Layouts: Demo plans & Hybrid up-scaled plants

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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 to be demonstrated*

- *State of the art of sCO2 cycles: immature and lacking demonstration data*
  - *Several R&D projects 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*
 - *STEP project (USA): first 10MW cycle demonstration at 700°C from NG – commissioning*

SOLARSCO2OL drivers

- *Demonstrate FOAK MW-scale sCO$_2$ cycle in EU*

- *Demonstrate FOAK molten salt driven sCO$_2$ cycle in real operating conditions*

- *Demonstrate MW-scale optimized molten salt electric heaters for CSP-PV hybrids*
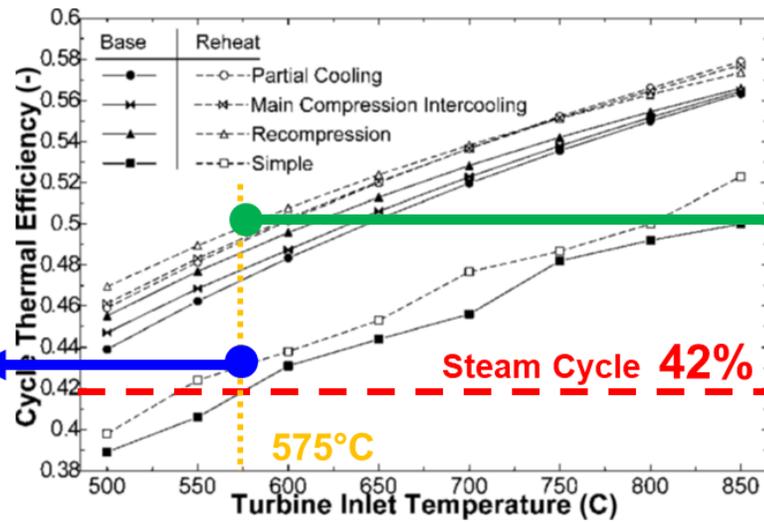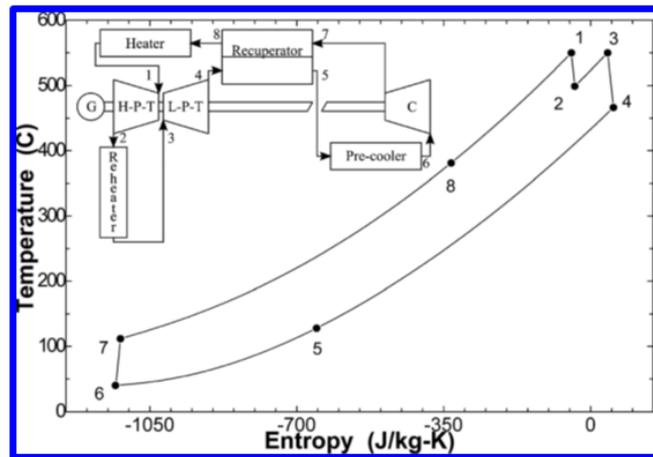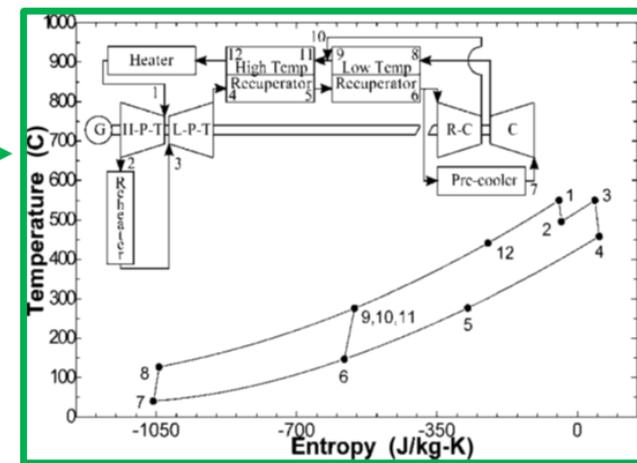
Turchi C. et al., 2013, "Thermodynamic Study of Advanced Supercritical Carbon Dioxide Power Cycles for Concentrating Solar Power Systems, ASME Journal of Solar Energy Engineering (135)

