26th SolarPACES Conference

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Overview of EU Research Priorities in Concentrating Solar Thermal Technologies

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GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN

Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

CSP/STE Implementation Plan

- **Approved by Steering Group of SET-Plan in 2017**
- **Research pillar: 12 R&I Activities focused on electricity production**

1. *Linear Fresnel concentrator with direct molten salt as HTF*
2. *Parabolic trough with molten salt circulation as HTF*
3. *Parabolic trough with silicon oil*
4. *Solar tower power plant + open volumetric air receiver technology*
5. *Improved central receiver molten salt technology*
6. *Next generation of central receiver power plants*
7. *Pressurized air cycles for high efficiency solar thermal power plants*
8. *Multi-tower central receiver beam down system*
9. *Thermal energy storage*
10. *Supercritical steam turbines optimised for CSP*
11. *Advanced concepts for improved flexibility in CSP applications*
12. *CSP hybrid air Brayton turbine combined cycle sCO_2 systems*

European Commission Support

European Union support for CSP/STE

"*Horizon 2020, the EU's funding programme for research and innovation in the period 2014-2020, has allocated almost EUR 6 billion to non-nuclear energy research through its societal challenge **'Secure, Clean, Efficient Energy'**. More specifically, the energy challenge supports the transition to a reliable, sustainable and competitive energy system. The projects in this Results Pack have successfully risen to meet this energy challenge, focusing on technologies that help reduce costs and increase performance of solar thermal plants. Their objectives are in line with the **European Strategic Energy Technology Plan** (SET Plan), specifically the **Implementation Plan for CSP**, which aims to maintain (or regain in some cases) the EU's global leadership on low-carbon technologies*".

https://cordis.europa.eu/article/id/421854-solar-heat-for-power-and-industry

Expected/estimated H2020 contribution to CSP/STE research initiatives: between 150 and 200 million Euros

PTC / FRESNEL + Molten Salt tech.

Topics #1 and #2: Linear Fresnel and Parabolic concentrators with Molten Salt as HTF

KEY RESEARCH & TARGET OBJECTIVES

- Demonstration of molten salt specific operations: filling process, maintenance procedures, drainage, emergency operations, etc.
- Demonstration of loop control concept in a full-size collector loop
- Testing and evaluating critical plant components: molten salt pumps and valves, Instrumentation, sensors, and pipe heating
- Development/demonstration of evacuated tubular receivers with selective coatings to be heat (no out-gassing) and corrosion resistant.
- Development of optimized designs of the whole plant to improve reliability and reduce freezing and environmental risks.
- To propose a scalable and dispatchable plant concept.

PTC / FRESNEL + Molten Salt tech.

Evora Molten Salt Platform (EMSP)

Facility located in Evora (Portugal) developed in close collaboration between Univ. of Evora and DLR.

Technical data:

Collector field

- *2 rows Heliotrough™2.0 , 360m each*
- *Thermal power: 2,7 MW*
- *Maximum Temperature: 565°C*

Steam generator

- *1.6 MW at 560°C/140 bar*

Two-tank thermal storage

- *Capacity 5 MWh*

PTC with Silicone Oil as HTF

Topic #3: Parabolic Trough technology with Silicone Oil

KEY RESEARCH & TARGET OBJECTIVES

- Construction of at least 2 loops of full scale parabolic trough collectors including oil/salt heat exchanger and steam generator
- Long term operation to identify durability issues
- Assessment of performance of collector and its subcomponents
- Analysis of solar flux and heat transfer at receivers to identify maximum film temperatures in fluid
- Analysis of HTF composition and verification of its durability and chemical stability during commercial plant operation
- Optimization of (oil/salt) heat exchanger for increased temperatures up to 430ºC, also under transient conditions

PTC with Silicone Oil as HTF

Demonstration of the applicability of silicone-based HTF (improved viscosity, lower vapor pressure and higher nominal operation temp), to replace current thermal oil in parabolic troughs power plants. New working temperature objective of this HTF: 425-450ºC.

SIMON (Silicone Fluid Maintenance and Operation)

Demonstration and analytics of HELISOL® XA for PTC applications (2017-2020, BMWi, DE). Project coordinator: DLR (Germany).

SING (Silicone Fluid Next Generation)

Demonstration and analytics of HELISOL® XLP for PTC (2020-2022, BMWi, DE) Project coordinator: DLR (Germany)

- Loop scale demonstration of HELISOL® XLP at 440°C.
- Pump test facility at 450°C during 3000 h - up to 480°C.
- International Standard for SHTF in line focusing applications.

