STAGE-STE **Grant agreement no: 609837**
Scientific and Technological Alliance for Guaranteeing the European Excellence in Concentrating Solar Thermal Energy

WP6 : International Cooperation Activities

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48-Month Final Progress Report

Deliverable D.6.7

03/03/2018

Editor: Werner Platzer

Content

1. Introduction

As WP6 deals with international cooperation activities, its different tasks were defined according to the activities carried out in specific regions of the world. However, the scientific content in the manifold activities should be a part of the technical work packages. WP6 mainly created a platform to integrate international partners.

WP6 is an activity with many individual tasks and subtasks, as it comprises a number of bilateral cooperations between European and International members of STAGE-STE: Each of this individual activities is a project in itself, and mainly financed by other sources than STAGE-STE. Some of the activities were of a character of initiation of cooperation, whereas others already have been established earlier and resulted already in a funded cooperative R&D action, which could be integrated into STAGE-STE. In all cases, the interaction of participants and extending that additional STAGE-STE partners has been facilitated by WP6.

WP6 Objectives:

- Ensuring efficient implementation of the research work plan and reinforcing cooperation and synergies among the partners through multilateral cooperation within the SolarPACES framework. Organizing common workshops and exchange of information shall foster higher level of excellence in participating organizations.
- Coordinating the R&D efforts on an international level. This cooperation shall avoid the development of parallel structure and repetition of research projects internationally and thus lead to faster innovation.
- Increasing the level of awareness for cultural and climatic differences in implementation of STE projects.
- Creating a knowledge pool on different regional framework conditions for STE implementation, local economical and climatic needs as well as support measures and regulations

WP6 Approach:

- Supporting increased bilateral cooperation between international institutions on specific RTD topics relevant to the region to create synergies
- Using international networks like SolarPACES, IRENA and ISES for broad coordination of standardization and information exchange

2. Achievements

2.1. Common achievements

Within the work package the individual coordination activities with different regions in the world were quite different and distinct. In order to raise the general knowledge of all STAGE-STE participants on R&D efforts on an international level, to increase the level of awareness for cultural and climatic differences and to support the colleagues with knowledge on different regional framework conditions for STE implementation, local economical and climatic needs as well as support measures and regulations, in excess to the required deliverables of the project work plan an additional report was developed by the individual cooperations.

WP6: Report on Regional Conditions for STE (Editor FISE, 144 pages, Jan 2018)

This report gives on 144 pages an overview over the regions covered within WP6 and also over the international development of Solar Thermal Electricity (STE) with chapters dealing with general political and geographic data of a countryor region, economic situation, electrical market, climatic data and solar potential, motivation and eventual policies for RE/STE, project pipeline and – if available - support measures and local stakeholders.

Deliverables and Milestones

D6.1 Report Environmental data with influence on performance of STE plant (DLR, Jul 2017)
D6.2 Report Design options of low cost process heat collector (FISE, Jan 2016)
D6.3 Report Thermal performances of absorbers materials for volumetric receivers (IMDEA, Jan 2017)
D6.4 Report Co-generation applications of STE application in agro-industrial applications (LNEG, Oct 2017)
D6.5 Report CSP options for desalination in Libya (CRAN, Jul 2017)
D6.6 Intermediate report on STAGE-STE International Collaboration activities (FISE, Jan 2016)
D6.7 Final report on STAGE-STE International Collaboration activities (FISE, Feb 2018)
D6.8. UCAM-PROMES collaboration activities on solid-gas solar reactors, (CNRS, May 2017).

2.2. Task 6.1 Coordination with international organizations (CIEMAT)

The main objective of Task 6.1 is the coordination of European STAGE-STE partners with relevant international related organizations (i.e., SolarPACES, ISES and IRENA) to exchange information and avoid repetition of research international projects. Three Subtasks were planned within Task 6.1 to achieve this objective.

2.2.1. Subtask 6.1.1 - Collaboration with SolarPACES

This subtask is coordinated by CIEMAT-PSA and its objective is the alignment of the activities performed in STAGE-STE with the interests of the international scientific community dealing with concentrating solar thermal technologies represented by the IEA SolarPACES Executive Committee members.

CIEMAT has kept SolarPACES Executive Committee informed about STAGE-STE activities presenting project progress reports at 6 SolarPACES ExCo meetings held between March 2015 and October 2017. Activities related to WP2 (alignment of national strategies for STE within Europe), WP3 (infrastructure needs of the STE industrial sector) and WP5 (development of new standards) were reported to the SolarPACES ExCo members in order to distribute the information to all the member countries of this implementing agreement of the International Energy Agency). SolarPACES ExCo was informed about the Implementation Plan to achieve the SET Plan targets

on CSP/STE and about the EERA JP-CSP Position Paper prepared and sent to the European Commission.

Taking into account the importance of an international participation in the development of new standards for the STE sector, CIEMAT promoted in 2015 category A Liason Agreement between IEC/TC-117 and SolarPACES. This Liason agreement allows a more intense information exchange between SolarPACES members and standardization committee IEC/TC117.

Participation of several members of the STAGE-STE project took place in the respective Task I (Systems), Task II (Solar Fuels), Task III (Components) and Task IV (Thermal storage) workshops before the SolarPACES Conferences 2015 in CapeTown, 2016 in Masdar and 2017 in Santiago.

The topics were the following guidelines for measurement: reflectance of mirrors, shape of mirrors, optical and thermal efficiency of receivers for Parabolic trough systems, storage performance, assessment of performance of heliostats, durability testing.