Project vision: Replication Layout
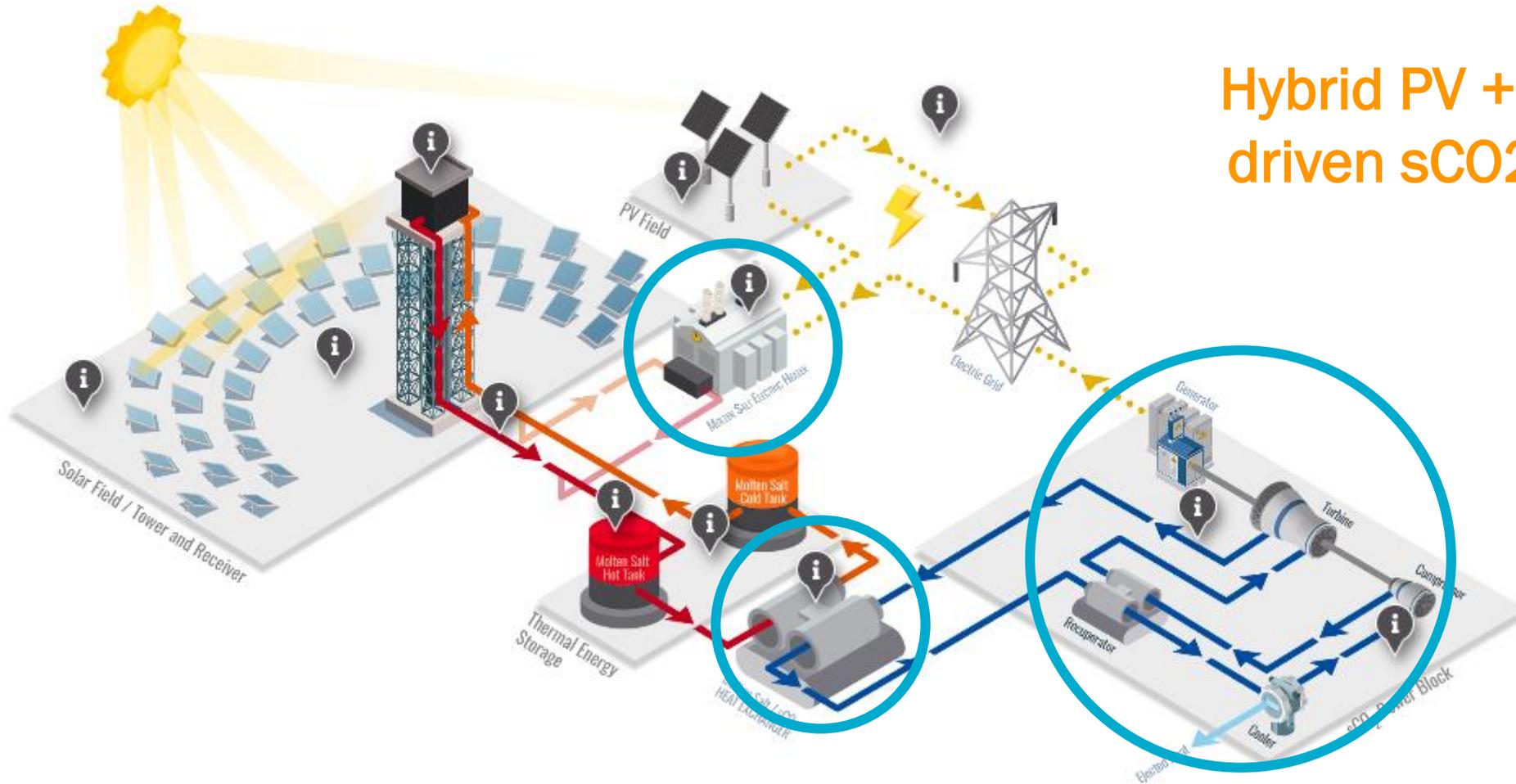
Hybrid PV + Molten salt driven sCO2 CSP plants by 2030

Project Vision: Towards Hybrid sCO2 CSP - PV
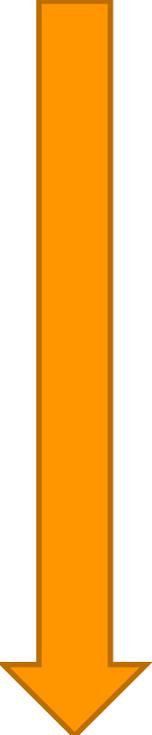
- *2020: SOLARSCO2OL component design, optimization and prototyping*

