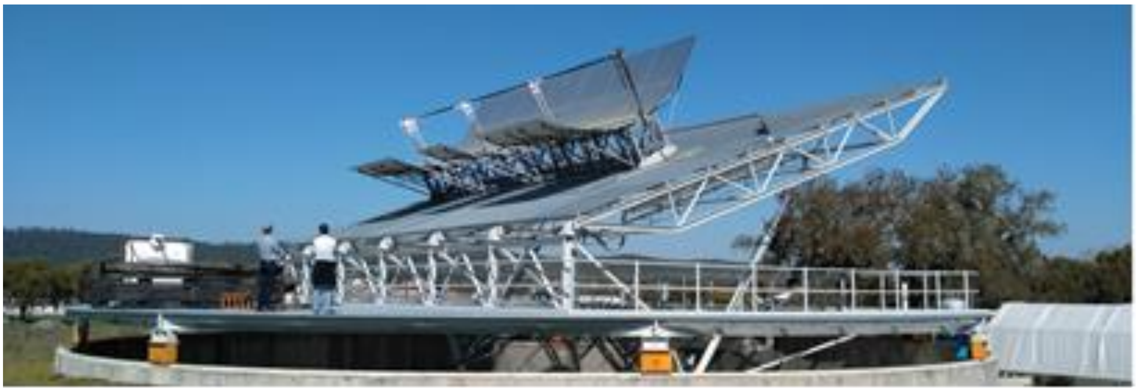


Figure 14. **Two-axis solar platform (PECS) for the testing of solar concentrators modules up to 400ºC with oil loop**.

The areas of research normally supported by the infrastructure are as follows:

1. Solar resource (DNI) and meteorological parameters assessment:
   1.1. Solar Radiation Measurement and Weather Station (DNI-N)
   1.2. Advising on Solar Radiation Measurement & Data Processing (DNI-N)
   1.3. DNI Measurement and Analysis (DNI-N)
2. Services on reflectors and concentrators:
   2.1. Optical Properties of Mirrors. Reflectance measurement. Facets characterization (PECS)
   2.2. Photogrammetry Measurement of Concentrator's shape (PECS/CER)
   2.3. Optical and thermal characterization of solar concentrators (PECS, INIESC)
3. Services on heat transfer fluids:
   3.1. Qualification HTF based on particles (INIESC)
   3.2. Characterization of HTF thermal properties (INIESC)
   3.3. Qualification HSM/HTF (INIESC)
4. Services on thermal energy storage (media & systems):
   4.1. Study on molten salts in PTCs and pipe section (INIESC)
   4.2. Advanced solid concepts for thermal energy storage (INIESC)
   4.3. Characterization of Materials and Components for TES systems with molten salts (INIESC)
   4.4. Qualification of Heat Storage using concrete under experimental conditions (INIESC)
   4.5. Simulation and modelling of thermal storage systems. Integration in STE plants or industrial heat processes (INIESC/CER)

2.6.3. Services offered by the infrastructure

The infrastructure can provide:

- Nonimaging optics expertise on the design of solar concentrators (this includes Innovative (patented) concepts of Etendue Matched Concentrators increasing end optimizing the optical performance of the line-focus Linear Fresnel Reflector concept)

- Development of stationary or quasi-stationary Compound Parabolic Concentrator for medium temperature applications and for solar thermal electricity (certification and process heat for industry)

- Solar Thermal energy storage (solid storage and molten salts storage). Innovative concepts as thermocline up to 565°C are currently being developed within the H2020 project NewSOL
- Materials related research and processes in particular dust control deposition in mirrors and covers (New techniques for cleaning are being developed and dust measurements are possible)
- Direct normal radiation measurement and statistics (Data can be provided as a service)

All these services (within solar thermal field) attracted many researchers and students during the last years. Currently, the CER has a French Post-Doc researcher and the Évora Molten Salt Platform (which belongs to the INIESC) has a joint management with DLR (Deutsches Zentrum für Luft- und Raumfahrt, Germany) and other companies such as TSK Flagsol. Eltherm, Steinmüller Engineering and Yara as currently using the installations. The infrastructure has several MSc and PhD students and some international Post-Docs are also working within the structure. Some of the most interesting results obtained by the users include the development of the solar loop with parabolic troughs under the project HPS-2 (http://www.emsp.uevora.pt/) and the tests with a parabolic trough module on PECS platform.

2.6.4. Contact Details for Research Infrastructure

Universiade de Évora, Renewable Energies Chair Address: Palácio Vimioso, Largo do Marquês de Marialva 7000-809 Évora, Portugal. Website: https://www.en.catedraer.uevora.pt/	
Hugo Silva Tel.: +351 266 760 803 E-mail: hgsilva@uevora.pt	

2.7. Eidgenoessische Technische Hochschule Zuerich (ETHZ)

2.7.1. Research Infrastructure

Name of the infrastructure:	ETH Zürich
Location:	Zürich, Switzerland
Web site address:	www.prec.ethz.ch

2.7.2. Description of the infrastructure

The ETH's Professorship of Renewable Energy Carriers conducts research aimed at the advancement of the thermal and chemical engineering sciences applied to renewable energy technologies. The research focus comprises high-temperature heat/mass transfer phenomena and multi-phase reacting flows, with applications in solar power, fuels, and materials production, decarbonisation and metallurgical processes, CO_2 capture and recycling, energy storage and sustainable energy systems. PREC has pioneered the development of solar thermochemical reactor technologies for producing clean transportation fuels using concentrated solar energy. The infrastructure is equipped with a high flux solar simulator for testing reactors and receivers used in CST technologies, as well as supporting characterisation techniques such as flux measurements and *in-situ* gas analysis. Additionally, there is a materials chemistry laboratory (PREC-CHEM), with state of the art facilities for characterizing materials, and the thermodynamics and kinetics of multi-phase reactions.

- **HFSS** - The high flux solar simulator is used for testing of CST components that are designed to be irradiated, such as reactors, steam generators, and solar receivers in general. It comprises an array of high-pressure Xenon arcs, each close-coupled with truncated ellipsoidal specular reflectors. It provides an external source of intense thermal radiation - mostly in the visible and IR spectra - that closely approximates the heat transfer characteristics of highly concentrating solar systems; yet it enables experimental work under controlled steady and unsteady conditions for reproducible measurements and model validation. It delivers 6 kW radiative power at a peak flux exceeding 5,000 suns (1 sun = 1 kW/m²), in a hot spot approximately 2-3 cm in diameter. The lab is also equipped with a suite of support and monitoring equipment, including a sophisticated flux system (lambertian target and calorimeter), gas analysis systems (gas chromatography andmass spectroscopy), temperature measurement (pyrometers, thermocouples), cooling systems etc. which can be utilized subject to availability. This allows for flexibility in accommodating a broad range of test campaign wants, and offers a suitably advanced range of measurements to characterise the performance of the tested components under steady state and/or varying high intensity illumination.

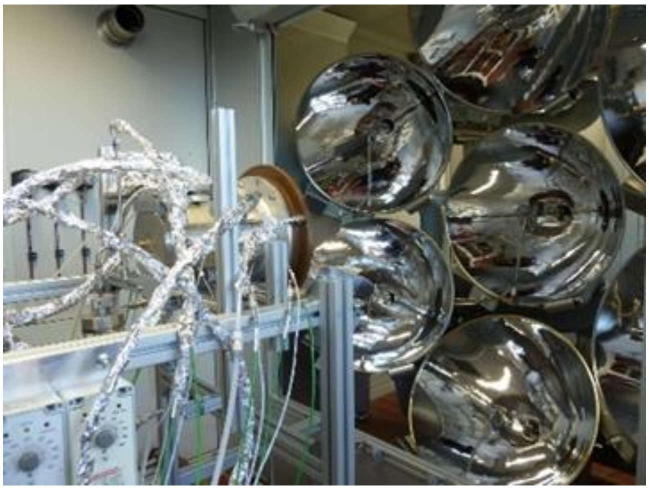


Figure 15. **The HFSS, photographed with a reactor at the focus ready for testing**.

- **CHEM** - The chemistry laboratory offers a unique suite of instruments, well suited for thermodynamic and morphological characterisation of materials for use in CST applications. The instrumentation is as follows, (1) two thermogravimetric analysis systems (TGAs, from Netzsch and Setarum), with gas analysis instrumentation (gas chromatography, mass spectrometry) and differential scanning calorimetry (DSC) capabilities, (2) a Netzsch laser flash system for measuring thermal diffusivity (conductivity/heat capacity) of materials, (3) a MicroMetrics Brunauer-Emmett-Teller (BET) a surface area analysis system, (4) a Horiba laser scattering particle size distribution analyser, (5) a Hitaschi scanning electron microscope (SEM) and (6) facilities for wet chemical synthesis. It is used to prepare and characterize materials, in terms of their thermodynamic properties such as heat capacity, thermal conductivity, phase changes, as well as other physical characteristics such as morphology, high temperature stability, etc. The thermogravimetric analysis (TGA) systems available in the lab also allow reaction systems such as redox cycles to be characterised, allowing for enthalpies of reactions to be determined. The systems are also suited to performing relaxation kinetics for many such reaction systems.

Figure 16. **The Netsch TGA from the CHEM installation, with a gas chromotography system monitoring the outlet gas**.

2.7.3. Services offered by the infrastructure

- The HFSS and CHEM labs, together with the PREC personal have been central to the success of the Professorship of Renewal Energy Carriers (PREC) infrastructure at ETHZ. The HFSS has been used to **test prototype solar fuel reactors**, and make a number of ground breaking first time demonstrations of CST solar fuel technologies. This includes **solar gasification**, **methane reforming**, **thermochemical redox cycles** and **membrane reactors**. The group has collaborated with international researchers, utilizing the HFSS lab to demonstrate the cerium redox cycle which was published in science back in 2010 [Chueh *et. al. Science,* 2010]. In summary, it can be used to perform a range of **experimental testing campaigns requiring high fluxes of solar** like radiation up to a maximum value of 5 kW/m^2.

