Solar Facilities for the European Research Area

SFERA-III
2nd Summer School
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Almería (Spain)

Lecture:

SHIPs applications within the updated Implementation Plan of CSP

Prepared by:
Julian Blanco
CIEMAT-PSA
julian.blanco@psa.es

Content:

- SET-Plan CSP Implementation Plan
- CSP Implementation Plan update
- SHIP medium temperature systems
- SHIP high temperature applications

SET-Plan (2016)

- *Europe decided in 2016 to achieve a global leadership on a number of fields, being Renewables one of then*
- *To this end, to each selected topic and technology, an specific Implementation Plan, agreed by the respective whole sector and targeting defined goals, should be prepared and approved*

SET Plan Integrated Roadmap (13 themes)	**ENERGY UNION R&I & Competitiveness priorities**	**SET Plan (10 key actions)**
T10: Development of renewables T8: System flexibility	**N°1 in Renewables**	**1. Performant renewable technologies integrated in the system** **2. Reduce costs of technologies**
T1: Engaging consumers T2: Smart technologies for consumers T6: Modernising the electricity grid T7: Energy storage T8: System flexibility T9: Smart cities & communities	**Smart EU Energy System with consumers at the centre**	**3. New technologies & services for consumers** **4. Resilience & security of energy system**
T3: Energy efficiency in buildings T4: Energy efficiency in heating & cooling T5: Energy efficiency in industry & services	**Efficient Energy Systems**	**5. New materials & technologies for buildings** **6. Energy efficiency for industry**
T7: Energy storage T13: Biofuels, fuel cells & hydrogen, alternative fuels	**Sustainable Transport**	**7. Competitive in global battery sector (e-mobility)** **8. Renewable fuels**
T11: Carbon capture storage/use		**9. CCS/U**
T12: Nuclear energy		**10. Nuclear Safety**

CSP Implementation Plan (2016-2017)

STAKEHOLDER INVOLVEMENT

CIEMAT (as JP-CSP coord.) and ESTELA coordinated the participation of the indicated organizations to define and provide inputs to R&D activities, linked to SET-PLAN CSP targets, to CSP Implementation Plan definition

RESEARCH CENTERS & UNIVERSITIES

- JP-CSP > 25 entities
- CIEMAT (Spain)
- UNIV. OF EVORA (Portugal)
- DLR (Germany)
- ENEA (Italy)
- FRAUNHOFER (Germany)
- CNRS (France)
- IMDEA (Spain)
- CEA (France)
- METU (Turkey)
- CYI (Cyprus)
- TECNALIA (Spain)
- CENER (Spain)
- IK4-TEKNIKER (Spain)
- FBK (Italy)
- UNIV. DI FIRENZE (Italy)
- LNEG (Portugal)
- METU (Turkey)

INDUSTRIES

- ESTELA (Belgium) > 100 entities
- EU-TURBINES (Belgium) = 6 entities
- SENER (Spain)
- ABENGOA (Spain)
- ARCHIMEDE SOLAR ENERGY (Italy)
- ACS-COBRA (Spain)
- SUNCNIM (France)
- ENI (Italy)
- RIOGLASS (Belgium)
- ALMECO (Italy)
- EMPRESARIOS AGRUPADOS (Spain)
- KRAFTANLAGEN (Germany)
- SCHLAICH BERGERMANN PARTNER - SBP SONNE (Germany)
- TSK DEVELOPER (Germany)
- TSK-FLAGSOL (Germany)
- MAGALDI (Italy)
- ACCIONA (Spain)
- INNOGY (Germany)
- SQM (Chile)
- ACWAPOWER (Saudi Arabia)

