Preliminary Results of the EU SolarSCO2OL Demonstration Project: Enabling the Integration of Supercritical CO2 Power Blocks into Hybrid CSP-PV Plants

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SOLARsCO2OL Project:
Project Overview

Aims of the project:

1. Demonstration of MW scale sCO2 cycle (FOAK in EU, operating from molten salts)
2. Demo of MW molten salt electric heaters
3. Techno-economic investigations of Hybrid PV -CSP layouts

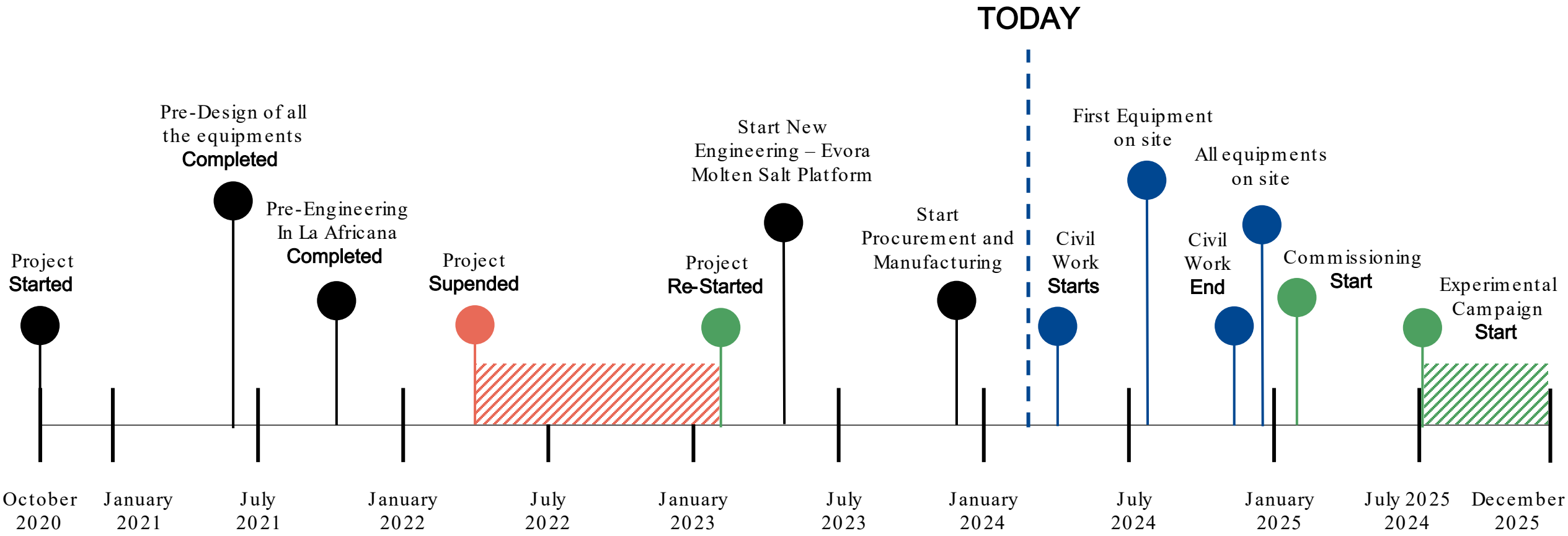
Timeline: October 2020 – September 2025.
DEMO campaign expected in summer 2025.

Partners: 17 Coordinated by KTH and RINA Consulting

Budget: Approx. 16 M€ total budget (10 M€ EU funding)

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

SOLARsCO2OL Project:
Project Timeline



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SOLARsCO2OL Project:
Project Location

HelioTrough® 2.0: 684 m, 4,500 m²
HTF: Molten Salts
Power: **3.5 MW_{th}**
Tmax: **565 °C**

Power: **1.8 MWth @ 14.0 MPa / 560 °C**
Economizer/evaporator, air cooled condenser, pressure reducing station

2-Tank TES
34 m3 (ca. 92 tons salt)
Capacity: **5.4 MWh @ 565 °C / ΔT = 275 K**

Project resumed in February 2023. 3 new partners: DLR, UEVORA, B2Z
Updated timeline: Construction start Q2 2024; Commissioning Q1 2025.

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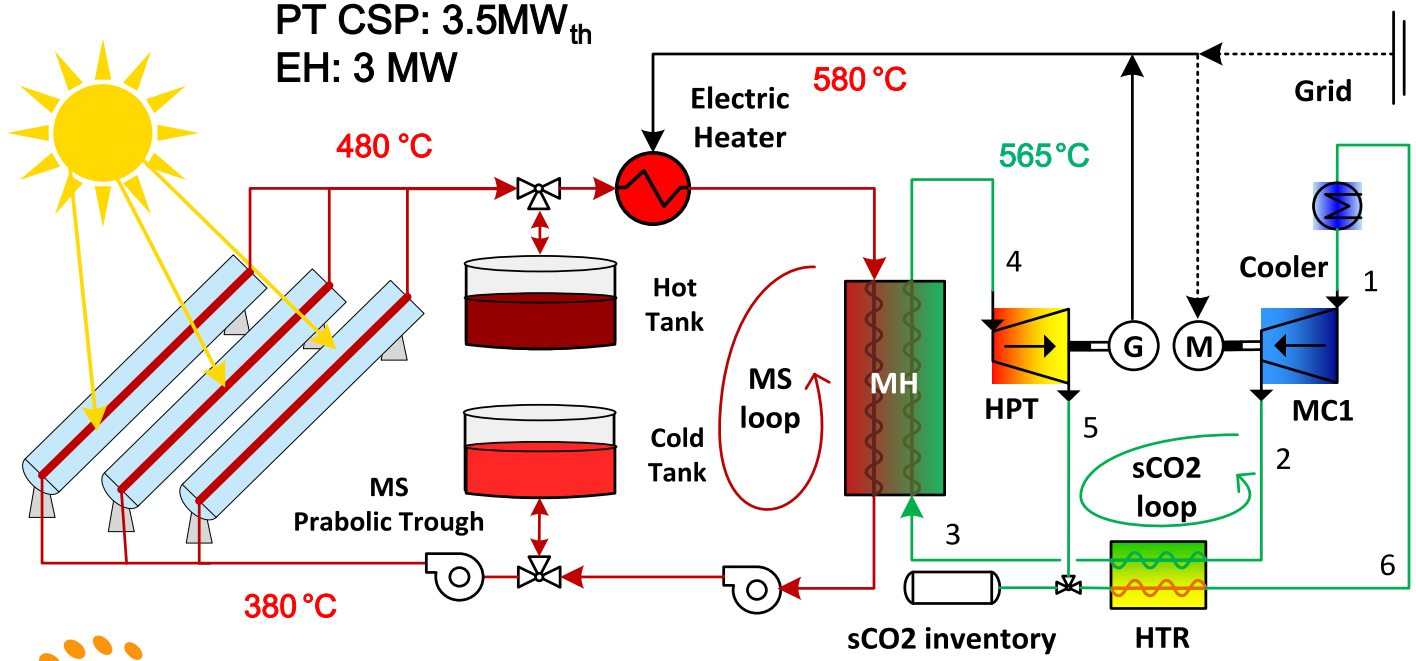
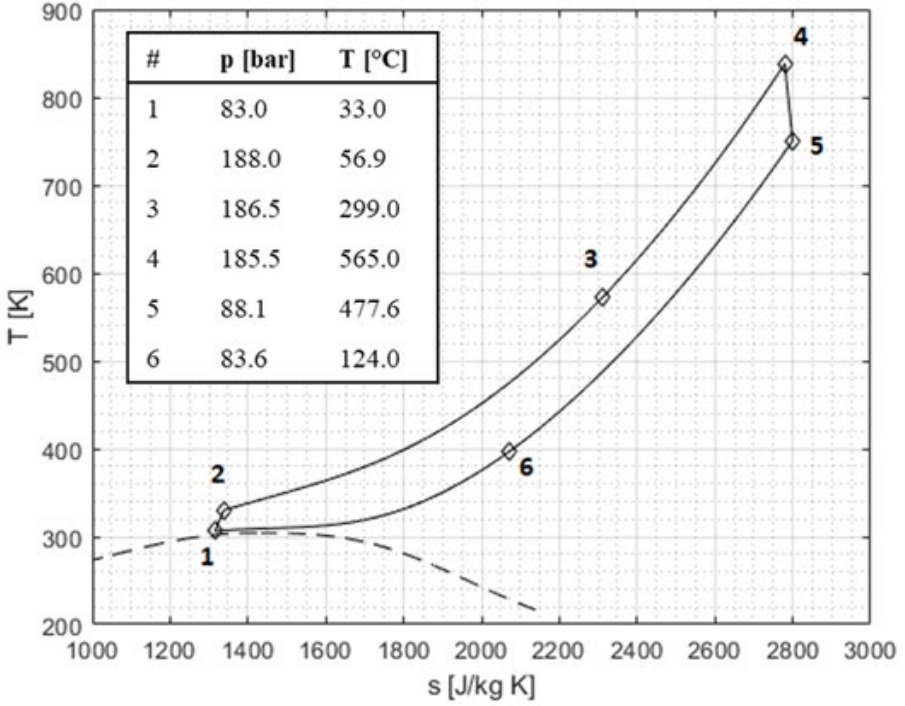
Demo at Evora Molten Salt Platform





