SOLAR based sCO_2 Operating Low-cost Plants

SOLARPACES Side Event – *27/9/2021*

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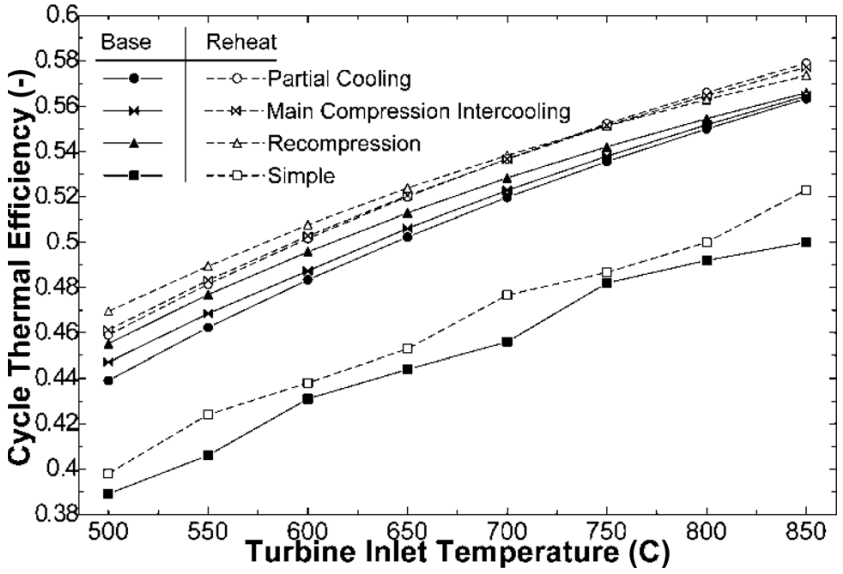
RINA Consulting
Project Coordinator

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.952953

CSP + sCO2 – why?

- ***To enable operation at higher temperatures (increase efficiency)***
- ***sCO_2 cycles are compact (high power density / potential for cost reduction)***
- ***Systems based on sCO_2 cycles can be cost-effective at smaller scales***



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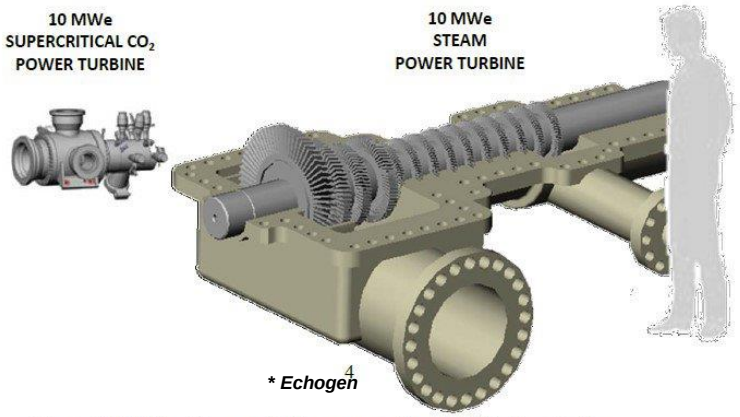
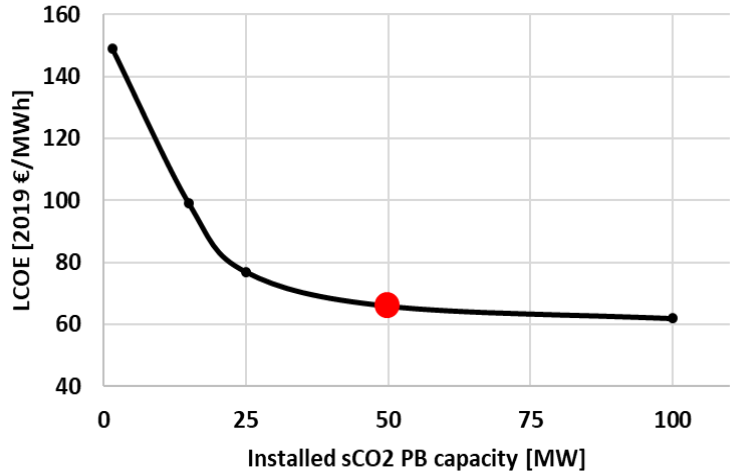


Echogen's 10 MWe sCO_2 power turbine compared to a 10 MWe steam turbine.