CSP Implementation Plan development

12 RTD ACTIVITIES DEFINED (from received inputs)

1) Advanced Linear Fresnel Concentrator technology with direct molten salts circulation as Heat Transfer Fluid (HTF) and for high temperature thermal energy storage.
2) Demonstration of Parabolic Trough with with direct molten salts circulation as Heat Transfer Fluid.
3) Demonstration of Parabolic Trough technology based on Silicon Oil as HTF for operation temp. up to 430 ºC.
4) Commercial scale-up and optimization of core CRS components of the Open Volumetric Receiver technology.
5) Improved STE plant with Molten-Salt Central Receiver, including cheaper heliostats, higher concentration receiver, cheaper O&M and improved storage tanks designs.
6) Next generation of STE plants adapting higher temp. supercritical steam cycles for CRS / Molten Salt systems.
7) Demonstration of Pressurized Air Cycles based on module assembly with ceramic Thermal Energy Storage.
8) Demonstration of Multi-Tower Beam Down Central Receiver Solar System.
9) Special Action on Thermal Energy Storage: a) new materials for Storage Media and Subsystems; b) Storage Subsystems and Components; c) Storage Integration on STE/CSP Plants.
10) Development of innovative concepts for supercritical turbine trains (650 ºC) for CSP-applications using high speed turbines with optimized speed for each turbine.
11) Development of Advanced Concepts for improved flexibility in STE/CSP applications to improve plant flexibility.
12) Development and Field Test of a CSP/STE Hybrid Air Brayton Turbine Combined Cycle sCO_2 System (1000 ºC)

CSP Implementation Plan development

STEP 1: INDUSTRIAL RISK ASSESSMENT. ASPECTS EVALUATED

1. Technological risk: incremental designs vs new designs, validated industrial equipment, conventional vs specific equipment, synergies with components used in other commercial technologies, commercial equipment scale-up, materials, process plant complexity, integration of subsystems and operational safety.
2. Supplier chain available, complete and secure, especially for those critical key components. Components/suppliers scarcity. Ability to enforce appropriate product guarantee.
3. Construction and plant commissioning times. Operation of the plant complexity.
4. Operational and maintenance costs of the plant based on components lifetime, degradation and recovery time after failure.
5. Nominal annual performance target risk, operation flexibility, start-up, transient and shutdown times.
6. Financial/Market risk. Bankability. Lack of confiden-ce of private sec-tor investment. Insurance. Lack of confidence in equipment manu-facturers given their sometimes short track records

Proposal 1		Probability of occurrence			
		D-Improbable	C- Remote	B- Occasionnal	A - Probable
Potential Project Risk		Highly unlikely	Unlikely but possible	Likely to occur sometime	Highly likely to occur
Aspects	Relevance				
1	*Major*	○	○	○	○
2	*Major*	○	○	○	○
3	*Medium*	○	○	○	○
4	*Medium*	○	○	○	○
5	*Minor*	○	○	○	○
6	*Minor*	○	○	○	○

CSP Implementation Plan development

STEP 2: TECHNOLOGICAL RELEVANCE EVALUATION

The % values in blue express the weighting = the relative importance you give to each criterion.

In the RESULT table, these weighting values are computed with the evaluation of each proposal related to each criterion.

The filling will be done horizontally confronting the Proposal 1 with each of the column Proposals (proposal 2, 3, etc.) with respect to the respective criterion.

	CRITERIA BEING COMPARED TO						
	Cost reduction	Innovation	Dispatchability/Storage	Market penetration	Scalability	TOTAL	%
CRITERIA	a	b	c	d	e		
a- Cost reduction		10	10	10	10	40	33,3%
b- Innovation	2		6	4	2	14	11,7%
c- Dispatchability/Storage	2	6		10	6	24	20,0%
d- Market penetration	2	8	2		4	16	13,3%
e- Scalability	2	10	6	8		26	21,7%
Column TOTAL	8,0	34	24	32	22	120	100,0%

Number to enter	Definition
2	It is extremely less important or preferred.
4	It is significantly less important or preferred.
6	The criterion being considered is equally important or equally preferred when judged against the criterion you are comparing it to.
8	The criterion being considered is significantly more important or more preferred.
10	The criterion is extremely more important or more preferred.