Tower + Volumetric Air Receiver

Topic #4: Open Volumetric Air Receiver

KEY RESEARCH & TARGET OBJECTIVES

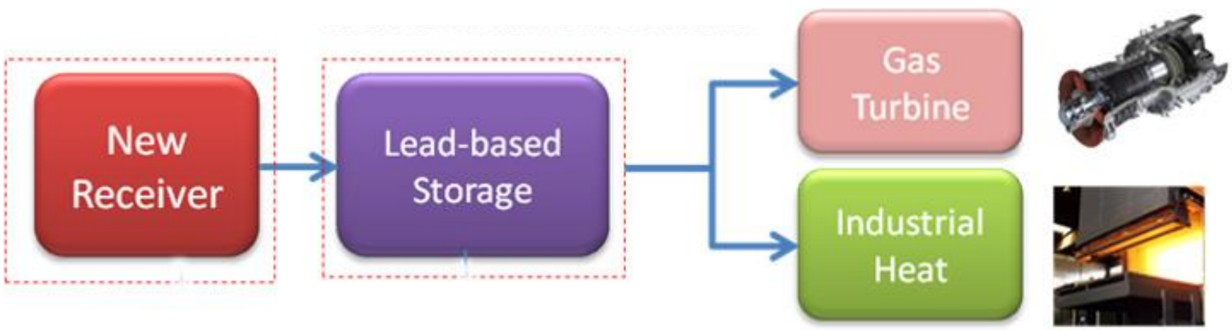
- Design of scaled-up open volumetric receiver (50-100 MW thermal) and optimization of the receiver design for increased efficiency, improved transient behavior and a longevity of >40 years.
- Design of scaled-up fixed bed thermal energy storage.
- Detailed overall plant design for an intermediate commercial plant size of approximately 10 MW (50-100 MW thermal) including the up-scaled and optimized components (receiver, thermal energy storage and optimized heliostat field).
- Optimized plant and operational concepts.

Tower + Volumetric Air Receiver

NEXTOWER (Advanced Materials Solutions for Next Generation High Efficiency Concentrated Solar Power Tower Systems)

NEXTOWER aims at demonstrating high-performance durable materials for the next generation of CSP atmospheric-air based tower systems (2017-2020, H2020). Project coordinator: ENEA (Italy).

- Ceramic solar receiver (durability & emissivity issues / 700-900ºC range).
- Thermal storage by liquid metals (liquid lead / tech. transfer from nuclear fission).
- Thermal fatigue and thermal shock (especially in joints).
- Corrosion issues (liquid metals).
- Standardization issues.



https://www.h2020-nextower.eu/

Improved Molten Salt Tower Tech.

Topic #5: Improved Central Receiver power plants

KEY RESEARCH & TARGET OBJECTIVES

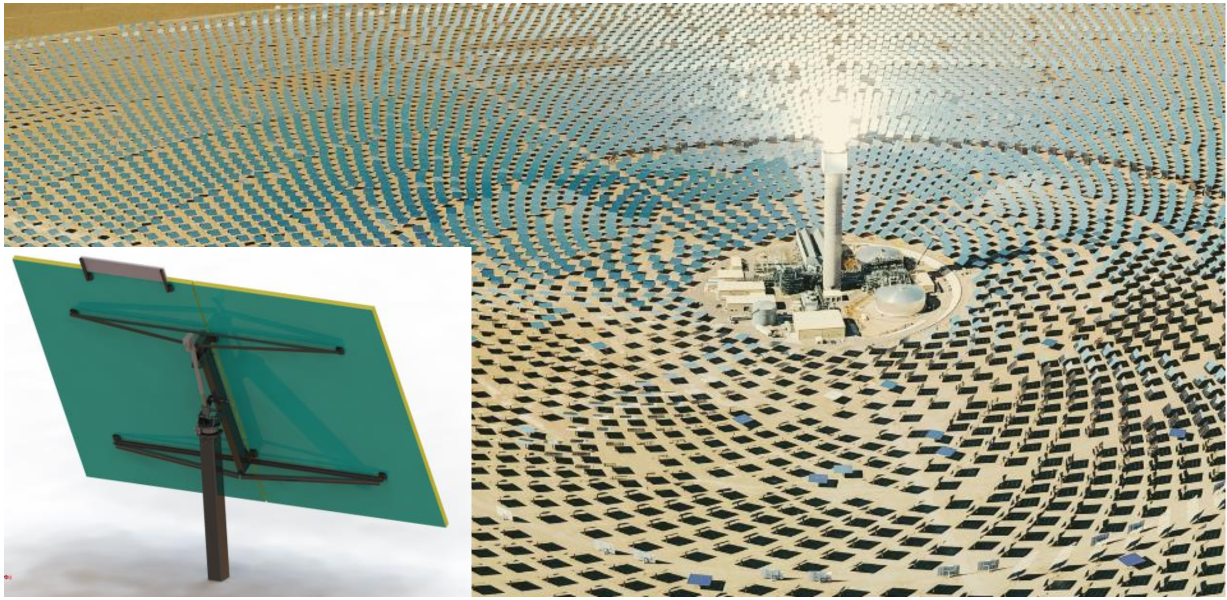
- Improved solar receiver design and performance.
- Increase nominal and annual performance of heliostats field by 5% (at least) and reduce heliostat cost to < 100€/m2 (installed), by means of:
    - i. Mirror reflectivity and optical quality improvement (> 95 %)
    - ii. Slope error reduction (< 3 mrad)
    - iii. Lower maintenance cost and cleaning requirements
    - iv. Longer life time
- Development of a completely automated procedure to calibrate the whole heliostat field in a short time (self-calibration heliostats).