- The CHEM lab has been used for **screening and testing of materials** at the laboratory scale **for application in heat storage**, **thermochemical redox cycles**, **gasification**, **catalysis**, with a focus on solar chemistry. In addition, it has been used more generally to **test the suitability of materials for high temperature operation and cyclability**, in terms of structure and durability. It offers a broad range of techniques, which allowed PREC to develop an excellent reputation in materials research for CST applications.

The infrastructure has been broadly publicised at conferences and in peer reviewed journals, and continues to receive positive recognition from the international CST community. Opening the available installations for the first time to non-partner international users, is an exciting development for the PREC group and we anticipate considerable interest in the facilities.

2.7.4. Contact Details for Research Infrastructure

ETH Zürich Address: Sonneggstrasse 3, 8092 Zürich, Switzerland Website: www.prec.ethz.ch	
Brendan Bulfin Tel.: +41 44 633 87 30 E-mail: bulfinb@ethz.ch	

2.8. Fundación IMDEA Energía (IMDEA)

2.8.1. Research Infrastructure

Name of the infrastructure:	IMDEA Energía
Location:	Móstoles (Madrid), Spain
Web site address:	www.energy.imdea.org

2.8.2. Description of the infrastructure

The IMDEA Energy's infrastructure provides support to the users for the design, simulation, optimization, testing and control of concentrating solar thermal technologies as well as other complex systems related to thermal processes. It gathers dedicated computational tools and experimental installations covering technology readiness levels (TRL) from 1 up to 6. The infrastructure has unique facilities able to achieve very high concentrations in a wide range of total power (from 1 kW up to 250 kW), which are of special interest in materials development and high-temperature applications.

Areas of research comprise advanced optical engineering; computational fluid dynamics and mechanics for solar receivers, reactors and energy storage systems; numerical integration analysis of solar thermal systems and components in industrial and thermal processes and supervisory control and data treatment and acquisition by means of computational tools; materials synthesis and characterisation under high irradiances; testing of solar absorber materials; testing solar reactor components under very-high irradiances.

IMDEA Energy offers four (4) installations for the TA in this Project:

- The **Computational Design Lab for High Temperature Processes (HTPU-CDL)** offers specific hardware and software tools for characterising, designing and modelling solar thermochemical and high temperature components and processes.
- The **High Temperature Processes Laboratory (HTPU-LAB)** provides support For characterization of tested materials: a bench-top Scanning Electron Microscope Model Hitachi TM-1000 that includes an Energy Dispersive X-Ray analyser from Oxford Instruments; X-Ray Diffractometer (XRD) X'Pert Por MPD and BrukerD8 Advanced; ICP-OES (Chemical Measurements) Perkin Elmer OPTIMA 7300DV with autosampler; Thermo-Gravimetric Analyser (TGA/DSC) for measurements at high

temperature and under reactive atmosphere (water vapour) Netzsch Jupiter F3 449. Laboratory-scale high-flux 7kWe-solar simulator. Sintering furnaces, Flux measurement systems with CCD cameras and high-flux calorimeters; temperature measurement by IR cameras and pyrometer.

- The **42kWe High Flux Solar Simulator (KIRAN42)** comprises the IMDEA Energy's 42 kW high flux solar simulator (HFSS) and various test rigs and measurement techniques specifically designed for exhaustive thermal, optical and chemical characterisation of solar receivers, solar reactors, thermal shielding and other components subjected to defined high irradiance distribution. Independent testing room fully equipped (gases, mono- three-phase electricity supply, computer data sockets). 42kWe Xe-arc high flux solar simulator. Beam attenuator and radiation homogenisers. Computer-controlled 3-axis positioning system (250 kg. load capacity). Test rig for aerothermal characterisation of components for high-temperature process heat applications. Test rig for chemical characterisation of materials and components of solar reactors for high-temperature process heat applications. Thermographic cameras, radiometers, bi-chromatic pyrometer. H_2, O_2, CO, CO_2, CH_4 gas analysers for continuous gas composition monitoring and micro-gas chromatograph.

Figure 17. **42kWe High Flux Solar Simulator (KIRAN42)**.

- The **Very High Concentration Solar Tower (VHCST)** is a unique infrastructure for testing components and devices under very high solar fluxes. The VHCST has a customized heliostat field that makes use of the most recent developments on small size heliostats and a tower with reduced optical height (15 m) to minimize visual impact. The heliostat field of 250 kWth (500 m^2 reflective surface) has been built adjacent to IMDEA Energy premises at the Technology Park of Móstoles, Spain, and consists of 169 small size heliostats (1.9 m x 1.6 m). In spite of the small size and compactness of the field, when all heliostats are aligned, it is possible to fulfil the specified flux above 2500 kW/m^2 for at least 50 kW and an aperture of 16 cm, with a peak flux higher than 3000 kW/m^2.

The VHCST installation will be available in SFERA-III from Sept. 2020 because of current testing commitments.

Figure 18. **Views of the VHCST facility**.

2.8.3. Services offered by the infrastructure

- **Services on reflectors and concentrators** (Characterization of optical properties of solar reflectors; outdoor exposure of solar reflectors; corrosion and materials protection studies under outdoor exposure, Measurement on material properties); Available services on concentrator's experimental characteristics (optical and thermal characterisation of solar concentrators, small-heliostat performance qualification),
- **Experimental services on absorbers** (accelerated aging of absorbers and absorbing coatings, optical properties/characterization of absorbers & receivers

and their coating),

- **Services on heat transfer fluids** (qualification HTF based on particles),
- **Services on thermal energy storage** (characterization of heat storage and components for TES, thermal & thermochemical properties evaluation for thermal storage materials, development and characterization of materials and components for TES, advanced solid concepts for thermal energy storage, simulation and modelling of thermal storage systems. Integration in STE plants or industrial heat processes),
- **Services on solar chemistry** (high temperature solar chemistry: high temperature thermochemical research units, thermal and thermodynamic characterization of prototype reactors for central receiver on tower technologies under real operating conditions, solar fuels and thermochemistry, qualification of solar driven processes under realistic conditions; solar hydrogen: solar hydrogen production process qualification, solar thermochemical hydrogen/syngas, water splitting thermochemical cycles), and
- **Services on material testing and qualification** (Surface materials treatment, Metallography. Micro-hardness analysis. Thermogravimetric analysis, Advanced materials analysis and characterization techniques, Material synthesis, Analytical Services -Other Materials-, Gas analysis, Thermal analysis).

Scientific achievements have been reached in the framework of research stays in other RD programmes funded by EU, national and regional entities. Currently approx. 4-5 international users use the IMDEA Energy's installations per year.

Examples of possible services and research activities are the analysis of thermal performance of materials for high-temperature heat processes by continuous monitoring of temperature and irradiance on the samples; use of a test rig for aerothermal characterisation of volumetric absorbers (which involves monitoring of pressure drop, temperature distribution along the sample, and thermal performance); and the use of a test rig for thermo-chemical characterisation of solar reactors at 10kW-scale (Continuous monitoring of temperature distribution and gas composition).

2.8.4. Contact Details for Research Infrastructure

IMDEA Address: Avda. Ramón de la Sagra 3. 28935 Móstoles, Madrid (SPAIN) Website: www.energy.imdea.org	
Name of contact person Tel.: +34 91 737 11 36 E-mail: jose.gonzalez@imdea.org	

2.9. The Cyprus Institute (CYI)

2.9.1. Research Infrastructure

Name of the infrastructure:	CyI Campus
Location:	Athalassa (Nicosia) Cyprus
Web site address:	www.cyi.ac.cy

2.9.2. Description of the infrastructure

The Cyprus Institute (CyI) has been developed as an international science and technology organization, to strengthen the research community of Cyprus, help transform its economy to a knowledge-based economy and to create a research hub for the Eastern Mediterranean region. For realizing its vision the Institute is developing pioneering research infrastructures and programmes involving cutting-edge, high throughput technologies, in order to address problems of local and regional significance and of international interest and providing high quality graduate education and training in related areas. The research conducted at the institute will continue to be relevant to many important scientific and technological areas and challenges relevant to Cyprus, as well as to regional and international society. The research thrusts of CyI include:

- Solar energy research and solar desalination
- Renewable energy sources and synergies with natural gas exploitation
- Environment and environmental monitoring
- Climate change and climate impact assessments
- Energy conservation with a focus on the built environment
- Natural Resources and water management
- High performance computing and its applications
- Visualization technologies
- Digital cultural heritage and digital libraries for use in Culture and Education.
- Cross-disciplinary approaches and technologies to archaeological sciences, bioarchaeology and cultural landscapes.
- Enabling technologies for Culture and Tourism.

CyI offers two (2) infrastructures for the TA in this Project:

- The **LiFE facility** is a Fresnel solar collector with a light structure integrated onto a building to support air-conditioning with the help of an absorption chiller and thermal storage. The facility is operational since July 2016. The facility provides a test-bench for conducting under realistic conditions, experiments geared at the development improvement and utilizations of Solar Energy in the built environment sector. The facility offers meteorological data in parallel to experiments. It consists of a The primary reflector is constituted by 288 mirrors, arranged in 18 rows, driven thanks to 72 DC motors controlled by 18 PLCs (SIEMENS 1214C). Dimension of each mirror is 0.32m x 2m. The mirrors are parabolic with a focal distance varying from 3.8m to 5.9m, according to the distance to the absorber. The global reflective area is 184.32 m^2. Reflectivity of the mirrors is superior to 92%. The field is oriented North-South with a 32 m long receiver including 8 absorbers in series under vacuum. The receiver is located at 3.7m above the roof level. A parabolic secondary reflector (90% reflective) is located on top of the receiver. The heat transfer fluid is oil (Durathem 450S) working at up to 180°C. A master PLC controls the PLCs for the motors and the pump of the oil. A weather station records data on the nearby building (Temperatures, wind speed, wind direction and DNI) and the DNI every second.