2.2.2. Subtask 6.1.2 - Collaboration with ISES (IMDEA)

This subtask is aimed at coordinating with ISES (International Solar Energy Society)the organization of joint events and specific sessions and workshops on CST technologies and their applications at the international and regional conferences of interest
In 2015 a webinar was organized with ISES devoted to “Solar driven thermochemical production of sustainable fuels”. This webinar was organized in cooperation with the EERA. 64 countries were represented at this webinar by a total number of attendees of 158
IMDEA and others supported strongly the incorporation of CSP into the Solar World Congresses of ISES as spearate theme, organizing the sessions and providing the chair persons. Also side events with related topics, e.g. a Forum on “Solar Thermal Electricity: Technology and Market Development” was organized at the ISES Solar World Congress 2015 in Daegu, South Korea. To support the importance of the theme also keynote lectures on CSP were given in the ISES SWC. As the Solar World Congress is a biennual Congress in the intermittent year 2016 the ISES Eurosun Congress has been utilized as a platform for STAGE-STE.

- ISES Solar World Congress 2015 in Daegu/South Korea
- ISES Eurosun Congress 2016 in Palma/Mallorca
- ISES Solar World Congress 2017 in Abu Dhabi/UAE

During the ISES Solar World Congress 2017 a special plenary talk was allocated to Prof. Robert Pitz-Paal of DLR that received the Farrington Daniels Award during the congress banquet and provided great visibility to CSP/STE technologies and developments led by DLR and partly shared under the umbrella of STAGE-STE network. In addition Prof. Aldo Steinfeld from ETHZ received the ISES Achievement through Action Award in memory of Christopher A. Weeks for his contributions to the fundamentals of high-temperature/high-flux solar energy conversion.
A special Issue in the Solar Energy Journal with selected manuscripts of the Congress Eurosun2016, where a specific forum on CSP was organized, was prepared by STAGE-STE.

2.2.3. Subtask 6.1.3 - Collaboration with IRENA (CTAER/US/ENEA)

This subtask was initially coordinated by CTAER and then trespassed to university of Seville and ENEA with the objective to promote the consideration of STE in the scope of IRENA’s activities to further promote concentrating solar technologies as key renewable technologies. Also the alignment of STAGE-STE activities with the interests of the renewable energy international community.

Activities in this Subtask have been started by CTAER aiming at implementing a fruitful collaboration with IRENA (International Renewable Energy Agency). Several e-mails and a video conferences were arranged in 2015 between CTAER and Dr. Rabia Ferroukhi, *Deputy Director - Knowledge, Policy and Finance Centre* of IRENA, to discuss the collaboration between IRENA and STAGE-STE, and to avoid overlapping and maximise synergies. IRENA can be an excellent platform to disseminate STAGE-STE information in the 106 member countries
The following IRENA´s activities have been found by CTAER of interest to STAGE-STE:

- The development of a software platform with a list of all the courses given in the world on renewable energies (RE)
- The development of information systems to identify existing policies to promote RE in different countries and specific studies to analyse the benefits of these policies and identify best practices
- Analysis of markets for renewable energy in terms of economic regions, identifying the current state of development of the industry, level of investment, etc.
- Studies of socio-economic impact (job creation, impact on GDP, etc.).
- Studies of scenarios for renewable energy penetration and analysis of the potential impact.
- Studies on the possibilities for access to energy (off-grid applications, etc.).

2.3. Task 6.2 Coordination with MENA (CIEMAT)

Task 6.2 has the main objective of collaboration with relevant research organizations within the MENA region in order to incorporate local desert conditions into the technological development. It is composed of the following 3 subtasks

2.3.1. Subtask 6.2.1 - Morocco (CNRS-PROMES)

In a cooperation of UCAM (Cadi Ayyad University) and CNRS/PROMES it was proposed to use concentrated solar power for phosphate ores thermal treatment. The thermal treatment is an important operation in industrial processing of phosphate ores also in Morocco.

This work was conducted both by three researchers from Cadi Ayyad University and a PhD student. The main objective of this work is to study the appropriate configuration to heat powder minerals by the focus of concentrated solar power. The temperature should be controlled and varied from a few hundred degrees up to 1000°C. These treatments aimed to dehydrate and calcinate the raw ores.

A characterization of the raw product to determine its particle size, chemical composition and structure was performed. First tests were carried out in a conventional oven to determine the evolution of the corresponding chemical complex system, however, during a visit in PROMES laboratory at Odeillo and at Themis in France, high air pressure treatment was used in order to convey the particles in the solar radiation concentration area. This facility is developed so as to control the temperature rise, the residence time and the treated material recovery system.

The results showed that the organic matter is decomposed completely at the temperatures around 400 °C, and then the calcination reactions begin that cause the oxidation of secondary metals and release sulfur oxide. Tthe dynamic flash calcinations in the furnace at 1000 °C gave the most interesting results, in terms of quality of calcined phosphate at the level of production of phosphoric acid. To round up a numerical study on a suitable high-temperature solar receiver options based on opaque metals walls and reaction in a fluidized bed has been carried out.

Together with its Moroccan Partner IRESEN, DLR has exposed about 350 samples of aluminum and silvered-glass mirrors in Morocco at the exposure sites of Oujda, Missour, Erfoud, Zagora and Tan Tan. The samples were analyzed together for corrosion and optical degradation in the laboratory at the Plataforma Solar de Almeria every 6 months. The samples also served as reference for the accelerated aging tests carried out in WP8. Dust sensors have been installed in Missour to characterize wind-blown particles in sand storm events. The measured parameters serve as reference for the developed accelerated erosion test in WP8.
The cooperation with IRESEN allowed to involve several moroccan universities to maintain the exposure site and the meteorological stations and to provide reliably the data to be analyzed by DLR and Ciemat.