CSP Implementation Plan development

STEP 3: TRL ASSESSMENT

Final Results

A) HIGH FINAL EXPECTED TRL (8-9)	RESULT STEP1		RESULT STEP 2		RELATIVE SCORING [(points,i)/(points,max)]			
	Points	Rank	Points	Rank	STEP1	STEP2	AVG	Rank
Proposal 5 MST Short term	129,17	*2*	*9,75*	*1*	0,96	1,00	0,98	1
Proposal 3 PT Soil	134,58	*1*	*7,75*	*6*	1,00	0,80	0,90	2
Proposal 6: MST long term	102,50	*4*	*9,61*	*2*	0,76	0,99	0,87	3
Proposal 1: LFR MS	105,83	*3*	*8,50*	*4*	0,79	0,87	0,83	4
Proposal 2 : PTC MS	97,92	*6*	*8,61*	*3*	0,73	0,88	0,81	5
Proposal 4: OVAR	100,00	*5*	*8,09*	*5*	0,74	0,83	0,79	6
Proposal 8 Beam Down MS	75,00	*7*	*7,33*	*7*	0,56	0,75	0,65	7

B) MEDIUM FINAL EXPECTED TRL (5-7)	RESULT STEP1		RESULT STEP 2		RELATIVE SCORING [(points,i)/(points,max)]			
	Points	Rank	Points	Rank	STEP1	STEP2	AVG	Rank
Proposal 9 : Advanced TES	116,25	*1*	*8,89*	*1*	0,86	0,91	0,89	1
Proposal 10: S-crit Steam Cycle 600°	108,33	*2*	*8,35*	*2*	0,80	0,86	0,83	2
Proposal 11: Flex Steam Turbine	107,08	*3*	*8,29*	*3*	0,80	0,85	0,82	3
Proposal 12: High Temp Brayton Sc. CO2	74,58	*4*	*7,54*	*4*	0,55	0,77	0,66	4
Proposal 7 Press Air Rec /w Storage	74,17	*5*	*7,30*	*5*	0,55	0,75	0,65	5

CSP Implementation Plan development

STEP 4: MAPPING OF ACTIVITIES

Assessment of national interest into the different activities and eventual needed financing (per country) to CSP-IP execution

	Spain	Portugal	France	Italy	Germany	Cyprus	Turkey	Belgium	**TOTAL**
Act. 1: Advanced Linear Fresnel tech.		5,50	5,50	4,00					**15,00**
Act. 2: P. Trough with Molten Salt		1,90		1,90	1,90				**5,70**
Act. 3: P. Trough with Silicon Oil	0,80			1,20	2,00				**4,00**
Act. 4: Open Volumetric Air Receiver				0,40	1,15		0,40	0,80	**2,75**
Act. 5: Improved Central Receiver Molten Salt tech.	3,00				3,00	1,00	2,00	2,00	**11,00**
Act. 6: Next Generation of Central Receiver plants	3,75		2,50			1,25	2,50	2,50	**12,50**
~~Act. 7: Pressurized Air Receiver~~									
Act. 8: Multi-Tower Beam Down		1,20		2,40		0,40			**4,00**
Act. 9: Advanced TES	1,00	0,50	1,50	1,00			1,00		**5,00**
~~Act. 10: Supercritical Steam Turbine~~									
~~Act. 11: Improved flexibility in CSP~~									
~~Act. 12: High Temp Brayton Sc. CO_2~~									
	8,55	**9,10**	**9,50**	**10,90**	**8,05**	**2,65**	**5,90**	**5,30**	**59,95**

CSP Implementation Plan officially approved by SET-Plan on Sept. 2017

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CSP Implementation Plan update (2021)

MOTIVATION

- Original CSP Implementation Plan only focused on electricity production and high TRL activities
- Necessity of an updated and integrated document that reflects the best reality and priorities of the sector
- Align the IP to the current conditions and priorities of the EU (time horizons, topics, instruments, etc.)
- Necessity to include additional topics such as SHIP applications and H2 production by high temp. CSP thermochemical processes