Figure 19. **Aerial view of the LiFE facility**.

- The **Athalassa's Heliostat Testing Laboratory** (**AHTLab**) was established in 2013 in CyI's Headquarters in Nicosia with objective to experimentally test heliostat performance and novel technologies relating to heliostat tracking. The facility consists of two heliostats, each with a single facet of 4.5 m^2 reflective area and a focusing distance of 35 m, along with a 12m high tower with a 2×2 m lambertian target. The laboratory has access to local meteorological data, including DNI. Additional instrumentation consists of an industrial camera with neutral density filters used to observe the heliostat image on the target to determine tracking errors. This laboratory is currently used for quantification of tracking errors, determination of heliostat shape through photogrammetry, and validation of ray-tracing codes. New areas of investigation include development of new tracking mechanisms and electronics for heliostat control.

2.9.3. Services offered by the infrastructure

The services offered at the **LiFE facility** are:

- **Outdoor optical and thermal performance of Linear Fresnel receiver**. CyI can offer an access to the facility including reflectometry measurements as well as thermo-sensors for the identification of heat transfer model (ISO 9806, quasi-dynamic). This facility hosts visitors for onsite experimentation to work on the reflectivity assessment of the primary reflector and asset the effect of the dust on the efficiency. The users also worked on the identification of the steady-state model of the absorber. A thermal camera, a weather station and a pyrheliometer are also available.

- **Linear Fresnel control algorithms**. The Fresnel collector hosted visitors for the tuning of the control of the motors to enhance the tracking strategy of the primary reflector. The facility is unique in the sense that it is an easily accessible facility and fully monitored. Also the facility offers a unique configuration with 72 DC motors that allows flexible control strategies for tracking unlike Fresnel collectors on which several rows are mechanically connected to the same gear.

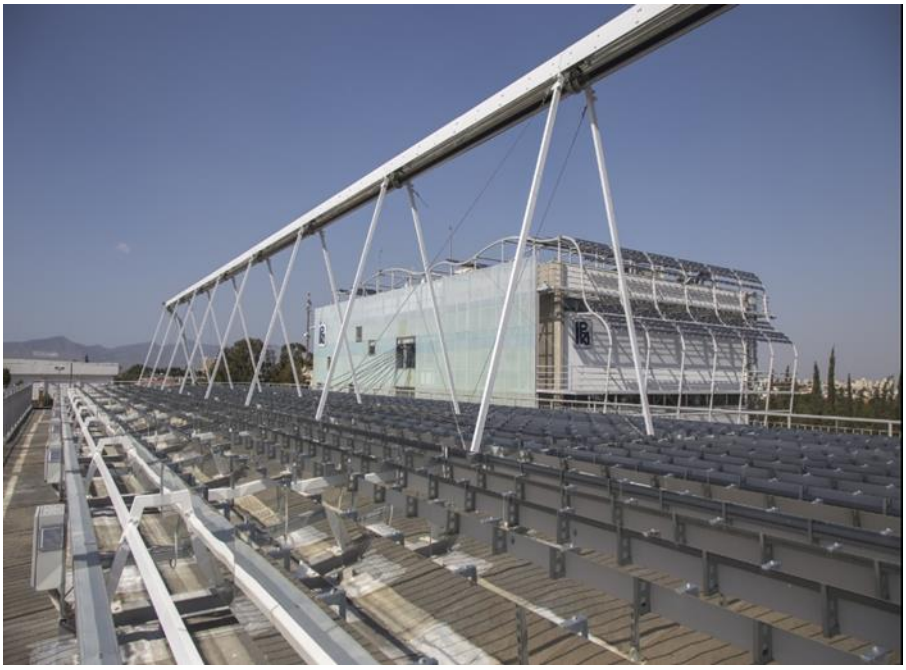


Figure 20. **Control algorithm testing at the LiFE facility**.

The services offered at the Athalassa Heliostat Testing Laboratory are:

- The Athalassa Heliostat Testing Laboratory provides users with access to heliostat hardware to test their own **control algorithms for heliostats**.
- The facility includes an instrumented lambertian target and video monitoring that can be used to **determine the effectiveness of the tracking algorithms or feedback methods developed**.

Several groups on the European level are working on developing both heliostat tracking algorithms and closed-loop feedback systems for heliostats, which need to be tested on a laboratory scale to verify their performance.

2.9.4. Contact Details for Research Infrastructure

<table>
<tr><td colspan="2">CyI Campus
Address: 20 Konstantinou Kavafi, Aglantzia, Nicosia, Cyprus
Website: www.cyi.ac.cy</td></tr>
<tr><td>Marios C Georgiou
Tel.: +357 22 208 604
E-mail: m.c.georgiou@cyi.ac.cy</td><td></td></tr>
</table>

2.9.5. Research Infrastructure

Name of the infrastructure:	PROTEAS
Location:	Pentakomo, Cyprus
Web site address:	www.cyi.ac.cy

2.9.6. Description of the infrastructure

The **PROTEAS Facility** is one of the most complete research and development facilities in Cyprus devoted to concentrating solar thermal energy systems. The facility uniquely combines ideal environmental conditions with a seaside environment for research, development and testing of technologies related to Concentrated Solar Power (CSP), Solar Thermal Energy (STE) and thermal Desalination of Sea Water (DSW). It consists of a field of 50 heliostats with a total reflective area of 250 m^2, concentrating the sun's light more than 800 times on a point and delivering a peak power of 150 kW of thermal energy. The field layout efficiently utilizes the hilly terrain with a high-density placement of heliostats. An 18-meter tall tower with multiple experimental stations is available for the central receiver placement and experimental work as well as distribution network for sea water intake and discharge for desalination experiments. Continuous monitoring of environmental conditions is available through a fully automated weather station.

The true strength of the PROTEAS Facility is the versatility it provides for the researchers and experiments hosted there via:

- Solar Receiver – iSTORE: A novel solar energy receiver that converts solar radiation into heat and simultaneously store it is being developed. The Integrated Storage and Receiver device is a proprietary development pioneered at the Cyprus Institute.
- Energy Storage: Experimentation in thermal energy storage is pursued in order to maintain continuous supply of electricity throughout periods of cloudiness and during night-time. The energy is stored in a molten mixture of salts that can reach temperatures of 560 °C and acts as a battery releasing thermal energy per the operational strategy of the plant.
- Solar Desalination: A steam engine produces electricity and a thermal desalination unit (Multi Effect Distillation) is used for seawater desalination. Both devices work continuously to supply the end customer with two essential products: electricity and water directly from the sun. This versatile facility complements the research carried out at CyI's Athalassa campus, providing a test-bed for testing under realistic conditions experiments developed through The Cyprus Institute's various research activities. Additionally, in the spirit of collaboration the facility is open to the international scientific community on a merit based priority scheme.

Figure 21. **Aerial view of the PROTEAS facility**.

2.9.7. Services currently offered by the infrastructure

The **PROTEAS facility** is located in challenging conditions close to the sea in a semi-arid island environment. The infrastructure is supported by qualified scientists, engineers and technicians, who operate a fully tooled machine shop. The facility is regularly hosting visitors for onsite experiments (3-4 visitors per year).

The visitors for instance tested sensors prior to their installation into an experimental facility, both hardware and software. Support in terms of machining implementation and electronic developments were also provided.

2.9.8. Contact Details for Research Infrastructure

PROTEAS Address: Pentakomo, Cyprus Website: www.cyi.ac.cy	
Marios C Georgiou Tel.: +357 22 208 604 E-mail: m.c.georgiou@cyi.ac.cy	

2.10. Fraunhofer Gesellschaft zur Foerderung der Angewandten Forschung EV (Fraunhofer)

2.10.1. Research Infrastructure

Name of the infrastructure:	Fraunhofer Institut für Solar Energiesysteme ISE
Location:	Freiburg, Germany
Web site address:	www.ise.fraunhofer.de

2.10.2. Description of the infrastructure

Founded in 1981, Fraunhofer ISE, with a staff of 1200, is the largest solar research institute in Europe. Fraunhofer ISE develops materials, components, systems and processes in five business areas. For concentrated solar thermal power-, energy storage- and water treatment-technology, we develop materials, components, systems and processes. In addition to its R&D, the institute offers testing and certification procedures. Furthermore, it features an excellent laboratory infrastructure. In the SFERA-III Project, we offer access to the following installations:

C-lab: Optical testing and simulation of materials and components for concentrated solar thermal. The laboratory is equipped with equipment for characterization of solar reflectors (reflectance and scattering), mirror facets (shape and slope), absorbers and transmittive materials (absorptance, transmittance and emittance). Specular reflectance (VLABS) is measured for acceptance angles between 1mrad and 30mrad and incidence angles between 8° and 60°. Shape and slope of mirrors are measured with deflectometry with resolution from 1 µm to 1cm, samples from 5cmx5cm to 6mx2m or photogrammetry. For validation and impact assessment, an interface to optical simulations with ray-tracing is used (from components up to system simulations for LFC, PTC and Tower systems).

C-Lab field: Concentrator optics heliostat- and mirror test-field. The concentrator optics lab test field offers outdoor testing of heliostats, heliostat tracking, focal point tests, outdoor exposure of solar mirrors and testing of soiling on curved and flat mirror facets. It is equipped with three heliostats, a flexible target for focal point analysis and exposure racks and curved mirror facets for soiling assessment.