Deliverables and Milestones

D6.1 Report on the environmental data with influence on performance of STE plant (DLR, 2017)
D6.8. UCAM-PROMES collaboration activities on solid-gas solar reactors, (CNRS, May 2017).

2.3.2. Subtask 6.2.2 - Libya (CRAN)

The original plan involved three activities, namely

- Whole solar field evaluation (WP11)
- Small heliostat manufacture (WP12)
- Desalination applications (WP10)

At a meeting at Cranfield in March 2014 with the new CSERS General Director these objectives were changed to the following:

- Sand erosion of collectors in Libya (WP8)
- Design of a 50 MW desalination plant (WP10)
- Small heliostat manufacture (WP12)

From May 2014 to March 2015 contact with CSERS was lost, until a new Director and Management Team were installed. At the STAGE-STE meeting in CEA-INES in June 2015 it was agreed to concentrate on a single objective until confidence had been restored in the ability of CSERS to carry out its tasks on the STAGE-STE project. This objective was selected by Cranfield in consultation with CSERS, namely

- Sand erosion of collectors in Libya (WP8)

Since June 2015, collaboration has been very good, and excellent progress has been made on the revised objectives. As a result it was decided to address another of the original planned activities, application of CSP to desalination in Libya (WP10).

Figure 1 - Glass sand erosion holder (left) and sand particle detection device (right)

CSERS (Libya) produced a report “Sand Erosion of CSP Plant Collectors” (Nov. 2016), summarising all the work done since June 2015 on the topic of Sand Erosion of Collectors in Libya (see STAGE-STE WP8). Some additional results have been added during 2017, which add to the database of results and re-enforce the earlier results. In addition the deliverable “Design of CSP plants for desalination in Libya” (Oct. 2017) has been provided.

Deliverables and Milestones

D6.5 Design of CSP plants for desalination in Libya (CRAN, May 2017)

2.3.3. Subtask 6.2.3 - Saudi Arabia (CIEMAT)

Activities in this subtask were a direct collaboration between KSU and CIEMAT, covering the following topics:

Within Task A “Modelling of novel receivers for process heat and desalination applications”, the design of a Point Focus Fresnel Concentrator (PFFC) has been finalized with the incorporation of a CPV array with waste heat sink. Laboratory characterization of mirrors manufactured by Saudi local companies was done at PSA. A number of PFFC prototypes have been built with area concentration ratio as high as 500 suns.

In Task B a modified tube receiver with insulating strips has been developed and installed in one of the loops of the small aperture parabolic trough solar field (NEP Solar PolyTrough 1200) at Plataforma Solar de Almería. Efficiency tests corresponding to 95, 130, 165 and 200ºC have been carried out for both, conventional receiver and a modified receiver, and the results analyzed. The insulation strips installed between the absorber pipe and the glass cover in the side of the tube not receiving heat flux gets to minimize around 20% heat lossses in the measured temperature range.

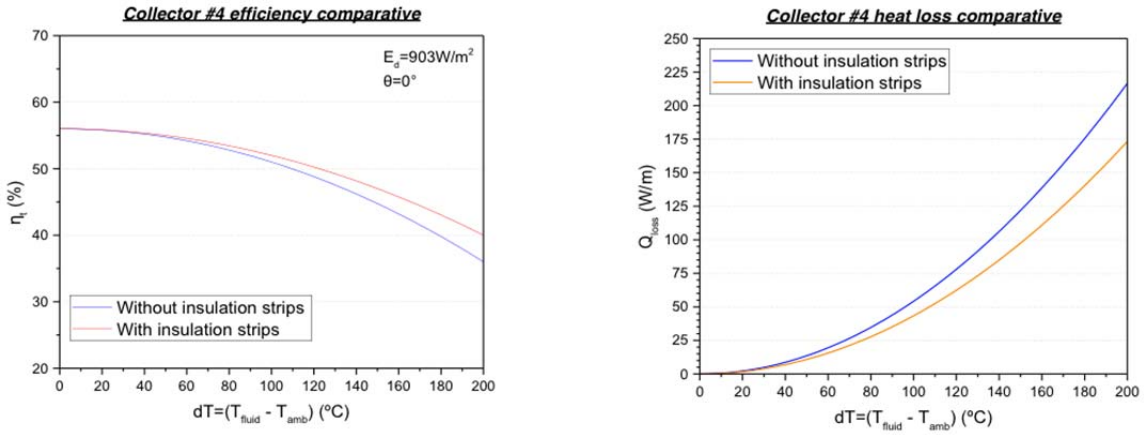

Figure 2 - Efficiency and heat loss comparative using the insulation strips proposed by KSU

The assessment of solar membrane destillation (MD) prototypes in Task C had problems with some replacement parts in the MD unit at KSU and the lack of direct support from the manufacturer (due to economic problems of the company MEMSYS) have meant a big delay in the collection of data from that unit. The Multi-Effect Vacuum Assisted Membrane Distillation (ME-VA MD) system at PSA has been assessed obtaining Gain Output Ratio (GOR) values of around 3 and recovery ratios of around 40%.

UNIPA analysed in Task D the coupling of MD technology with CSP and has implemented a distributed parameters model for MD that in principle was going to be incorporated into the STE plant based on the PFFC (KSU development). However it has been impossible to get complete yearly data of the performance of the PFFC system in order to carry out yearly simulations and the corresponding techno-economic analysis to get levelized electricity and water cost of this type of STE+MD plants.