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CSP + sCO2: challenges

- ***Low maturity of heat collection and storage systems above 600°C***
  - ***Molten Salt Systems are the "only" bankable technology widely acceptable.***
  - ***New fluids and TES media being investigated, yet far from commercialization***

- ***State of the art of sCO2 cycles: immature and lacking demonstration data***
  - ***Several R&D projects (also in EU) focused at fluids, components and system analysis***
    - ***No demonstration or MW-scale prototyping in EU***
  - ***Several R&D projects with kW prototypes with inlet temperatures below 500°C***
  - ***2 companies in USA offer waste heat recovery CO2 driven engines (500°C, not supercritical)***
  - ***STEP project (USA): first 10MW cycle demonstration at 700°C from NG – commissioning***

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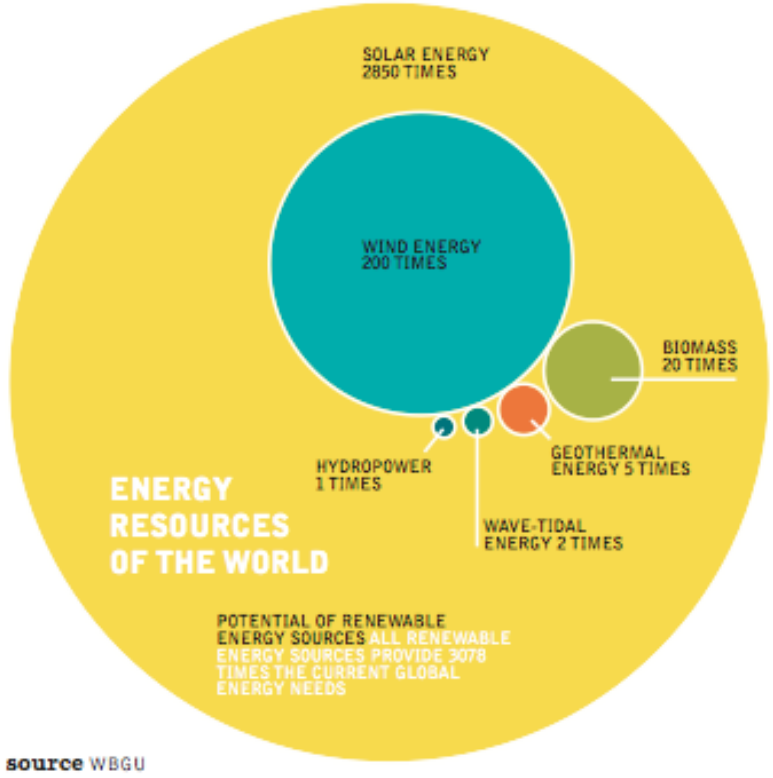
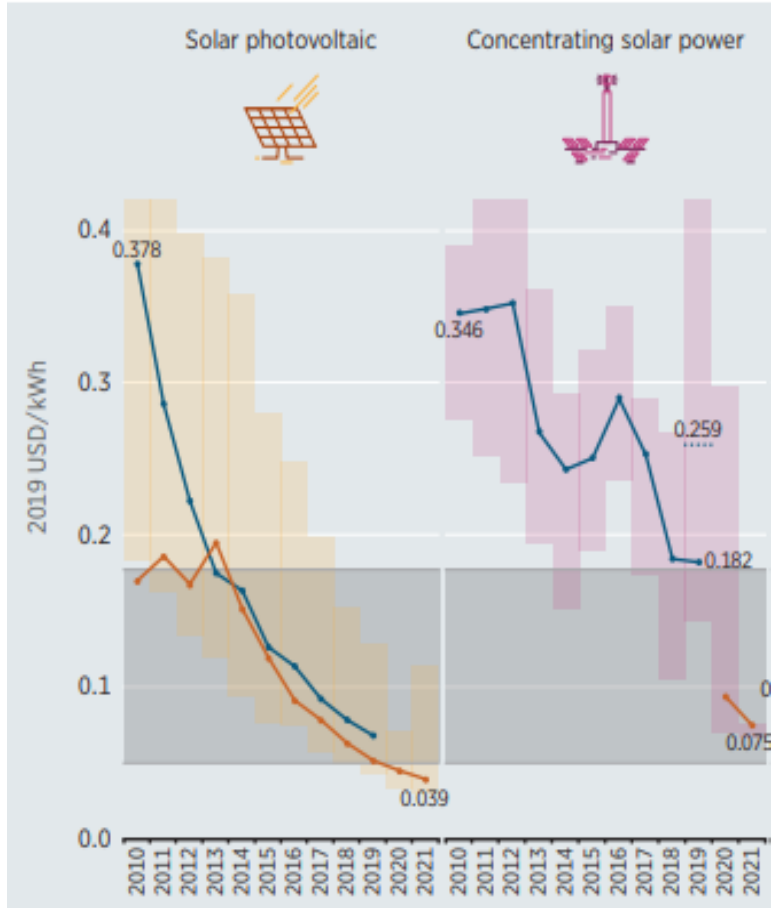
CSP and PV – how to make them friend?