CD-Lab: Durability testing of materials for concentrated solar thermal. The durability lab comprises outdoor and indoor facilities. Outdoor test sites to expose materials / components are located at Freiburg, Germany, Gran Canaria, Spain, Negev Desert, Israel and Zugspitze, Germany. The outdoor test benches are equipped with systems for high-resolution climate data and sample monitoring. All sites are equipped with similar monitoring equipment: Temperature, Wind speed, Relative humidity, Irradiance (global and UV), corrosion information. For accelerated aging tests, we offer two climatic cabinets. Combined testing with controlled irradiation

(UV), temperature and humidity. Salt spray testing with possibility to adapt testing conditions (salt concentration, temperature, cycles) for large size samples.

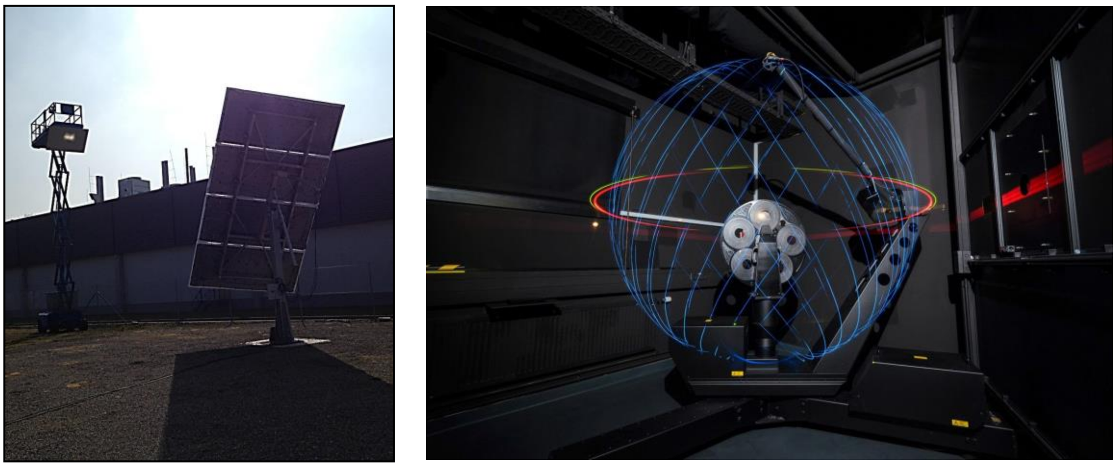


Figure 22. **Helisotat test field with flexible target. Right: PGLII Goniophotometer for characterization of scattering of solar materials**.

TES-Lab: Testing of materials and components for molten salt storage. The TES-Lab is equipped with laboratory set-ups for testing of molten salt materials, characterization of components for usage in molten salt environment (flow meters, valves, heating systems) and a single-tank molten salt facility. The storage vessel for testing of molten salt mixtures has a comprehensive temperature measurement system and wall heating measures to compensate heat losses and prevent salt mixing. We offer the evaluation of the salt stratification with special focus on the thickness of the thermocline zone of the storage tank during charging and discharging processes at various temperature differences (up to a maximum temperature of 550 °C) and various mass flow rates. Different salt mixtures and other fluids can be tested.

WT-Lab: Water treatment and desalination laboratory. The water treatment lab is equipped with laboratory set-ups for testing of water quality, industrial anorganic waste water treatment and desalination. With a special focus on testing and application of membranes for MD, RO, ED, DD from lab-scale to industrial scale. We offer detailed simulation models of MD-membrane processes, dimensioning of advanced ED processes and flexible operation of RO-processes. Further we offer simulation of water treatment processes and water saving plans for CST plants.

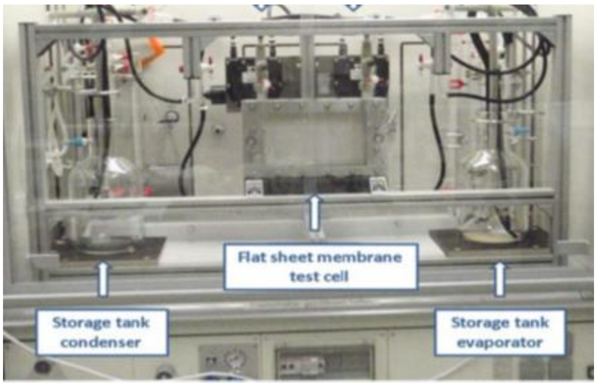


Figure 23. **Membrane distillation field operation testing plant (Left). Flat membrane test facility for aggressive media (Right)**.

2.10.3. Services currently offered by the infrastructure

We offer R&D related testing and certification services to industrial clients and in public research projects. Laboratory infrastructure can be used to analyse very different materials and components, from first lab samples to market-ready products, with TRL levels between 2 or 3 and 9.

Optical materials and components:

- Development and testing of solar reflector materials, absorber and glass- or foil-based coatings
- Development and testing of solar mirror facets for CST technology
- Development and testing of PTC, LFC and CSR components and prototypes
- Characterization of soiling

Heliostat field:

- Development of camera-based measurement methods for heliostat and receiver characterization
- Qualification of heliostats, tracker testing for heliostats and other technologies

Durability and lifetime:

- Development and manufacturing of PV modules, solar thermal collectors and mirrors
- Reliability, durability, energy yield of PV modules, solar thermal collectors and solar mirrors

- Qualification and testing equipment and procedures for PV components, BOS and grid connection, solar tracker, solar mirrors, absorber coatings.

Molten salt storage:

- Development of single-tank storage concepts, characterization of temperature distribution, flow pattern and heat losses
- Testing of industrial components for usage in molten salt environment
- Characterization of molten salt mixtures

Water treatment and desalination:

- Development and manufacturing of membrane-based desalination and water treatment processes. Characterization of ion-selective ED-membranes, characterization of MD-membranes via liquid entry pressure
- Vapour pressure measurement of unknown solutions
- Development of new energy recovery systems for RO
- Mineral extraction and fluid recovery, energetic optimization of separation processes

Our service units attracted many researchers and students during the last years. The access activity will provide unique opportunities for testing of materials and components for collectors, storage and water treatment to European research teams. We offer scientific and laboratory support from planning, testing to evaluation. Fraunhofer ISE campus offers a stimulating research environment and office space for users. Fraunhofer ISE has experience in offering support to external users in the framework of international projects, such as STAGE-STE, INSHIP or EERA PV projects.

2.10.4. Contact Details for Research Infrastructure

Fraunhofer Institut für Solar Energiesysteme ISE Address: Heidenhofstr. 2, 79110 Freiburg, German Website: www.ise.fraunhofer.de	
Anna Heimsath Tel.: +49 (0) 7 61/ 4588-59 44 E-mail: anna.heimsath@ise.fraunhofer.de	

2.11. Laboratorio Nacional de Energia e Geologia I.P. (LNEG)

2.11.1. Research Infrastructure

Name of the infrastructure:	National Laboratory for Energy and Geology
Location:	Lisbon, Portugal
Web site address:	www.lneg.pt

2.11.2. Description of the infrastructure

The **National Laboratory for Energy and Geology (LNEG)** carries out research, testing and technological development related to activities in the areas of Energy and Geology. Its mission is the promotion of technological innovation focused on science and technology, competitiveness and sustainable economic progress.

Within LNEG the **Laboratory of Energy** develops its research activity organized in two main research units:

- Unit of Renewable Energies and Integration of Energy Systems
- Unit of Bioenergy

LNEG has **testing facilities transversal to many research areas** within the field of renewable energy which have **proven to be relevant in the field of CST**.

LNEG is **one of the nodes** of "**INIESC - National Research Infrastructure in Solar Energy Concentration**". This infrastructure is one of the four research infrastrutures in the field of Energy identified in the national ESFRI infrastructures roadmap. INIESC has two nodes, UEVORA and LNEG. The access to the facilities of the INIESC infrastructure is performed directly to each of the responsible institutions.

LNEG's installations available to the SFERA-III Project are: **Materials and Solar**

Laboratories (testing laboratories accredited in accordance to EN ISO/IEC 17025); **Fuel Cells and Hydrogen installation**; and the **High-Performance Computing Cluster**.

Materials and Solar Laboratories facility

The **Laboratory of Solar Energy (LES)** and the **Laboratory of Materials and Coatings (LMR)** are complementary in their activities, which have been consolidated in the frame of National and International projects, namely STAGE-STE Project, forming a single facility.

The **Laboratory of Solar Energy** is dedicated to **testing of Solar Thermal Systems and its components**. Within the context of this SFERA III project, this laboratory will be dedicated to the **optical characterization of collector components**, e.g., reflectors and absorbers, giving support to the activities on durability of these components performed by LMR. For the optical characterization the Laboratory has a Spectrophotometer Perkin Elmer Lambda 950 with a 150 InGas Integrating Sphere and a Spectrophotometer FTIR Perkin Elmer Frontier with a gold coated integrating sphere (see Figure 24).

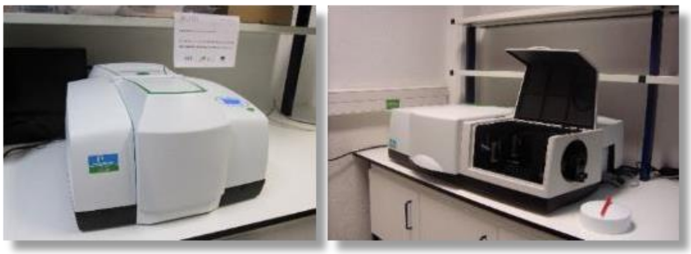


Figure 24. **FTIR Perkin Elmer Frontier (left) and Spectrophotometer Perkin Elmer Lambda 950 (right)**.

The **Laboratory of Materials and Coatings (LMR)** is specialized in the areas of durability, corrosion and anticorrosive protection of materials. This laboratory can perform research in the following topics:

- **Durability of solar reflectors, absorbers and absorbers coatings under accelerated aging environments** with and without cycles of temperature, humidity, radiation (UV and Xenon-arc) and contaminants (salt spray, SO_2, NO_2); The main equipment for this service are aging chambers: BINDER MKF 240,

LIEBISCH KSE 300-3003, VLM CON 400, WEISS WK3-340/0-BSB, Q-PANEL Q-Fog, ERICHSEN 606/400, Q-LAB QUV and Q-SUN Xe 3HS).