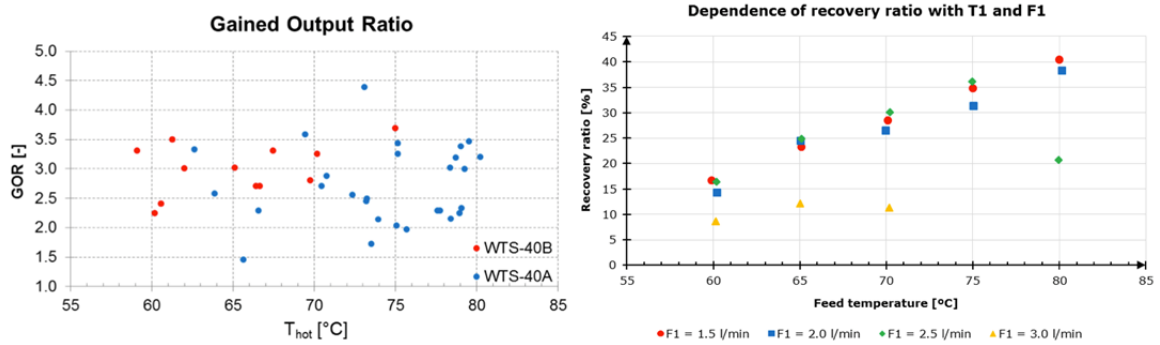

Figure 3 - Gain Output Ratio (left) and Recovery Ratio (right) vs hot inlet temperature and flow for ME-VA MD modules

2.4. Task 6.3 Coordination with Latin America region (LNEG)

Task 6.3 has the primary objective of collaboration with reference organisations within the Latinamerican region to incorporate local conditions into the technological development. It is composed by the following three subtasks:

2.4.1. Subtask 6.3.1 - Mexico (CENER)

Subtask 6.3.1 aims to foster cooperation with Mexico and is led by CENER with contributions from IMDEA, PSI and UNAM. The main specific collaborative activities for this subtask are:

In the beginning the activity was focused onto the topic "*Solar steam gasification of petroleum coke*", with the aim of developing a solar-driven characterization at the solar furnace located in Cuernavaca, Mexico. Successful solar steam gasification tests demonstrated the conversion of Mexican petcokes into high quality syntheses gas. The design of the solar reactor was started.
The cooperation CENER and UNAM developed a small size heliostat and assessed the new designs by modelling a group of linked mini-heliostats, and evaluation of tracking accuracy by means of ray tracer techniques. Also they evaluated heliostats facets deformation by means of an improved fringe projection technique.

Significant results:

- Design and construction of a small prototype heliostat (1 m2) with azimuth and elevation movements;
- Design of a receiver/calorimeter to be installed at the CEToC in Hermosillo, Sonora;
- Construction and testing of a small prototype of the receptor/calorimeter to be tested at HoSIER in Temixco, Morelos;
- Campaigns of pyrolysis and gasification at solar simulator scale;
- Design, construction and operation of a rotary thermochemical reactor for the reduction of metal oxides to produce solar fuels.
- Characterisation of different Mexican petcokes including thermogravimetric testing as well as pyrolyses and gasification testing in small 1 kW_{th} solar simulator at IMDEA;
- Successful steam gasification tests with Mexican petcokes in PSI's 50 kW_{th}High Flux Solar Simulator using a laboratory two-cavity solar reactor (radiative power input about 5kW).
- Development of techniques for tracking and slope evaluation.

The activities contributed in detail to relevant work packages WP9 and WP12.

2.4.2. Subtask 6.3.2 - Brazil (LNEG)

Subtask 6.3.2 aims to foster cooperation with Brazil and is led by LNEG with contributions from U. Évora and USP. LNEG and USP are studying the application of small scale central receiver systems in the agro-industry sector. UEVORA is cooperating with UFP on linear concentration technology (PT and LFR) both for electricity production and process heat.
Task A: After a review of available software for modelling and simulation of CSP central receiver systems, Tonatiuh was chosen for the solar field modeling and TRNSYS for the simulation of the full plant, including the industrial applications. The next step was the development of models for central receiver systems. Detailed modeling of the individual components, both at individual heliostat, receiver and at complete field level, was developed.
Due to procurement issues the project of the pilot plant at USP facilities in Pirassununga had to be significantly altered, impacting particularly both the receiver and power block, leading to a change of technology for both of these systems (the power block was modified from a Brayton cycle micro gas-turbine to an Organic Rankine Cycle micro system and the receiver was modified from a pressurized air receiver to an open volumetric receiver). Subsequent changes in field configuration and thermodynamic cycle were implemented in the previously developed models (for both individual heliostats and the heliostat field).