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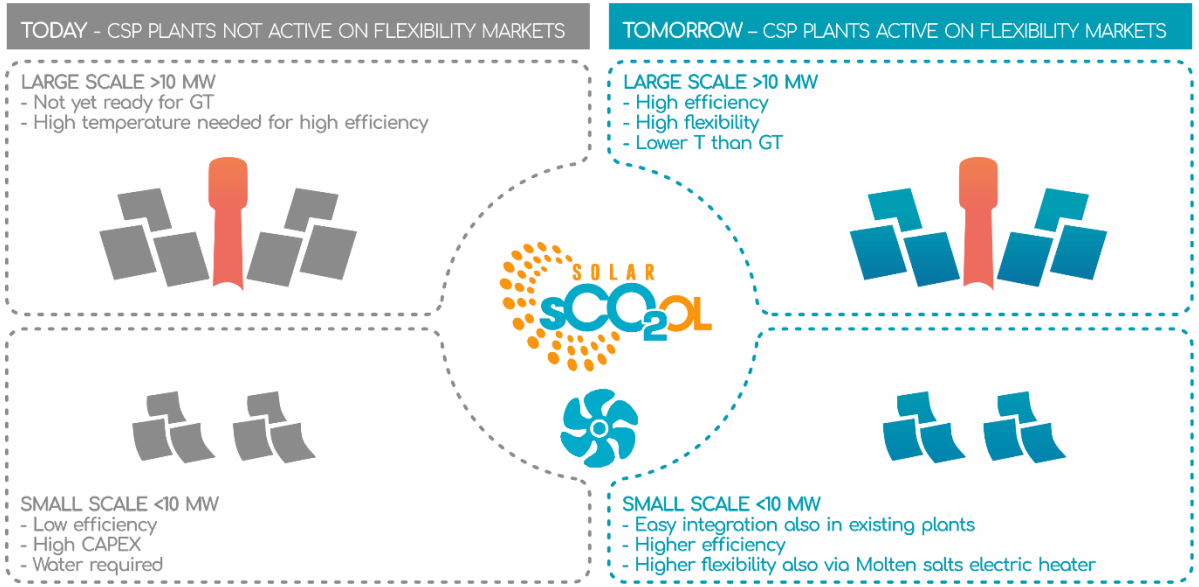
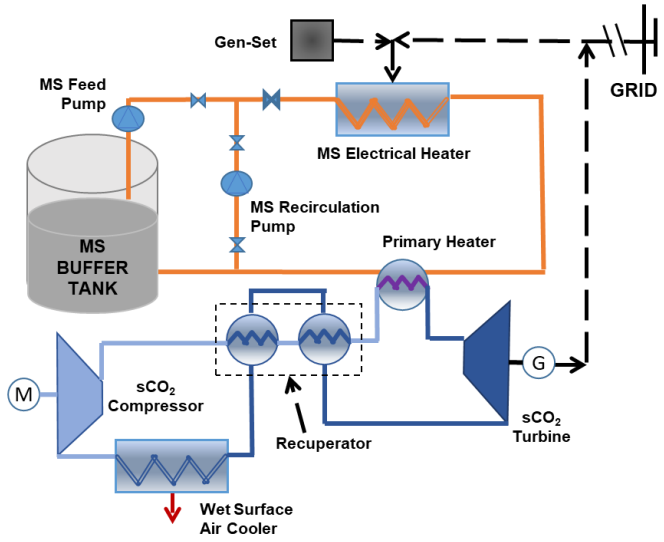
SOLAR based sCO_2 Operating Low-cost Plants

Tackling CSP and sCO_2 turbomachinery challenges in a demonstration to market project





SOLARSCO2OL aims to become the EU MW scale FOAK CSP sCO_2 plant demonstrating sCO_2 potential for cheaper/more flexible CSP energy. In this way, the project will strengthen EU industrial leadership in both CSP and turbomachinery sectors.