Improved Molten Salt Tower Tech.

PHOTON project (New generation of central tower CSP plants)

Development of a new, more efficient tower plant model built around the design and prototyping of a new heliostat technology and tailored receiver design, aiming to reduce construction and maintenance costs, as well as energy production costs (2018-2022, EUROSTARS-2). Project coordinator: TEWER (Spain).

- New solar power plant configuration for power between 50 and 150 MW.
- High-performance optical solar field (optical quality down to 0.6 mrad).
- Heliostat field cost reduction / Autonomous Heliostats.
- Optimized tailored asymmetric receiver to improve plant efficiency.



https://projectphoton.eu/

Next Generation of Tower Tech.

Topic #6: New generation of Central Receiver power plants

KEY RESEARCH & TARGET OBJECTIVES

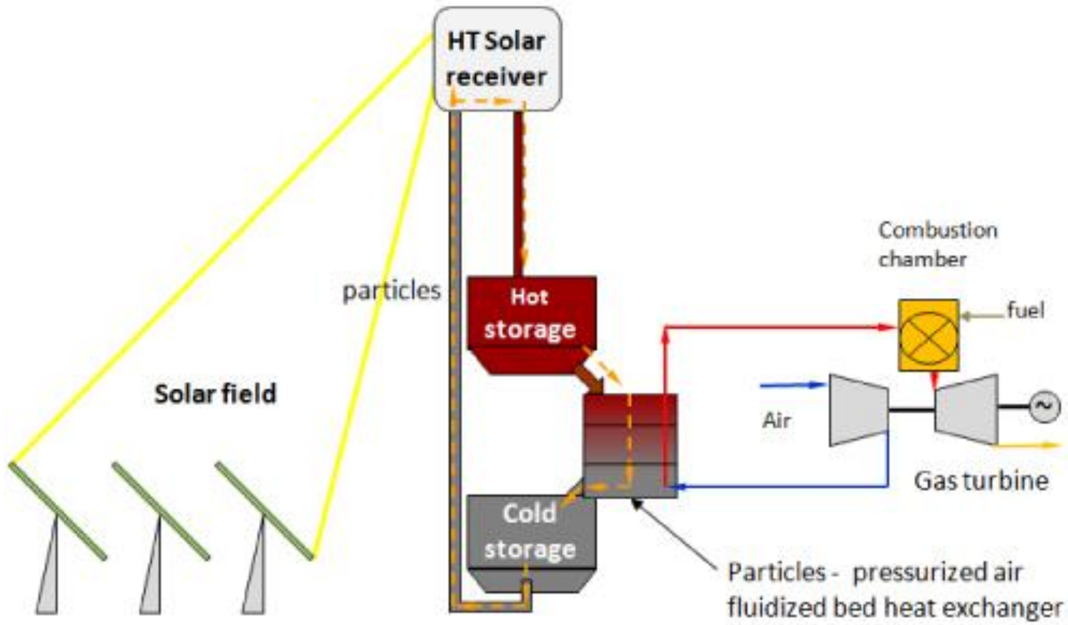
- Receivers with improved performance characteristics:
  1. Mean solar fluxes > 1MW/m^2
  2. Nominal operation temperature > 600ºC
  3. Efficiency > 85% (for temperatures above 600 ºC)
- Innovative molten salts HTF to allow a wider operation range 160ºC – 650ºC.
- New heat transfer fluids for high temperature cycles.
- Smart heliostats (self-calibrated, self-diagnosis).
- Monitoring of HTF degradation status and potential corrosion.
- Recovering of HTF gravitational energy.