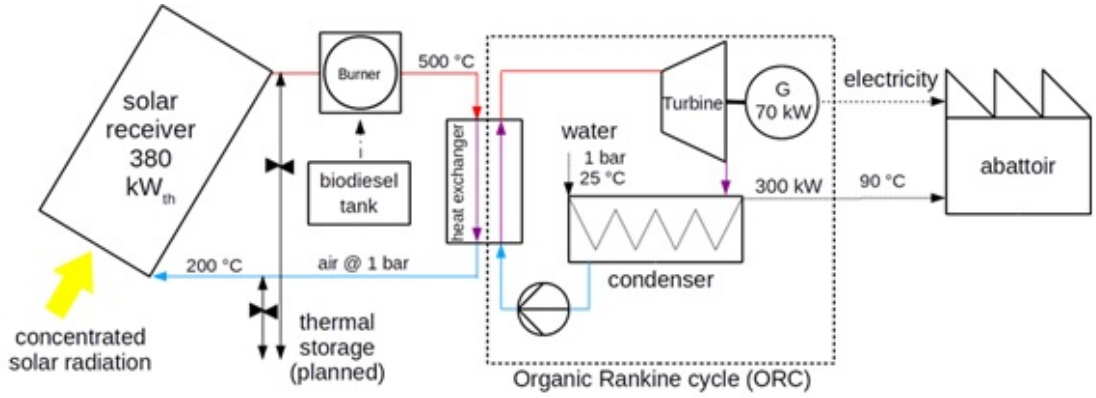

Figure 4 - Process schematic of the modified Pirassununga pilot plant

As a consequence of the delays in the pilot plant construction, both the solar field and plant model validation activities will only be possible during the second half of 2018, after the STAGE-STE project termination. However, three heliostat prototypes have already been installed at USP Pirassununga facilities and optically calibrated using a Lambertian target. Initial flux measurements of these prototypes have been carried out.

Task B, "*Study of cogeneration applications within the agro-industrial sector*", has been carried out this year. Three agro-industrial applications, selected for their economic relevance in Brazil, as well as their aptitude to be integrated with solar thermal energy (sugar cane, meat processing, and dairy industries), were analyzed in more depth. Typical consumer sizes and consumption profiles were established. A strong focus was placed in the meat processing industry not only due to its relevance in Brazil but also because it corresponds to the application of the pilot plant being built in USP Pirassununga campus.

Presentations (SolarPACES conferences and national events) and dissemination activities completed the work.

Deliverables and Milestones

D6.4 Co-generation applications of STE application in agro-industrial applications (LNEG, 2017)

2.4.3. Subtask 6.3.3 - Chile (FISE)

Subtask 6.3.3 aims at fostering the cooperation with Chile, being led by FISE with contributions from UDC.

In Task A applications in the mining industry were investigated. An overview of requirements (demand profiles, demand levels for heat and electricity, mining process description and temperature requirements) and climatic data for different mines in Chile was prepared (UDC), also simulation development on the use of concentrating collectors for the use of heat in mining processes (electrowinning, bioleaching) was performed by FISE and a complete model based on TRNSYS was designed and implemented. There are results on the impact of solar systems dimensioning on the electro-winning processes, and also for heap leaching using temperature dependent bacteria. Substantial solar factions can be achieved.

Task B dealt with possible thermal desalination (MED and CSP) in Northern Chile. FISE researchers visited Chile in order to prepare a study and discuss with UDC on cooperation possibilities within SERC. A paper at the SolarPACES conference 2017 in Santiago showed that even with conservative assumptions inland desalination by means of CSP+MED seems feasable.

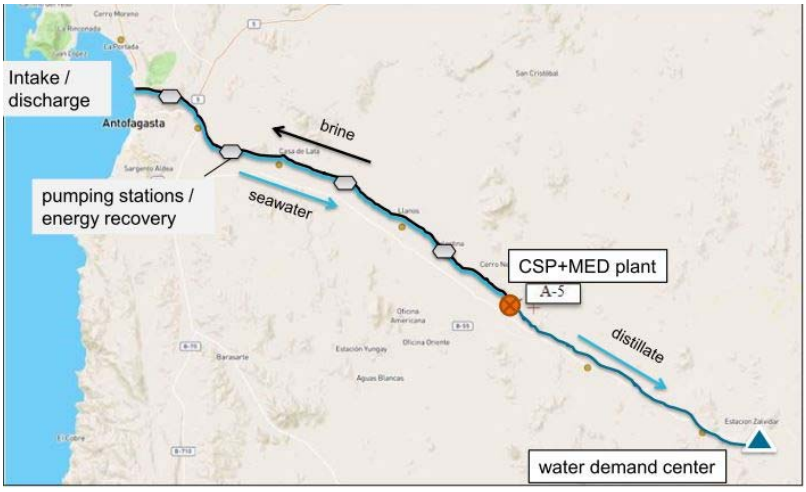

Figure 5 - Possible pipeline for inland desalination in Chile

In Task C high temperature storage was investigated. UDC contributed with a literature search on physical properties and corrosion investigations for different nitrate salts from Chile with various impurity levels. FISE reported on the stability of different construction steels suitable for storage construction (with Solar salt of industrial and refined grade purity). Different testing devices were presented. A meeting with US entities at the SolarPACES conference in Santiago, Chile, was looking into the possibility of cooperation between Fraunhofer, University of Antofagasta and Catholic University on the topic of corrosion. However it was found out that US wants to concentrate on Chlorides which is not the resource in Chile. A possible outcome could be that the Strategic Solar Program in Chile (PES) will design a project on Molten Salt storage.

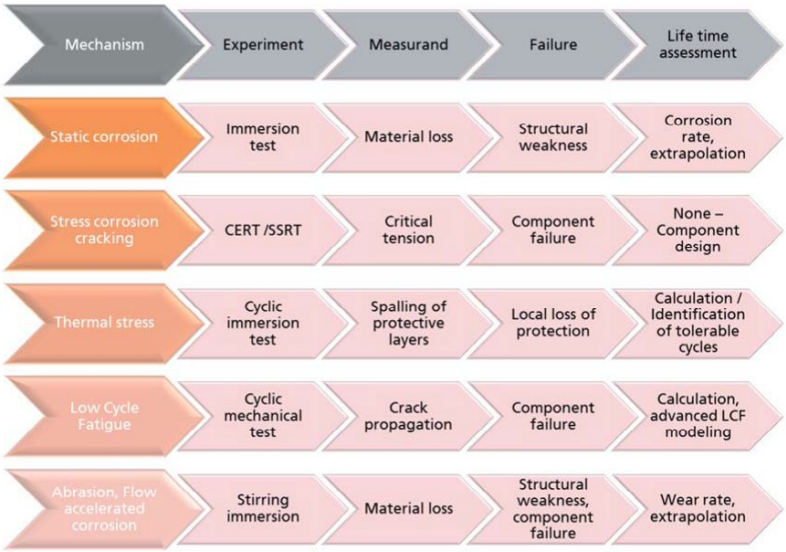

Figure 6 - Different testing routes for degradation mechanisms

Significant results

- Report on Literature search on different nitrate salts from Chile with impurity levels and physical properties and corrosion investigation.
- Overview of energy requirements for different Chilean mines.
- Simulation model for the use of solar thermal collectors in different mining processes and for combined heat and power (CHP)