#	p [bar]	T [°C]
1	83.0	33.0
2	188.0	56.9
3	186.5	299.0
4	185.5	565.0
5	88.1	477.6
6	83.6	124.0

MS: 22 kg/s, 3 bar
CO_2: 21 kg/s 83 – 188 bar

Cycle Efficiency	22.1%
Total Efficiency	20.3%
Recuperator Effectiveness	80%
Turbine Efficiency	83%
Compressor Efficiency	67%
Mechanical Efficiency	96%
Electrical Efficiency	96%

Heater – Q	6.8 MW_{th}
Cooler – Q	5.3 MW_{th}
Recuperator – Q	8.7 MW_{th}
Turbine – P	1.96 MW_{th}
Compressor – P	0.47 Mw_e
Net Power	1.38 MW_e

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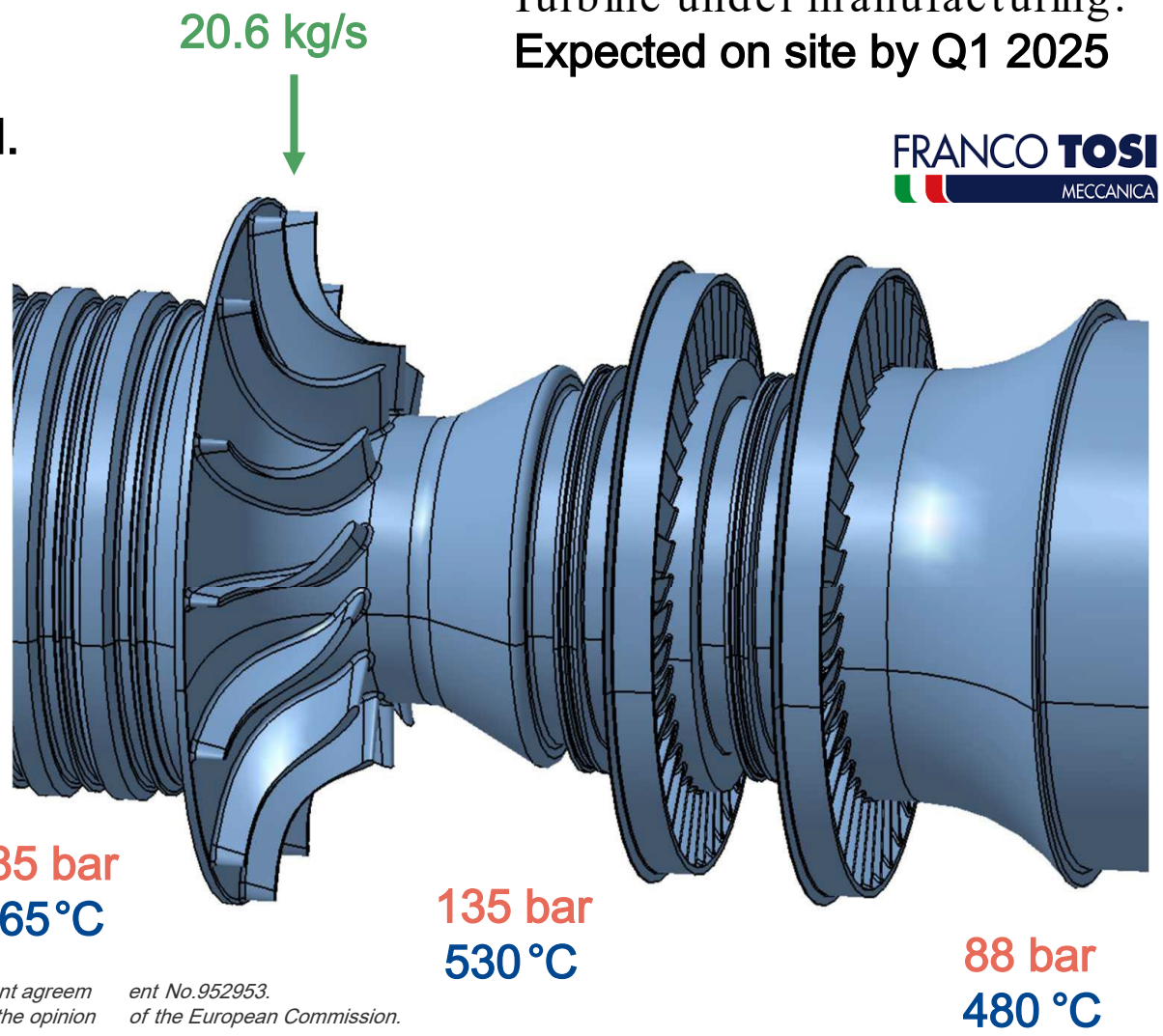
sCO2 Turbine

Turbine under manufacturing:
Expected on site by Q1 2025

- Three-stages machine: first **one radial**, other **two axial.**
- **Isentropic Efficiency** : 84%
- **Power:** ~2 MW (780 kW + 660 kW + 635 kW)
- **TIT and maximum pressure:** The design consider 650 °C and pressure up to 210 bar.
- **Rotational speed** : 30000 rpm
- **Scalability:** Scalable up to 10 MW with no major manufacturing process variations.
- Turbomachinery can **reduce load** down to 40% preserving efficiency
- Shaft-end: **DGS seals** Internal: **brush seals.**