Thermal Energy Storage

NEXT CSP project

High Temperature concentrated solar thermal power plan with particle receiver and direct thermal storage (2016-2021, H2020). Project coordinator: CNRS (France).

- Use of high temperature (800°C) particles as heat transfer fluid and storage medium.
- Technology to be demonstrated at a significant size (4 MWth tubular solar receiver).
- Two-tank particle heat storage and a particle-to-pressurized air heat exchanger coupled to a 1.2 MW_e gas turbine.
- Fluidized particle-in-tube concept.



http://next-csp.eu/

Pressurized Air Solar Technology

Topic #7: Pressurized air cycles for high efficiency solar thermal power plants

KEY RESEARCH & TARGET OBJECTIVES

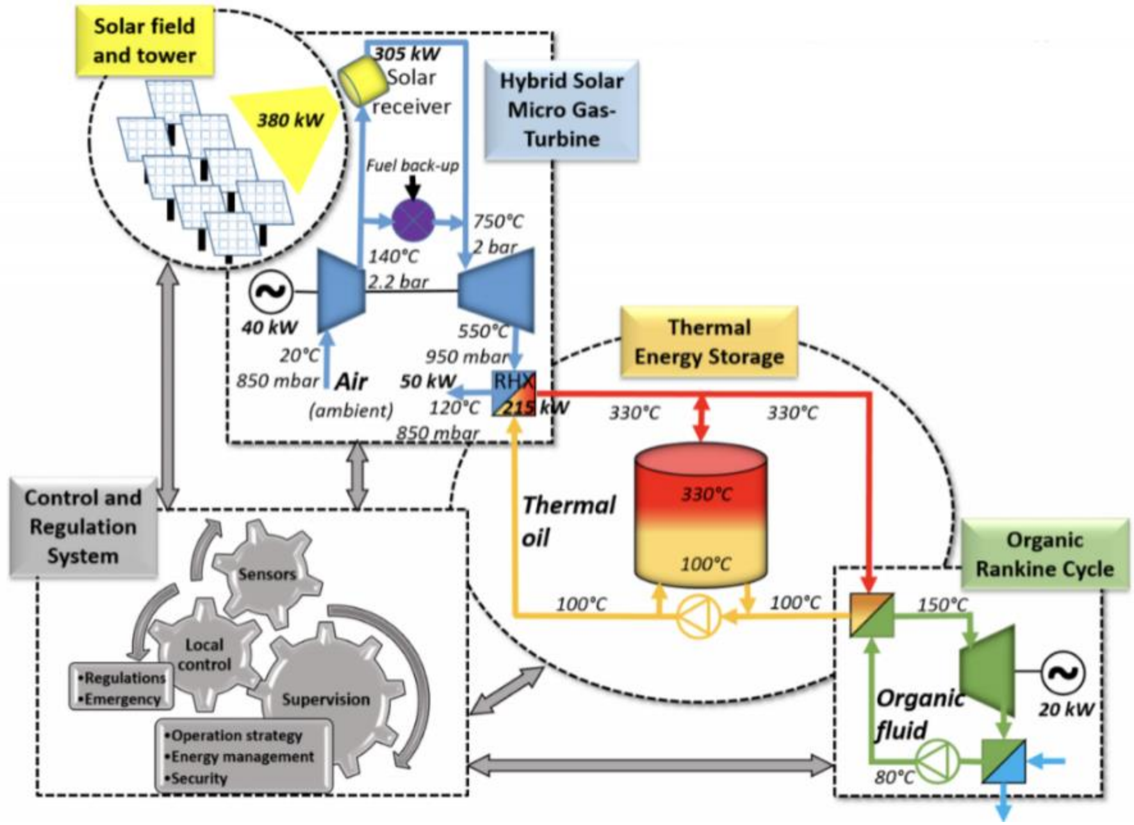
- Demonstration of 500 kW thermal solar receiver.
- Demonstration of a ceramic high temperature thermal heat storage with pressurized air as working fluid.
- Development status of efficient and affordable thermal energy storage (TES) system for pressurized air at T > 700ºC.
- Integration of pressurized-air solar receiver and storage in a single loop.
- Efficient solar receiver prototype for ≥ 10 MWth and T > 700ºC.