- Development of concepts for desalination using Solar Thermal Power plants in the North of Chile and publication
- Investigations on different construction steels in combination with molten salt (Solar Salt) and testing methodologies

The Chilean climate provides a very hard challenge to materials. The impact of high-radiation levels with high UV-content, corrosive environments and strong soiling tendencies on materials and components should be investigated experimentally. In order to strengthen local R&D relevant to solar and country issues, Fraunhofer Chile representing FISE in Chile is now also member of SERC, the Solar Energy Research Center of Chile, with all relevant Chilean Universities active in Solar as members. This should ensure a continous collaboration also for the following years.

2.5. Task 6.4 Coordination with Australia/South Africa (FISE)

Task 6.4 has the primary objective of collaboration with two region in the Souther Hemisphere which have rather similar country conditions in relation to climate. Important players should be incorporated and giving information on local conditions for the technological development. It is composed by the following two subtasks:

2.5.1. Subtask 6.4.1 - Australia (CENER/CYI)

One key objective of the work with Australia was related to WP9 to initiate a joint pilot scale solar thermochemical reactor testing using the solar tower at CSIRO. In a visit of Christian Wieckert (PSI) at CSIRO the options for pilot scale testing of thermochemical processes/reactors based on PSI's beam-down two-cavity solar reactor technology was explored. However due to the phase-out of PSI this work was not continued.
The Australian Roadmap for Solar Fuels Project was completed and the final report submitted to the Australian Government with signficant expert input of DLR and PSI. It showed that using CSP for solar reforming was more cost effective for hydrogen production than PV electrolysis. It also indicated the potential for solar reforming to be used for other products such as methanol and diesel.

Figure *7 - CSIRO heliostats at Pentakomo facility (Cyprus)*

On the other hand the collaboration of CYI with CSIRO on the development of small low cost heliostats and a field layout software showed good progress. Cyprus Research Institute built a 50 heliostat field at Pentakomo using CSIRO heliostats. This involved transfer of manufacturing techniques, surface measurement, ray tracing and field layout and optimisation. Reflective surfaces and actuators were being monitored for degradation rates and mechanisms. The field was formally opened by the President of the Republic of Cyprus and the Director of Research for the European Commission in October, 2016. Cyprus Research Institute has been undertaking fabrication and installation of its molten salt receiver.

Significant results

- Technology transfer and delivery of 50 heliostat field for CSIRO heliostats
- Fabrication and installation of CYI molten salt receiver.
- Contribution to Australian Roadmap for Solar Fuels Project

2.5.2. Subtask 6.4.2 - South Africa (FISE)

In Task A FISE and SUN were working on the development of low cost concentrating collectors for process heat up to 250°C with emphasis on Fresnel including the local value chain. The local costs were investigated by a literature study and market screening. The final design options were described in a deliverable report.

In Task B monitoring and testing data of a Linear Fresnel Collector locally installed in South Africa have been used to check and validate a dynamic outdoor testing methodology. The measurement methodology and the selection of sensors and equipment had been jointly defined. SUN facilitated the monitoring, the contact to the local company and supervises sensor installations and data collection. Data from about 30 highly dynamic measurement days have been collected. Diverse evaluations of optical/thermal parameters and their conjunction have been performed.

Figure 8 - Monitoring equipment installed for Linear Fresnel Collector in South Africa

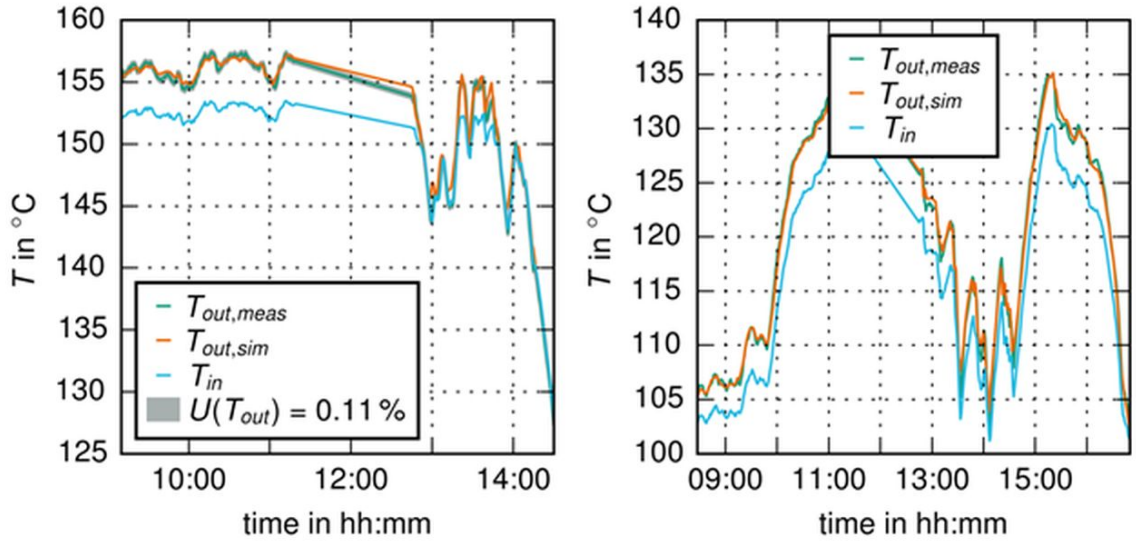

Figure 9 - Example evaluation of dynamic testing - comparison of simulation using identified parameters and measurements