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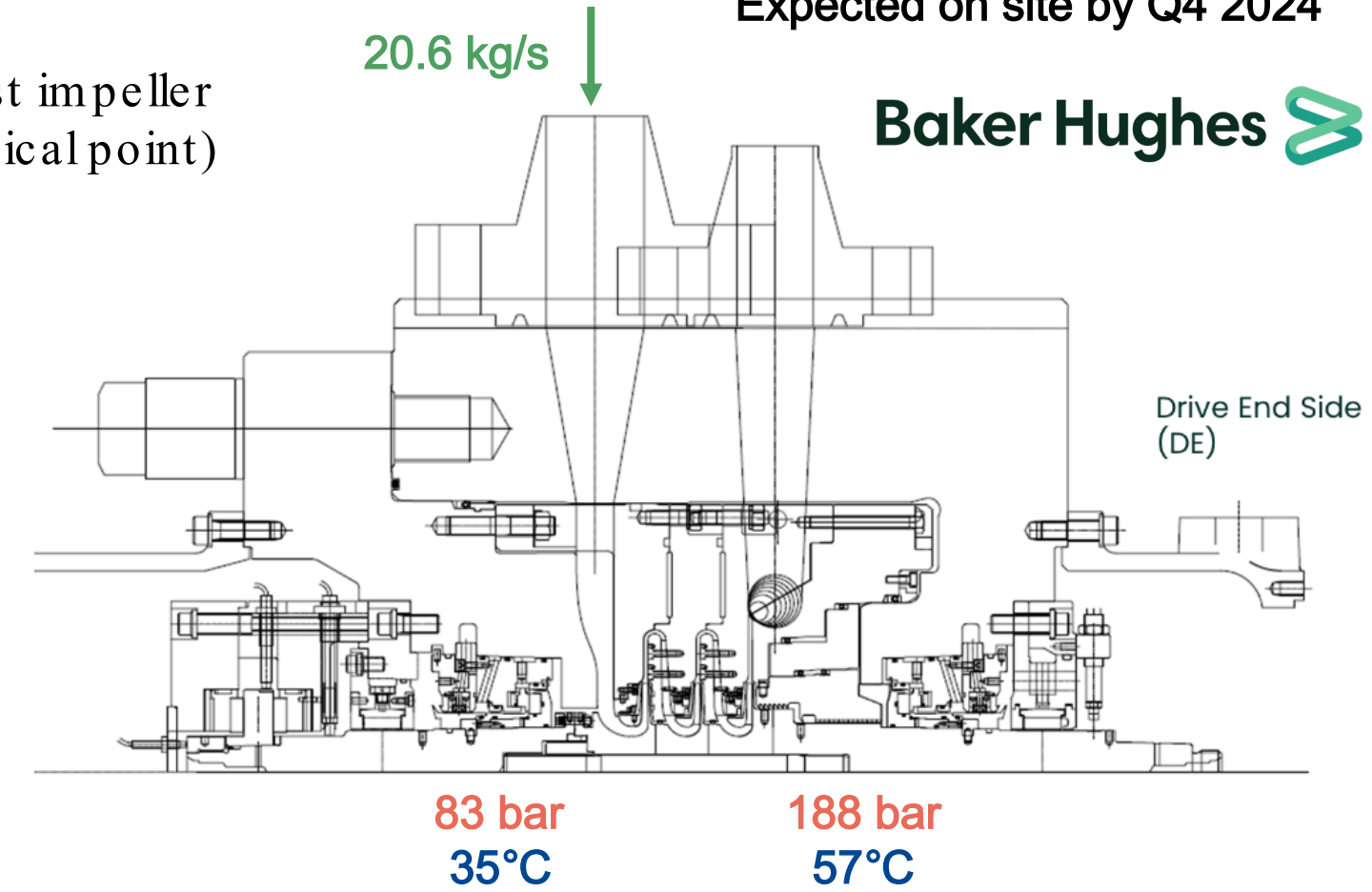
SCO2 Compressor

- Three-stages **centrifugal compressor** (first impeller ad hoc design to handle sCO_2 close to critical point)
- **Isentropic Efficiency** : 67%
- **Motor Power:** 0.47 MW
- **Rotational speed :** 12686 rpm – nominal
- **Scalability:** Scalable up to 10 MW.
- Turbomachinery can **reduce load** down to 40% preserving efficiency
- Separate shaft. Flexibility in operation.
- Single type DGS

Compressor under manufacturing:
Expected on site by Q4 2024



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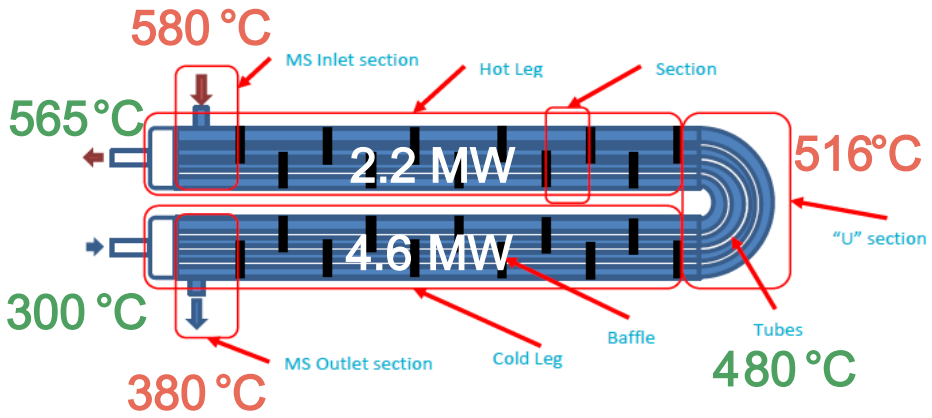
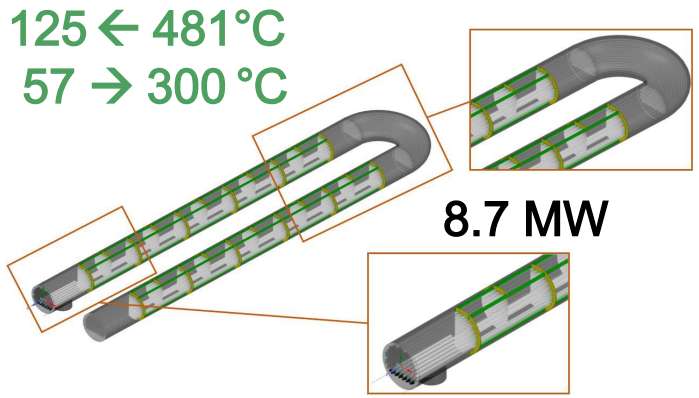
Primary Heater, Recuperator, and Electric Heater

- Components designed for direct scaling up to 10 MW
- Heat Exchangers under procurement / manufacturing:
  Expected on site by: Q3/Q4 2024



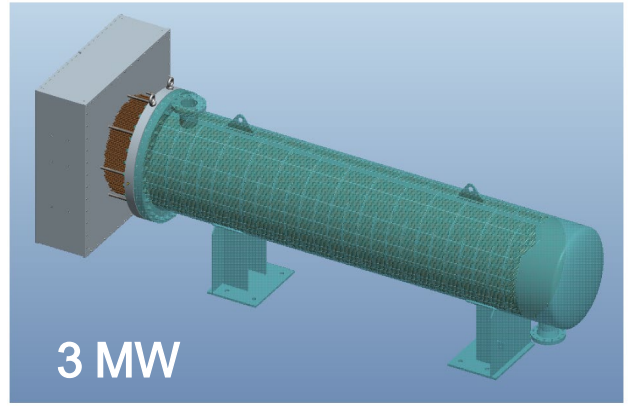
Primary Heater
(Stainless Steel 347H)