Pressurized Air Solar Technology

POLYPHEM project (Small-Scale Solar Thermal Combined Cycle)

Combined cycle for small-scale power generation in the range 40 to 2000 kW (2018-2022, H2020). Project coord: CNRS (France).

- Pressurized air solar receiver to drive a 60 kW micro gas-turbine and coupled with a 1,3 MWh thermal storage unit.
- Air Brayton cycle as top cycle and an Organic Rankine Cycle (ORC) as bottom cycle.
- To be validated at Themis solar tower.



https://www.polyphem-project.eu/

Multi-tower central receiver

Topic #8: Multi-tower central receiver (beam down) system

KEY RESEARCH & TARGET OBJECTIVES

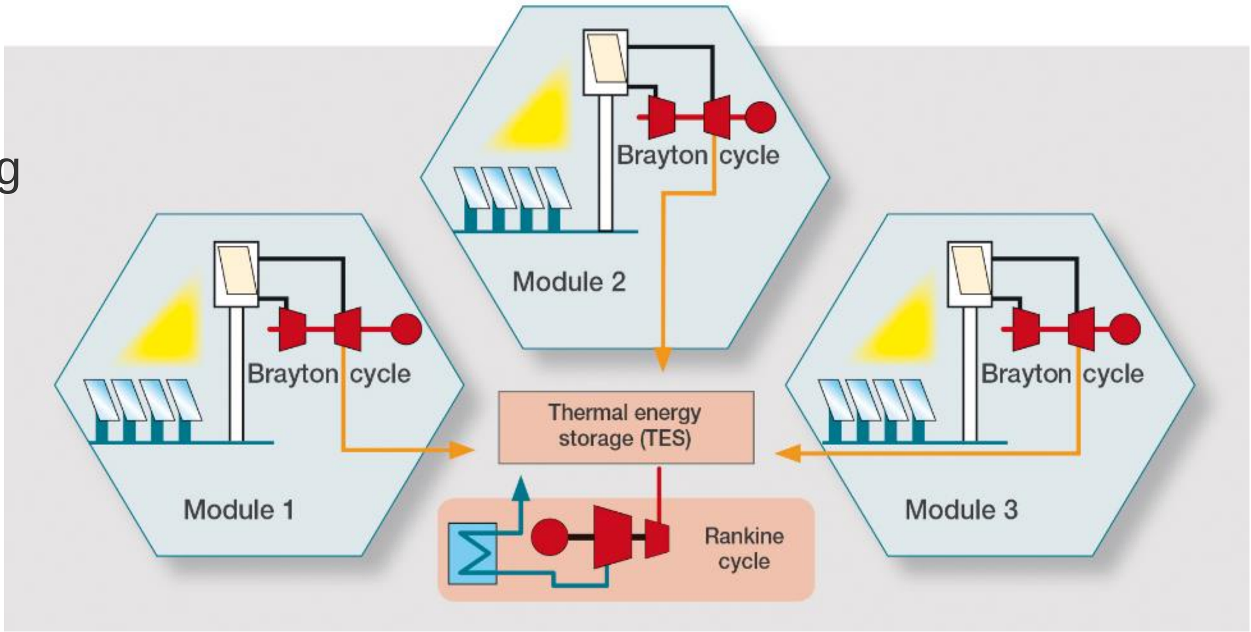
- Industrial optimization of heliostat design and manufacturing with an installed cost of 70-80€/m^2.
- Optimization of cavity integrated with storage.
- Industrial optimization operating at very high temperatures (e.g., research in terms of materials).
- Cost reduction and optimization (O&M) of tracker.
- Study and test of high temperature components (fluidized bed materials, power unit, heat exchanger).
- Operating control strategies for power plant with thermal energy storage.
- Operate a 2 MW thermal solar receiver.

Multi-Tower Central Receiver

CAPTURE project (Competitive Solar Power Towers)

Innovative plant configuration based on a multi-tower decoupled solar combined cycle (2015-2020, H2020). Project coordinator: CENER (Spain).

- Demonstration of solar combined cycle by a 300 kW_{th} open volumetric air receiver prototype operating a solar-driven gas turbine.
- Centralized TES, air-solid packed-bed thermocline storage.
- Development of small-area downsized heliostats to enable improved solar flux control through automatic heliostat field calibration.