CONSIDERATIONS

- Build on the work done in the context of the Strategic Research Agenda o the Clean Energy Transition (CETP)
- Perform modification that will not require a full consultation and endorsement process by the CSP community (as previous exercise)

New IP activity areas

1. *Line-focus solar power plant technology*
2. *Central Receiver power plant technology*
3. *Reliable and cost-effective medium and high-temp. thermal storage systems*
4. *Turbo-machinery developed for specific conditions of solar thermal power plants*
5. *Medium-and high temp. systems for industrial solar heat applications*
6. *High temperature solar fuels*

CSP Implementation Plan update (2021)

PROPOSED NEW STRATEGIC TARGETS TO BE ACHIEVED

1. Cost reduction of electricity provided during periods with low wind, PV or hydropower infeed, to prices below 8 c€/kWh in Southern Europe locations by 2025, targeting 6.5 c€/kWh by 2030, considering 2050 kWh/m2/year as reference conditions and no constraints regarding the size/type of the plant and Power Purchase Agreements (PPA) with a duration of at least 20 years.
2. Development of new generation of CSP/STE technology to achieve at least 3 points of increase in the overall power plant efficiency (reference value 39.4 percent) by 2025.
3. At least one First of a Kind (FOAK) integrated in the energy system by 2025, demonstrating either the cost reduction or the efficiency increase.
4. **Thermal energy cost for industrial process heat applications below 3 c€/kWh (T < 400 °C, small scale applications) and below 2 c€/kWh (T > 600 °C, large scale applications), by 2025.**
5. Demonstration of 24/7 economically viable solar thermal baseload production of hydrogen and other solar fuels by 2030.

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SHIP medium temperature systems

Achievements since 2017

- Improved designs of linear Fresnel collectors
- Implementation of international working groups to contribute to the commercial development of this solar energy application
- Several installations for industrial heat in operation
- Concentrating collectors are getting part of IEA SHC Task 55 follow up on district heating

Previous IP related research activities

- SECASOL (2017-2020), ASTEP (2020.2024)
- Modulus (Germany, 2021-2024)
- INSHIP (EU, 2016-2020)
- IEA SHC/SolarPACES Task Solar Process Heat
- SHIP2FAIR (2018–2021)
- Italian National Research Program PTR on the Electric System (2019-2021)
- LIFESOLAR (Portuguese funding 2016-2020)

SHIP medium temperature systems

Projects can/should include the following subjects:

- Best practices study which investigates the status quo and identifies **problematic issues, along with potential solutions** or approaches to address those issues. Lessons learned from the **engineering, construction, commissioning, operations and maintenance of existing concentrating solar plants**.
- Development of **new components or new collector concepts** which reduce costs in investment or operation and/or improve the performance of the solar field, the balance of plant and integration of heat.
- Highly **autonomous solar fields** to further reduce maintenance requirements and to increase the amount of thermal energy delivered to the industrial process.
- A row of **demonstration projects** incorporating best practises and new developments accompanied by a scientific evaluation of performance, reliability and durability.
- Development of **international standards** related to the monitoring and commissioning of industrial projects.
- **Dissemination** which addresses planners, potential customers and other stake holders, especially those who are not familiar with the technology.

Aim at reduction of thermal energy cost for industrial process heat applications and for district heating below 3 c€/kWh (T < 400 °C, large scale applications > 2 MW) by 2025

SHIP medium temperature systems

Expected deliverables

- Cheaper collector designs for line-focus and point-focus solar systems
- Specification of materials by typology of industrial sectors
- Standardized components for the balance of plant (interface between the solar field and the industrial process)
- New international standards and guidelines defining qualification, monitoring and commissioning protocols
- Demonstration of the technology in commercial surrounding (process heat or district heating)
- Long term operation to identify operational and durability issues