- **Durability of materials by exposure in two Outdoor Exposure Testing (OET) Sites**: LUMIAR/LISBOA-PORTUGAL with corrosivity C2-C3 (low-medium corrosivity) and SINES-PORTUGAL with corrosivity C5-CX (very high-extreme corrosivity). Lumiar test site is referred in European standards as reference site of high Ultraviolet radiation and Sines test site is reference test site with very high and extreme corrosivity;

- **Corrosion and anticorrosive protection studies under artificial aging environments** with and without cycles of temperature, humidity, radiation (UV and Xenon-arc) and contaminants (salt spray, SO_2, NO_2) and under outdoor exposure;

- **Compatibility and corrosion behaviour of metallic construction materials in contact with the molten salts (MS) mixtures and chemical stability of MS**. The main equipment for this service are high temperature furnaces, 15-30 L capacity cylindrical pot bath with and without mechanically stirred mixtures and TG/DTA/DSC;

Figure 25. **Main equipment for accelerated aging tests**

- **Morphological, physical and chemical characterization of materials and coatings** (polymeric and metallic materials, conversion coatings, and metallic and organic coatings. The main equipment for this service are optical and metallographic microscopes, XRD, SEM/EDS, tensile testing machines, EIS, thickness, colour and gloss equipment)

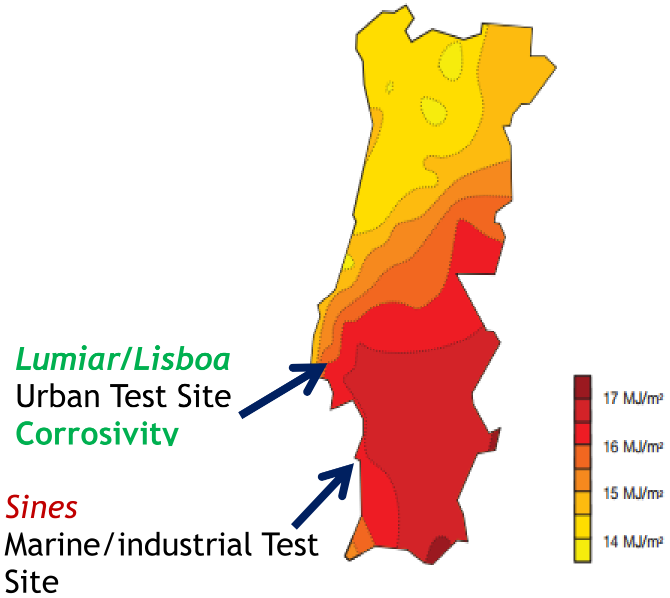


Figure 26. **Location and characteristics of the two Outdoor Exposure Testing (OET) Sites: LUMIAR/LISBOA-PORTUGAL and SINES-PORTUGAL**.

Fuel Cells and Hydrogen facility (H2) aims to achieve key sustainable goals in **renewable hydrogen production and CO_2 utilization**. The approach is materials to fuel. The goals require novel materials development that may harness efficiently light absorption with sufficiently high catalytic activity while also exhibiting chemical stability and durability under specific design protocols, without leaving behind the issues regarding competitive cost.

Facilities for **materials synthesis** are available using various routes for the production of catalysts and membranes. Laboratory reactors, metal or quartz vessels, are available for the production of nanostructured semiconductors either as nanotubes or particles, modified for more efficient charge generation and separation, using different doping strategies, supported or unsupported, applicable for solar hydrogen production from waste waters, solar treatment of residual industrial waters and renewable hydrogen generation and CO_2 utilization. Structural characterization of materials is available as well as optical and electrochemical characterization. Main equipment available: X-Ray diffractometer, FEG-SEM with coupled EDAX, FTIR spectrophotometer, UV-vis diffuse reflectance spectrometer, potentiostat/galvanostat for current-voltage curves, frequency response analysers for electrochemical impedance spectroscopy studies. Gas chromatographer with columns suited for identification of solar fuels. Development of modified membranes and separators is pursued as well as their characterization and evaluation of their conducting properties. Equipment available includes vacuum oven, membrane coater, temperature and pressure control press, cell facilities for evaluating conductivity using electrochemical impedance.

A **High-Performance Computing (HPC) Cluster** is also available at LNEG. The HPC Cluster capabilities are very interesting for a non-IT facility/infrastructure, considering the 96 computation cores, the 768 GB of RAM, the 32 TB for storage and a Infiniband (56 Gb/s) communication infrastructure among nodes for MPI computation.

Figure 27. **HPC Cluster with 96 computation cores, 768 GB of RAM, 32 TB for storage and an Infiniband (56 Gb/s) communication infrastructure and nodes for MPI computation**.

Naturally, this resource is dependent on the packages of applications available or to be available but at the moment it's **mainly devoted to Concentrated Solar Power**, namely Thermal Energy Storage problems. However, within the scope of the Project it will be available to other areas of CST research.

The High-Performance Computing Cluster is available for research of:

- Thermal energy storage (TES) systems;
- Solar Thermal Systems designed for power production (STE) or for solar heat application in industrial processes (SHIP);
- Optical simulation of solar concentrating systems;

2.11.3. Services offered by the infrastructure

The facilities of the LNEG infrastructure described above in the frame of SFERA III project can offer the following services:

- **Materials and Solar Laboratories installation (LMR-LES)**:
  - ☐ Optical characterization of collector components, either for durability studies or in the frame of development of new of reflectors and absorbers;
  - ☐ Durability of solar reflectors, absorbers and absorbers coatings under accelerated ageing and natural exposure;
  - ☐ Compatibility and corrosion behaviour of metallic construction materials in contact with molten salts mixtures and chemical stability of molten salts mixtures;
  - ☐ Morphological, physical and chemical characterization of materials and coatings;
  - ☐ Computation in High-Performance Computing Cluster.

- **Fuel Cells and Hydrogen facility (H2)**:
  - ☐ Studies on solar treatment of residual industrial waters;
  - ☐ Studies on solar hydrogen generation from waste waters;
  - ☐ Studies on CO_2 reduction to fuels and feedstocks.

- **High-Performance Computing Cluster (HPC)**:
  - Computer fluid dynamics (CFD) simulation;
  - Simulation of transient systems (including CST plants and components);
  - Optical simulation of solar concentrating systems using ray-tracing;
  - Computing time for user developed software.

These services are based on existing commercial and open source software such as an ANSYS Package for CFD; TRNSYS and Tonatiuh. Additionally, users may use their in-house developed software.

2.11.4. Contact Details for Research Infrastructure

National Laboratory for Energy and Geology Address: Estrada do Paço do Lumiar, 22, 1649-038 Lisboa Website: www.lneg.pt	
Maria João Carvalho Tel.: +351 210 924 766 E-mail: mjoao.carvalho@lneg.pt	

2.12. Middle East Technical University (METU)

2.12.1. Research Infrastructure

Name of the infrastructure:	ODAK
Location:	Ankara, Turkey

Web site address:	http://gunam.metu.edu.tr

2.12.2. Description of the infrastructure

The Center for Solar Energy Research and Applications (GÜNAM) is a multi-disciplinary center of excellence in the area of solar energy science and technology built up in the great campus area of Middle East Technical University (METU). It has been supported by the Turkish Ministry of Development since 2009. With rich infrastructure and human capital, GÜNAM is the leading and most comprehensive national center in the development of solar energy technologies including photovoltaic, **concentrating solar thermal**, and cross cutting technologies such as high performance buildings, smart grids, and smart cities with a mission to be a global player in this field.

GÜNAM consists of several research laboratories focusing on specific fields of solar energy conversion. These laboratories are

- Cristal Si (c-Si) Photovoltaic Solar Cell Research Laboratory
- GÜNAM Photovoltaic Pilot Line (PVPL)
- Inorganic Thin Film Photovoltaic Solar Cell Technologies (a-Si and CIGS)
- Organic Photovoltaic Research Laboratory (OPV)
- Dye Synthesized Solar Cell (DSSC) Research Laboratory
- Nano Materials Development Group (METU NANOLAB)
- **Solar Thermal Energy (STE) Laboratory called ODAK**

This **ODAK laboratory** is a high flux solar simulator (HFSS) with three 6 kWe Xenon short arc lamps for a total lamp power of 18 kWe. The lamps can be moved and rotated to change the target area and simulate both a point and line focus.

2.12.3. Services offered by the infrastructure

The HFSS allows testing under tightly controlled laboratory conditions throughout the day and year; i.e. unlike an outdoor solar furnace the operation of the simulator is independent of the outside solar resources. The simulator can be used for lower TRL **testing and development of a wide range of solar receivers, accelerated aging of materials**, **thermal shock and life-cycle testing**, **characterization of material properties**, and **photochemistry/photocatalysis experiments**. This is the only solar-simulator in Turkey and one of the few in the Eastern Mediterranean region.