In Task C dissemination during April 2015 in a seminar FISE presented the state of the art of todays solar process heat. Also during the SolarPACES Conference in Cape Town FISE and SUN researchers had several working meetings. The state of the art of high temperature concentrating solar thermal was presented by FISE at SASEC conference 2016.

Significant results

- Preparation of outdoor dynamic testing methodology for Fresnel collector
- General design of low-cost Fresnel collectors for process heat
- Testing and evaluation of local Fresnel collector installation
- The work supported the development of a new SolarPACES Best Practice Guideline DISPAT "Dynamic in situ Performance and Acceptance Testing of Line-Concentrating Collectors and Solar Fields" (to be published 2018)

Deliverables and Milestones

D6.2 Design of Low-cost Fresnel Collector (FISE, 2016)

2.6. Task 6.5 Coordination with Asia (IMDEA)

Task 6.5 has the primary objective of collaboration with the largest countries active in CSP in the Asian region. Relevant academic partners have been identified and were incorporated, also giving information on local conditions for the technological development. It is composed by the following two subtasks:

Both collaborations with China and India are specific of this WP6 and therefore are not reported elsewhere in the STAGE-STE project and have their own programme of work. However, the activity on absorber materials for volumetric receivers has some points of common interest with the WP12.. Also the activity of FBK with India has some common points with the Task 11.1.1 Medium temperature (150 – 250 ºC) solar collectors for industrial or distributed applications.

2.6.1. Subtask 6.5.1 - China (IMDEA)

The main objective of Task 6.5.1 was the collaboration between IMDEA and IEECAS on the development and performance testing of volumetric receivers for central tower systems operating at high temperature high irradiance conditions. As a result of the collaboration, cooperation and synergies were reinforced among the partners, which fostered a high level of excellence, and research efforts were coordinated on an international level in order to create a knowledge pool based on a dataset acquired at different experimental conditions. In this framework, volumetric absorbers manufactured from high performance silicon carbide ceramics have been investigated at both partnering institutions. Experiments at IMDEA were conducted employing a 1 kW_{th} high flux solar simulator, whereas experiments at IEECAS were conducted both in a 30 kW_{th} high flux solar simulator and in a 10 kW_{th} solar furnace under on-sun conditions. Receiver air outlet temperatures and thermal conversion efficiencies were measured for the three experimental scales, and results were shown to be in good agreement. In addition, a numerical model of a foam absorber was developed at IEECAS using object-oriented programming to study the effects of several geometric parameters on thermal conversion efficiency.

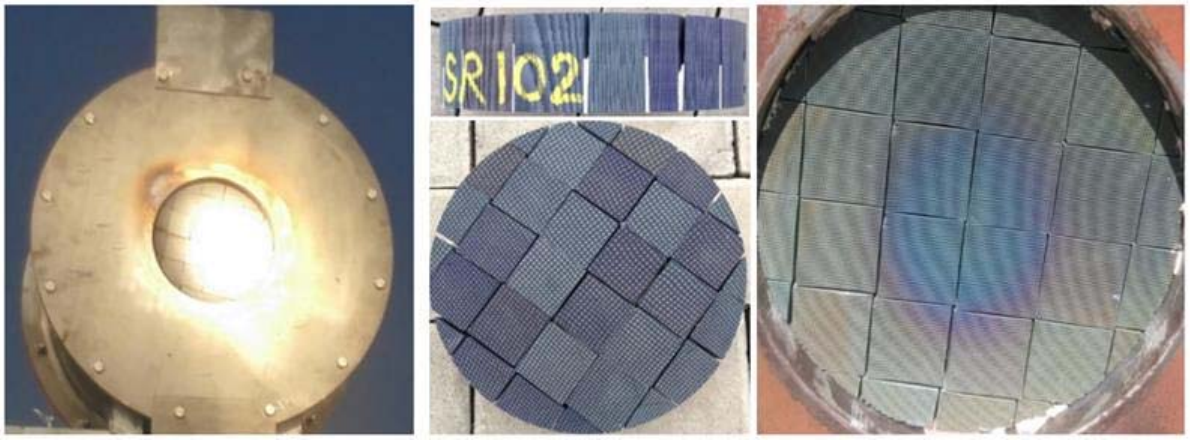

Figure 10 - Volumetric absorber material. (left) During testing; (center) before (right) after 20h

