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. 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's infrastructure available to the project is composed by three main facilities: Materials and Solar Laboratories (testing laboratories accredited in accordance to EN ISO 17025); Fuel Cells and Hydrogen; High-Performance Computing Cluster.

Laboratory of Solar Energy (LES) focuses on Solar Thermal Systems and its components. Within the context of this project, the main service provided by this facility is optical characterization of collector components, e.g., reflectors and absorbers, using 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.

Laboratory of Materials and Coatings (LMR) is specialized in the areas of durability, corrosion and anticorrosive protection of materials.

The main services provided within the project are:

- 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 equipments 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 equipments for this service are high temperature furnaces, 15-20 L capacity cylindrical pot bath with and without mechanically stirred mixtures and TG/DTA/DSC;
- Morphological, physical and chemical characterization of materials and coatings (polymeric and metallic materials, conversion coatings, and metallic and organic coatings. The main equipments for this service are optical and metallographic microscopes, XRD, SEM/EDS, tensile machines, SRET, EIS, thickness, colour and gloss equipments)

The two Laboratories 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.

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. Main equipment available: X-Ray diffractometer, FEG-Scanning Electron Microscope 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.
Naturally, this resource is dependent on the applications packages' 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 main services provided within the project are:

- 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.

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

- **Materials and Solar Laboratories**
  - Durability of materials for CST technology (reflectors and metallic materials in contact with molten salts at high temperature);
  - Durability of materials for solar thermal collectors;
  - Anticorrosive protection systems for different environments and different industrial sectors.
- **Fuel Cells and Hydrogen Facility**
  - Solar treatment of residual industrial waters;
  - Solar Hydrogen generation from waste waters;
  - CO2 reduction to fuels and feedstocks.
- **High-Performance Computing Cluster**
  - 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.

<u>Services currently offered by the infrastructure:</u>
In the present proposal it was decided to focus on three main facilities:

- Materials and Solar Laboratories;
- Fuel Cells and Hydrogen facility;
- High Performance Computing Cluster.

These facilities can offer several services in the frame of CST, most notably:

- Optical characterization 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.

LNEG has participated in the STAGE-STE project and in the frame of the mobility programme of this project received the visits of researcher from other institutions. Within this framework LNEG received a total of 6 foreign researchers and students for a total of approximately 29 person-weeks. The countries of origin of these researchers were Spain, Switzerland, Italy and Brazil. Activities ranged from

modelling and simulation to durability studies and material characterization for solar fuel production. Furthermore, LNEG has several protocols established with universities, namely the University of Lisbon and has received national and international students in the frame of their work to accomplish the graduation degree. Achievements of high-quality research produced in the infrastructure by research from national and foreign students are:

- Innovative technology for the production of low carbon foot print syngas. Novel composite bimetallic cathodes with electrochemical activity for syngas production that allow tunable H_2/CO ratios by selecting composition of the developed catalyst (published in **Journal of CO_2 Utilization**, 18, 62-72 (2017)).
- Structural and electronic modifications of N-TiO_2 achieved by surface deposition of noble metals Pt and Pd. Synergistic effect and visible-light induced photocatalytic activity, theoretical and experimental study (published in **Phys. Chem. Chem. Phys**., 19, 7062-7071 (2017)).
- Photoreforming of short chain alcohols present in industrial effluents integrated with hydrogen generation. Production of hydrogen evolution high rates using suitable semiconductor photocatalyst, composite with graphene oxide, with tailored electronic structure. Allows sustainable valorisation of alcohols, present in wastewaters, to green fuels (**International Journal of Hydrogen Energy**, available on line 2018, https://doi.org/10.1016/j.ijhydene.2018.09.148).
- Design, modelling and simulation of a solar thermal system integrated into the feedwater pre-heating stage of the steam generation unit of an ECA (Expanded Cork Agglomerate) production plant was performed, demonstrating the technical feasibility and potential of integrating solar process heat at the steam supply system of the ECA manufacture process. (**AIP Conference Proceedings 2033**, 150002 (2018), https://doi.org/10.1063/1.5067155)