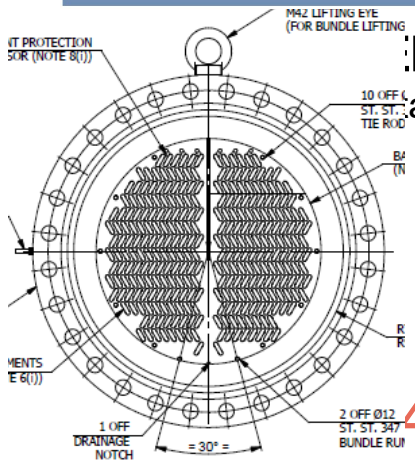


sCO2/sCO2 Recuperator
(Stainless Steel 347H)

lointek

SEICO
AN EXHEAT GROUP COMPANY





Electric Heater
(Stainless Steel 347H)

EH can reduce load down to 30%

480 → 580 °C

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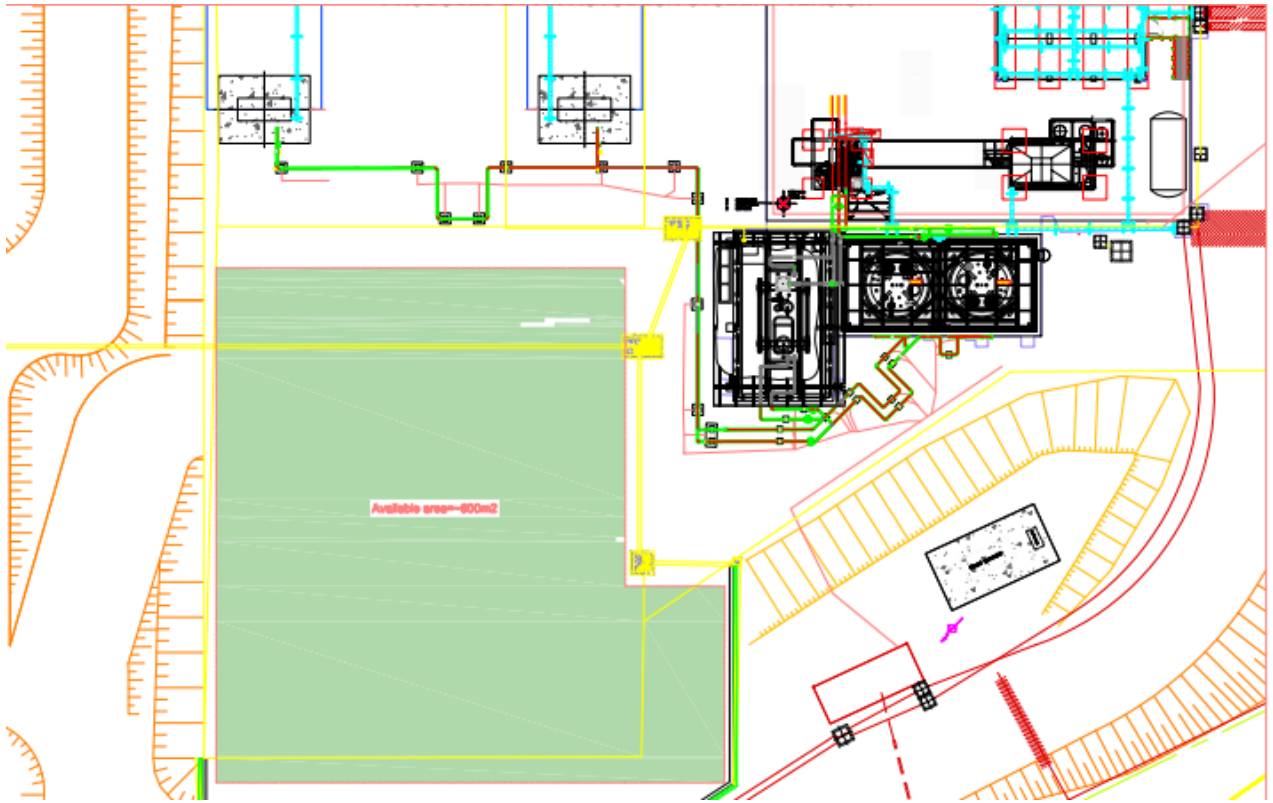
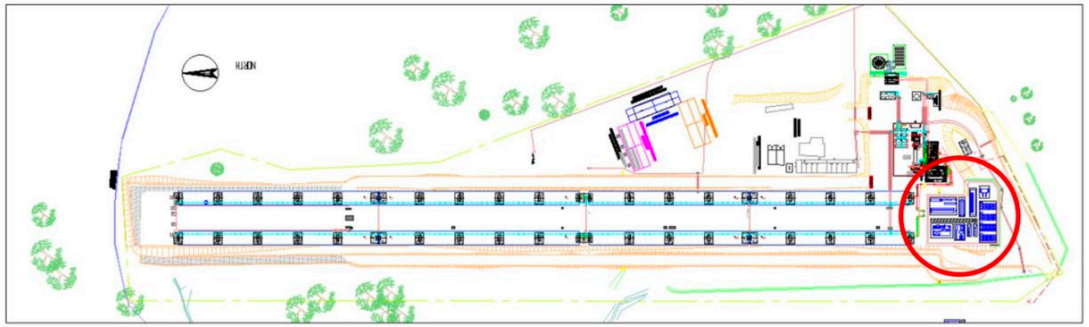
Demo Layout Engineering





- 600 m2 with easy access to MS loop/TES
- Need to upgrade power sub-station (+ 3 MW).
- On-going Permitting. Civil works planned to start in Q2 2024

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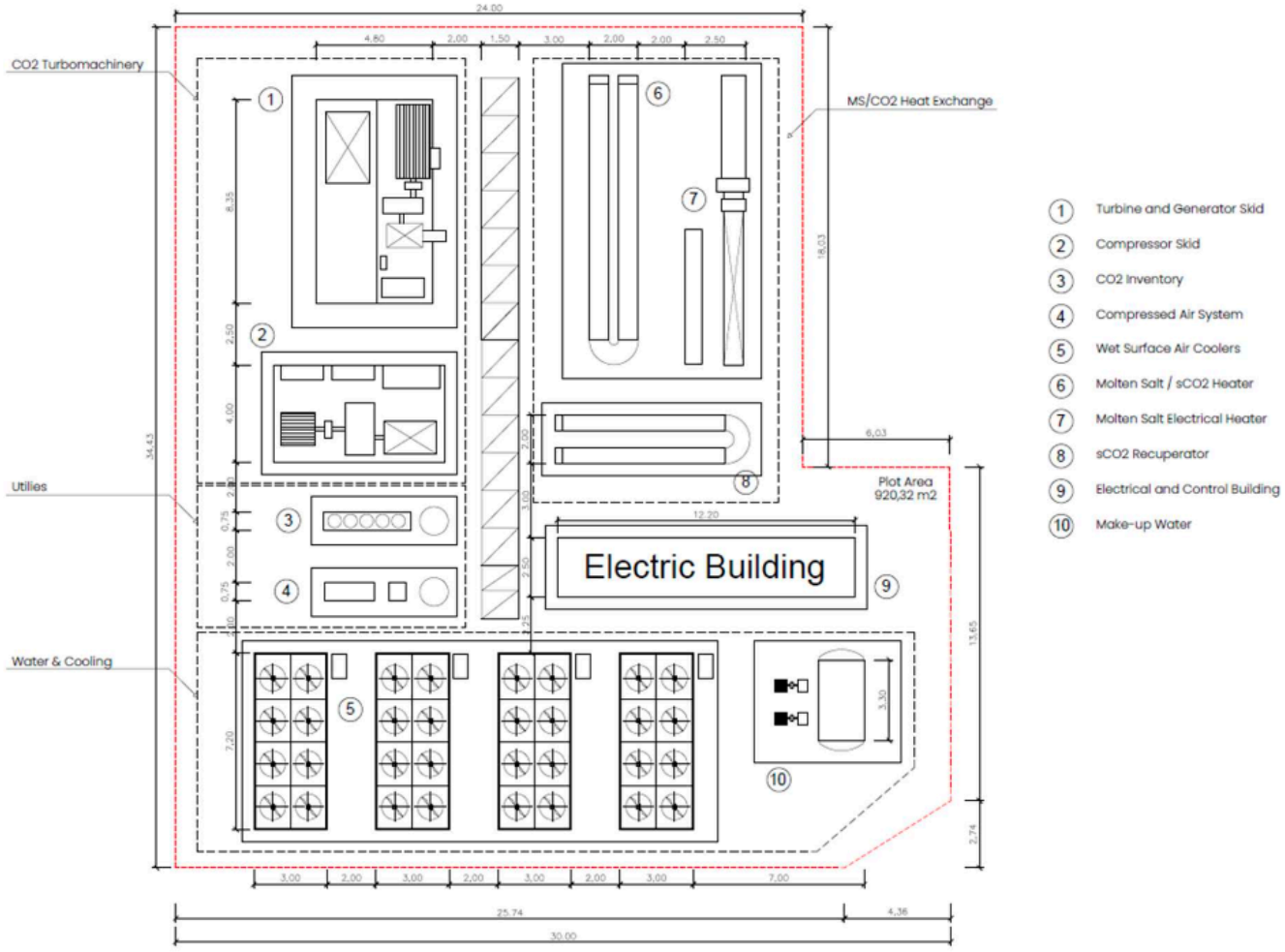
System Integration