Figure 28. **GunSolSim: ODAK High Flux Solar Simulator**

2.12.4. Contact Details for Research Infrastructure

<table>
<tr><td colspan="2">ODAK
Address: METU, Dumlupinar Bul. No:1, Ankara 06800, Turkey
Website: www.gunam.metu.tr</td></tr>
<tr><td>Name of contact person
Tel.: +90 312 210 2551
E-mail: itari@metu.edu.tr</td><td></td></tr>
</table>

2.13. Universidad de Almería (UAL)

2.13.1. Research Infrastructure

Name of the infrastructure:	Solar Energy Research Center
Location:	Almeria, Spain
Web site address:	www.ciesol.es

2.13.2. Description of the infrastructure

The Solar Energy Research Center (CIESOL) was built as a single-store building using bioclimatic standards and its design is aimed at efficient energy use. To fulfil this goal, CIESOL applies solar energy technology for the heating and cooling systems, as well as solar photovoltaic electricity, to guarantee the building's self-sufficiency. CIESOL has all necessary infrastructures for using control systems to achieve thermal, visual and air quality comfort and energy efficiency in buildings. As for water treatment, CIESOL has advanced analytical equipment for characterizing complex effluents, microcontaminant analysis and identification of transformation products, solar pilot plants for photocatalytic removal of toxic substances and water disinfection, as well as synthesis of homo- and hetero-metal-polymers with photocatalytic activity. CIESOL engages in research and technology transfer activities in the field of solar energy applications concerning organometallics and photochemistry, water treatment, environmental ANALYSIS, photosynthesis and desalination, modelling and automatic control of solar systems, home automation for energy efficiency, as well as solar cooling and solar resources assessment.

Water analysis laboratories

Three water analysis laboratories equipped with several analytical devices very convenient for the developed research line, which are ready and available to work on wastewater treatment, such as Ultra Performance Liquid Chromatography with Diode Array Detector (UPLC-DAD), Ionic Chromatography (IC) and Total Organic

Carbon (TOC) analyser provided with automatic injectors; spectrophotometer, devices for BOD5, COD and respirometry analysis. Advanced analytical equipment comprises a liquid chromatography-quadrupole linear ion trap mass spectrometry (LC-QqLIT-MS) system (Sciex QTRAP 5500) for quantitative determination of low-level organic microcontaminants, a liquid chromatography hybrid triple quadrupole time-of-flight mass spectrometer (LC-QqTOF-MS/MS) system (TripleTOF 5600+), useful for non-target identification of metabolites and transformation products and a gas chromatography triple quadrupole mass spectrometry (GC-QqQ-MS/MS) system for less polar and volatile compounds determination. The lab also has an automated solid phase extraction system and a nitrogen evaporator. Solar pilot plants for photocatalytic removal of toxic substances and water disinfection like solar tubular reactors with compound parabolic collectors (CPCs), raceway pond reactors (RPRs) and membrane biological reactors (MBRs) are available at CIESOL, all of them with instrumentation control systems.

(a) (b) (c)

Figure 29. **(a) Sciex QTRAP 5500, (b) Tubular photoreactor with compound parabolic collector (CPC), (d) Raceway pond reactor (RPR)**

Smart-grid:

In order to develop and validate both modelling and control algorithms a pilot micro-grid that incorporates renewable energy sources and an electric vehicle is available. More in detail, it is composed of a test-bed to characterize the DC-motor propelling the electric vehicle, a photovoltaic-battery system and electronic loads. The first element includes a flywheel that reproduces the inertia of the vehicle, so it is possible to test the DC-motor close to real conditions. Hence, the power exchanged between the vehicle's batteries and the micro-grid can be analysed under different driving scenarios. The second element comprises four photovoltaic panels developing up to 1000 Wp, a battery pack with a capacity of 5000 Wh and a charger-inverter. Another inverter will be installed in order to simulate the power exchange with the public grid. Finally, there are electronic loads used to reproduce the energy consumption registered in a laboratory of the CIESOL building. A computer is in charge of collecting the datasets of each component and it allows testing control algorithms and energy management strategies in order to optimize the power exchanges between the different systems.

On the other hand, a Smart Panel from Schneider Electric to counteract energy consumption of the building is available. Concretely, it allows to measure the characteristics of the electric network, to know the quality of the energy supplied and to have an energy-efficient facility. In this way, it is possible to gather the information related to building's electrical devices in real time in a computer or a smart device.

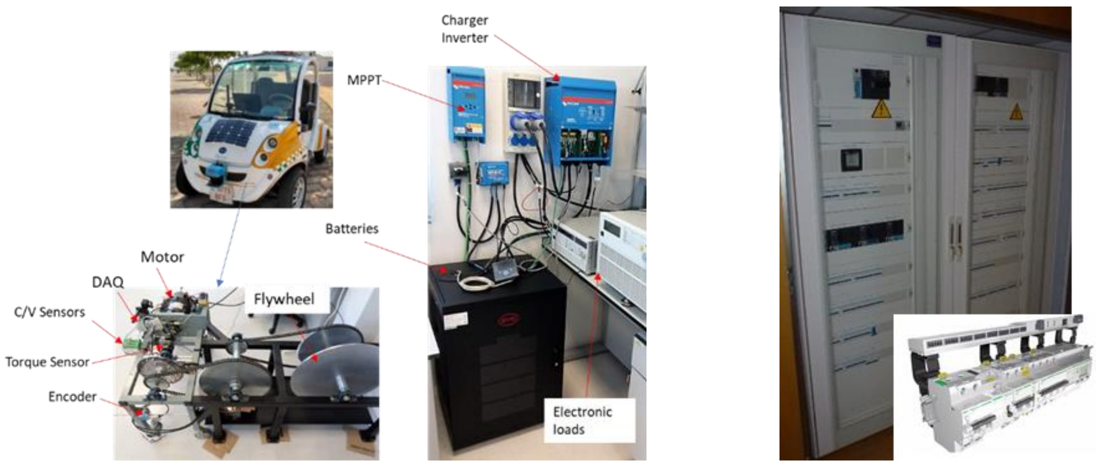


Figure 30. **Smart-grid (left) and smart-panel (right) located at CIESOL building**.

Home automation building

CIESOL has all necessary infrastructures for using control systems in order to achieve air quality, thermal and visual comfort and energy efficiency in buildings. More specifically, two rooms of the building have been selected and prepared to develop and analyse comfort control techniques. On the one hand, the first room has a total surface of 76.8m³ (4.96m × 5.53 m × 2.8m) and north orientation, and it is located on the second floor of the building between two other rooms with similar characteristics. In addition, it has one window of 4.49 m^2 (2.15 m × 2.09 m) placed at north wall. The window is one of the most important elements to model into the room, since it directly affects the use of energy from several points of view. More in detail, it allows the exploitation of natural light instead of artificial lighting, the use of shading devices, such as blinds, which can be used to control heat gains through it. Finally, it can be integrated into natural ventilation control strategies which can be translated into a reduction of energy consumption from the heating, ventilation, and air-conditioning (HVAC) system and an improvement of indoor air quality. Furthermore, this room is characterised by being one of the most monitored in the building since it counts with a huge variety of sensors (air temperature, air velocity, plane radiant temperature sensors,...), and also a set of actuators (automatized window and blind), that provides more freedom degrees to users' comfort control.

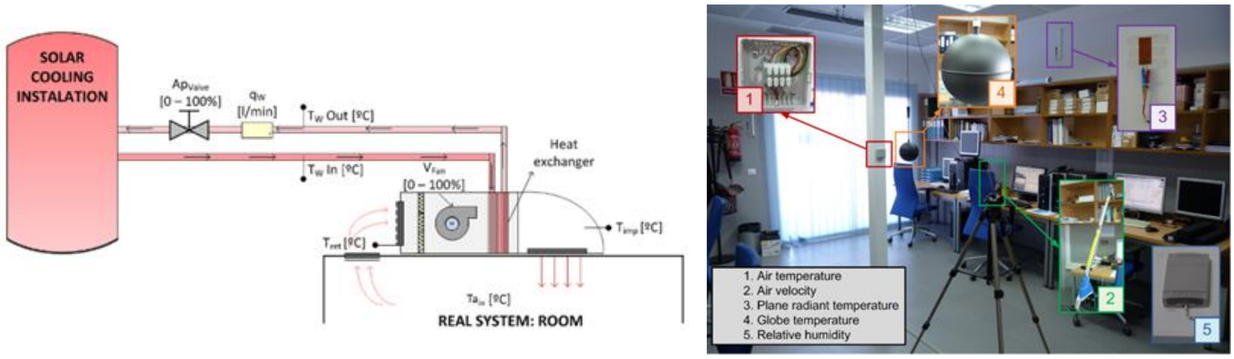


Figure 31. **Fancoil architecture (left) and the network of sensors and actuators (right)**.

The other selected environment is the meeting-room. It has a total surface of 13.37x5 m^2 and it is located on the first floor of the building with south orientation. It has three windows that are placed on the south and west facades with its associated inside Venetian blinds. Besides, by its distribution, it has been divided into two different zones: projector zone and windows zone. Moreover, it counts with a pendant-mounted artificial lighting system consisting of twelve luminaries containing each one four TL-D 18W/54-765 Philips fluorescent lamps. In the projector zone are included eight luminaries and in the windows zone there are four luminaries that assure an average illuminance level at the workspace of 500 lux. Furthermore, this room has different actuators and sensors, such as, two indoor low-cost luxometers, which are placed in a middle point of each zone, an outdoor luxometer located at the meteorological station of the building, and a presence sensor used to detect when the room is empty. On the other hand, the set of actuators is composed by the motors of the blinds that allow controlling the venetian blinds degree of aperture and orientation and an artificial light switch (On/Off actuator).