TRL 7 – FOAK MW Scale – Reliable

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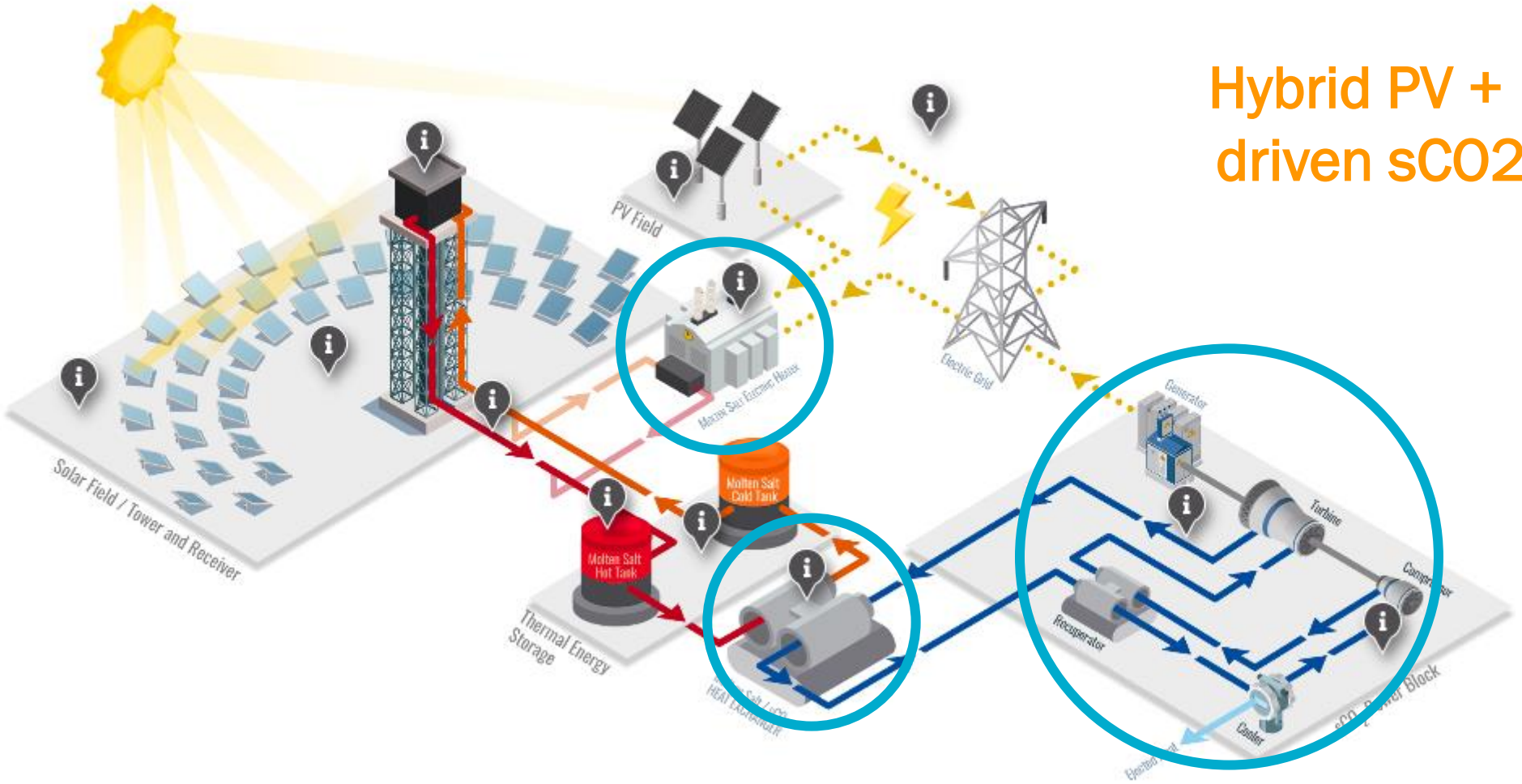
SOLARSCO2OL - Vision