- **New Balance of Plant** related equipment and processes which also limit operation. CO2, instrumentation, air, service/potable water.
- **Key target of layout** : piping/valves costs.
- **Serviceability** and room for new components
- Large area covered by cooler. Cheaper.
- **CO2 inventory and make -up system** DGS implemented but limited due scale
- Separate shaft. **Flexibility in operation**
  - Start-up from CO2 side (compressor) to meet min conditions in HEx



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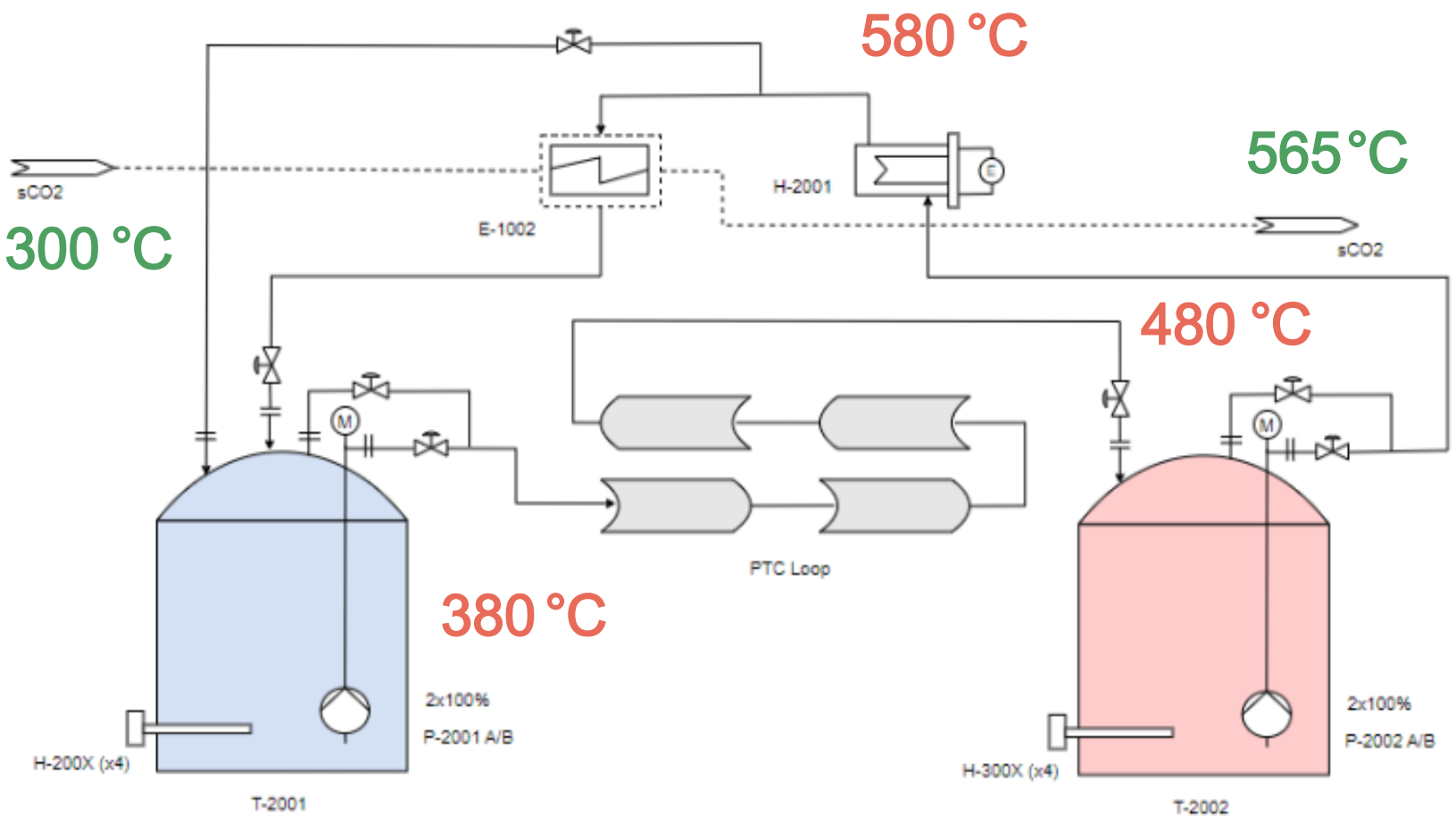
Demo MS-sCO2 Proposed Integration

CO_2: 21 kg/s, ~186 bar
MS: 22 kg/s, 3 bar



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Planned Operational Scenario

- It can/will take up to 4 hours to start and reach the conditions for boosting the temperature with the EH.
- Daily shut-down of the cycle. Night circulation of HTF at min flow.
- During the “steady” on-Sun operation the net consumption will be “only” 1 MW
- Many unforeseen system requirements from a Balance of Plant.