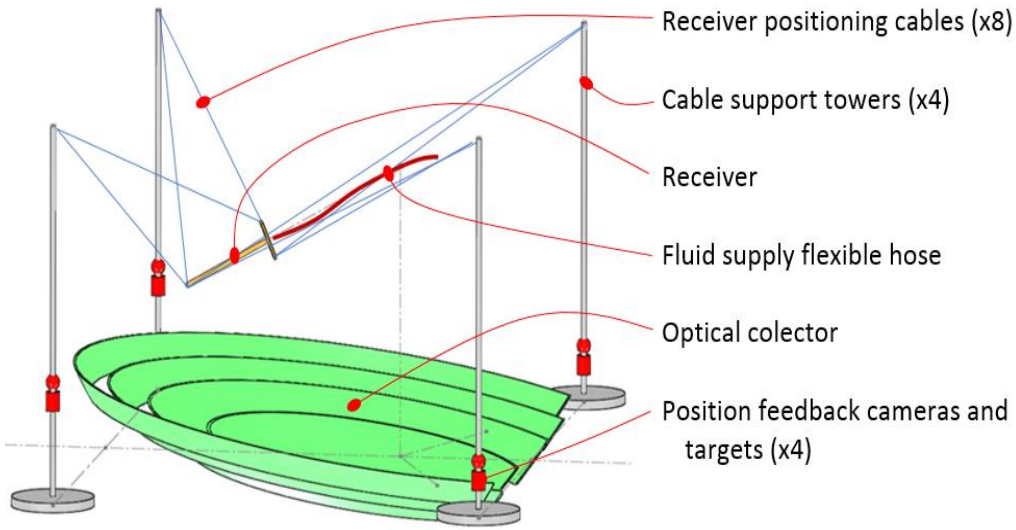
http://capture-solar-energy.eu/

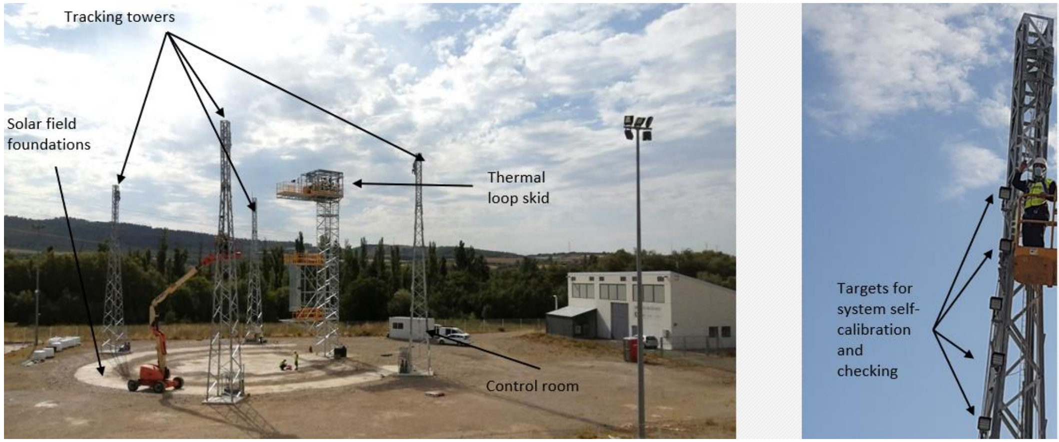
Multi-Tower Central Receiver

MOSAIC project

Modular high concentration solar conf. Innovative 3D solar concent. units with spherical fixed reflectors and moving receivers (2015-2020, H2020). Project coord: TEKNIKER (Spain).

- Fixed spherical mirror concentrator arranged in a semi Fresnel manner and an actuated receiver based on a low cost closed loop cable tracking system.
- This configuration reduces the moving parts of the whole system decreasing solar field cost while keeping high concentration ratios.





https://mosaic-h2020.eu/

Thermal Energy Storage

Topic #9: Thermal Energy Storage (TES)

KEY RESEARCH & TARGET OBJECTIVES

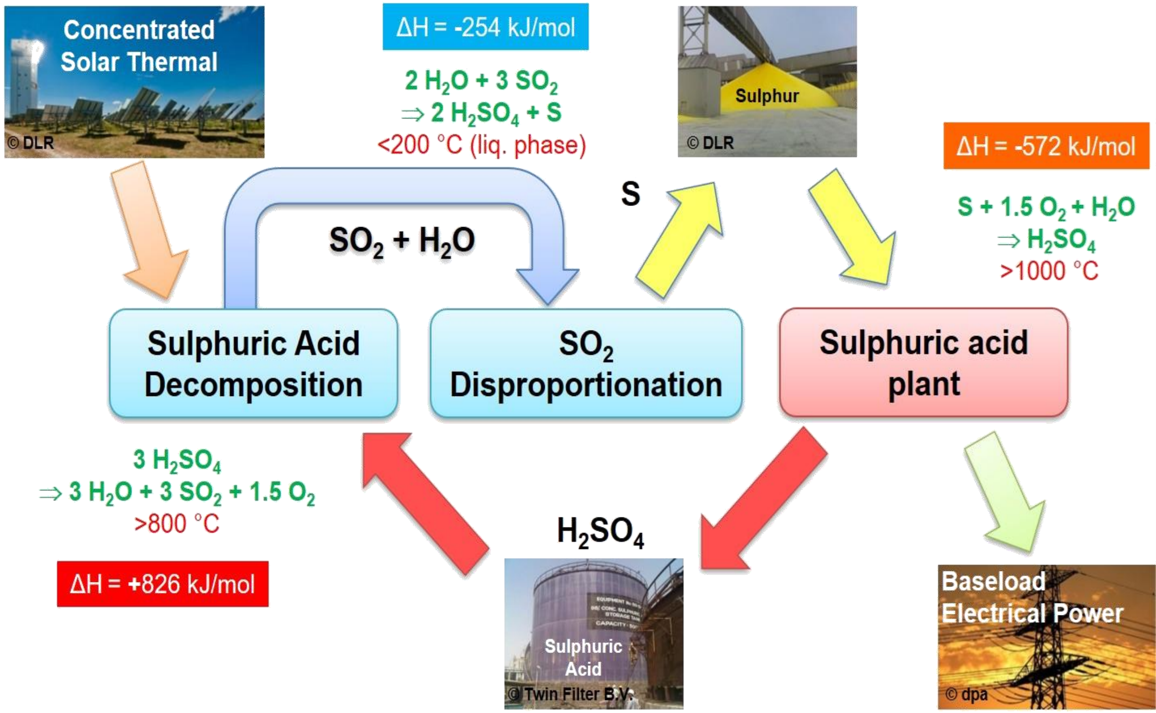
- Suitable thermal storage systems and materials for T > 600ºC, with cost lower than 15 EUR/kWh (thermal) of stored energy, including heat exchangers.
- Demonstrator at a representative scale.
- Suitable thermal storage systems and materials for T > 750ºC.
- Thermal storage systems and materials for T < 550°C with improved cost effectiveness.
- Suitable and cost-effective PCM thermal storage systems and materials for the 200–300ºC range, with investment cost lower than 40 EUR/kWh (thermal) of storage capacity.

Thermal Energy Storage

PEGASUS project

Renewable Power Generation by Solar Particle Receiver Driven Sulphur Storage Cycle (2016-2021, H2020). Project coordinator: DLR (Germany)

- Use of high temp. (900°C) ceramic particles as HTF and intermediate storage.
- Cost-effective material < 200 €/t
- Very high storage density (more than one order of magnitude higher than molten salt).
- Use of sulphur as cheap long-term storage as granulate on open pile or as liquid in tank at ~140°C.
- Energy can be retrieved at const. T>1000ºC, higher than that of original heat input.



https://www.pegasus-project.eu/

Supercritical steam turbines

Topics #10 and #11: Supercritical steam turbines optimised for CSP / Advanced concepts for improved turbine flexibility

KEY RESEARCH & TARGET OBJECTIVES

- Optimized supercritical steam turbine (temperatures ≥ 600°C) developed for power range < 200 MW, with improved efficiency and operational flexibility:
  - Upgraded steam turbine design (thin walled components, lower weight and optimized speed, advanced 3D airfoils, quasi-hermetic seals, advanced bearings).
  - Robust large last stage blades to maximize efficiency and operational flexibility - e.g. number of starts, steam purity requirements, etc.
  - Cost-effective and oxidation resistant alloys by extending the application of steel to higher temperatures (up to 650°C).
- Assessment of innovative measures for improved steam turbine flexibility and operational performance. Development of CSP/STE plant analytics.

Supercritical CO_2 solar cycles

Topic #12: Development and field test of CSP hybrid air Brayton turbine combined cycle sCO2 systems

KEY RESEARCH & TARGET OBJECTIVES

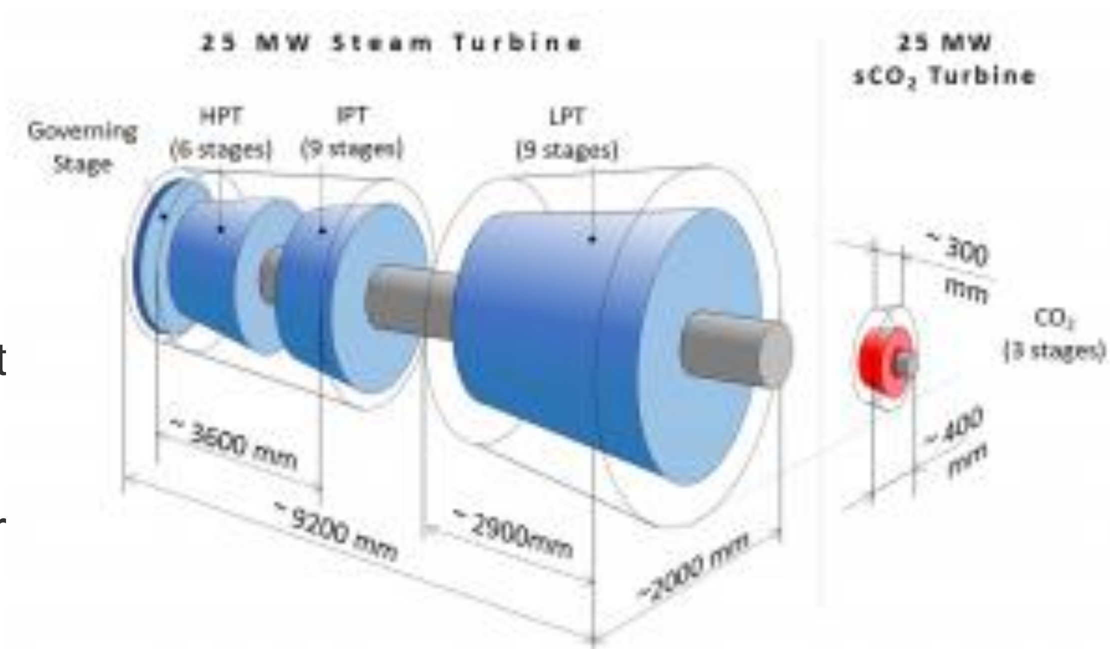
- Development and test of a sCO2 bottoming cycle for CSP/STE operation.
- Supercritical CO2 turbine development (design, operational concepts, rotordynamics, etc.) for high cycle efficiencies and more compact turbomachinery.
- Design, develop and field test a 1000 °C air receiver, including combustion system.
- Optimization of conventional molten salt storage integration into the Brayton and sCO2 plant.

Supercritical CO_2 solar cycles

SCARABEUS project (Competitive Solar Power Towers)

Supercritical CARbon dioxide/Alternative fluids Blends for Efficiency Upgrade of Solar power plants (2019-2023, H2020). Project coord: POLITECNICO DI MILANO (Italy)

- To develop a new working fluid based on blended supercritical CO_2 (dopant added), enabling condensation at ambient temp. and achieving thermal eff. > 50%
- To demonstrate the thermal stability of the new working fluid at 700ºC for 300 hours in real working conditions.
- To reduce LCoE to <96 €/MWh for project specifications yielding 150 €/MWh when conventional, state-of-the-art technology is used.



https://www.scarabeusproject.eu/

Clean Energy Transition Partnership

Updated Scientific Research and Innovation Agenda (SRIA) for CSP in the context of CETP initiative / Contribution to SET-Plan CSP Implementation Plan updating

Defined General Challenges:

1. Central Receiver power plants with lower LCOE.
2. Line-focus solar power plants with lower LCOE.
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. Cost-effective and highly autonomous medium- and high temperature systems for industrial solar heat applications.
6. Reliable and cost-effective solar fuels production.

Key Expected Impacts (*under discussion*)**:**

- LCOE reduction of CSP technology to 0,09 EUR/kWh in Southern EU locations by 2025, targeting 0,08 EUR/kWh by 2030, without any additional constraint.
- Feasibility of novel and cheaper thermal energy storage materials (liquid, solid, PCM or TCS media).
- Thermal energy cost ≤ 0.03 EUR/kWh (T<400ºC, small scale applications) and ≤ 0.02 EUR/kWh (T>600ºC, large scale applications).
- Demonstration of H_2 solar thermal production viability (target cost of 3 €/kg H_2 by 2030).

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Thank you very much for your attention