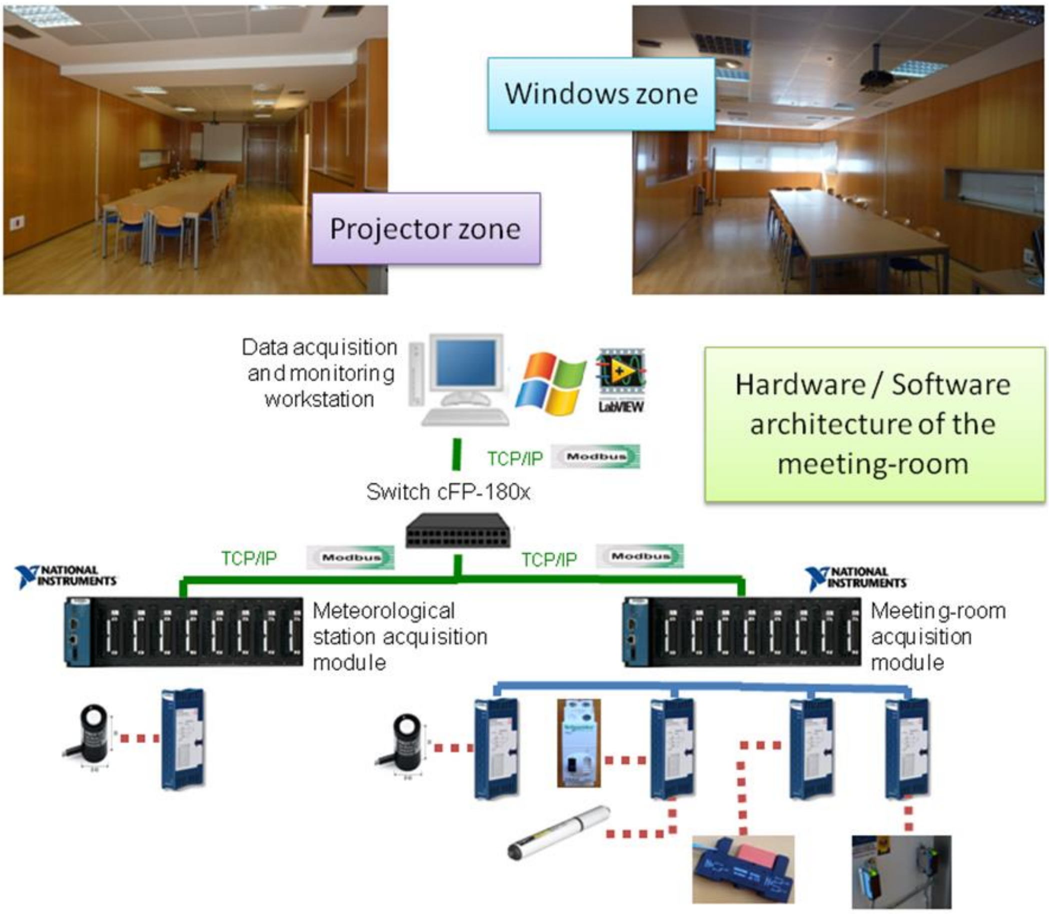


Figure 32. **Meeting room and its software and hardware architecture**.

Solar cooling installation

The CIESOL building has an active HVAC system based on solar energy and it is composed of a solar collector field, a hot water storage system, a boiler and an absorption machine with its refrigeration tower, with a total cooling power of 70kW. The scheme of the solar cooling installation is divided into three main circuits: the primary that is responsible for providing the necessary energy for the HVAC system. The secondary is in charge of flowing cold water (in summer) or hot water (in winter) to the different fancoil units distributed all around the building. Finally, there is a third auxiliary circuit that is responsible for connecting the absorption machine with the refrigeration tower.

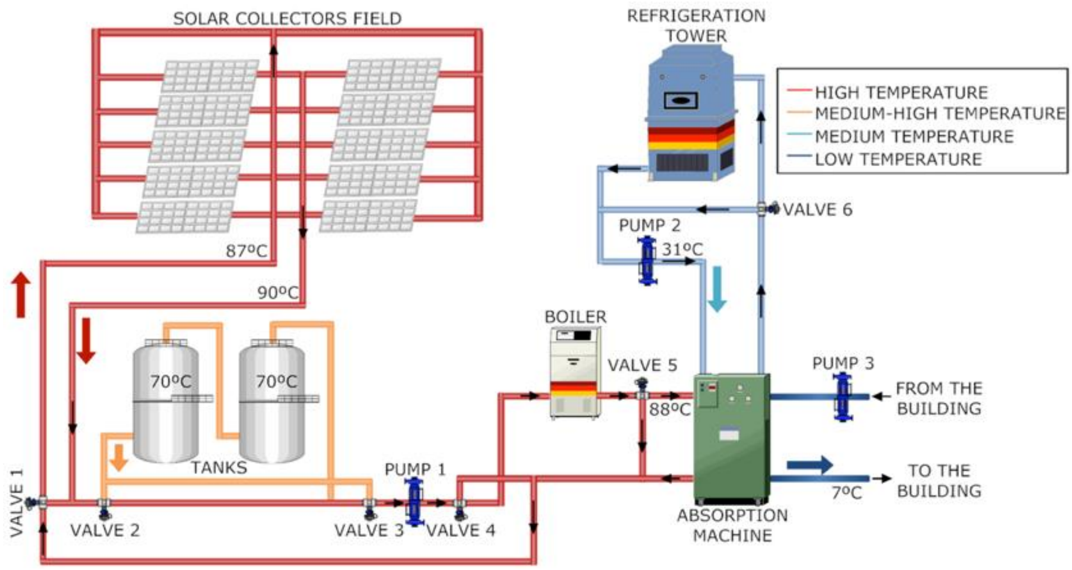


Figure 33. **Diagram of the solar cooling installation with its solar collector field**.

Under ideal conditions, the HVAC system has the following behaviour: the water flows through the solar collector field rising its temperature. This hot water goes into the absorption machine, which refrigerates the water adequately, and thus, it is injected into the fancoil system with the main objective of covering the temperature necessities of the environment where this service is demanded. On the other hand, and mainly as a function of environmental conditions, it could be impossible using only the solar collector field, to heat enough the water so that the absorption machine can chill it, since it needs a specific water temperature input in order to work properly. For this reason, the use of a hot water storage system and a boiler is justified. The hot water storage system is composed of two tanks of approximately 5,000L each. Moreover, they are thermally isolated in order to maintain the heat of the stored water and, in this way, when the system is free and the solar radiation can be useful, the hot water generated by the solar collector field is stored in these tanks.

Finally, although the main objective of the solar cooling system is to minimise the use of auxiliary energies, a boiler is used to provide the necessary power under any environmental condition in order to supply the correct service to the users of the HVAC system. Furthermore, it can be used alone, or to heat the water that comes from the hot water storage system or the solar collector field until the appropriate temperature for the absorption machine is reached. Moreover, it is possible also to develop modelling and control strategies for the solar collectors field with the main aim of regulate outdoor water temperature as a function of water flow.

2.13.3. Services offered by the infrastructure

CIESOL has gradually increased the number as well as capabilities of its scientific and technological facilities. This extensive and advanced equipment, allows offering a quality and highly competitive service including, on one hand **modelling and automatic control of micro-grids and thermal energy storage systems**, **energy analysis of buildings**, **solar cooling and solar resources assessment**. On the other hand, six pilot plants for contaminated **water treatment** by solar photocatalysis equipped with radiometers and on-line measurement of main parameters, along with a membrane distillation using solar energy plant.

Regarding off-line measurements of water and gas composition, advanced equipment comprises an AB SCIEX QTRAP 5500 LC/MS/MS for metabolite identification, detection and confirmation of low-level contaminants, a TripleTOF 5600+ System and a BRUKER 320MS Mass spectrometer triple quadrupole coupled to BRUKER 450GC gas chromatograph, which allows for **water and environmental analysis**.

2.13.4. Contact Details for Research Infrastructure

<table>
<tr><td colspan="2">CIESOL
Address: University of Almería, La Cañada de San Urbano s/n, ES04120, Almería, Spain
Website: www.ciesol.es</td></tr>
<tr><td>José Antonio Sánchez Pérez
Tel.: +34 950 014 140
E-mail: jsanchez@ual.es</td><td></td></tr>
</table>

3. Support offered under the SFERA-III TA programme:

The schedule for the integration of the users in the RI will be part of the preparation of the annual plan of the activities of the RI, guaranteeing the necessary conditions for the user to develop the work planned. Once accepted by the User Selection Panel (USP), the projects hosted through SFERA-III TA will be fit into the general schedule of each installation. They will be given priority over the projects conducted locally in order to simplify the travel issues with compatibility of their own local correspondent schedule. Depending on the facility operation, on the project complexity, on safety issues and on the users' experience, the users' status may vary from "permanently assisted" (by technical and/or scientific local staff) to as "independent" as local researchers. In any case, they will undergo a short training of the facility operation and safety requirements in addition to practical information on the RI, and on the activities of the laboratory where applicable. Users will also be informed in writing of the confidentially policy of the RI.

Users of the RIs will be welcomed into a vibrant research community. They will enjoy scientific and technical support from a cohesive and strongly motivated team in a working environment that nurtures the development of innovative solutions for the studies to be carried out. These advanced solar laboratories are committed to excellence in research and education. They perform pioneering R&D projects in the CST field, operates state-of-the-art research infrastructures and experimental laboratories which are to be made available to Users under this TA programme. These R&D centres are comprised of staff with a focus on research and development. Experienced scientific and technical staff are on hand at all times to assist with the use of the various installations offered under this TA programme. Support will also be offered in the lead up to use of the installations, to insure that realistic timeline and goals can be set for the experimental campaigns.

In order to facilitate access, RIs are encouraged to offer support to Users such as guidance through User manuals, provision of User support, provision of accommodation, and guidance with immigration procedures. This section of the document is dedicated to the establishment of guidelines to implement a methodology to support researchers using the RIs.

The support of the RIs to the users includes technical and scientific support, as well as administrative and logistical support (e.g., customs, transport), and for these supports, the supporting actions should be defined according to three different stages:

- preparation and submission of Access applications,
- access period, and
- post-Access period.

3.1. User support during the preparation and submission of Access applications

Once the Call for Proposals for access the RIs has been opened, the requested Access Providers must be contacted by the User to discuss the project idea before submitting the Application. This first approach should be made by simply sending an e-mail directly to the Access Manager (AM) of the selected Research Infrastructure.