- *2024: SOLARSCO2OL demonstration campaign*
  - *Up-scaled design optimization (10 MW – 50 MW).*

- *2025-2028: Up-scaling and demonstration at larger scales*
  - *Market entry of sCO2 power block in other applications*

- *2030: Commercial molten salt CSP sCO2 + PV plants*

- *2035: Market entry of advanced hybrid CSP-PV layouts (700°C)*

WP1 Objectives and Tasks

WP1 Main Objectives

- To **develop** flexible **simulation tools** for assessing the techno-economic viability of the novel CSP layouts with sCO2 under different market and cost boundary conditions, also including hybridization with PV.

- To **carry pre-engineering work** and **de-risking analysis** for optimization and ultimately definition of the pilot demonstration layout and integration strategies for key components and infrastructure.

Task Number	Task Description	Leader	When	Status
T1.1	Definition of novel SolarSCO2OL layouts: schematics, operating modes, limitations and scope	KTH	M1 - M6	✔
T1.2	SOLARSCO2OL Demo layout definition: schematics, operating modes and BoP	ABE	M1 – M12	✔
T1.3	Definition of targeted KPIs, bottom-up cost model and market-related input for techno-economic optimization models	KTH	M4 – M9	✔
T1.4	Techno-economic Model Development and Verification	KTH	M7 – M32	On-going

Up-scaled Techno-economic Analysis

- *Cost competitive LCOE (< 80 €/MWh) at smaller scales than traditional CSP → financing, modularity*

- *66 €/MWh estimate for typical Southern-EU conditions for a 50 MW hybrid PV-CSP with load factor > 70%*
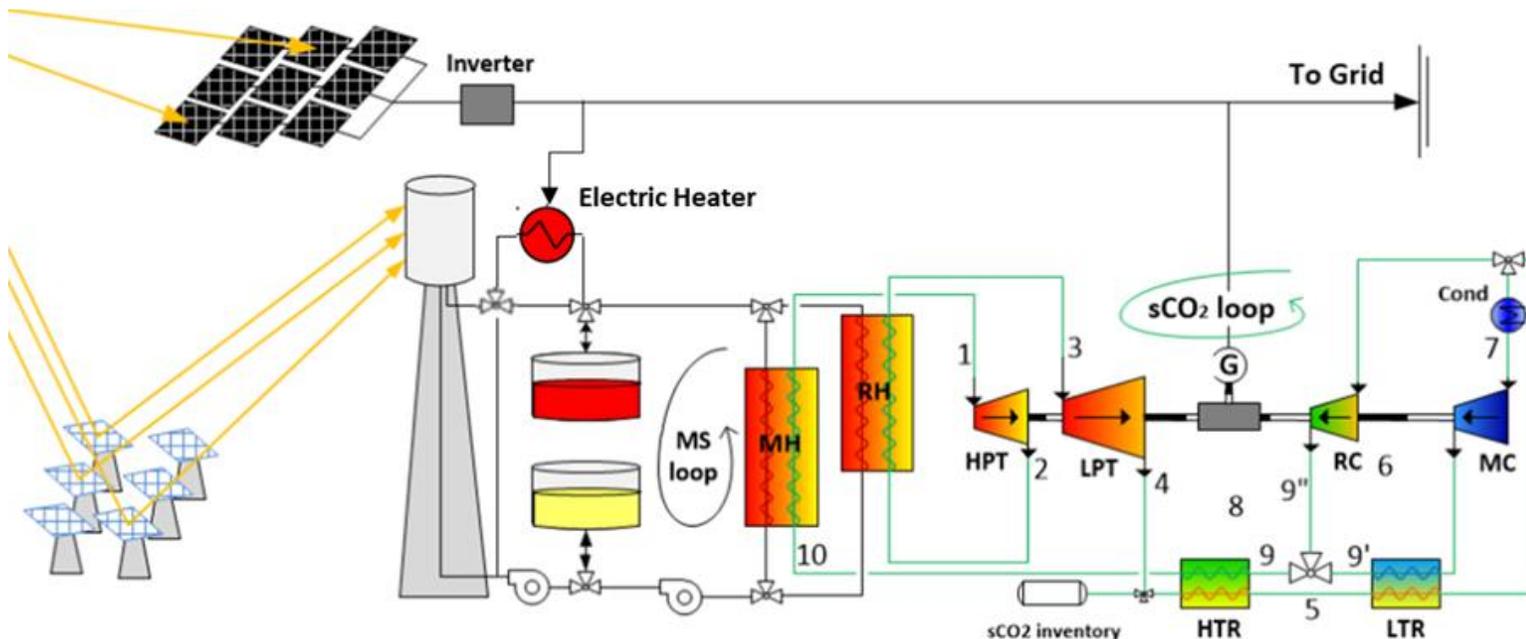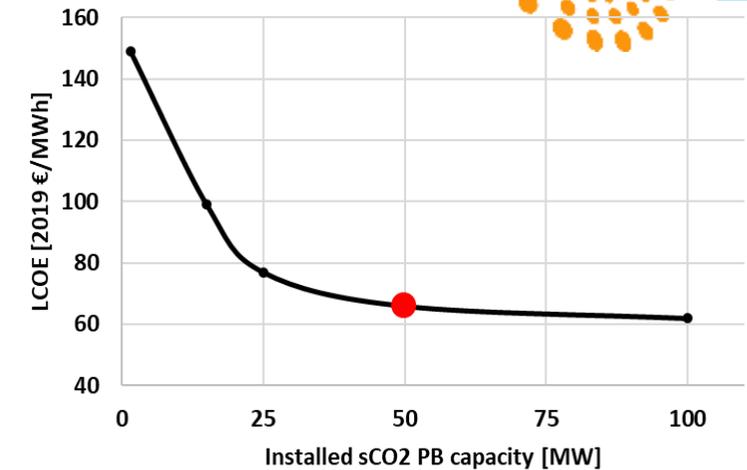
Layout (50 MW plant)	LCoE [€/MWh] 1900 kWh/m²	3400 kWh/m²
CSP steam cycle	106.1	85.5
CSP sCO₂ (no PV)	98.3	77.9
CSP sCO₂ + PV (co-located)	66.3	44.4
CSP sCO₂ + PV (+ El. Heater)	65.9	42.8

Preliminary Demo Layout Definition

50 MW CSP   6 MW PV

Placed on the premises of La Africana

Existing infrastructure will be used within possibilities (grid connection, access to utilities and others)

Preliminary Demo Layout Definition
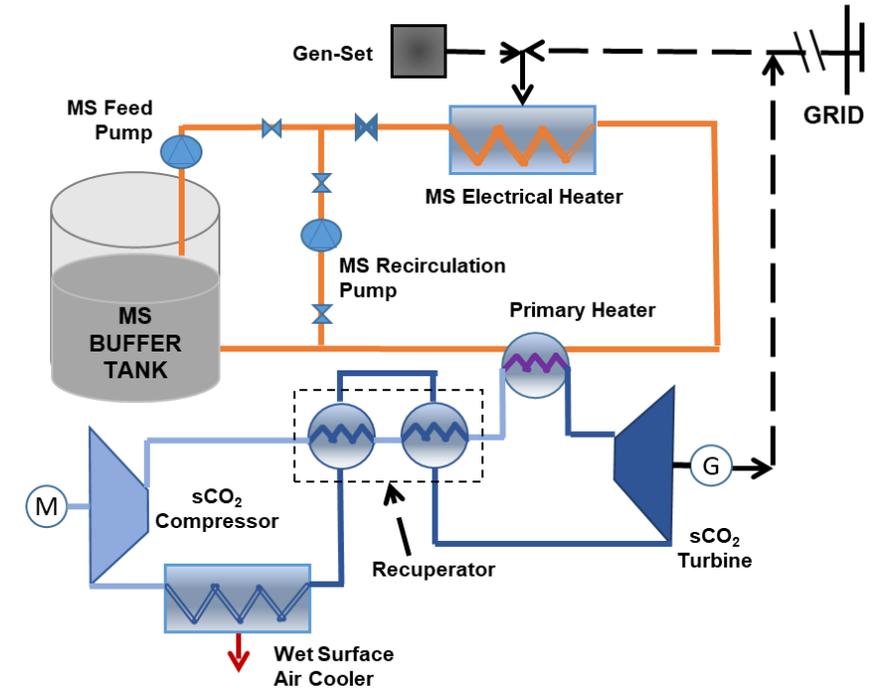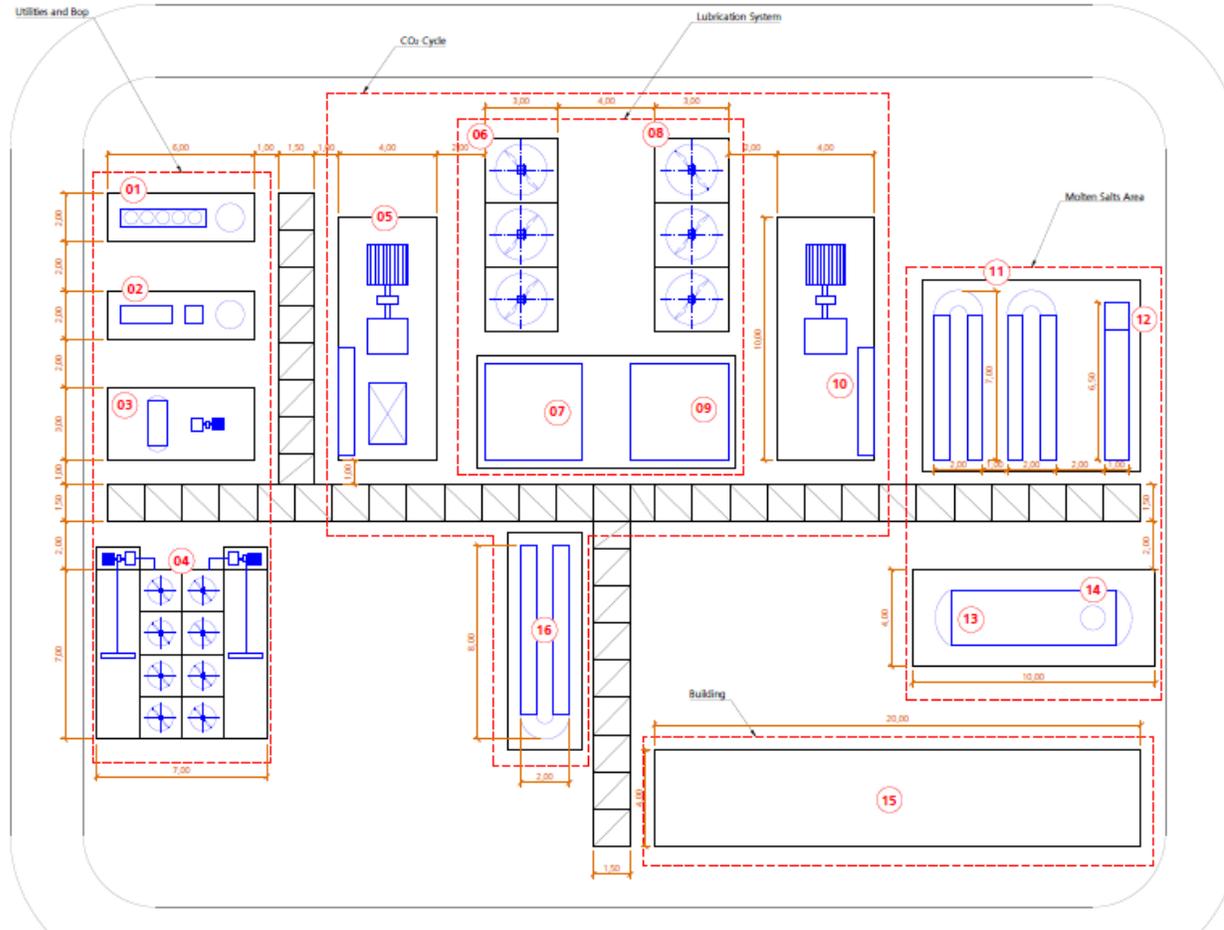
- **TIT 565°C; P = 186 bar**
- **2.0 MW gross, 1.4 MW net**
- **6 MWe Electric Heater**

# Preliminary Demo Layout Definition
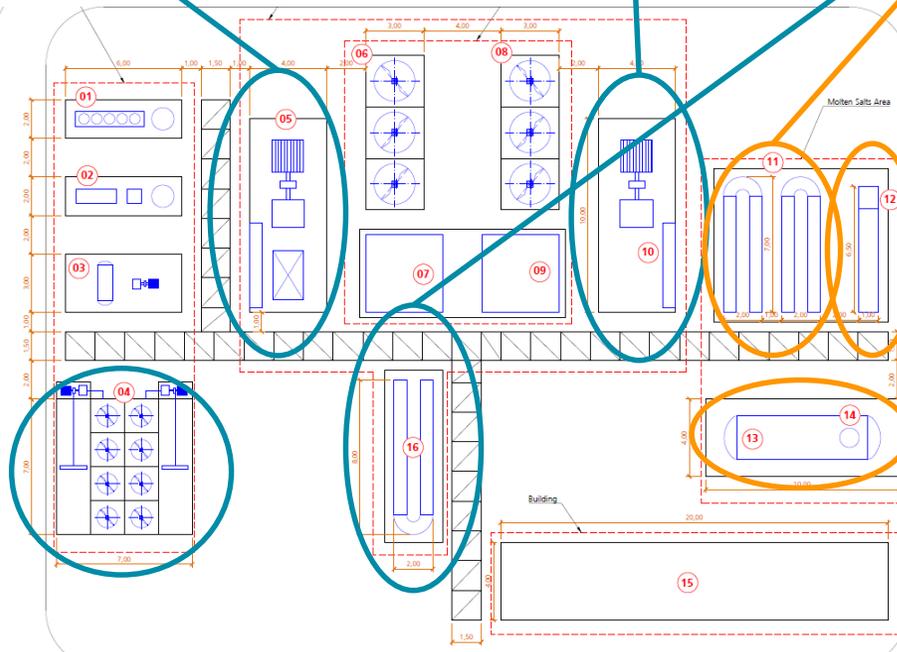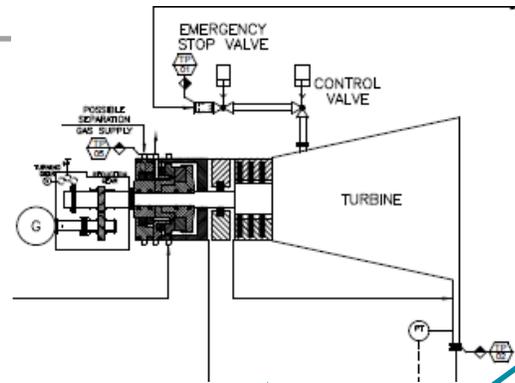
- **500 hours tests**
- **Different operating modes:**
  - **Start-up**
  - **Cold / Hot stand-by**
  - **Normal:**
    - **Nominal load**
    - **Partial load**

Future Advanced Layouts

Particle-based
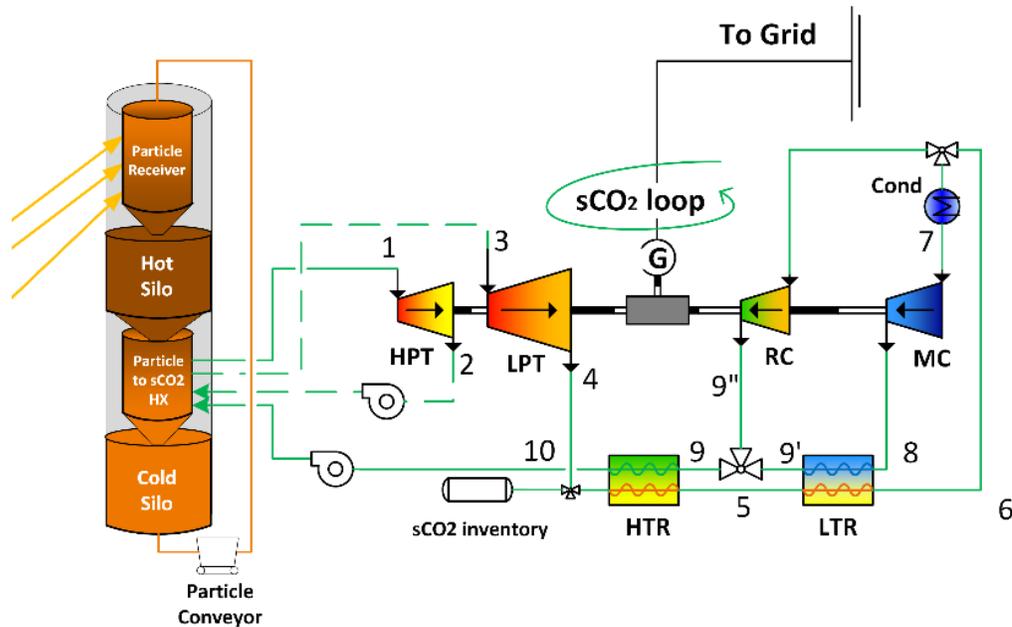
Air-based
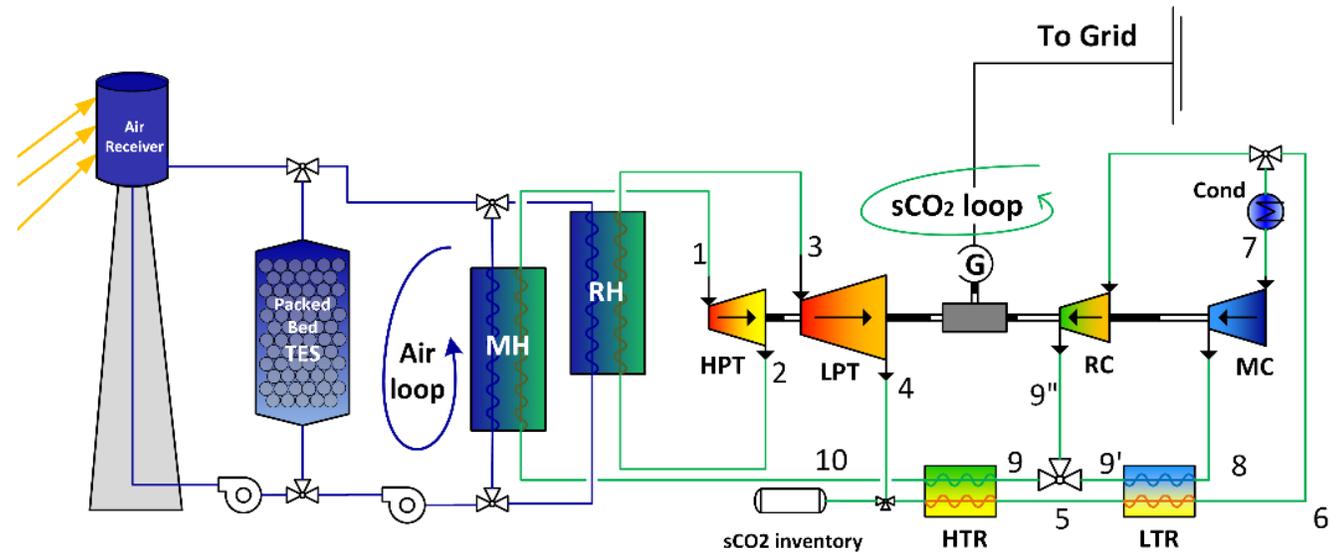
THU-1C **Guccione et al, 2021, "Techno-economic Analysis of an Air-driven Concentrating Solar Power Plant with Particle storage and supercritical CO2 Power Block"**
Guccione et al, 2021, "Thermodynamic Analysis of a Hybrid PV-Particle Based sCO2 Concentrating Solar Power Plant"

Trevisan et al, 2020, "Thermo-economic optimization of an air driven supercritical CO2 Brayton power cycle for concentrating solar power plant with packed bed thermal energy storage", Solar Energy, 211.