Monitoring mechanism

- Total thermal power installed
- Commercial offers for new plants
- New experimental platforms for testing components, monitoring & maintenance procedures
- Evaluation and feasibility studies
- Demonstration in 2 MW scale
- Validation in real scale possibility the use new HTF

Required budget: 25 M€

Targets

- Thermal energy cost below 3 c€/kWh (T < 400 °C)
- Development of new generation tech. (collectors and key components)
- New solar HTF
- New standards defining qualification protocols for components and plant commissioning procedures

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High temp. solar treatment of minerals

Context and reasons behind

- High temperature calcination of minerals, such as colemanite (around 600 °C), phosphate ores (around 700 °C), limestone (around 900 °C), etc., are particularly suitable to CSTE technology, providing also dispatchable energy.
- Just the calcination of limestone is a big factor in the global anthropogenic CO2-emissions, contributing to at least 8 % of the emissions due to the cement production.
- Some of the regions with highest solar radiation also coincide with locations of mines (e.g., Chile, South Africa, Australia, …). The utilization of solar energy in such locations would be a sustainable and economic alternative.

Achievements since 2017

- Pre-pilot scale demonstration under relevant conditions
- Proof-of-concept validation of certain systems and key components
- Demonstration of 15 kW lab scale solar rotary kiln for the calcination of cement raw meal
- Preliminary cost estimations showing tech. competitiveness
- Guidelines for future development & identification of challenges to be tackled

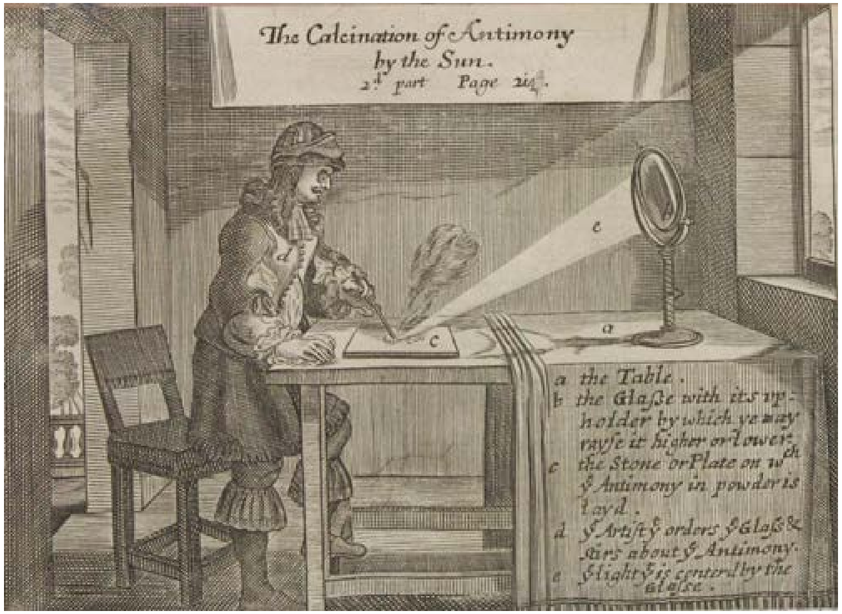
Previous IP related research activities

- SOLPART (2016-2020),
- CaLyPSOL (2018-2021),
- INSOLMIN (2017-2018),
- SolarTwins (2019-2022)
- Italian National Project: PON Biofeedstock

High temp. solar treatment of minerals

Targets

- Definition of process requirements and of a suitable reactor
- Pilot-scale operation
- Long-term continuous operation
- Up-scaling and implementation in plant environment
- Cost reduction



Expected deliverables

- Operating system at >100kW scale
- Reliable operation for 8 h/day and several consecutive days
- Product quality comparable or superior to conventional ones
- Suitable implementation strategy in a solar field
- Price competitive with conventional systems

Required budget

- 10 M€ (about 4 projects from 2.5 M€ each)

Monitoring mechanism

- Demonstration under relevant conditions and >100 kWth scale
- Benchmarking with conventional technologies

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End of Presentation

- Thank you for your attention
- Questions ?

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