Hybrid PV + Molten salt driven sCO2 CSP plants by 2030

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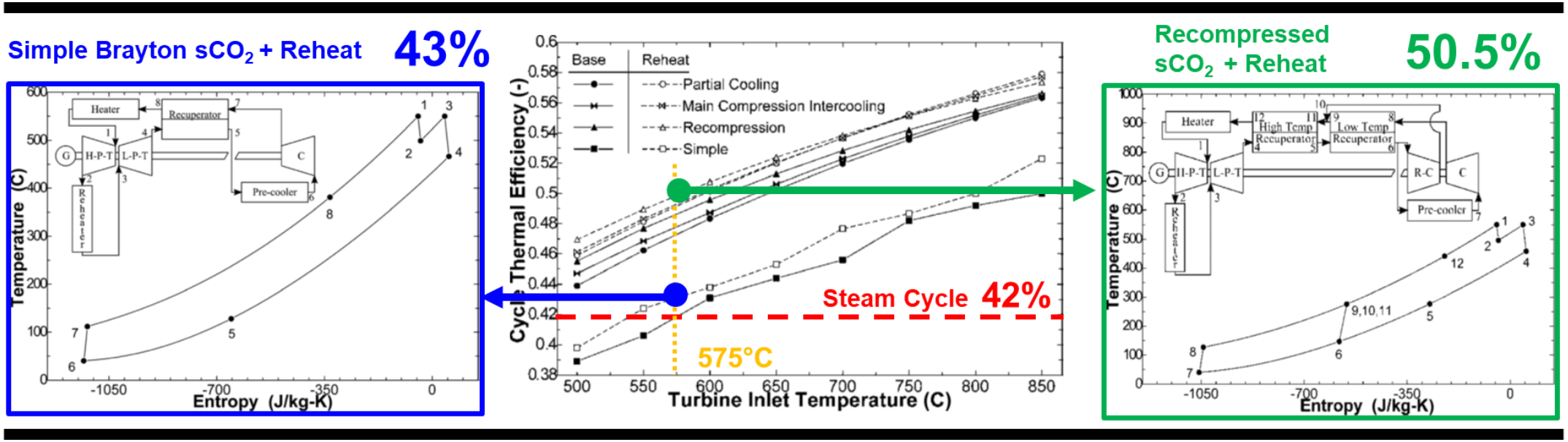
SOLARSCO2OL drivers

- *Demonstrate FOAK MW-scale sCO2 cycle in EU*
- *Demonstrate FOAK molten salt driven sCO2 cycle in real operating conditions*
- *Demonstrate MW-scale optimized molten salt electric heaters for CSP-PV hybrids*



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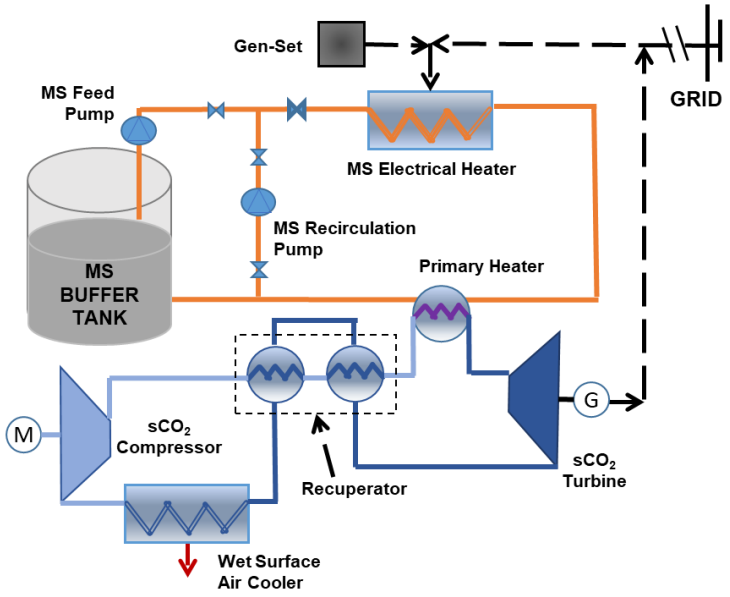
SOLARSCO2OL DEMONSTRATION

Potential hybridization with PV too driving the electric heater



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SOLARSCO2OL OBJECTIVES

- MO1: Demonstrate at TRL8 a flexible FOAK sCO2 CSP power plant (CAPEX, LCOE, Emission reduction and higher yearly efficiency): via experimental and thermoeconomics (WP1-WP4-WP6)
- MO2: Making sCO2 turbomachinery able to operate with solar input (WP2-3)
- MO3: Integration of SOLARSCO2OL components via grid oriented advanced control systems (WP5)
- MO4: Demonstration of economic, safety and environmental sustainability of SOLARSCO2OL (WP6-WP7): multi impact assessment (socio-envi-economic) and replication studies
- MO5: Dissemination and Stakeholders Engagement at policy and industrial level (both “solar and turbomachinery sectors”)

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SOLARSCO2OL - Project Overview

- ***Molten Salt driven sCO2 cycle demo (2 MWe) to enable CSP+sCO2 systems by 2030***
- ***15 Partners, industry driven consortium***
- ***4 Years – Oct 2020 to Oct 2024***
- ***Project Coordination:***
  Dr. Stefano Barberis, RINA Consulting
- ***Scientific Coordination:***
  Dr. Rafael Guédez, KTH
- ***EU funded - Grant Agreement #952953***
- ***Budget: approx. 15M€, 10M€ funding from EC***

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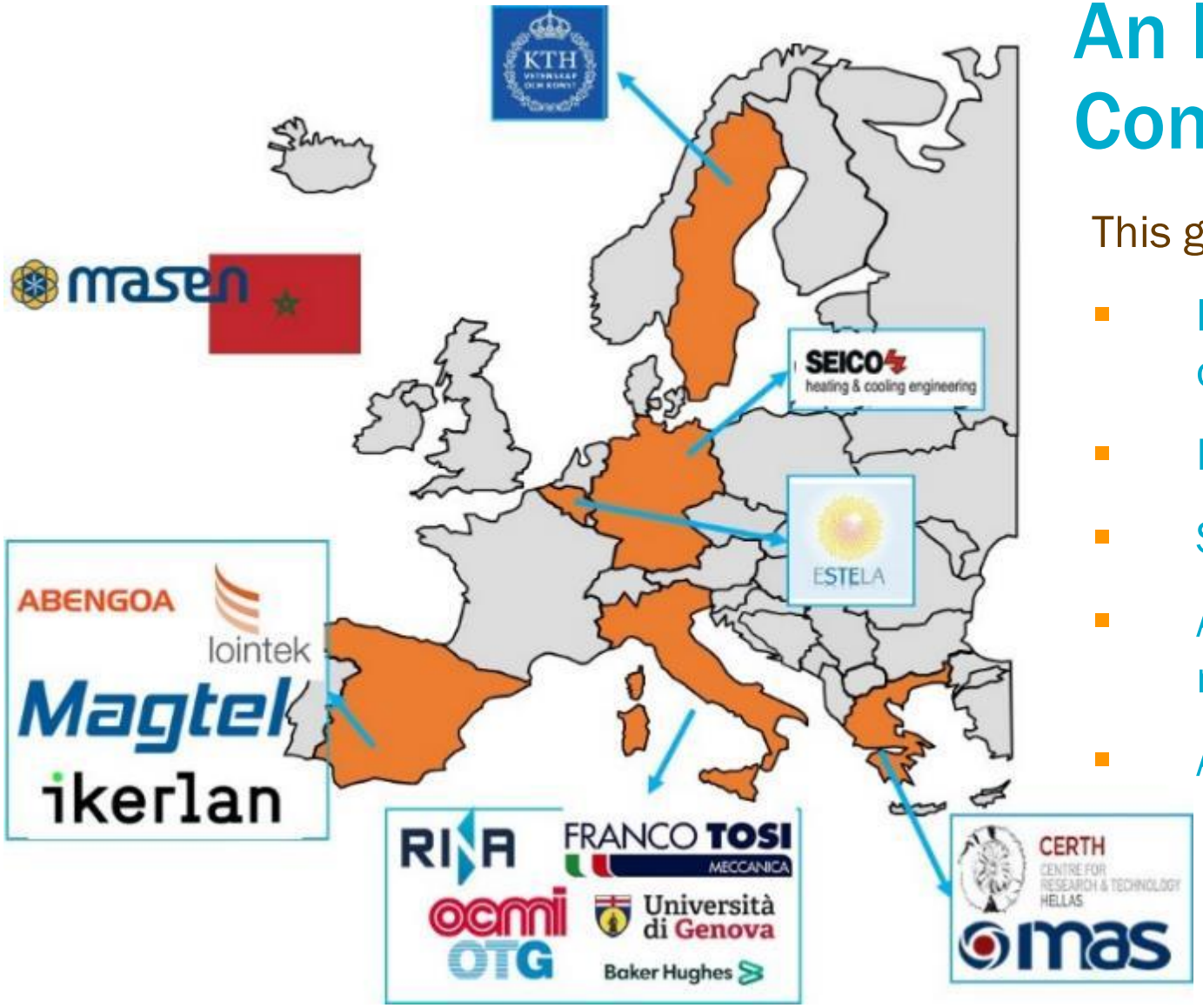
An Industry Driven Consortium