Table 1. **Access Managers of the Research Infrastructure Service Providers.**

Access provider short name	Full name	Email address
CIEMAT	Ricardo Sanchez	ricardo.sanchez@psa.es
CNRS	Emmanuel Guillot	emmanuel.guillot@promes.cnrs.fr
ENEA	Walter Gaggioli	walter.gaggioli@enea.it
DLR	Dmitrij Laaber	dmitrij.laaber@dlr.de
CEA	Valéry Vuillerme	valery.vuillerme@cea.fr
UEVORA	Hugo Silva	hgsilva@uevora.pt
ETHZ	Brendan Bulfin	bulfinb@ethz.ch

Table 1. **Access Managers of the Research Infrastructure Service Providers.**

Access provider short name	Full name	Email address
IMDEA	José González	jose.gonzalez@imdea.org
CYI	Marios C. Georgiou.	m.c.georgiou@cyi.ac.cy
Fraunhofer	Anna Heimsath	anna.heimsath@ise.fraunhofer.de
LNEG	Maria João Carvalho	mjoao.carvalho@lneg.pt
METU	Ilker Tari	itari@metu.edu.tr
UAL	José Antonio Sanchez	jsanchez@ual.es

The Access Manager should support the User in the drafting of the Application (proposal). The AM and the Applicant should discuss the technical and logistic details (technical requirements of the Research, materials needed, estimated Access duration, installation to be used for the Access ...) related to the requested Access.

If the Applicant so requires, those specific questions related to technical details of the installation should be addressed to the AM who might forward them to the relevant Installation Project Leader (IPL). Adequate sample preparation, expertise and experience with the experimental methods as well as data treatment are indispensable components for successful and efficient use of the RI. Therefore, the Applicant should address to the AM any technical requirement related to the experiments to be performed, and the AM will forward these technical questions to the IPL, who will be responsible for the preparation and development of the experiments requested by the Applicant during the Access.

Before installation access begins, Applicants should previously be informed about options for travel and accommodation. Then, the User must be asked to fill in a 'Travel and Accommodation form' indicating dates for the Access stay and must sign the 'Travel Information form'. Once signed, this form must be sent together with the 'Travel and Accommodation form' to the AM so that s/he can begin to organise the Access stay. The management of the hotel booking and tickets may be undertaken by the SFERA-III staff in charge of the TA Activity, a logistic team at each RI to provide the Users with the administrative and logistic support they may require.

If shipping is required for samples needed for Project execution to the Access Provider, it is the User's responsibility to inform the AM at this stage and to request this transport (the User must inform the AM of the shipment schedule), then the Access Providers should arrange the transport (door-to-door and clearance from Customs). This service will be agreed on and specified between the parties. If deemed necessary by one or both Parties, a material transfer arrangement (MTA) should be filled out and signed.

All contractual conditions under which the Access will take place should be defined in the User Access Policy, which will be managed and supervised by the Access Manager of the selected RI and signed by the Applicant, who passes to the category of User from that moment on. The User Access Policy will define the contractual terms related to: scope of the Access, duration, confidentiality, property rights, dissemination of results, exploitation of results, safety rules and policies.

Once signed the User Access Policy, the AM should put the User in contact with the IPL of the Access Provider, with the aim of preparing the technical details for the activities planned by the User.

Table 2. **User support actions to be undertaken during the preparation phase of the submission of an Application.**

Application form available on the SFERA-III web site
Internal quality control and tracking system for applications
Information about the eligibility criteria, the evaluation process, and what is cover by SFERA-III available on the SFERA-III web site
Contact details of the AM of the RIs available on the SFERA-III web site
If Access application is successful:
• Accommodation and transport information provided for the stay at the RI where the Access will take place
• Preparation and signature of the User Access Policy

Meetings with Users can be organised at the RI prior to the Access stay to help making the access project a success, if required.

3.2. User support during the Access stay

When a proposal is accepted, a focussed interaction between the proposing User Group (Applicant) and the host research infrastructure starts. The estimated access period and the number of Users indicated in the proposal must be confirmed and agreed between the User Group and the host RI.

The AM will be the contact person of the User at the RI of the Access Provider where the Access will take place, and any technical, administrative or logistic question arising during the Access must be discussed by the User with the AM, who in turn may re-direct non-technical questions related to the RI where the Access is developed (e.g., on-site issue of identification cards, options for transport and accommodation, etc..) to other people of the RI staff, and technical questions related to the installation to the IPL, if necessary.

For each accepted User Project (linked to a proposal), the AM of the Research Infrastructure selected by the User Group Leader should nominate an IPL, who will support the User or User Group during the Access stay on any research and scientific aspects regarding the experiments to be performed and will provide the User with the on-site technical assistance that s/he may require to perform the experiments, keeping the AM informed in all cases.

Upon arrival at the RI where the Access will take place, the AM should give the User a document with the Health and Safety Rules implemented in the installation. Then, a working place with telephone and internet connection should be assigned to the User. The AM should also inform the User about internal rules concerning transport, meals, working time and any other topic that might be of interest for the User.

A User manual of the facilities to be used if the installation may be operated directly by the User should be provided by the AM or the IPL upon commencement of the Access stay. Moreover, User training for the use of appropriate software should also be provided by the Access provider, as well as specific training for the use of the installation should the experiments be run by the User. On the other hand, RI should offer the User the opportunity to have the User's experiments performed as part of the service by local personnel, without Users having to be trained in how to perform the experiments. In other words, there are no obligations of training of the Users before the access and for those facilities whose complexity require very skilled manpower for operation and must therefore be operated by the local staff. The Access provider have the sole responsibility of providing training depending of the needs of the Users and if training is necessary regarding safety rules or if the Users are in the position of running the installation on their own.

Assistance with analysis of data by trained and experienced research staff should be provided to the User by the Access provider during the Access stay as part of the service. In this sense, the IPL will be responsible for the recording and storage of the test data, a copy of which will be given to the User at the end of the Access stay.

3.3. User support after the Access stay

Once the Access stay is finished and the User gets back to his/her institution, he/she must prepare two reports related to the Access:

- -An **Access Summary Report**, which will contain the description of the activities performed by the User during the Access, their results and any other additional information the User may consider convenient concerning the Access.
- -An **Access Evaluation Report**, for evaluating the quality of the Access (e.g., research installation availability during the Access, support given by the Access Provider, etc.). The main objective of the Access Evaluation Reports is to detect potential improvements of the quality of the Access provided by SFERA-III and the degree of satisfaction of the User.

The Access Summary Report should be sent to the AM of the RI where the Access stay took place, while the Access Evaluation Report should directly be sent to the Trans-national Access Coordinator (TAC) (access-sfera@sollab.eu). Both must be delivered before the payment of expenditures by SFERA-III to the User.

The IPL should provide the User with any information s/he could need for the processing and evaluation of the tests data collected during the Access. This collaboration should continue until results of the work carried out during the Access is disseminated in any way (poster presentation, oral presentation in a conference, article published in SCI publications, etc.).

In exceptional cases, a meeting with Users can be organised at the RI after the Access stay to help making the Access project a success, if deemed necessary by the Access provider to fulfil the provider's obligations.

If shipping is required for samples gathered or generated during the Access to the User's Home Institution, then the Access Providers should arrange the transport (door-to-door and clearance from Customs). As mentioned before, this service will be agreed on and specified between the parties, and if deemed necessary by one or both Parties, a material transfer arrangement (MTA) should be filled out and signed.

List of abbreviations

AM	Access Manager
CCD	Charge-coupled device
CFD	Computer fluid dynamics
CPC	Compound Parabolic Collectors
CSP	Concentrated Solar Power
CST	Concentrating Solar Thermal
DAD	Diode Array Detector
DCS	Digital Control System
DMTA	Dynamic Mechanical and Thermal Analyser
DNI	Direct Normal Irradiance
DSC	Differential Scanning Calorimetry
DSG	Direct Steam Generation
DSW	Desalination of Sea Water
DTA	Differential Thermal Analysis
EDS	Energy Dispersive X-Ray Spectroscopy
EIS	Electrochemical Impedance Spectroscopy
EN	European Norm
EU	European Union
FEG	Field Emission Gun
FO	Forward Osmosis
FTIR	Fourier-Transform Infrared
GC	Gas Chromatography
HVAC	Heating, Ventilation, and Air-Conditioning
IC	Ionic Chromatography
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
HAST	High Accelerated Stress Test
HEXs	Heat Exchangers
HFSS	High Flux Solar Simulator
HSM	Heat Storage Media
HTF	Heat Transfer Fluid
IPL	Installation Project Leader
IR	Infrared

LC	Liquid Chromatography
LFC	Linear Fresnel Collectors
MBR	Membrane Biological Reactor
MD	Membrane Distillation
MED	Multi-Effect Distillation
MGT	Micro-gas turbine
MPI	Message Passing Interface
MS	Molten Salt
MS	Mass Spectrometry
MTA	Material Transfer Arrangement
PCM	Phase Change Materials
PLC	Programmable Logic Controller
PRO	Pressure-retarded osmosis
PTC	Parabolic Though Collectors
PV	Photovoltaic
R&D, RD	Research and development
RI	Research Infrastructure
RPR	Raceway Pond Reactor
SAAF	Solar Accelerated Aging Facility
SEM	Scanning Electron Microscope
SEP	Single Entry Point
SHIP	Solar Heat Industrial Processes
ST	Solar Thermal
STE	Solar Thermal Electricity
TA	Trans-national Access
TAC	Trans-national Access Coordinator
TBT	Top Brine Temperature
TES	Thermal Energy Storage
TGA	Thermo-Gravimetric Analyser
TOC	Total Organic Carbon
TRL	Technology Readiness Levels
UPLC	Ultra-Performance Liquid Chromatography
UV	Ultraviolet
XRD	X-Ray Diffractometer