Future Advanced Layouts

Chloride Salt
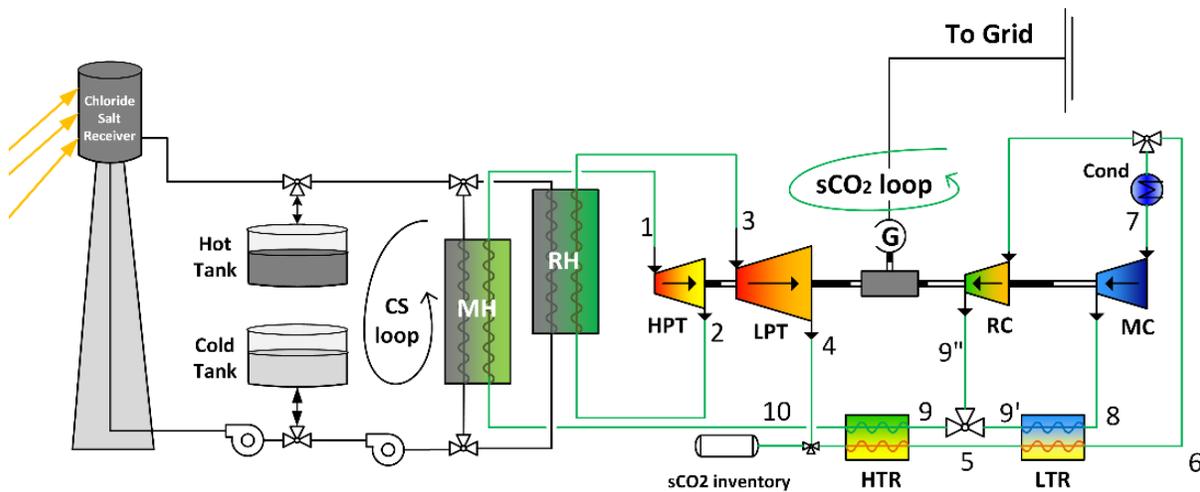
Sodium + Chloride Salts
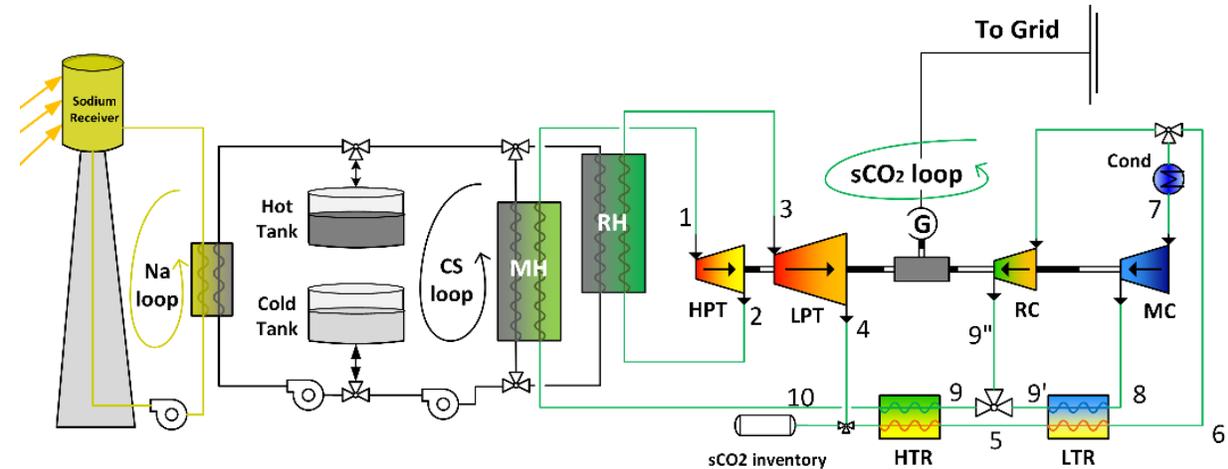
Summary - Takeaways

- **There are many opportunities yet for enhancing cost-competitiveness of CSP**

- **Among these, shifting to sCO_2 cycles can enable higher efficiencies and open new markets**
  - **But sCO_2 cycles and TES technologies at 700°C are yet to be proven though.**

The SOLARSCO2OL project is a step towards commercial hybrid PV + CSP-sCO_2 plants

- **Targets the first demonstration of a molten salt driven sCO_2 cycle**
  - **Demo plant to be built in the premises of La Africana (Spain)**

- **4 year EU funded project (Oct 2020 – Oct 2024)**

- **Industry-driven consortium of 15 partners, led by RINA-C and KTH**

- **MW-scale components to be designed, integrated and tested for first time in EU, including turbine, compressor, heat exchangers, and an optimized molten salt electric heater**

- **New advanced layouts to be assessed techno-economically**

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