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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24-Month Intermediate Progress Report

Deliverable D.6.6

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Content

1. Introduction

As WP6 deals with international cooperation activities, its different Tasks are defined according to the activities carried out on a specific area of the World.

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. However the interaction of participants and also the cooperation with additional STAGE-STE partners is 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:

- The methodology for implementing the individual tasks is by:
- 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. Project management

The overall progress in the workpackage WP6 and the contributions of the beneficiaries in the two periods 1-12 month and 13-24 month are described in the next paragraphs and tables.

Work package no.	**WP 6**	Plan-Start:	**M01**	Plan-End:	**M48**
Lead Participant	**FISE**	Actual-Start:	**M01**	Actual-End:	**M48**
Work package title	International Cooperation Activities				
Activity Type	Coordination activities				
Participant involved	**DLR, PSI, FISE, ENEA, CYI, CTAER, CENER, CRS4, SUN, CSIRO, IMDEA, IEECAS, FBK, CIEMAT, UEVORA, TKN, CNRS, CEA, CRAN, UNIPA, KSU, CSERS, UCAM, LNEG, UNAM, FUSP, UDC**				
Work package summary of progress towards objectives					

WP6 General Achievements:
MS22 Definition of the complete and final schedule plan of international collaboration activities and their relevance to defined RTD activities (in month 4)
MS23 Submission of intermediate report on STAGE-STE International Collaboration (month 24) – achieved in month 28

An important achievement was the positive evaluation from the review meeting in July 2015 in Chambery/France.

During the last 12 months it was decided to monitor the manifold short-term visits of scientists from and to international partner countries. A website with a form has been created and programmed where all short-term mobilities of partners can be documented. This website is operational since December 2015. Due to this completion date not all forms have been filled retrospectively for all the past activities. It was requested during the project meeting in Freiburg in January 2016 that partners complete these forms also retrospectively.
Since then 13 trips have been registered.

Task no.	**Task 6.1**	Activity:	**Coordination**	Plan-Start:	**M01**	Plan-End:	**M48**
Lead Participant	**CIEMAT**			Actual-Start:	**M01**	Actual-End:	**M48**
Task title	**Coordination with relevant international organizations**						
Participant involved	**CIEMAT, DLR, PSI, FISE, ENEA, CYI, CTAER, CENER, UEVORA, IMDEA, TKN**						

Status of Deliverables and Milestones
Task 6.1 has no specific Deliverable nor Milestone, but contributions to Milestones (i.e., M22, M23 and M24) and Deliverables (i.e., D6.6 and D6.7) of the overall WP6.

Justification of Resources allocated / Plan vs. Actual	Plan (period)	Actual (period)	Plan (total)	Actual (total)
	12.26	**13.45**	**24.5**	**13.49**

CIEMAT (M01-M12): Contributions and presentations made at SolarPACES ExCo meetings (Eduardo Zarza) (0.16PM)
DLR (M01-M12): Coordination of activities with Solarpaces, Tasks II and III (0.5PM)
PSI (M01-M12): Coordination with SolarPACES: Reporting on worldwide Solar Fuels Activities including STAGE-STE at ExCo and Task II (Solar Chemistry Research) Meetings; Special Task II Activity "Roadmap to Solar Fuels" (Workshops with industry, governments, academia in selected countries such as AUS, RSA, CHN; Plenary Session at SolarPACES Conference 2014). (0.56PM)
CNRS (M01-M12): (0.04PM)
FISE (M01-M12): (0.05PM)
CTAER (M01-M12): T6.1.3: Initiation of coordination activities with IRENA. Start of information gathering on IRENA to define the most suitable ways for collaboration and coordination with STAGE-STE. (0.26PM)
UEVORA (M01-M12): Collaboration into Task 6.1 activities (Manuel Collares) (0.1PM)
SUN (M01-M12): (0.22PM)
FUSP (M01-M12): (3.05PM)

CIEMAT (M13-M24): Presentations at SolarPACES ExCo meetings conferences (0.5PM)
DLR (M13-M24): coordination of activities with Solarpaces, Tasks II and III
4 Tasks 4 Tasks 4 Tasks 3 Tasks 2 Tasks 2 Tasks Due Report (M13 - M24) Previous Reports (M01 - M12) Project Total (Contractor)
coordination of activities with Solarpaces, Tasks II and III (0.53PM)
PSI (M13-M24): Coordination with SolarPACES: Reporting on worldwide Solar Fuels Activities including STAGE-STE at ExCo Meetings in Rome & Cape Town and Task II (Solar Chemistry Research) Meeting in Cape Town; Special Task II Activity "Roadmap to Solar Fuels" (Workshop with industry, governments, academia in Xi'an, China); Plenary Session at SolarPACES Conference 2015 in Cape Town). (1.04PM)
FISE (M13-M24): (0.43PM)
CTAER (M13-M24): T6.1.3. Progress in coordination activities with IRENA. Share of information on STAGE-STE and IRENA activities to define the most suitable ways for collaboration and coordination with STAGE-STE. (0.87PM)
UEVORA (M13-M24): Contribution to coordination with relevant international organizations (0.45PM)
IMDEA (M13-M24): Link with ISES. International dissemination of STAGE-STE at international level. (1.33PM)
TKN (M13-M24): Cooperation activities with SolarPACES (heliostat) (0.4PM)
IEECAS (M13-M24) Cooperation activities with SolarPACES and IEC to edit the CSP standard (2.3PM).

Task no.	**Task 6.2**	Activity:	**Coordination**	Plan-Start:	**M01**	Plan-End:	**M48**
Lead Participant	**CIEMAT**			Actual-Start:	**M01**	Actual-End:	**M48**
Task title	**Cooperation with MENA region**						
Participant involved	**CIEMAT, DLR, CNRS, ENEA, CEA, CYI, CTAER, CENER, CRAN, UNIPA, KSU, CSERS, UCAM**						

Justification of Resources allocated / Plan vs. Actual	Plan (period)	Actual (period)	Plan (total)	Actual (total)
	68.26	**61.24**	**136.5**	**61.24**

CIEMAT (M01-M12): Activities carried out in Solar Desalination, parabolic troughs and reflector materials according to the detailed planning of CIEMAT-KSU collaboration (subtask 6.2.3). Meeting and specific workshop organized at PSA (after Perpignan meeting) (2.04PM)
DLR (M01-M12): Cooperation with MENA region supporting WP8 (1.65PM)
CNRS (M01-M12): (0.04PM)
FISE (M01-M12): (0.05PM)
CEA (M01-M12): (0.25PM)
CYI (M01-M12): (0.11PM)
CTAER (M01-M12): Participation in the plenary session of the Hassan II Academy of Science and Technology. Meetings with Université Euro-Méditerranéenne de Fès to develop joint CST project for INNOTHERM III programme of IRESEN. Development of collaboration agreement with Université Euro-Méditerranéenne de Fès on joint CST project for INNOTHERM III programme of IRESEN. (1PM)
CRAN (M01-M12): Collaborations with CSERS in Libya on workpackages 8,11,12 (Paul Kirby and Chris Sansom) (1.21PM)
TKN (M01-M12): (0.3PM)
KSU (M01-M12): Activities related to KSU works within subtask 6.2.3 (3.15PM)
SUN (M01-M12): (0.22PM)
FUSP (M01-M12): (3.05PM)
UCAM (M01-M12): Contributions to subtask 6.2.1 (9PM)

CIEMAT (M13-M24): Cooperation and research activities with King Saud University (1.91PM)
DLR (M13-M24): cooperation with MENA Region supporting WP8 (0.73PM)
CNRS (M13-M24): (0.11PM)
FISE (M13-M24): (0.43PM)
CEA (M13-M24): (1.2PM)
CYI (M13-M24): Cooperation with MENA region via cooperation with the STS-MED project (0.5PM)
CENER (M13-M24): Coordination meetings with UNAM (6PM)
CRAN (M13-M24): 3 research staff to a total of 2.89 person months on international cooperation with Libya (2.89PM)
KSU (M13-M24): Development of insulation system to parabolic trough receiver. Collaboration with PSA on defined solar desalilnation activities (2.4PM)
CSERS (M13-M24): Collaboration with Cranfield University within Sub-Task 6.2.2 defined ativities (10PM)
IEECAS (M13-M24) Cooperation with Masdar Institute to develop the simulation tool of CSP plant. Based the Chinese Academy of Scineces project (1PM).
UCAM (M13-M24): Collaboration with CNRS on Subtask 6.2.1 activities (10PM)

Task no.	**Task 6.3**	Activity:	**Coordination**	Plan-Start:	**M01**	Plan-End:	**M48**
Lead Participant	**LNEG**			Actual-Start:	**M01**	Actual-End:	**M48**
Task title	**Cooperation with Latin America region**						
Participant involved	**PSI, FISE, ENEA, LNEG, CTAER, CENER, UEVORA, IMDEA, TKN, UNAM, FUSP, UDC**						

Justification of Resources allocated / Plan vs. Actual	Plan (period)	Actual (period)	Plan (total)	Actual (total)
	72.00	**63.73**	**144**	**66.73**

PSI (M01-M12): Preparation of mobility of PhD Student A. Bautista from UNAM at PSI and supervision during his stay at PSI (Jan-Mar 2015). (0.58PM)
CNRS (M01-M12): (0.04PM)
FISE (M01-M12): (0.05PM)
CEA (M01-M12): (0.25PM)
CYI (M01-M12): (0.11PM)
LNEG (M01-M12): Main activities: Coordination of task 6.3; Review of current available tools for simulation of CSP power tower plants and adaptation of existing models to design and simulate small central tower receiver plants applied to agro-industry facilities in cooperation with USP. (3.16PM)
CTAER (M01-M12): Initiation of collaboration activities between researchers from CTAER and from México (University of Sonora). Meetings with the Sonora University General Secretary to define collaboration agreement to develop joint research projects and innovation activities and share knowledge on measurement techniques, optics characterisation and error detection for solar concentrators… Development of an Era-NET-LAC project proposal focused on the reduction of CO2 emissions by means of CST technologies for heating and cooling in the industrial processes. Visit to the Hermosillo Solar Platform. Meeting with the representative of the National Council of Science and Technology. Attendance to the WP6 meeting to coordinate the activities of WP6, WP9 and WP12. Participation in the XI Iberoamerican Congress of Solar Energy. (0.33PM)
CENER (M01-M12): Attendance to coordination meeting with UNAM during ANES-ISES congress. Analysis of capabilities of UNAM for testing small size heliostats , including control and calibration systems. (1.25PM)
UEVORA (M01-M12): Contributions to subtask 6.3.2 (collaboration with Brazil). Manuel Collares (0.4PM)
IMDEA (M01-M12): Cooperation with UNAM (mexico) on gasification of Mexican petcoke. Hosting Mexican researchers from UNAM. (0.98PM)
TKN (M01-M12): (0.3PM)
UNAM (M01-M12): Collaboration in activities related to subtask 6.3.1 (10.5PM)
SUN (M01-M12): (0.22PM)
FUSP (M01-M12): Contributions to subtask 6.3. Attendance to kick-off meeting. Design and detailing of prototype heliostat. Attendance to workshop and congresses in Rio de Janeiro (meeting with partners), Julich (INOPA) and Mexico (XI Congreso Iberoamericano + CYTED seminar) (3.05PM)
UDC (M01-M12): Technical activities related with contribution to subtask 6.3.3. Atendance to General Assembly meetings (kick-off and Perpignan) (8.69PM)

PSI (M13-M24): Hosting of Ph.D: student from UNAM including performance of steam gasification test campaign with Mexican petcokes in PSI's solar simulators (2.47PM)
FISE (M13-M24): (0.43PM)
LNEG (M13-M24): Main activities: Coordination of task 6.3; Cooperation activities with USP (Brazil) in the field of small central receiver systems. (2.84PM)
CTAER (M13-M24): - Mobility programme to UNAM on Deflectometry as measurement technique. - Studies of possibilities for further cooperation with UNAM: development of an extended test campaign in order to further analyse the difference between Photogrammetry and Deflectometry. - Visit to UNAM's solar furnace at Temixco: discussion on the possibility of collaborating in a research project focused on the use of concentrating solar energy for Calcium carbide production. - Attendance to the XXXIX National Solar Energy Week 2015, organised by ANES in Campeche - Continuation of collaboration activities initiated during P1 between researchers from CTAER and University of Sonora to define collaboration agreement to develop joint research projects and

innovation activities and share knowledge on measurement techniques, optics characterisation and error detection for solar concentrators… (0.14PM)
CENER (M13-M24): Coordination meetings with CSIRO (1.2PM)
UEVORA (M13-M24): Contributions to subtask 6.3.3 (collaboration with Chile: FISE+UEVORA+UDC): develop solutions for CHP+Desalination solutions for the industry and agriculture (0.25PM)
IMDEA (M13-M24): Cooperation with UNAM (mexico) on gasification of Mexican petcoke. (1.01PM)
TKN (M13-M24): Coordination with the mexican partners (0.6PM)
UNAM (M13-M24): (6PM)
FUSP (M13-M24): Development of models for central receiver systems: - Ray-tracing model of faceted heliostat prototype with Tonatiuh - Ray-tracing model of Brazilian pilot plants with Tonatiuh - Steady-state-based model of Brazilian solar/biofuel hybrid pilot plants co-generation of electricity and heat in agro-industry. . Organization of two international dissemination events. (14PM)
IEECAS (M13-M24):): Interaction with CSIRO in the dynamic testing method of solar collector, one assistant professor has been working in CSIRO one year .(5PM)
UDC (M13-M24): Junior Researcher 1 - Task 6.3.3 C - Research on molten salts from Chile (1.96 PM) Junior Researcher 2 - Task 6.3.3 A - Research on solar heat and power for mining operations in Chile (2.50 PM) Senior Researcher 1 - Task 6.3.3 A - Research on solar heat and power for mining operations in Chile (0.42 PM) (4.88PM)

Task no.	**Task 6.4**	Activity:	**Coordination**	Plan-Start:	**M01**	Plan-End:	**M48**
Lead Participant	**FISE**			Actual-Start:	**M06**	Actual-End:	**M48**
Task title	**Cooperation with Australia/South Africa**						
Participant involved	**DLR, PSI, FISE, ENEA, CYI, CTAER, CENER, CRS4, SUN, CSIRO**						

Justification of Resources allocated / Plan vs. Actual	Plan (period)	Actual (period)	Plan (total)	Actual (total)
	30.50	**24.51**	**61**	**24.51**

DLR (M01-M12): Cooperation with CSIRO concerning solar fuels and heliostat ageing (0.5PM)
PSI (M01-M12): One week staff exchange stay (C. Wieckert) at CSIRO for discussions of potential joint work (including preparation work). (1.15PM)
CNRS (M01-M12): (0.03PM)
FISE (M01-M12): (0.03PM)
CEA (M01-M12): (0.25PM)
CYI (M01-M12): (0.11PM)
CTAER (M01-M12): T6.4.2: Liaise through the CTAER's delegate in South Africa with Universities and with the national Solar Thermal Energy Research Group (STERG) of Stellenbosch University (SUN) to coordinate future joint RTD and training programmes in CST. Development of a H2020 project proposal focused on the integration of solar heating in industrial processes. Study of the SUN's pilot plant. Active collaboration of some researchers from SUN in CTAER's research projects. Participation in the Southern African solar energy conference,(SASEC) hosted by SUN and supported by SolarPACES. Relationships with the South African research, industrial and public entities in the sector, presentation and dissemination of information about the STAGE-STE project. (1PM)
CENER (M01-M12): Coordination meetings with CSIRO Analysis of capabilities of UNAM, CSIRO for testing small size heliostats , including control and calibration systems. (0.75PM)

TKN (M01-M12): (0.3PM)
CRS4 (M01-M12): (1.15PM)
SUN (M01-M12): Subtask A: First investigations on cheap Fresnel collector design started (literature study and market screening) Subtask B: Preparation of measurements started Discussion measurement devices between FHG and SUN (0.13PM)
FUSP (M01-M12): (1.78PM)

PSI (M13-M24): Interaction with CSIRO (0.04PM)
FISE (M13-M24): (0.43PM)
CYI (M13-M24): Visit to CSIRO and MoU with CSIRO (0.53PM)
CTAER (M13-M24): T6.4.2. South Africa Liaise through CTAER's researchers and its delegate in South Africa with Universities and with the national Solar Thermal Energy Research Group (STERG) of the University of Stellenbosch (SUN). Meeting in Stellenbosch with the STERG (20-21/10/2015) to review the achievements in the cooperation frame established during the first mission and try to develop it further. CTAER and SUN reviewed the collaboration activities carried out during the last year and explored potential synergies and conflicts in different areas of activity. It was agreed to work on the establishment of a formal collaboration frame covering not only the collaboration in project proposals, but also training at different levels in the field of solar thermal concentrating systems. Relationships with the South African research, industrial and public entities in the sector, presentation and dissemination of information about the STAGE-STE project. (1.09PM)
CRS4 (M13-M24): W P 6 Task 6.4 in Force (0.25PM)
SUN (M13-M24): WP6.4.2 (South Africa) Part A) Development of a low cost Linear Fresnel Collector (LFC) It was done by SUN during that time period: A1. Design requirements for a LFC in South Africa (SA) defined A2. Possible suppliers for components available A3. Discussions on design with component suppliers Part B) Implementation and Testing of Dynamic Collector Test Method It was done by SUN during that time period: B1.&B2. Site evaluation and choosing test site B3. Installation test equipment and first measurements (12PM)
IEECAS (M13-M24): Cooperation with IMDEA on volumetric ceramic absorbers. (5PM)

Task no.	**Task 6.5**	Activity:	**Coordination**	Plan-Start:	**M01**	Plan-End:	**M48**
Lead Participant	**IMDEA**			Actual-Start:	**M01**	Actual-End:	**M48**
Task title	**Cooperation with Asia**						
Participant involved	**ENEA, IMDEA, IEECAS, FBK**						

Justification of Resources allocated / Plan vs. Actual	Plan (period)	Actual (period)	Plan (total)	Actual (total)
	37.50	**31.70**	**75**	**31.70**

CNRS (M01-M12): (0.04PM)
FISE (M01-M12): (0.05PM)
CEA (M01-M12): (0.25PM)
CYI (M01-M12): (0.11PM)
IMDEA (M01-M12): Cooperation with IEE-CAS (China) on volumetric ceramic absorbers. (2.84PM)
TKN (M01-M12): (0.3PM)
SUN (M01-M12): (0.22PM)
FUSP (M01-M12): (3.05PM)

IEECAS (M01-M12): Contributions to subtask 6.5.1. Attendance to project meetings (Kick-off and Perpignan) (16PM) FBK (M01-M12): Preparation of the collaboration with India. Drafting of the proposal, predesign of the Technology to be developed, identification of the proposed rural community, workshop in Trento (1.4PM)
FISE (M13-M24): (0.43PM) IMDEA (M13-M24): Cooperation with IEE-CAS (China) on volumetric ceramic absorbers. (3.01PM) IEECAS (M13-M24): (3PM) FBK (M13-M24): collaboration with India in setting up the bilateral cooperation project, kick off and initial activities with initial design of the solar system for rural communities (1PM)

3. Results

3.1. T6.1 Coordination with relevant international organizations (CIEMAT)

Since no deviation has taken place, the activities performed in 2015 within the three subtask composing Task 6.1 are those defined in the detailed planning of WP6 for this Task. The main objective of this Task for the second year (i.e., the reinforcement of the collaboration between STAGE-STE and SolarPACES, ISES and IRENA communities) has been fully achieved.

There is not a great deviation between the manpower devoted to this Task in the second year (3,37 manmonths) and the manpower initially planned for the second year (2,83 manmonths). A summary of the activities in 2015 is given in the following paragraphs.

3.1.1. Activities performed in Subtask 6.1.1: Collaboration with SolarPACES (Solar Power and Chemical Energy Systems

CIEMAT has kept SolarPACES Executive Committee informed about STAGE-STE activities presenting project progress reports at the 88th and 89th SolarPACES ExCo meetings held in March and October 2015 in Rome and Cape Town respectively. 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)

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 will allow a more intense information exchange between SolarPACES members and standardization committee IEC/TC117.

PSI, as Operating Agent of SolarPACES Task II (Solar Chemistry Research) has also participated in this Subtask. The activities performed by PSI are related to “Solar Fuels” and include reporting to the SolarPACES ExCo members, organization of the annual Task II Meeting, attending the annual SolarPACES Conference and related events (e.g., SolarPACES Workshop on Solar Fuels), as well as preparing/editing the SolarPACES Annual Report for Task II. PSI activities in 2015 within Subtask 6.1 have been mainly related to STAGE-STE WP9 (Solar Fuels).

DLR has organized a SolarPACES TASK III workshop on the 12th of October 2015 in South Africa (Kapetown) to discuss the actual progress of development of guidelines for standards. More than 65 participants from research and industry were present. 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. A summary of the status was then presented at the 89th SolarPACES Exco Meeting. Two proposals for the financing of workshops were transmitted to the ExCo and assigned. A working group for reflectance measurement of mirrors organized a workshop in July 2015 in Freiburg and the working group on storage held a workshop in May 2015 in Madrid.

3.1.2. Activities performed in Subtask 6.1.2: Collaboration with ISES (International Solar Energy Society):

During the second year of the project IMDEA has been very active in this Subtask, which is aimed at collaborating with ISES. The Main activities performed in this Subtask are:

- IMDEA organized a webinar with ISES on 17 April 2015 devoted to “Solar driven thermochemical production of sustainable fuels”. In this webinar distinguished experts in solar-driven thermochemical conversion technologies from IMDEA, PSI, DLR and FUSP provided up-to-date information about the international programs on R&D and recent successful demonstration projects. This webinar was organized in cooperation with the EERA. 64 countries were represented at this webinar by a total number of attendees of 158 http://ises.org/what-we-do/events/webinars/webinar-17-april-2015/
- IMDEA organized the Forum on “Solar Thermal Electricity: Technology and Market Development” at the ISES Solar World Congress 2015, November 11, Daegu, South Korea. Experts from :SUN, FUSP, UNAM, IEECAS, IMDEA, CNR and FISE participated in this Forum. Specific information about the R&D network STAGE-STE was provided in this Forum.
- Dr. José González-Aguilar (IMDEA) and Prof. Zhifeng Wang (IEECAS) were Theme Chairs on CSP at the ISES SWC2015. http://www.swc2015.org/index.php?g_page=intro&m_page=intro04
- IEECAS (Dr. Huibin Zhu) gave the CSP Keynote on November 11 at ISES SWC2015. Dr. Manuel Romero (IMDEA) chaired the session and debate. http://www.swc2015.org/index.php?g_page=program&m_page=program06&cate=3

3.1.3. Activities performed in Subtask 6.1.3: Collaboration with the IRENA (International Renewable Energy Agency):

Activities in this Subtask have been performed by CTAER and were aimed at implementing a fruitful collaboration with IRENA. 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 a possible 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). <--> WP4
- 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. <--> WP2
- Analysis of markets for renewable energy in terms of economic regions, identifying the current state of development of the industry, level of investment, etc. <--> WP5
- The conduct of studies of socio-economic impact (job creation, impact on GDP, etc.). *General info.*
- The study of scenarios for renewable energy penetration and analysis of the potential impact. *General info.*
- The study of the possibilities of access to energy (off-grid applications, etc.). *General info.*
- Study of scenarios for RE penetration and analysis of the potential impact. *General info.*
- The study of possibilities of access to energy (off-grid applications, etc.). *General info.*

3.1.4. Main achievements

Subtask 6.1.1:

- Efficient communication channel implemented between STAGE-STE and SolarPACES ExCo, thus providing updated information to non-European Countries that are not participating in STAGE-STE.

- Implementation of a formal Liason between IEC/TC-117 and SolarPACES
- Preparation of a comprehensive solar fuels roadmap document for two selected countries (Australia and South Africa).
- Initialization of a solar fuels roadmap for China (2015-16).

Subtask 6.1.2:

- Fluent collaboration with ISES International Headquarters in Freiburg and with ISES Europe.
- International dissemination of STAGE-STE at international level and beyond the classical CSP community (collaboration in webinars)
- STAGE-STE presence in ISES Solar World Congress (Korea 2015) and Regional Congresses (e.g. Latin-American in Queretaro, Mexico 2014) through organization of specific Forum and technical sessions

Subtask 6.1.3:

- Implementation of a communication line between CTAER and Dr. Rabia Ferroukhi, Deputy Director - Knowledge, Policy and Finance Centre of IRENA, to discuss possible collaboration between IRENA and STAGE-STE to avoid duplications and maximise synergies.
- Identification of many activities carried out by IRENA of interest to STAGE-STE.

3.2. T6.2 Coordination with MENA (CIEMAT)

3.2.1. Introduction

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

3.2.2. Subtask 6.2.1 (Morocco)

UCAM activities

During the first year of this project, we were proposed to use concentrated solar power for phosphate ores thermal treatment. The thermal treatment is an important operation in industrial processing of phosphate ores.

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 aim to dehydrate and calcinate the raw ores.

The phosphates considered are the sedimentary one and were represented mainly by fluorapatite-hydroxyl poles [Ca_{10} (PO_4) 6 (OH, F) $_2$] and / or carbonate fluorapatite (called Francolites) [$Ca_{10}(PO_4)_{6-x}(CO_3F)_x(OH,F)_2$] where x is generally close to 1.

The proposed experimental procedure is based on mastering of phosphates thermal treatment processes through a multidisciplinary study involving thermal parts, thermodynamic, chemical, recovery and control processes.

On the sidelines of the work already carried out, further study and physicochemical characterization were conducted to complete the necessary data (temperature measurement, physical and chemical analysis, mechanical, thermal and hydraulic properties during several phases of treatment, ...)

In the first stage, a characterization of the raw product to determine its particle size, chemical composition and structure was performed.The first tests were carried out in a conventional oven to determine the evolution of the corresponding chemical complex system.

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 show that the organic matter is decomposed completely to the temperatures around 400 ° C, and then begins the calcination reactions that cause the oxidation of secondary metals and release sulfur oxide. It follows that the dynamic flash calcinations in furnace at 1000 ° C give the most interesting results, in terms of quality of calcined phosphate at the level of production of phosphoric acid.

Two operations include this heat treatment:

Dehydration and carbonates decomposition. In fact, just after removal water included in ores, all carbonates are decomposed on dolomite and calcite.

UCAM contribution was to carry out the study of phosphate calcinations by using solar concentrator power. The main parameters used to characterize phosphates reactivity are: solubility, PO_4/CO_3 ratio, surface area and porosity. Also, the main parameter for the classification of phosphates, BPL (bone phosphate of lime), TPL (triphosphate of lime) is the P_2O_5 concentration in phosphate. Actually, the phosphate rock reserves in morocco are found in sedimentary marine deposits of the Upper Cretaceous and Eocene ages of the Mediterranean phosphogenic province. Only 28-38% P_2O_5 can be considered as commercial phosphate deposits. The mined ore is usually processed for upgrading to about 28-38% P_2O_5. Around the world, the use of phosphate is in increase and it is necessary to explore phosphate at low rate. To achieve this goal, calcination at high temperatures (800-1000°C) are performed to achieve high grade P_2O_5. Calcination leads to the enrichment of phosphates by dissociation of carbonates. The thermal dissociation of carbonates is carried out at temperatures ranging from 850 to 1000°C according to the chemical reactions:

$$CaCO_3 \leftrightarrow CaO + CO_2 \quad 600\text{-}750°C$$

$$MgCa(CO_3) \leftrightarrow MgO + CaO + 2CO_2 \quad 750\text{-}840°C$$

The chemical composition and the structure of final product depend on the nature of technique of enrichment (see following figure):

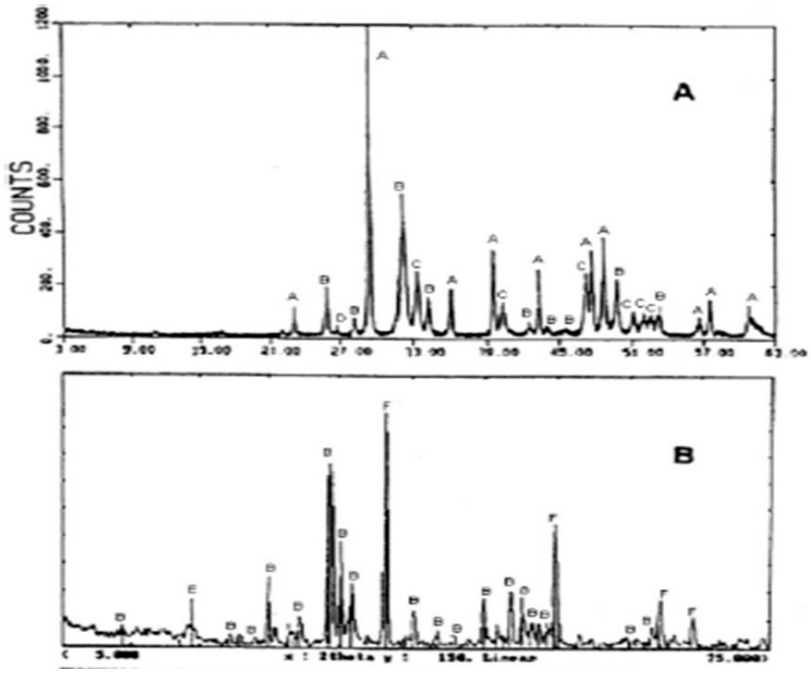

Figure 1 - XRD spectra: (A) raw ore,(B) calcined ore during15 min at T= 850°C

According to this figure, the main minerals in raw ore are calcite ($CaCO_3$), fluroapatite ($9CaO,3P_2O_5$,CaF_2) and carbonate-fluroapatite ($9CaO$, $3P_2O_5$, Ca (F,CO_3) H_2O), whereas the main components in the completely calcined samples are fluroapatite and calcium oxide. As it can be seen, carbonate-fluroapatite has changed to fluroapatite as a result of calcination. At high temperature, all organic matter is completely decomposed at 400°C whereas the decomposition of carbonates is performed to 800°C. The thermodynamic study of this chemical system is being investigated to define the released vapor and the residue compositions at each temperature. The first tests were carried out in a conventional oven and they will be followed by solar furnace tests in the next few months.

DLR activities

Together with its Moraccan Partner IRESEN, DLR is exposing 135 samples of aluminum and 40 samples of silvered-glass mirrors in Morocco at the exposure sites of Oujda, Missour, Erfoud, Zagora and Tan Tan. The samples are analyzed together for corrosion and optical degradation. The samples also serve as reference for the accelerated aging tests carried out in WP8.1. 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 WP8.3. A measurement campaign for the site of Zagora is planned in 2016.

3.2.3. Subtask 6.2.2 (Libya)

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 good progress has been made on the revised objective.

A meeting took place between Dr Mohammad Abdunnabi (Head of Thermal Energy conversion Department at CSERS Libya) and Dr Peter King of Cranfield University at the STAGE-STE meeting in Freiburg in January 2016. Glass samples were supplied to CSERS to mount in the sample holder recently built by CSERS in Ghadames and shown in Figure 2:

Figure 2 - Glass sand erosion holder.

CSERS has also mounted a sand collection device (shown on Figure 3) in Ghadames, aimed at collecting sand particles at different heights ranging from 0.5m to 2m above the ground Figure 3 also shows the weather station that will enable us to correlate sand particle data with climate date.

Figure 3 - Sand particle detection device.

The collaborative project between Cranfield University and CSERS (Libya) is now proceeding well, in accordance with the amended plan that was agreed in June 2015.

We expect to obtain results from the samples that are being exposed in the Libyan desert towards the end of the calendar year 2016. There are logistical problems in sending and receiving samples, especially as CSERS staff find it difficult to obtain visas to travel to Europe and UK staff are not currently able to travel to Libya under UK government guidelines. However, both Cranfield and CSERS are committed to provide and receive samples.

3.2.4. Subtask 6.2.3 (Saudi Arabia)

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

Task A: Modelling of novel receivers for process heat and desalination applications

During this period the final design of the point focus Fresnel concentrator has been concluded with the incorporation of a CPV array with waste heat sink. A preliminary test has been conducted and full-fledged tests are expected during the first quarter of 2016. Laboratory characterization of mirrors manufactured by Saudi local companies was done at CIEMAT-PSA in January 2015 (Report 6.2.3.A.2.1 issued in April 2015)

Task B: Development and testing of novel receivers

During the reporting period, 55 insulating strips (Promat MicroTherm Overstitched) have been acquired for their installation in one of the loops of the small aperture parabolic trough solar field (NEP Solar PolyTrough 1200) at Plataforma Solar de Almería.

Preliminary tests have been carried out in order to investigate the behaviour of the insulating strips under concentrated solar radiation. For that goal, the strips were firstly fixed to the outer suface of the absorber tube and the collectors were put in tracking. Some burning effects were observed and it was necessary to cover the strips with aluminum film in order to avoid such burning effects. Then, a procedure to insert the protected strips within the tube was established.

Full-fledged test will start in February 2016.

Figure 4 - Assessment of insulating strips under concentrated solar radiation

Task C: Assessment of solar-MD prototypes

The assessment of the first experimental results in Saudi Arabia with their MD pilot plant has revealed that some parts need replacement. As soon as the system is fixed, the test campaign in KSU will start in Q1 2016.

Parallel tests with the same MD techology (vacuum assisted multi-effect membrane distillation) have been carried out during 2015 at CIEMAT-PSA and the results are available for comparison as soon as the KSU campaing finishes.

Task D: Theoretical analysis and conceptual design of the coupling between the MED technology and CSP energy production cycle

This task was scheduled to start in M19. However, it has been decided to delay it until finishing all the MD experimental campaign (at least the one at CIEMAT-PSA) and start to work from the results obtained. The new start date for Task D is M25.

3.3. T6.3 Coordination with with Latin America region (LNEG)

3.3.1. Introduction

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:

- Development of small size heliostats (WP12);
- Evaluation of control methods for the heliostat field (WP12);
- Development of a fast ray tracing code (WP12);
- Research in heliostat calibration and testing procedures (WP12);

- Research and development of flux measurement tools in central receiver plants (WP12);
- Kinetic and solar reactors design studies (WP9).

Subtask 6.3.2 aims to foster cooperation with Brasil and is led by LNEG with contributions from USP, UEVORA and UP. The main specific collaborative activities for this subtask are:

- Development of central receiver components and systems numerical models (WP12);
- Study on co-generation application of STE systems in agro-industrial applications (WP12);
- Linear focus solar energy concentrators for thermal and thermal electricity applications (WP11).

Subtask 6.3.3 aims to foster the cooperation with Chile and is led by FISE with contributions from EVORA and UDC. The main specific collaborative activities for this subtask are:

- Industrial generation of heat and electricity in mining industry in Chile (WP11);
- Investigation of integration schemes for low temperature desalination processes in CSP plants using simulation tools (WP10);
- Investigation of suitability of high temperature storage construction materials in interaction with molten salts having different mixtures and contamination levels; (WP7/8);
- Joint workshops and short term exchange.

3.3.2. Subtask 6.3.1 - Cooperation with Mexico

Subtask 6.3.1 aims to foster cooperation with Mexico and is led by CENER with contributions from IMDEA, PSI and UNAM. During the project's second year activity was focused onto the topic "*Solar steam gasification of petroleum coke*", involving the following partners: UNAM/México; IMDEA/Spain; PSI/Switzerland. The main objective of this activity is to study steam gasification of Mexican petroleum coke (feedstock characteristics, kinetics, reactor technologies, etc.) and develop a solar-driven characterization at the solar furnace located in Cuernavaca, Mexico.
UNAM's Ph.D. student Alejandro Bautista stayed for 3 months at PSI (January 2016 to March 2015) following a previous two onth stay in IMDEA (November to December 2015), performing campaigns of pyrolisis and gasification at solar simulator scale in the PSI's 50 kW_{th} High Flux Solar Simulator using a laboratory two-cavity solar reactor (radiative power input about 5 kW). Successful solar steam gasification tests demonstrating the conversion of Mexican petcokes into high quality syntheses gas were performed. From March 2015 to January 2016 additional TGA tests were performed in Mexico and the design of the a solar reactor was started.
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).

Other issues
Delay associated to the operation of the TGA in Mexico and the implementation of the solar reactor in the furnace at IER/UNAM in Cuernavaca. Still some additional TGA tests are required for

complete chemical kinetics analysis of the process and finish the planned publications. The TGA at UAM (Universidad Autónoma Metropolitana) Iztapalapa is to be used and tests finished by June 2016. Additional tests of gasification with one coke foreseen before summer 2016 at 1kW solar simulator in IMDEA Spain for comparative assessment with TGA in Mexico, completing the section on apparent kinetics at solar reactor.

Planning for next six months

- Complete the TGA tests at UAM Iztapalapa (UNAM, April 2016);
- Test campaing of gasification of petcoke at 1kW IMDEA's solar simulator (IMDEA, June 2016);
- Submission of kinetics publication (UNAM, IMDEA, PSI, October 2016).

3.3.3. Subtask 6.3.2 - Cooperation with Brazil

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 working on the development of models for central receiver systems that will be used to study the application of small scale central receiver systems in the industry sector, namely the agro-food industry.

First year activities focused on the review of available software for modelling and simulation of CSP central receiver systems, ending with the selection of Tonatiuh as the tool of choice for the solar field modeling and TRNSYS for the modeling and simulation of the full plant, including the simulation of industrial applications.

During the second year activities were concentrated on collaborative Task A.3 (Month 12-30), "Development of models for central receiver systems". In this first part of the task, available TRNSYS types for central receiver systems models were reviewed in order to define the component model's upgrade necessities. Afterwards, models for individual components of the central receiver plant have been developed. Particularly, this entailed modeling of the optical components, both at individual heliostat and at complete field level. Those have been included in a steady-state-based model of the complete plant and used to predict the performance of the pilot plant being constructed at USP campus in Pirassununga, Brazil. Work currently in progress comprehends the modeling of the absorber tube receiver and the improvement of the complete plant model to include transient behavior.

Significant results

- The review of current available tools for simulation of CSP power tower plants (USP and LNEG);
- Start of the development and adaptation of existing models to design and simulate central tower receiver plants (USP and LNEG).
- Preparatory talks with UP to establish the work plan related with cooperation between UEVORA and UP (UEVORA)
- Steady-state modeling of the optical components, both at individual heliostat and at complete field level (USP)
- Development of steady-state plant model (USP.

Other issues

Due to delays in the plant construction, Task A.4. (Monitoring of USP’s demonstration facilities), scheduled in Month 21, could not start yet. These activities will start as soon as the plant construction is finished which is currently estimated for the Winter of 2016.

Dissemination

Two publications were presented at the ISES Solar World Congress 2015. Two events aimed at divulgating CSP expertise among Latin-American professionals and students were organized by

USP, involving invited speakers from STAGE-STE partners, namely Prof. Manuel Collares-Pereira (University of Évora), Dr. Eduardo Zarza (CIEMAT), and Dr. Jesús Fernández Reche (CIEMAT).

Planning for the next 12 months

- Conclusion of the development of models for central receiver systems (July 2016);
- Beginning of the monitoring of USP's demonstration facilities (estimated Winter 2016);
- Experimental validation of the models developed within A3 and WP12 using USP plant data (January 2017);
- Start of the study of cogeneration applications within the agro-industrial sector through USP plants simulation (October 2016).

3.3.4. Subtask 6.3.3 - Cooperation with Chile

Subtask 6.3.3 aims at fostering the cooperation with Chile, being led by FISE with contributions from U. Évora and UDC. During the project's second year a literature survey on different nitrate salts from Chile was performed, including information such as impurity levels, physical properties. Additionally, investigations regarding the use of different construction steels for thermal energy storage construction were performed.

FISE researchers visited Chile in order to prepare a study on desalination and further discuss with UDC on cooperation possibilities within SERC and PSDA, including the preparation of a joint proposal. The preparation of 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 is ongoing (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.

Also the development of a simulation model for a CHP plant suitable for modelling a typical mining heat and electricity demand using TRNSYS-simulation has been completed. The first result was a simulation of the electro-winning process, in a next step it has been applied to heap leaching (FISE).

Significant results

- Report on Literature search on different nitrate salts from Chile with impurity levels and physical properties and corrosion investigation.
- 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
- Investigations on different construction steels in combination with molten salt (Solar Salt) have been performed

3.4. T6.4 Coordination with Australia/South Africa (FISE)

3.4.1. Introduction

A cooperation between South Africa and Europe is organized by FISE with the SUN. The topics are related to work within WP11

- Development of an indigenous low cost version of a direct steam Linear Fresnel (WP11):
- Implementing and testing a methodology for dynamic solar field testing (WP11)

The key objective of geh work with Australia is related to WP9 to initiate joint pilot scale solar thermochemical reactor testing using the solar tower at CSIRO. Specific actions up to now was a one week stay of Christian Wieckert (PSI) at CSIRO (June 2014). The purpose was the exploration of options for pilot scale testing of thermochemical processes/reactors based on PSI's beam-down two-cavity solar reactor technology reactor at CSIRO. This activity is under further consideration.

3.4.2. Subtask 6.4.1 - Cooperation with Australia

In Subtask 6.4.1 the cooperation with Australia is led by CSIRO/CENER with contributions from CYI, DLR, CRS4 and PSI. The objectives an involvement and participation in appropriate RTD work packages to advance components for high temperature solar towers
CYI has worked on the Task A: Development of small low cost heliostat and field layout software, whereas PSI and CSIRO are working on the Task D Solar fuels from carbonaceous feedstock. The objective here is to initiate a joint pilot scale solar thermochemical reactor testing using the solar tower at CSIRO.
Significant results

- Completion of 50 heliostat field for Cyprus Research Institute using CSIRO heliostats. This involved transfer of manufacturing techniques, surface measurement, ray tracing and field layout and optimisation. Reflective surfaces and actuators are being monitored for degradation rates and mechanisms on an ongoing basis. This field was formally opened by the President of the Republic of Cyprus and the Director of Research for the European Commission in October, 2016.
- There has been a two weeks stay of Prof. Costas N. Papinolas at CSIRO with the purpose of discussing testing procedure and MoU signature between CYI and CSIRO for future cooperation on STE technologies.The objective is testing heliostats designed by CSIRO at Pentakomo CSP facility on Cyprus.
- Cyprus Research Institute has been undertaking fabrication and installation of its molten salt receiver.
- The Australian Roadmap for Solar Fuels Project was completed and the final report submitted to the Australian Government. This project involved 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 indictaed the potential for solar reforming to be used for other products such as methanol and diesel.

Other issues

PSI and CSIRO cooperation within Task D is currently on hold, as the future situation of PSI does not allow longterm cooperation any more.
Dissemination

Formal opening of Pentakomo heliostat field by the President of the Republic of Cyprus and the Director of Research for the European Commission in October, 2016.
Planning for the next 12 months

- Testing of heliostats at Pentakomo site

3.4.3. Subtask 6.4.2 - Cooperation with South Africa

Subtask 6.4.2 aims to foster cooperation with South Africa and is led by FISE with contributions from SUN. FISE and SUN are working on the development of low cost concentrating collectors with emphasis on Fresnel. Also the monitoring and testing data of a Linear Fresnel Collector locally

installed in South Africa shall be used to check and validate a dynamic outdoor testing methodology and evaluation.

- First investigations on cheap Fresnel collector design (literature study and market screening) were done within a students work
- Preparation of measurement methodology and procedure for concentrating collector has started between FISE and SUN; especially a discussion of possible measurement devices and required procurement between FHG and SUN has been going on since July 2014
- An existing installed Fresnel collector has been identified – possibly the first measurement are being done with this collector as the requirement for testing the measurement procedure is urgent and a delay when waiting until a new collector has been built is unavoidable

During the second year activities were concentrated on the procurement and installation of the sensors and monitoring equipment by SUN. FISE consulted during the selection of sensors. On-site visits were needed to discuss the monitoring with the owners of the collector.
On the other hand a study was made looking into design options for a Linear Fresnel collector. This is considered as an option providing a good opportunity for creating local content. FISE researchers visited SUN for development of a monitoring concept and sensor selection as well as for the discussion of the design study. In April 2015 in a seminar FISE presented the state of the art of todays solar process heat. During the SolarPACES Conference in Cape Town FISE and SUN researchers had several working meetings.

Significant results

Results by FISE:

- Preparation of outdoor dynamic testing methodology for Fresnel collector
- Suggestions for testing equipment and discussion of uncertainties
- General design of low-cost Fresnel collectors for process heat
- 2 working visits to SUN
- Presentation on Solar Process Heat within SUN seminar

Results by SUN:

- Preparation of testing of local Fresnel collector installation
- Support to FISE in cooperation with local Fresnel clients
- Investigation on local content possibilities for low-cost Fresnel

Other issues

The final report on the low cost Fresnel is being completed parallel tothis report (Deliverable was due in month 24).

Dissemination

Presentation on Solar Process Heat collectors and system have been given within public seminar at University Stellenbosch by FISE (W. Platzer). During working visits information on Fresnel technology has been presented to industrial customers.

Planning for the next 12 months

- Continuation of the monitoring and analysis of the data for the Fresnel collector
- Dissemination of high temperature concentrating solar thermal at SASEC conference 2016

3.5. T6.5 Coordination with Asia (IMDEA)

3.5.1. Introduction

Task 6.5 involves the collaboration between IMDEA (Spain) and IEECAS (China) on the development and performance testing of absorber materials and volumetric receivers for high temperature solar towers and the cooperation between FBK (Italy) and IIT Delhi, IIT Roorkee and University of Delhi South Campus (India) on the development of indigenous miniaturized CSP technologies and energy poly generation for rural communities of India. 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 cooperation IMDEA and FBK have in Task 12.2.2.4 Identification and selection of suitable materials for solar receivers. At the same time, 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.

3.5.2. T6.5.1 Collaboration with China (IMDEA and IEECAS)

The key objective of cooperation is the development and experimental characterization of volumetric ceramic absorbers for use in central receiver systems. The main objectives and activities planned in this Task are:

- 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)
- Design, construction and testing of a 10kWth receiver (IMDEA, IEECAS)
- Technical feasibility study of a 100kWth prototype (IMDEA, IEECAS)

The IMDEA-IEECAS collaboration was scheduled in a 48-months research program. Coordination between IMDEA and IEECAS was assured through internal milestones and deliverables, meetings (face-to-face and teleconferences) and researcher mobility. Thus, Dr. José González-Aguilar stayed at IEECAS 3weeks (Sep.-Oct. 2014) for screening of candidate materials and specification of tests at solar furnace took place. Dr. Fengwu Bai of IEECAS visited IMDEA, Spain on Jan. 19, 2015. Other meetings were planned taking advantage of STAGE-STE general assembly meetings.
In the first 24-months period, most of the activity has been focused on items 1, 2 and 3. Asian and EU markets on commercial ceramic monolith and foams were explored in order to select the most suitable specimens for being use in solar receivers with the main objective of choosing low-cost supplier. The absorbers finally selected for the characterization were based upon monolithic prismatic channels and foam, both ceramics with SiC. In parallel, two test rigs were prepared to evaluate the performance of selected materials (see figure below). A test bed with a calorimetric loop was designed by IMDEA using a 7kWe high-flux solar simulator (HFSS). The text bed was fully erected and operational to host first ceramic samples during 2015. Simultaneously IEECAS implemented a calorimetric test bench at Badaling solar furnace. The test bench was completed by October 2014 and first test campaigns were conducted November and December 2014.

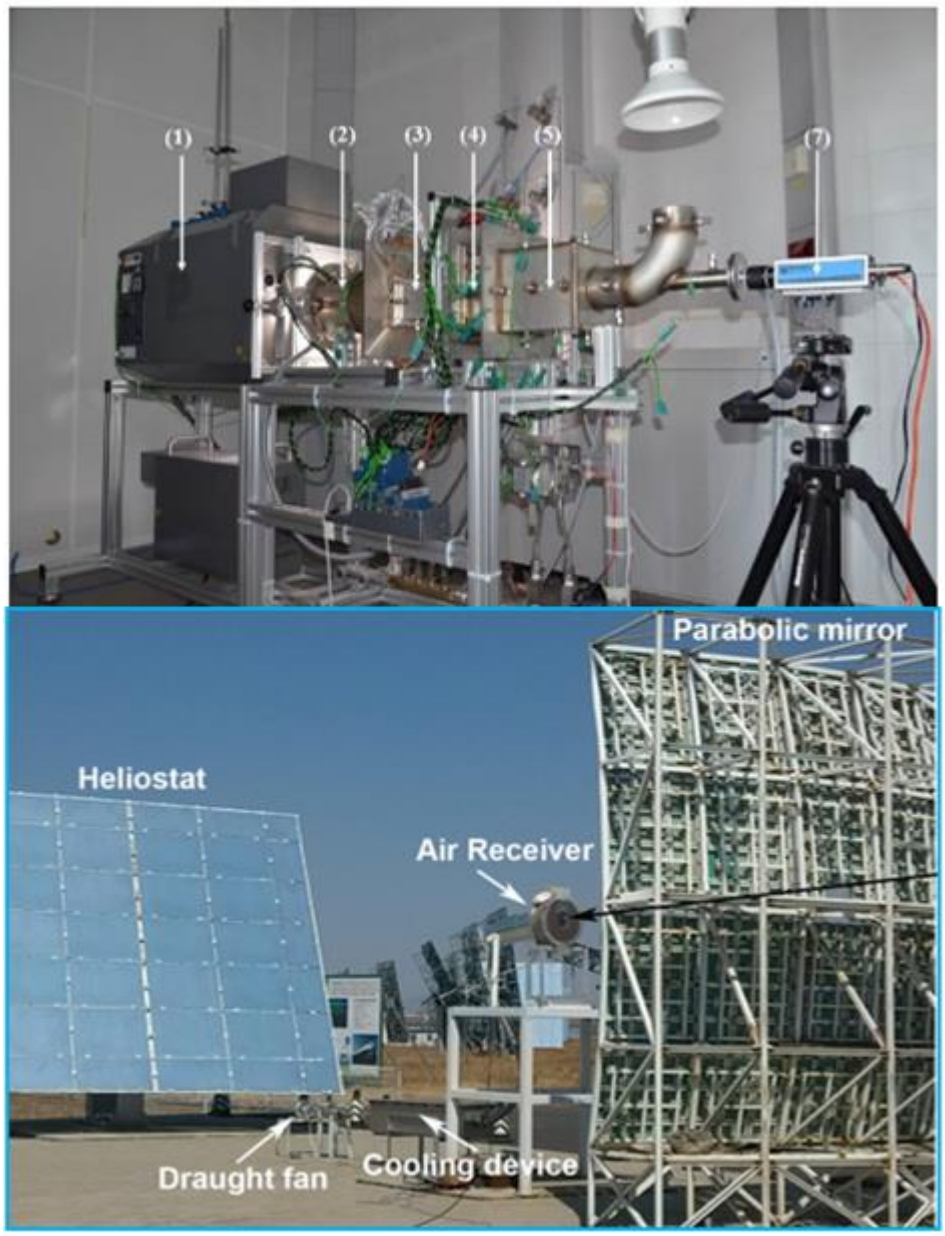

Figure 5 - Test rigs currently in operation. (Top) 1kWth in HFSS (IMDEA, Spain); (Bottom) 10kWth in solar furnace (IEECAS, China)

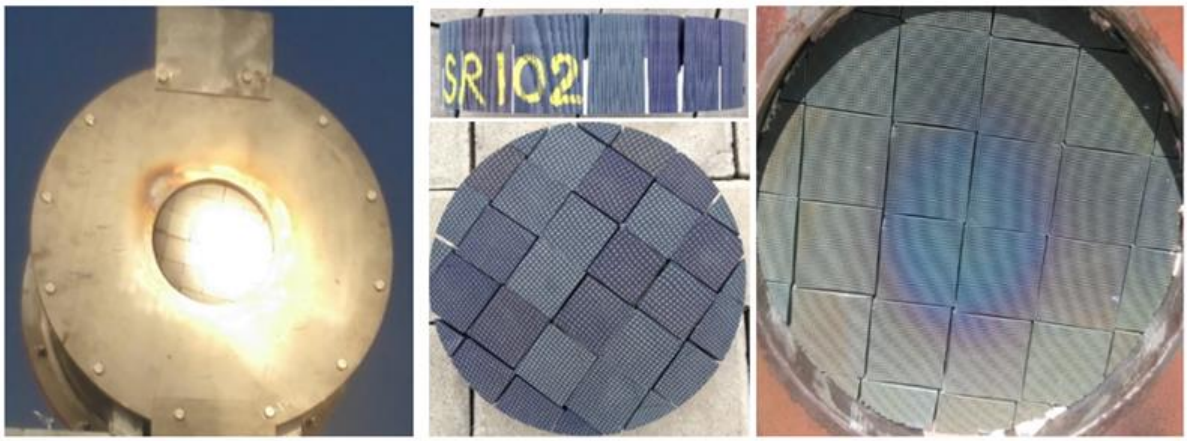

Figure 6 - Volumetric absorber material. (Left) During testing; (Center) before assay; (Right) after 20 h.

IEECAS and IMDEA were able to characterize more than 20 samples with various porosities and lengths (see Figure above). Thermal efficiency, temperature distribution, and pressure drop were measured in relevant operating conditions of heat transfer fluid flow and high radiation fluxes (TRL3-4). In some case, optical properties at ambient temperature were also obtained.
Ending 2015, the design of a 10kW test bed to be installed in the IMDEA's 42kW HFSS in 2016 has started. Experiments in this facility will complement those performed by IEECAS in the solar furnace.
Numerical analyses on thermal characteristics of volumetric absorbers have also been carried out in this 24-month period. IMDEA was mainly focused on radiation heat transfer in monoliths honeycombs and IEECAS performed dynamic simulation of air receiver using SiC ceramic foam as absorber. The one-dimensional Dymola simulation model was validated with the experimental results on solar furnace and it is expected to be applied on system analysis and receiver design.
Significant results:

- Technical specifications on absorber materials issued (December 2014)
- First test campaign done at solar furnace in China with three samples of SiC honeycomb and foam 100-50 mm thick (Nov.-Dec 2014)
- Specification of material properties and search of appropriate absorber between commercial materials
- Two test rigs for aerothermal characterization of absorbers materials are currently in operation located at IEECAS, China (10 kWth in a solar furnace) and IMDEA, Spain (1.5 kWth in a high-flux solar simulator)
- The aerothermal characterization of materials at high-flux solar simulator and solar furnace of SiC ceramic honeycombs and foams has been accomplished. This (China/EU) joint characterization of common samples, including detailed analyses on geometry and radiation incidence influence.
- Numerical analysis on heat and mass transfer in volumetric absorbers based on radiation heat transfer modelling in SiC ceramic honeycoms and dynamic modelling of the 10 kWth test rig using DIMOLA and SiC ceramic foam as absorberTechnical specifications on absorber materials issued (December 2014)
- Qing Li , Fengwu Bai, Zhifeng Wang, José González-Aguilar, Sijie Liu. Dynamic simulation and experimental research of open air receiver system with ceramic foam absorber. ISES 2015, Nov 8-12, Korea

3.5.3. T6.5.2 Collaboration with India (FBK)

Along 2014, FBK started to prepare the framework for collaboration with India.
The framework for collaboration includes:

- Overall agreement of bilateral collaboration between FBK and IIT Delhi, IIT Roorkee, University of Delhi South Campus and the Solar Energy Center of the Ministry for New and Renewable Resources. This initiative 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.
- Definition of topics included in the collaboration.
- Definition of the target objective: this has been identified in supporting the rural communities of India in their specific needs.

The full proposal was completed by the end of 2014. A meeting took place in Trento, between the political and scientific partners involved on October 6th, 2014.

Along 2015, a further revision to the proposal was required by Indian DST. The Solar Energy Center was excluded from the Consortium and activities and all further requests were completed by both FBK and the main Indian partners, IIT Roorkee and IIT Delhi.

In September 2015 the project was finally approved. FBK and Indian partners has the kick off meeting in Trento on October 26th – 28th. A second meeting was organized in India between December 8th – 11th. On 8th and 9th there were a Scientific committee meeting in Jodhpur between all projects participating to the bilateral cooperation. On 10th and 11th December, FBK visited IIT Roorkee and some potential rural villages, to confirm the best candidate.

All the meetings defined the following elements that will be realized in the next 6 to 12 months. Two PhD students (1 from IIT Roorkee and 1 from IIT Delhi) will spend a visiting period in FBK. This will have the scope to train the two students to the specific technology and activate a collaboration focused on the indigenization of the target technology. The two students arrived in Trento on January 8th.

Figure 7 - Meeting by a private school in a rural village 20 km from Roorkee

Main points addressed by the collaboration:

- Design of a solar thermal technology, evolving and indigenizing the solar collector developed in DIGESPO project, realized in small scale concentrators, vacuum receiver, thermal oil and working temperatures in the range of 150 – 220°C;
- cooling technology: integration of a solar adsorber with desiccant materials such as zeolites;
- DSG and related application for sterilization porpuses;
- solar cooker;
- demo activity, to be performed within the rural community addressed.

Main goals of the project that will be modelled and designed in the first 6 month of 2016:

- Climatization -> demonstration of solar cooling technology. Approximately 3 of cooling power and heating. Thermal insulation will be necessary;
- Hay processing -> sterilization purposes of hay, processing of hay. From an experimental laboratory setup, the following data are available:
    1. 50 Kg of hay has to be kept for 30 min at 120°C;
    2. Through this process, the hay is purified from bacteria;
    3. Beneficial microorganisms are added to process the hay;
    4. In 10 days is possible to obtain an improvement of the nutritional values of the feedstock (source: Professor Khad, University of Delhi).
    5. Solar cooking technology: two main cooking modes will be tested. Boiling water to cook vegetables and Hot plate at 200°C;
    6. Hot water for heating purposes: the design will comprise a tank of 200 liters of water at 65°C. Other systems to store higher temperatures can be evaluated (e.g. concrete materials at 200°C).
    7. Sterilization (small tools and medical gears).
    8. Refrigeration for medical purposes (For instance, vaccines)

Components of the Solar Plant

The solar plant will be designed using two kind of technologies integrated: “Standard” vacuum tubes solar collectors at 120°C (14 collectors). CSP based on the Digespo prototype to increase temperature at operating conditions (8 collectors). The total surface for thr CSP system will be 40m^2. The circuit could be an Open loop, close loop. Different configuration has been considered, but at the moment it is premature to focus directly the develoment on one single direction.

- Issues regarding the water quality from the river close to the village;
- Temperature variation, daily and yearly;
- Companies involved (realization, manufacture, assembly of the components).

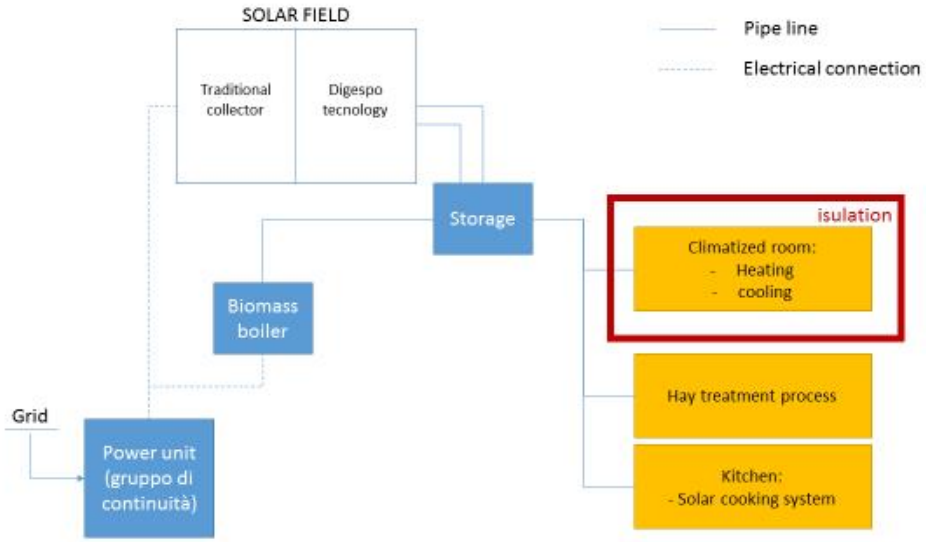

Figure 8 - DRAFT OF THE LAYOUT

ACTUAL STATUS OF COLLABORATION: partners started the collaboration at the end of 2015. At the present it was not possible to move faster with the activities. PhD students arrived in Trento as planned and the collaboration is now active. In the next 6 to 12 months FBK will introduce the 2 students to dynamic modelling and to engineering design of solar collectors. The target is to complete the full technology design by July 2016 and move then the activity of manufacturing components or the system to India.

Significant results:

- Initial design of the technology (2014)
- Identification of the rural community involved for pilot installation (started in 2014, finalized in 2015);
- Start up of the project (October 2015);
- 2 visiting Indian students to Trento (January 2016).

Reasons for deviations from Annex I and their impact on other tasks as well as on available resources and planning:

The collaboration had a delay due to a change in the responsible on the Indian side and to the late feedback of the Indian DST. The coordination of the activity has moved from IIT Delhi to IIT Roorkee.

Reasons for failing to achieve critical objectives and/or not being on schedule and explain the impact on other tasks as well as on available resources and planning

The start up of the project was pending until the end of 2015, due to delay during the approval phase, by the partners and the DST of the Indian Government.

Proposal of corrective actions:

Partners have partially started to collaborate even outside the official project and before its start up. The project end is planned by July 2017.

4. Summary

4.1. Summary Task 6.1

Activities performed in Subtask 6.1.1:
Two project progress reports were prepared and presented by CIEMAT at the 86th and 87th SolarPACES Executive Committee meetings held in 2014, thus assuring the alignment of the activities performed in STAGE-STE with the interests of the international CST energy community represented by the SolarPACES Executive Committee members. These meeting were held in Abu-Dhabi (march 2014) and Beijing (September 2014). The reports presented at these meetings informed the Executive Committee members about the status of the STAGE-STE project and feedback from these people was gathered concerning STAGE-STE.

Within this subtask PSI, as Operating Agent of SolarPACES Task II (Solar Chemistry Research) has been coordinating joint activities of STAGE-STE WP9 ("Solar Fuels") with international SolarPACES member countries / institutions working in *Solar Fuels*. So, during the first year of STAGE-STE PSI has provided information on STAGE-STE WP9 (Solar Fuels) at SolarPACES Task II meetings. PSI has been also developing "*Roadmaps to Solar Fuels*" for selected countries (currently Australia, South Africa, and China) to enhance industry involvement and market penetration

Activities performed in Subtask 6.1.2:

During the first year, IMDEA has coordinated the participation of a delegation of STE-STE members at the XI CIES of ISES Iberoamerican Congress of Solar Energy held in Querétaro, México, 8-10 October 2014, with almost 800 participants. 10 delegates from IMDEA, CIEMAT, CTAER, CENER, TKN and UNAM (partners of STAGE-STE) participated actively in this conference with about 15 communications. Also several contributions of the European STAGE-STE partners in collaboration with UNAM were presented at the conference. It must be pointed out here that in this conference three specific sessions on CST technologies and applications were organized by IMDEA and chaired by IMDEA, CTAER and UNAM respectively.

Other activity in this subtask was the technical workshop hosted by UNAM in Temixco, on 6th October, 2014. This meeting was a coordinating activity with Mexico related to WP6, WP9 and WP12 of STAGE-STE. The Universities of Sonora (México), Antofagasta (Chile) and Sao Paulo (Brazil) also participated in this workshop.

Activities performed in Subtask 6.1.3:

In this subtask coordinating activities are progressing more slowly than in the other two subtask because the links of the European CST technology sector with IRENA are not so mature and well-developed as they are with SolarPACES and ISES. This is the reason why a new activity has been defined within this subtask in order to define its objectives more clearly and thus implement the links to assure a proper coordination between IRENA and the European CST technology sector. CTAER has started to gather information on IRENA to define the most suitable ways for collaboration and coordination with STAGE-STE.

Task 6.1 concerns cooperation with relevant international organizations and the main activities/achievements are listed below:

- Efficient communication channel implemented between STAGE-STE and SolarPACES ExCo, thus providing updated information to non-European Countries that are not participating in STAGE-STE.

- Implementation of a formal liaison between IEC/TC-117 and SolarPACES
- Preparation of a comprehensive solar fuels roadmap document for two selected countries (Australia and South Africa).
- Initialization of a solar fuels roadmap for China (2015-16).
- Fluent collaboration with ISES International Headquarters in Freiburg and with ISES Europe.
- International dissemination of STAGE-STE at international level and beyond the classical CSP community (collaboration in webinars)
- STAGE-STE presence in ISES Solar World Congress (Korea 2015) and Regional Congresses (e.g. Latin-American in Queretaro, Mexico 2014) through organization of specific Forum and technical sessions
- Implementation of a communication line between CTAER and IRENA, through Dr. Rabia Ferroukhi, Deputy Director - Knowledge, Policy and Finance Centre.

4.2. Summary Task 6.2

Task 6.2 concerns cooperation with MENA region. Cooperation with Morocco (IRESEN) is being carried out mainly by DLR through exposure of samples in Morocco for further joint analysis of corrosion and optical degradation. Cooperation with Libya (CSERS) is being handled by Cranfield. This cooperation has been downsized to only one activity ‘Sand erosion of collectors under Libyan desert conditions’. The collaborative project between Cranfield University and CSERS (Libya) is now proceeding well, in accordance with the amended plan that was agreed in June 2015. Last but not least, CIEMAT is leading cooperation activities with KSU (Saudi Arabia) in three complementary ways: Modelling of novel receivers for process heat and desalination applications, development and testing of novel receivers and assessment of solar-md prototypes. All activities have progressed as expected during this reporting period.

4.3. Summary Task 6.3

Cooperation with Latin America region is led by LNEG under **Task 6.3.** Activities with Mexico during the project's second year activity focused onto the topic "*Solar steam gasification of petroleum coke*", and encompass the following:

- 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).

Activities with Brazil concern the development of models for central receiver systems that will be used to study the application of small scale central receiver systems in the industry sector, namely the agro-food industry and within this reporting period have included:

- Steady-state modeling of the optical components, both at individual heliostat and at complete field level;
- Development of steady-state plant model.

Cooperation with Chile: during the project's second year a literature survey on different nitrate salts from Chile was performed, including information such as impurity levels and physical properties. Additionally, investigations regarding the use of different construction steels for thermal energy storage construction were performed. FISE researchers visited Chile in order to prepare a study on

desalination and further discuss with UDC on cooperation possibilities within SERC and PSDA, including the preparation of a joint proposal.

4.4. Summary Task 6.4

Cooperation with Australia and South Africa is the topic of **Task 6.4.** The objectives of the cooperation with Australia concern the involvement and participation in appropriate RTD work packages to advance components for high temperature solar towers. CYI has worked mostly on the 'Development of small low cost heliostat and field layout software', whereas PSI and CSIRO are working on the 'Solar fuels from carbonaceous feedstock' subtask. The objective here is to initiate a joint pilot scale solar thermochemical reactor testing using the solar tower at CSIRO. The most significant result is the completion of a 50-heliostat field for CYI using CSIRO heliostats. This field was formally opened by the President of the Republic of Cyprus and the Director of Research for the European Commission in October, 2016. Cooperation activities with South Africa are led by FISE with contributions from Stellenbosch University (SUN). FISE and SUN are working on the development of low cost concentrating collectors with emphasis on Fresnel. In the first year preparatory studies and exchange of information was the main activity. During the second year, activities were concentrated on the procurement and installation of the sensors and monitoring equipment by SUN. FISE consulted during the selection of sensors. The final report on the low cost Fresnel has not yet been completed (Deliverable due in M24) but is expected by M28 parallel to this report.

4.5. Summary Task 6.5

Task 6.5 deals with cooperation with Asia. In particular, with China (IMDEA-IEECAS) and with India (FBK and IIT Delhi, IIT Roorkee and University of Delhi South Campus). The key objective of cooperation with China is the development and experimental characterization of volumetric ceramic absorbers for use in central receiver systems. Main activities carried out within this reporting period are:

- Specification of material properties and search of appropriate absorber between commercial materials
- Two test rigs for aerothermal characterization of absorbers materials are currently in operation located at IEECAS, China (10 kW_{th} in a solar furnace) and IMDEA, Spain (1.5 kW_{th} in a high-flux solar simulator)
- The aerothermal characterization of materials at high-flux solar simulator and solar furnace of SiC ceramic honeycombs and foams has been accomplished. This (China/EU) joint characterization of common samples, including detailed analyses on geometry and radiation incidence influence.

The full proposal was completed by the end of 2014. A meeting took place in Trento, between the political and scientific partners involved on October 6th, 2014. Concerning the cooperation of FBK with several Indian institutes, a further revision to the proposal was required by Indian DST along 2015. The Solar Energy Center was excluded from the Consortium and activities and all further requests were completed by both FBK and the main Indian partners, IIT Roorkee and IIT Delhi. In September 2015 the project was finally approved. FBK and Indian partners has the kick off meeting in Trento on October 26^{th} – 28^{th}. All the meetings defined the following elements that will be realized in the next 6 to 12 months. 2 PhD students (1 from IIT Roorkee and 1 from IIT Delhi) will spend a visiting period in FBK.