Load sCO_2 Cycle	MS Mass Flow Rate	sCO_2 Mass Flow Rate	EH Thermal Power	PTC Thermal Power	MS-sCO_2 HX Thermal Power	Recup. sCO_2 Thermal Power	Compressor	Turbine	Operation Time
%	kg/s	kg/s	MW_t	MW_t	MW_t	MW_t	MW_e	MW_e	h
100	22.2	21.01	3.1	3.7	6.8	8.7	0.51	1.77	1.5
90	19.8	18.91	2.7	3.3	6.1	7.8	0.44	1.70	2.6
80	17.6	16.81	2.4	2.9	5.4	6.9	0.39	1.51	4.3
70	15.4	14.56	2.1	2.6	4.7	6.0	0.35	1.25	steady

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Start-up Operation

1. Molten Salts Pre-heating:
Recirculation of MS in the PTC to achieve ~450°C in the hot tank

2. CO_2 Pre-heating:
Auxiliary EH heats sCO2 up to ~250°C to preheat the primary heater

3. Molten salt Electric Heating :
EH boosts MS temperature up to 580°C

4. Switching to heat CO_2 with MS :
Primary heater + CO_2 EH in parallel to rise the CO2 temperature to 320 °C, then CO_2 EH OFF

5. Load increase in MS and CO2:
Compressor hits nominal pressure by making up CO2 from the inventory → steady conditions

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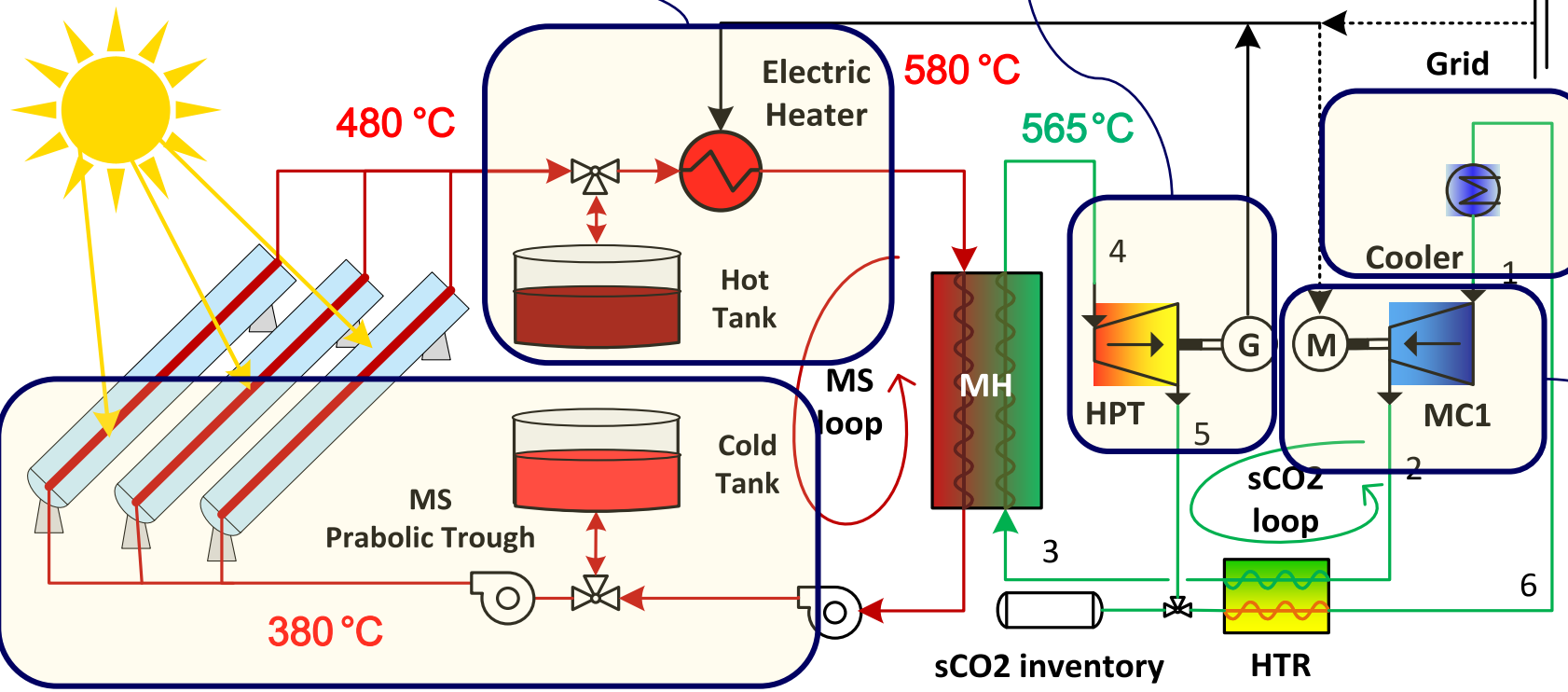
Normal Operation

MS flows from the **hot molten salt tank** to the EH, to meet set point temperature.

The **turbine** controls the flow using the inlet control valve.

The **cooler** return the sCO2 to 35°C, actuating on the amount of water (wet/dry) and fans speed.

The **solar field loop** operates during sun hours. If set point temperature is not achieved, the salts are recirculated.



The **compressor** controls the CO2 pressure + Two valves, for making up or venting CO_2

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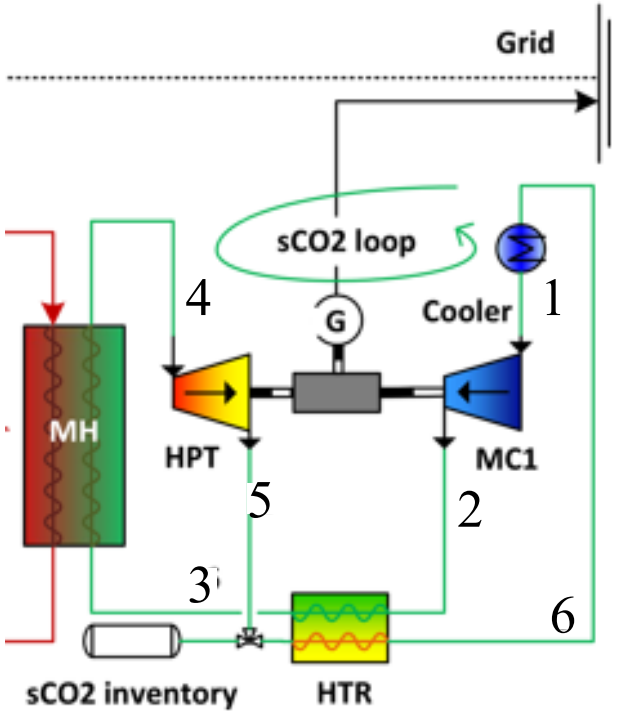
SOLARsCO2OL Project

Up-scaling the Demo

Simple Cycle + Recuperation



Techno-economic optimization of Upscaled SOLARSCO2OL

Parameter	DEMO SC-R 2 MW	Upscaled SC-R 10 MW	Upscaled RR 100 MW
Total efficiency [%]	21.3	31.4	49.5
Compressor eff. [%]	67.2	75.0	84.0
Re-compressor eff. [%]	-	-	88.0
Re-compressor slit [%]	-	-	31.0
Turbine(s) efficiency [%]	86.5	88.5	92.0
Mechanical eff. [%]	96	98	99
Electrical efficiency [%]	96	98	99
Turbine Inlet P [bar]	185.5	185.5	250.0
Intermediate P [bar]	-	-	165.0
Δp Heater [bar]	1	1	1
Δp Hot side Recup. [bar]	4.5	2	2
Δp Cold side Recup [bar]	1.5	1.5	1.5
Δp Cooler [bar]	0.6	0.6	0.6
Recuperator(s) Eff. [%]	80	95	95