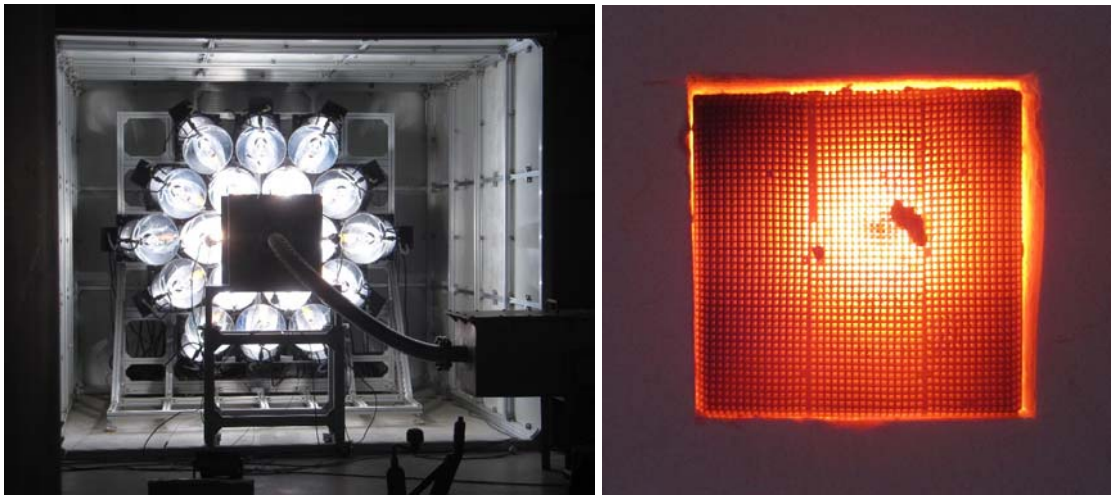

Figure 11 - Left, photograph of the IEECAS new 30 kWth high flux solar simulator during operation. Right, siliconized silicon carbide monolithic honeycomb photographed immediately after ceasing operation of the solar simulator, at temperatures in excess of 1300 ºC

Significant results:

- Specification of material properties and search of appropriate absorber materials (IMDEA, IEECAS)
- Characterization of materials in high-flux solar simulators (IMDEA) and solar furnace (IEECAS)
- New 30 kW_{th} high flux solar simulator developed at IEECAS for absorbers materials
- Design of new 10 kW_{th} calorimetric facility for the experimental aerothermal assessment of volumetric receivers using a 42 kW_e high flux solar simulator at IMDEA, Spain
- Numerical analysis on heat and mass transfer in volumetric absorbers based on radiation heat transfer modelling in SiC ceramic honeycoms and dynamic modelling
- Design, construction and testing of a 10kWth receiver (IMDEA, IEECAS)
- Technical feasibility study of a 100kWth prototype (IMDEA, IEECAS)

Deliverables and Milestones

D6.3 Report on thermal performances of absorbers materials for volumetric receivers (IMDEA/CAS, Jan. 2017)

2.6.2. Subtask 6.5.2 - India (FBK)

The cooperation between FBK (Italy) and IIT Delhi, IIT Roorkee and the University of Delhi South Campus (India) focuses on the development of indigenous miniaturized CSP technologies and energy polygeneration for rural communities of India. Along 2014, FBK started to prepare the framework for collaboration with India, however, due to revision on the Indian side the project was finally approved October 2015. The agreement started a collaboration between FBK IIT Delhi, IIT Roorkee and the University of Delhi South Campus, and is included within a Programme of bilateral collaboration between the Province of Trento and the Italian Ministry of Foreign Affairs and the Department of Science and Technology of the Indian side.

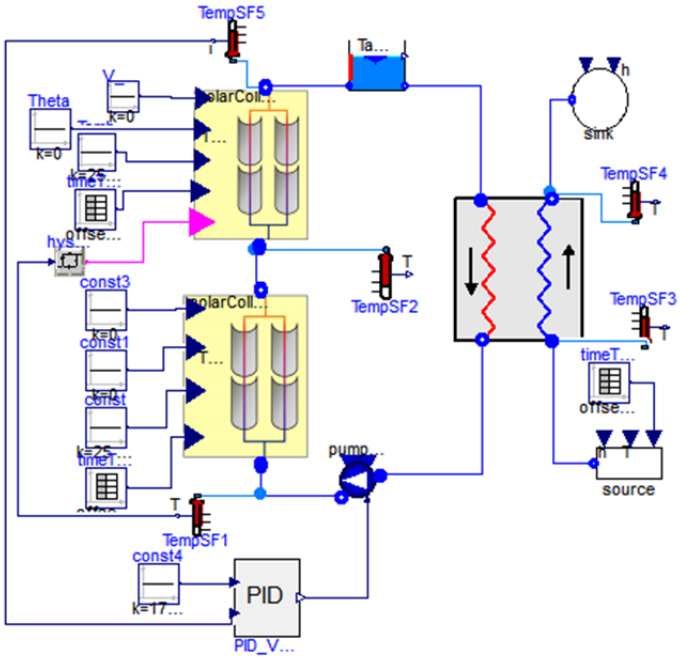

Figure 12 - Plant layout in Dymola environment simulation

The work has started with an interactive design using a dynamic simulation tool (Dymola / Modellica), looking at the issues of low cost and local availability of components. The selection and procurement of the components is partially completed. As the research project is financed completely outside STAGE-STE and needed to look for different funding, it started late and will continue after the termination of STAGE-STE. Nevertheless, the cooperation with IIT in India was established and it is believed that further collaboration projects will result.

Significant results:

- Establishment of bilaterally funded collaboration
- Design and simulation model of polygeneration plant
- Selection of local supply components

3. Summary

The WP6 International coordination provided successfully a platform to enhance existing and new partnerships and cooperations between European and international R&D organizations from countries relevant to Solar Thermal Electricity (STE). Although not all countries could be motivated in the beginning to join the STAGE-STE IRP (here to mention certainly United States and Israel), with the supported bilateral cocperation activities the common knowledge and awareness of the strongly varying conditions, chances and prospects of regional development of STE projects and technology increased. The possibilities and chances for future cooperation projects in this world wide R&D development have certainly increased through STAGE-STE: