European Commission
FP7 Grant Agreement
No: 609837

STAGE –STE IRP

General Objectives and Materials Developments

Dr. Peter Heller, DLR

European workshop on nanotechnologies & advanced materials for PV and CSP
Brussels
24-25 October 2017

European Energy Research Alliance

STAGE-STE Project

- **Full name**: Scientific and Technological Alliance for Guaranteeing the European Excellence in Concentrating Solar Thermal Energy
- **Coordinator**: Julian Blanco Galvez (CIEMAT-PSA)
- **Duration**: 48 months, starting on February 2014
- **Budget**:
  - Current total project budget: 21.198.352 €
  - Maximum Commission Contribution: 9.997.207 €
- **Manpower devotion**: 2.504,45 pm
- **Participants**: 41
  - European Research Centers: 23 (practically, the whole sector)
  - Large European Companies of the sector: 9
  - International (non EU) Organizations of reference: 9
- **7th FP call:** FP7-ENERGY-2013-IRP. Project achieved 15 points/15

STAGE-STE Consortium

Participant no.	Participant organisation name	Country
1 (Coord.)	CIEMAT	SPAIN
2	DLR	GERMANY
3	PSI	SWITZERLAND
4	CNRS-PROMES	FRANCE
5	FRAUNHOFER	GERMANY
6	ENEA	ITALY
7	ETHZ	SWITZERLAND
8	CEA	FRANCE
9	CYI	CYPRUS
10	LNEG	PORTUGAL
11	CTAER	SPAIN
12	CNR	ITALY
13	CENER	SPAIN
14	TECNALIA	SPAIN
15	UEVORA	PORTUGAL
16	IMDEA	SPAIN
17	CRANFIELD	UK
18	IK4-TEKNIKER	SPAIN
19	UNIPA	ITALY
20	CRS4	ITALY
21	INESC-ID	PORTUGAL

Participant no.	Participant organisation name	Country
22	IST-ID	PORTUGAL
23	SENER	SPAIN
24	----	----
25	HITTITE	TURKEY
26	ACCIONA	SPAIN
27	SCHOTT	GERMANY
28	ASE	ITALY
29	ESTELA	BELGIUM
30	ABENGOA SOLAR	SPAIN
31	KSU	SAUDI ARABIA
32	UNAM	MEXICO
33	SUN	SOUTH AFRICA
34	CSERS	LYBIA
35	CSIRO	AUSTRALIA
36	FUSP	BRAZIL
37	IEECAS	CHINA
38	UDC	CHILE
39	UCAM	MOROCCO
40	FBK	ITALY
41	CNIM	FRANCE
42	COBRA	SPAIN

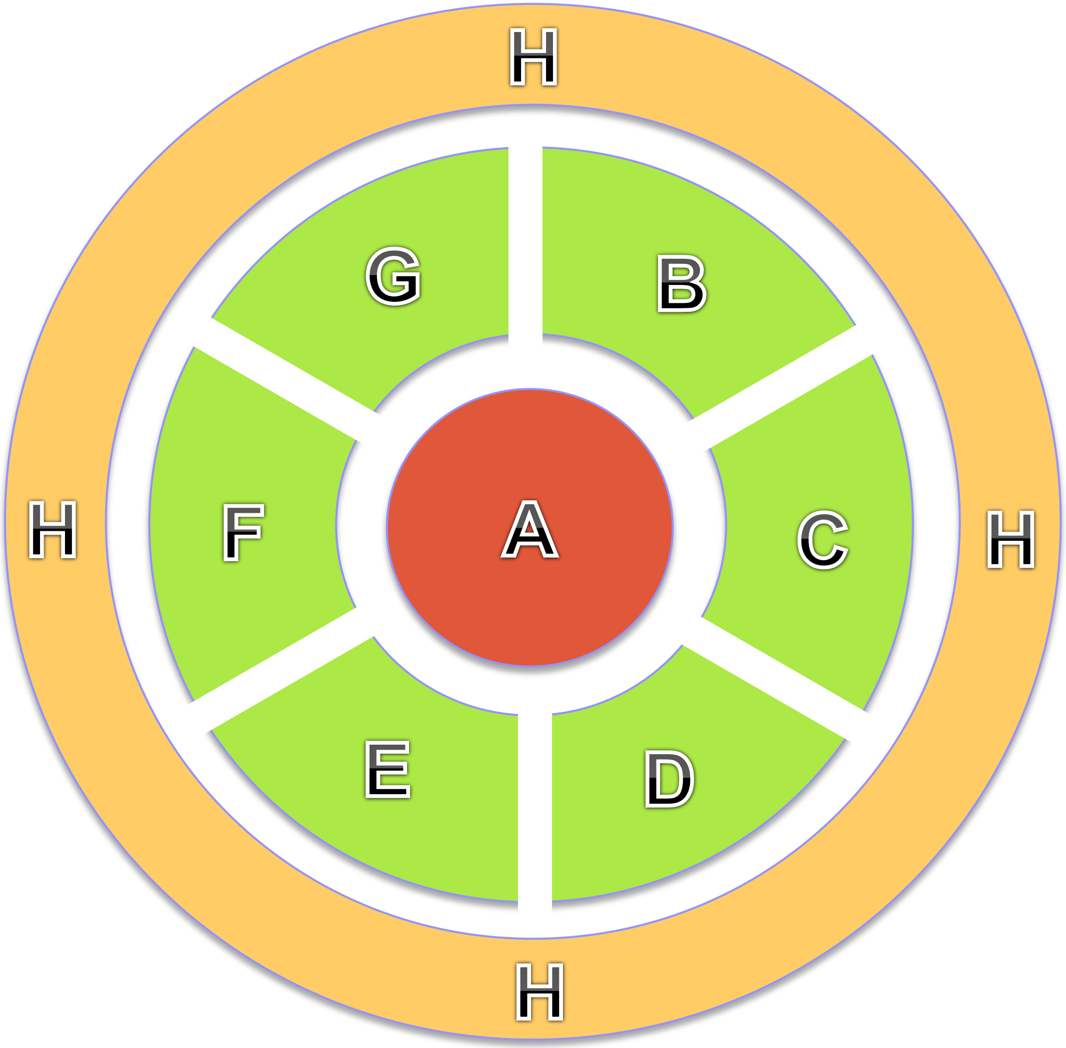
Coordination and Support Work Packages

Formed by a group of activities addressed to intensify the cooperation to more efficiently coordinate, complement and reinforce the activity of the different R&D European Research Centers on the CSP/STE field. Therefore, adding efforts and reducing overlaps, a more comprehensive portfolio of capacities and installations could be offered to accelerate the technology transfer to the European industry and to make possible the maintenance of its current world leadership.

No	Work Package name	Nature[1]	Coordinator
WP1	Consortium governance and management issues	MGT	CIEMAT
WP2	Integrating Activities to Lay the Foundations for Long-lasting Research Cooperation	COORD	CYPRUS INSTITUTE
WP3	Enhancement of STE Research Facilities cooperation	COORD	CTAER
WP4	Capacity Building and Training Activities	OTHER	CNRS-PROMES
WP5	Relationship with Industry & Transfer of Knowledge activities	COORD	CEA
WP6	International Cooperation Activities	COORD	FRAUNHOFER

*[1]: **COORD** = Coordination; **MGT** = Consortium Management, **OTHER** = dissemination activities, courses, staff exchange, etc.*

STAGE-STE Core Objectives



A. Main core objective: increased real collaboration among EU research organizations
B. Cooperative technical and scientific development (WPs 7 to 12)
C. Research infrastructures effective sharing (strong interaction with SFERA and EU-SOLARIS)
D. Substantial staff exchange
E. Training and capacity building
F. Alignment of national and EC financial resources + co-sharing
G. International collaboration
H. Interaction with industry

Research Work Packages

It is formed by 6 additional Work Packages which are addressing *Coordinated Research Activities* that cover the whole spectrum of topics related with Concentrated Solar Energy and addressing, within the 4 years of project duration, the considered as most urgent activities to be done.

In addition to the multiple and specific technical objectives of the different activities, the whole research component of STAGE-STE project intends to demonstrate and start to run the feasibility of deeper and effective integral European collaboration and coordination.

No	Work Package name	Nature[1]	Coordinator
WP7	Thermal Energy Storage for STE Plants	RTD	ENEA
WP8	Materials for Solar Receivers and STE Components	RTD	DLR
WP9	Solar Thermochemical Fuels	RTD	PSI
WP10	STE plus Desalination	RTD	CIEMAT
WP11	Linear focusing solar concentrating technologies	RTD	CIEMAT
WP12	Point focusing STE Technologies	RTD	CENER

*[1]: **RTD** = Research and Technical Development*

Research Work Packages

WP7: Thermal Energy Storage for STE Plants (Walter Gaggioli, ENEA)

- Task 7.1: Advanced fluids and materials for high temperature heat storage
- Task 7.2: Aging of components with MS, High Tech Systems and Materials (HTSM) and PCM
- Task 7.3: Advanced thermal storage systems
- Task 7.4: Integration/hybridization of TES in STE plants

WP8: Materials for Solar Receivers and STE Components (Peter Heller, DLR)

- Task 8.1 Development of an integrated methodology for accelerated aging of reflectors
- Task 8.2 High temperature absorbers and materials
- Task 8.3 Performance of CSP components in desert environment
- Task 8.4 First surface mirrors with high reflectivity

WP9: Solar Thermochemical Production of Fuels (Anton Meier, PSI)

- Task 9.1: Solar fuels from carbonaceous feedstock
- Task 9.2: Solar fuels from thermochemical cycles
- Task 9.3: Innovative materials for next generation solar chemical reactors
- Task 9.4: Technology assessment of solar thermochemical fuel production

Research Work Packages

WP10: Concentrated Solar Power and Desalination (Diego Alarcón, CIEMAT)

- Task 10.1- Low temperature desalination processes for integral power & water production
- Task 10.2- STE cooling issues and desalination
- Task 10.3- Model development and simulation of STE+D configurations

WP11: Linear Focusing STE Technologies (Loreto valenzuela, CIEMAT)

- Task 11.1- Small scale and low cost installations for power and industrial process heat applications
- Task 11.2- Methodologies for dynamic testing and predictive maintenance of large solar fields

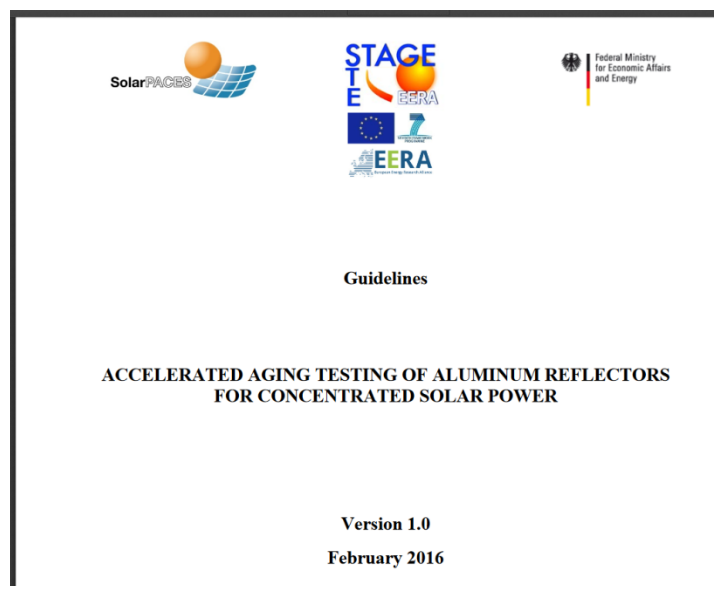
WP12: Point Focusing CSP Systems (Marcelino Sanchez, CENER)

- Task 12.1: Development of low cost heliostat fields
- Task 12.2 High concentration optical systems and new receiver concepts for next generation solar towers

WP8 Technical Progress

WP8.1 Development of an integrated methodology for accelerated aging of reflectors

- Testing Guideline was published on SolarPACES website
- Test procedure is available to make realistic predictions on outdoor behaviour of aluminum reflectors
- Procedure is already applied to assist a mirror manufacturer in the development of an improved material
- Method is adopted for development of glass reflector procedure



Guidelines

ACCELERATED AGING TESTING OF ALUMINUM REFLECTORS FOR CONCENTRATED SOLAR POWER

Version 1.0

February 2016

http://www.solarpaces.org/tasks/task-iii-solar-technology-and-advanced-applications

WP8 Technical Progress

Guideline for testing of aluminum reflectors - ALUMIR

CASS for Pitting

Soil pipe for Erosion

CASS for PVD-layer corrosion

UV/Hum for Micropitting

Test procedure

4 steps

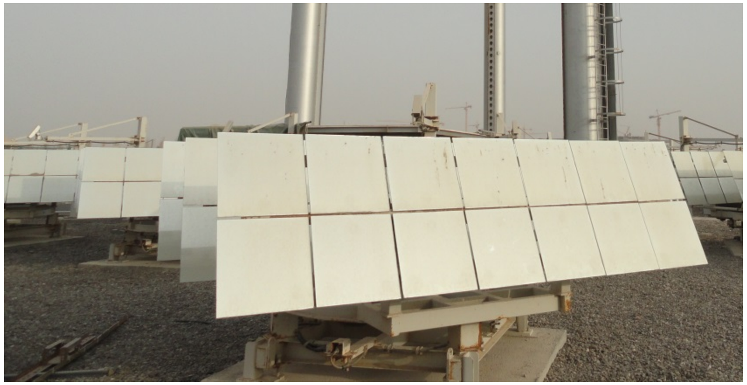
Parameters for different sites and exposure durations

Mechanism		Pitting	Top coating erosion	PVD-corrosion	Micropitting
Site	Years	CASS (h)	Sand trickling (g)	CASS (h)	UV/humidity (h)
Extreme Desert	3	-	180	2	480
	10	-	600	8	480
Desert	3	-	5	8	480
	10	-	15	24	480
Coastal site	3	96	5	8	480
	10	312	15	24	480

Guideline for testing of glass reflectors

- Development of guideline for glass mirrors similar to ALUMIR approach
- Based on test protocols that are already in use
- Outdoor exposure and laboratory tests, comparison of degradation
- Main problem: glass mirrors are more durable, need longer exposure times to show noticeable degradation
- Two approaches: Analysis of
  1. exposed samples at our sites + lab tests
  2. In-service samples from different sources that were exposed longer + if possible lab tests of new material

Guideline for testing of glass reflectors

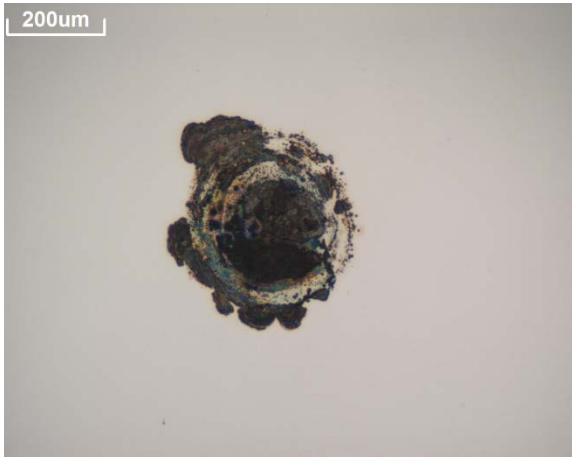


Exposed samples	Samples from in-service material
• Exposition of small samples at sites in Morocco, Spain, Abu Dhabi • Accelerated aging test in the lab (standard tests: NSS, QUV, Damp, Heat, etc.) • Disadvantage: little degradation on outdoor samples due to short exposition (max. around 3 years)	• Testing of in-service samples from facets, mainly from power plants. • Longer exposure times, realistic exposure • Hard to get "new" material

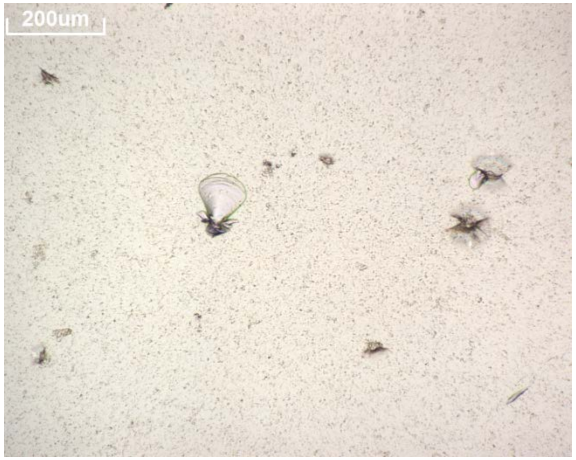
Glass mirror sample analysis outdoor

Sample	Site	Exposition Months	Material	$\Delta\rho_h$(SW,8°,h) (%)	$\Delta\rho_s$(660nm,15°, 12.5mrad) (%)	Degradation mechanisms
1	Erfoud	20	Thick glass	0.5	2.3	Abrasion, minimal edge corrosion
2	Erfoud	20	Thick glass	0.6	1.8	Abrasion, minimal edge corrosion
3	Erfoud	26	Thin glass	0.6	3.6	Abrasion, minimal edge corrosion
4	Missour	12	Thick glass	0	-0.2	
5	Missour	26	Thin glass	-0.1	0.8	
6	Missour	12	Thick glass	-0.1	0.4	
7	Tan Tan	12	Thick glass	0	0.3	Corrosion spots, strong edge corrosion
8	Zagora	20	Thin glass	0.4	5.9	Strong abrasion, minimal edge corrosion
9	Zagora	20	Thin glass	0.3	4.9	Strong abrasion, minimal edge corrosion
10	Zagora	26	Thick glass	0.8	10.8	Strong abrasion, minimal edge corrosion

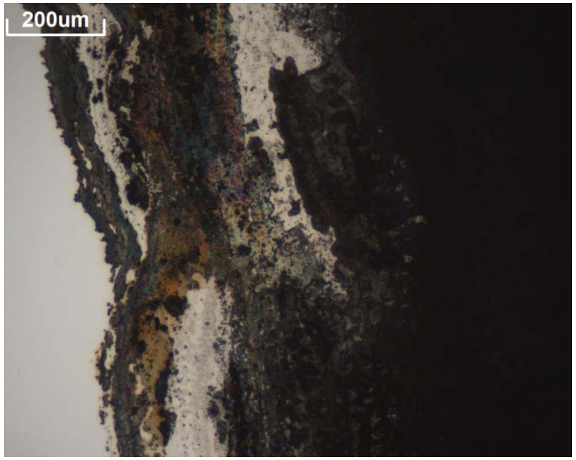
Main degradation mechanisms glass reflectors



Corrosion spots silver



Abrasion



Edge corrosion

Glass corrosion

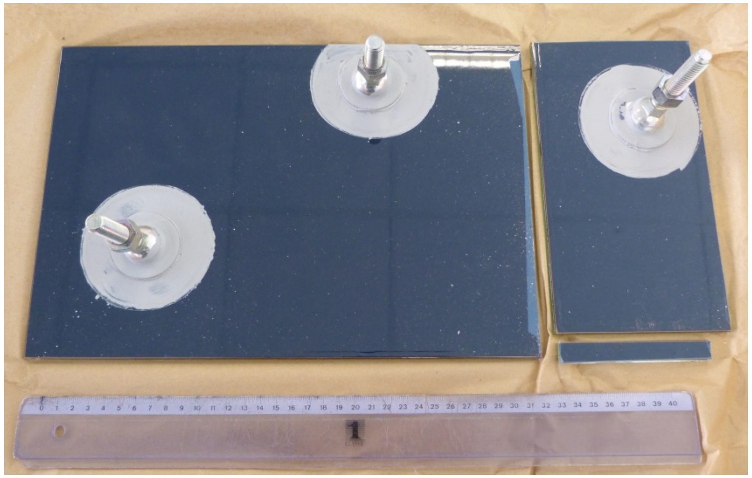
Overview accelerated test results

Test	Duration	Corrosion	other effects
NSS	3000 h	glass corrosion, small and medium spots, edge corrosion	-
CASS	480 h	edge corrosion, spots	-
Damp Heat	2000 h	edge corrosion, spots, glass corrosion	-
UV/Water	2000 h	edge corrosion, spots, glass corrosion	degradation paint, chalking
Thermal Cycling	275 h	-	paint cracks at unprotected edges
Thermal Cycling+NSS	275 h + 3000 h	glass corrosion, edge corrosion, stronger at 1 edge with crack, spots	-
Thermal Cycling+Damp Heat	275 h + 2000 h	edge corrosion, change silver layer, spots	-
Dust storm	14 min	-	surface damage

- Similar effects in accelerated tests compared to outdoor
- Effect of dust/sand abrasion is investigated separately
- Some side effects in several test (cracking)
- Outdoor data still needs to be expanded

In-service samples

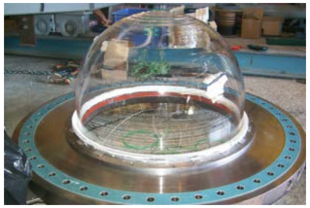
- Now samples available from site in Abu Dhabi
- Glass mirrors that were exposed ca. 7 years and show strong degradation – weak material
- Samples from the warehouse will be tested in accelerated tests



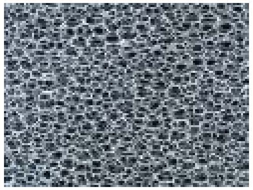
Advanced Materials for CST Systems

CST systems need advanced materials for extreme conditions in order to reduce cost and/or increase efficiency:

- Special Coatings:
  - Selective coatings for solar receivers
  - Anti-reflective coatings for quartz windows



- Advanced raw materials for Central Receivers



- Advanced materials for thermal storage at high temperatures (>700ºC)

- New working fluids for temperatures >650ºC

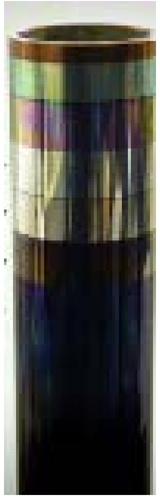
Advanced Materials for CST Systems

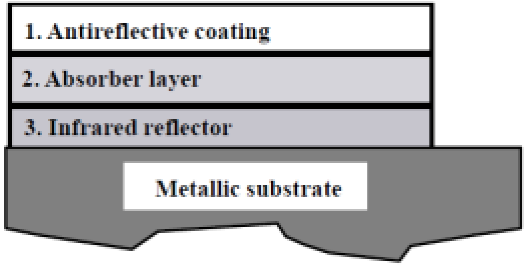
➢ Selective coatings for solar receivers

Solar receivers transform the concentrated solar radiation into thermal energy. There are two different groups of receivers

a) Linear Receivers (receivers for parabolic troughs and linear Fresnel concentrators)

- High absorptivity (>95%) and low emissivity ($\varepsilon \leq 0.15$ at 500ºC)
- Stable in hot air at 600ºC and with thermal cycles from ambient to 600ºC
- Solar flux of about 75 kW/m^2





Advanced Materials for CST Systems

- Selective coatings for solar receivers

Solar receivers transform the concentrated solar radiation into thermal energy. There are two different groups of receivers

b) Central Receivers (receivers for solar tower systems)

- High absorptivity (>92%) and low emissivity ($\varepsilon \leq 0.35$ at 800ºC)
- Stable in hot air at 800ºC
- Solar flux of about 1 MW/m^2

View of a Tube-bundle solar receiver

Central receiver in operation

Advanced Materials for CST Systems

➢ Advanced raw materials for Central Receivers

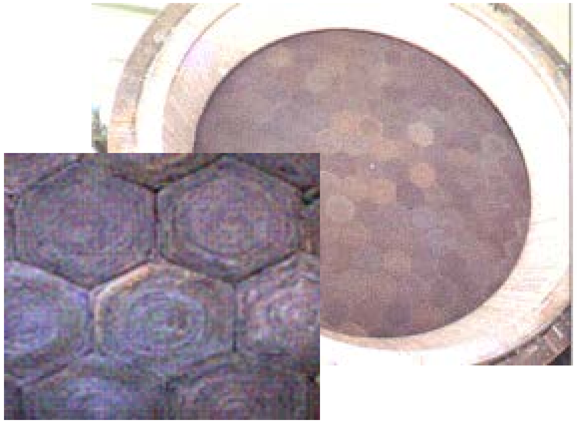
- Receiver types:

  Tube, Volumetric

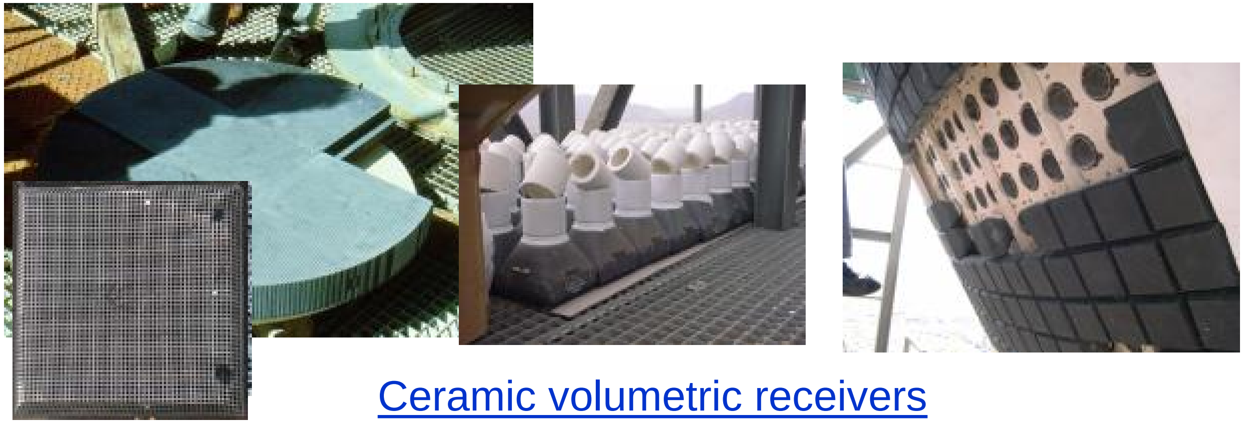
- Receiver raw material:

  Steels: for tube and volumetric receivers
  Ceramics: for volumetric receivers

Tube-bundle solar receiver



Metallic volumetric receiver



Ceramic volumetric receivers

Relevance of STAGE-STE Project

- As the project achieved the involvement of, practically, the whole European sector and significant participation from all over the world, this could be a very good opportunity to internationally reinforce and consolidate the relevance of CSP/STE technologies.
- As IRP projects are a new Commission tool (and STAGE-STE achieved the max. possible score) many people in Europe will be closely following and paying attention to our project evolution.
- Therefore, the success or failure of this project could have implications far beyond the own technical project objectives.