This guarantees:

- Industrial and Market interest to project outcomes and marketability
- Facility to involve stakeholders
- Strong commitment to prototypes realization
- A common «project business» to be pursued made by «different actors' business»
- Ability to overcome contingencies

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SOLARSCO2OL DEMONSTRATION TO MARKET

Key Exploitable Results	TRL
sCO_2 compressor:	5
sCO_2 turbine:	5
Pressurized sCO_2 HEXs:	6
Molten Salt flexible electric heater:	6
CSP Plant Grid flexibility controller:	4
sCO_2 CSP Plants:	**5**

Key Exploitable Results	TRL
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CSP Plant Grid flexibility controller:	6
sCO_2 CSP Plants:	**5**

PROJECT STARTS — 2020 — TRL 5

2022 — TRL 6

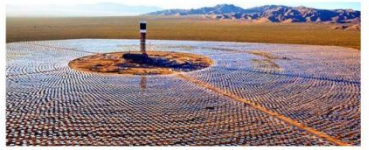
2024 — TRL 7

PROJECT ENDS

2025 — TRL 8

2030 — TRL 9

MAIN APPLICATIONS:



ALL SCALE CSP Plants

MARKET DRIVERS:

- Promotion of RES Based plants able to act as grid flexibility actors
- Increase of affordability and economic attractiveness of CSP plants
- Overall decarbonization of EU power plants

ADDITIONAL MARKETS:

Industrial Plants

Fossil Based Power Plants

Project Starts

Project Drivers

- RES plants will be required to be more and more active in EU flexibility markets
- sCO_2 turbomachinery year by year closer to technology maturity
- Increased penetration of non-dispatchable RES in EU Grid
- MENA countries more and more active in CSP sector

Lab Validation

Demonstration at MWh scale

Upscale

Technological Barriers:	• Integration of sCO_2 cycles also in solar tower plants • Reduce the manufacturing costs of sCO_2 machines • Study how to couple sCO_2 compressor/turbine matching also at higher scale • Reduce CAPEX
Non Technological Barriers:	• Definition of best practices and measures for the sizing and installation of SOLARSCO2OL in different type of CSP plants • Standardization of control and monitoring systems protocol for CSP Grid flexible schemes to interact with local grid • Increase social acceptability also via dedicated policies/supporting schemes • Increase grid and electric market acceptability via dedicated policies/supporting schemes • Health and Safety Certification for the sCO_2 machines
Further Demonstrations	• Demonstration of the SOLARSCO2OL in larger solar fields plants and in different irradiation areas • Application of the sCO_2 turbomachines for industrial waste heat application (steel, ceramic, glass) • Application of molten salt electric heater also to increase flexibility of fossil based power plants (CCs, GTs, Rankine cycles...)
Marketing	• Start to promote SOLARSCO2OL HW&SW technologies among CSP plant owners/managers, DSO/TSO, energy utilities, turbomachinery manufacturers etc. • Selection of the first entry markets: Southern EU and MENA countries with high DNI and presence of grid flexibility needs • Assessment of the final business model for the commercial exploitation of the SOLARSCO2OL Technologies

On the Market

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SOLAR sCO2OL

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INTRODUCING SOLARSCO2OL

SOLARSCO2OL is a EU H2020 funded project aiming at developing an innovative, economically viable and easily replicable supercritical CO_2 (sCO_2) power block for demonstrating the use of sCO_2 cycles as a potential key technology to increase the flexibility of concentrated solar power (CSP) plants. This will reduce their Levelised Cost of Electricity (LCOE) to values below 10 c€/kWh in Europe and promote an innovative power plant cycle layout not requiring water.