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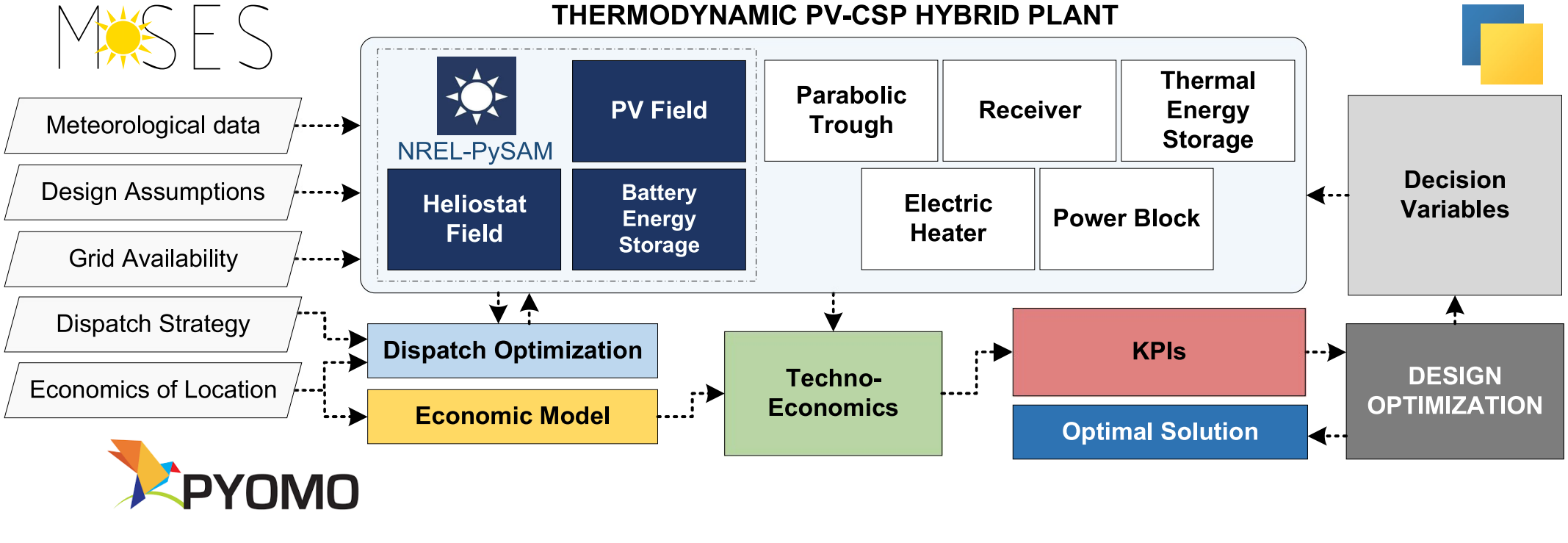
Techno-economic Modeling



Open-source tool available at the end of the project for techno-economic modeling of sCO2 Power Cycles

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Conclusions

SOLARSCO2OL aims to demonstrate a FOAK CSP hybrid driven 2 MW -scale sCO_2 cycle

- Large committed consortium co -funded by EU with 10 M€ (17 partners, KTH-RINA).
- Demonstration in Evora Molten Salt Platform
- Project engineering resumed in Feb 2023, expected campaign in summer 2025.

Conceptual design and engineering takeaways:

- Concepts/Components designed all to be ready for a 10 MW commercial offer.
  - Conservative design and testing (CO_2 pressures, temperatures).
  - Flexibility embedded: hybridization, efficiency at variable loads to be demonstrated.

- Intended to operate on -Sun PTC + EH booster. Challenges in control.

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Thank you for your attention!

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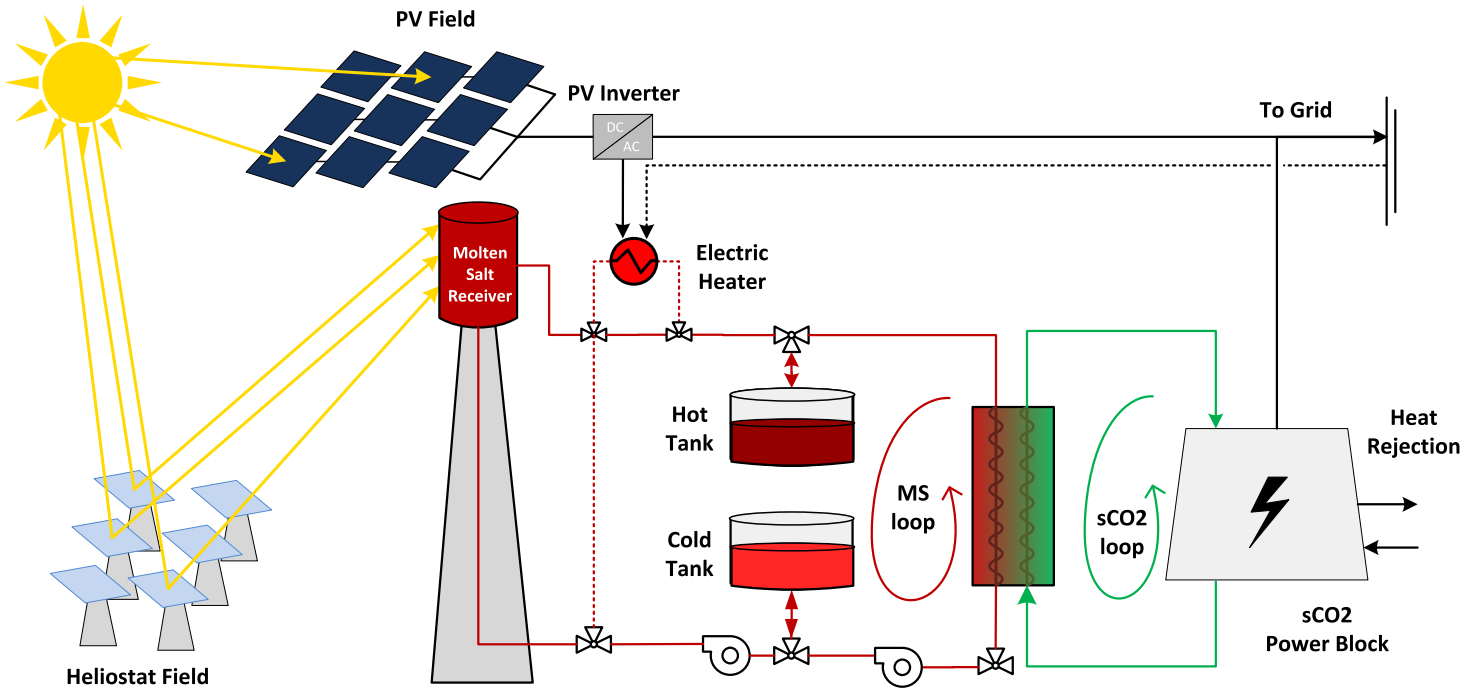
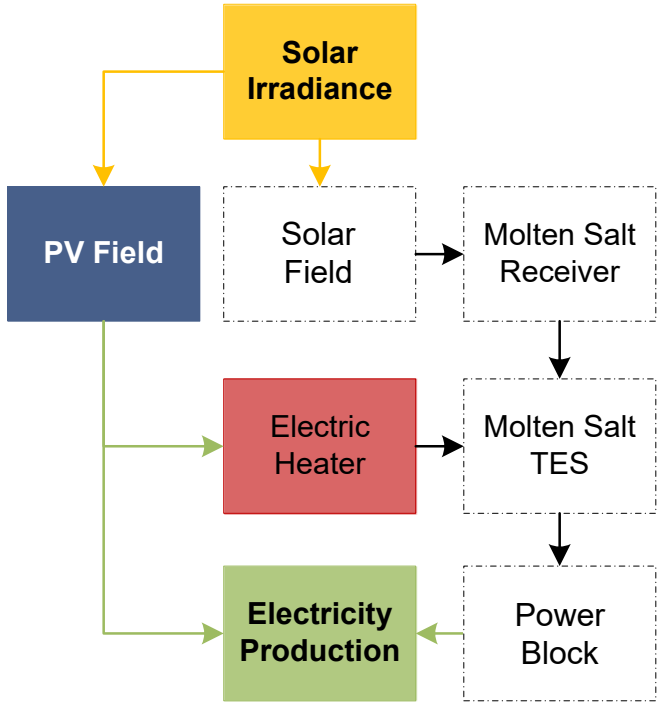
Up-scaling the Demo – Project vision