The innovative SOLARSCO2OL plant layout, coupled with fast-reactive electric heaters and efficient heat exchangers (HEXs), will enable the operation and design of novel integrated CSP plant layouts.

SOLARSCO2OL KEY OBJECTIVES

Flexibility & Efficiency

Increase the operational flexibility and efficiency of existing and future CSP plants by using sCO_2 power cycles able to be operated at temperature levels achievable by state-of-the-art concentrators, thereby also eliminating the use of water in the power cycle.

Cost-Competitiveness

Use novel sCO_2 plant designs for generating solar thermal electricity in a more cost-competitive way.

Sustainability

Help unlock the potential of CSP in Europe and worldwide to reach decarbonisation targets.

PROJECT GOALS

A first-of-a-kind, MW-scale sCO_2 cycle, operating in a real CSP plant

The SOLARSCO2OL project will realise a first-of-a-kind MW-scale sCO_2 power cycle operating with molten salts in an existing CSP plant facility. The project will also study its replication potential in solar tower plants, supported by MASEN and Abengoa, thus unlocking the strong replication potential in EU and worldwide.

Unlocking the potential of integrating sCO_2 in all kinds of CSP plants in EU and worldwide

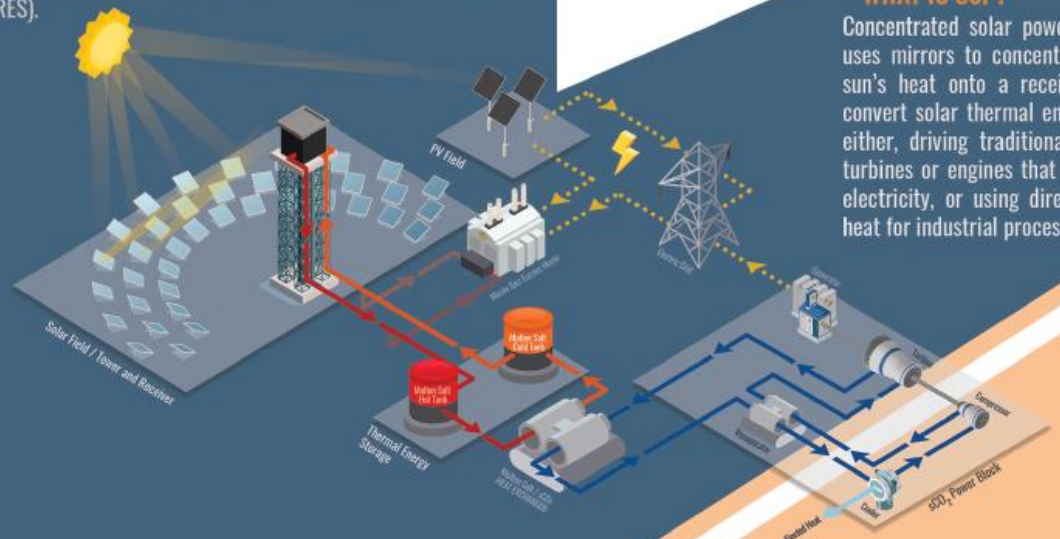
SOLARSCO2OL pursues unlocking the potential of integrating sCO_2 in all kinds of CSP plants, towards higher efficiency and higher responsiveness to grid flexibility requests, thus demonstrating them on the field and planning next steps towards technical maturity and marketability within 2030, also studying sCO_2 application in other market segments (industrial application, waste heat, other thermal RES).

WHY SCO_2?

Making next-generation CSP plants more cost-competitive

sCO_2 power cycles can perfectly operate CSP current temperatures, producing power with higher efficiency if compared with Rankine cycles traditionally used in CSP plants and without using water as operating fluid. sCO_2 power cycles have a large room for cost reduction and also considering their reduced required volume/size footprint.

In this sense, as heat exchangers can comprise up to 60%-70% of the total cost of a CSP sCO_2 power cycle, a relevant attention has to be put on this topic. So, a new design with fast-reactive electric heaters (that would also enable PV hybridization of the CSP plant) and efficient heat exchangers (HEXs), can help sCO_2-CSP plants become more cost-competitive.



WHAT IS CSP?

Concentrated solar power (CSP) uses mirrors to concentrate the sun's heat onto a receiver and convert solar thermal energy for either, driving traditional steam turbines or engines that produce electricity, or using directly the heat for industrial processes.

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