Hybrid PV-CSP → Cost-competitive, Sustainable Energy Storage, Firm production, Services to the grid





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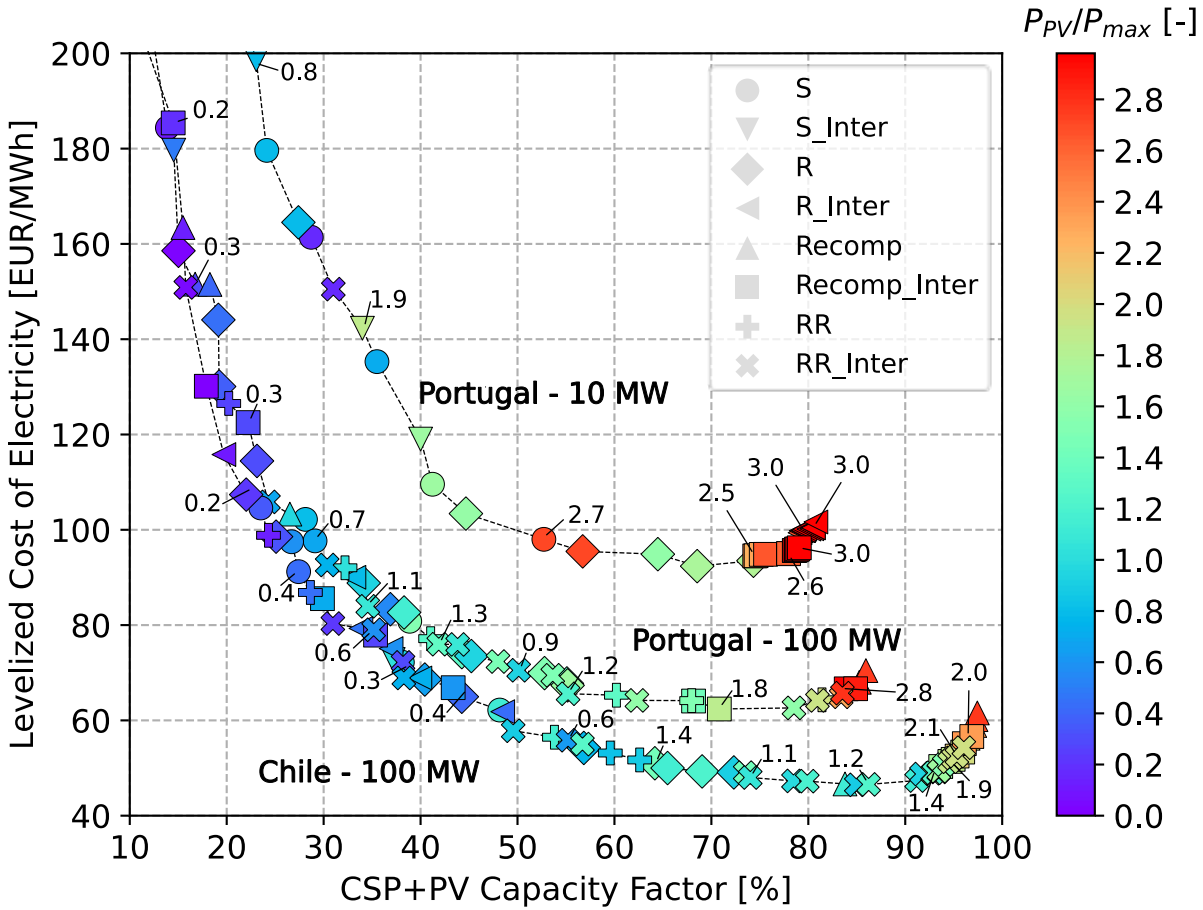
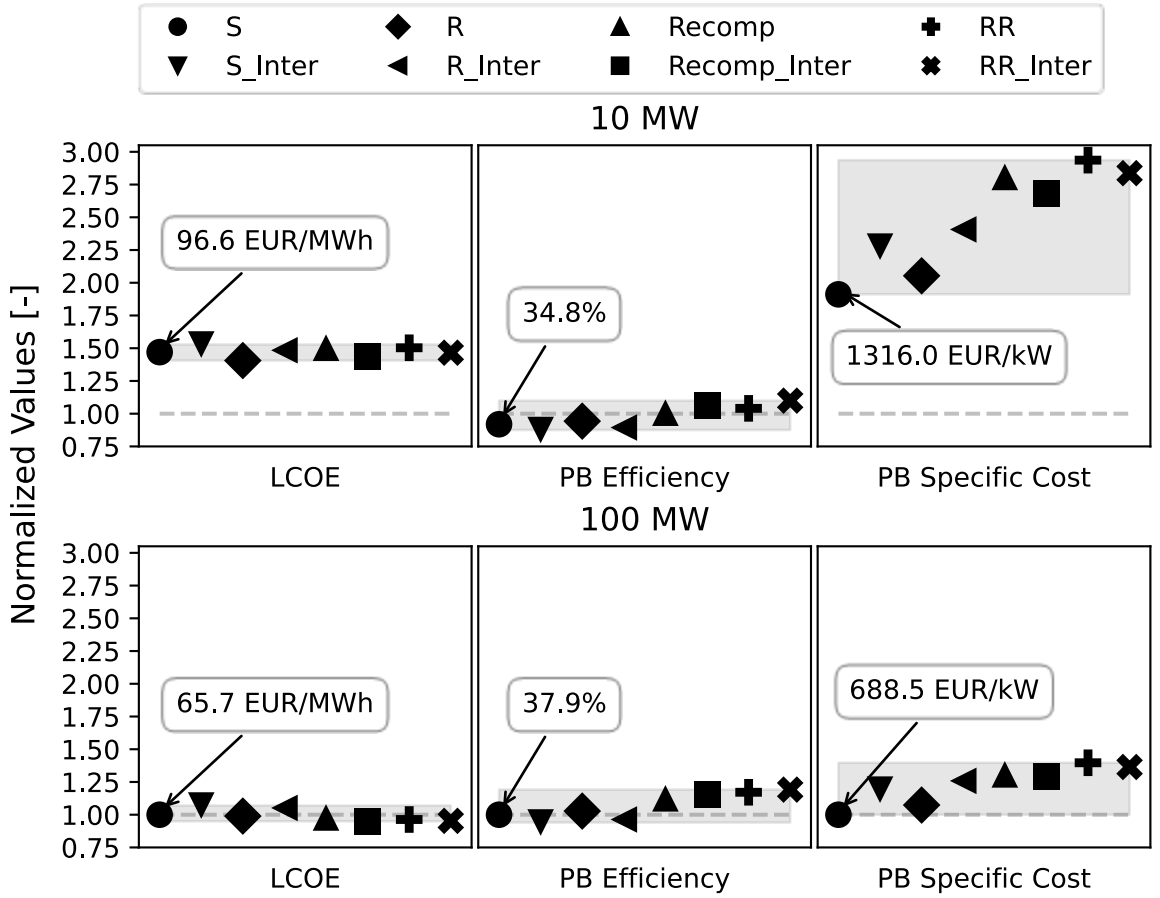
SOLARsCO2OL Project

Up-scaling the Demo – Project vision





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