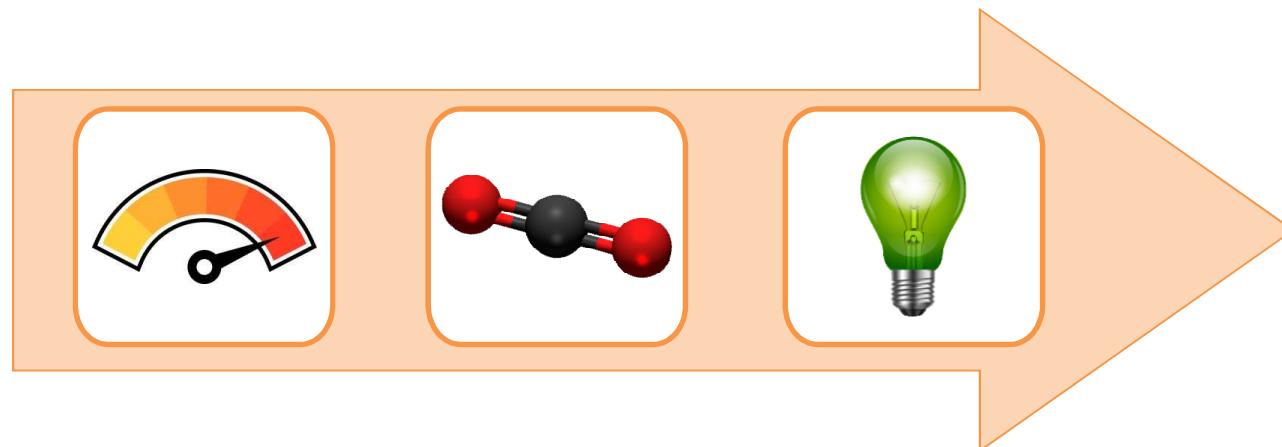


Industrial Thermal Energy Recovery Conversion and Management Workshop

High Temperature Heat to Power Conversion: Supercritical CO₂ Cycle



Brunel
University
London

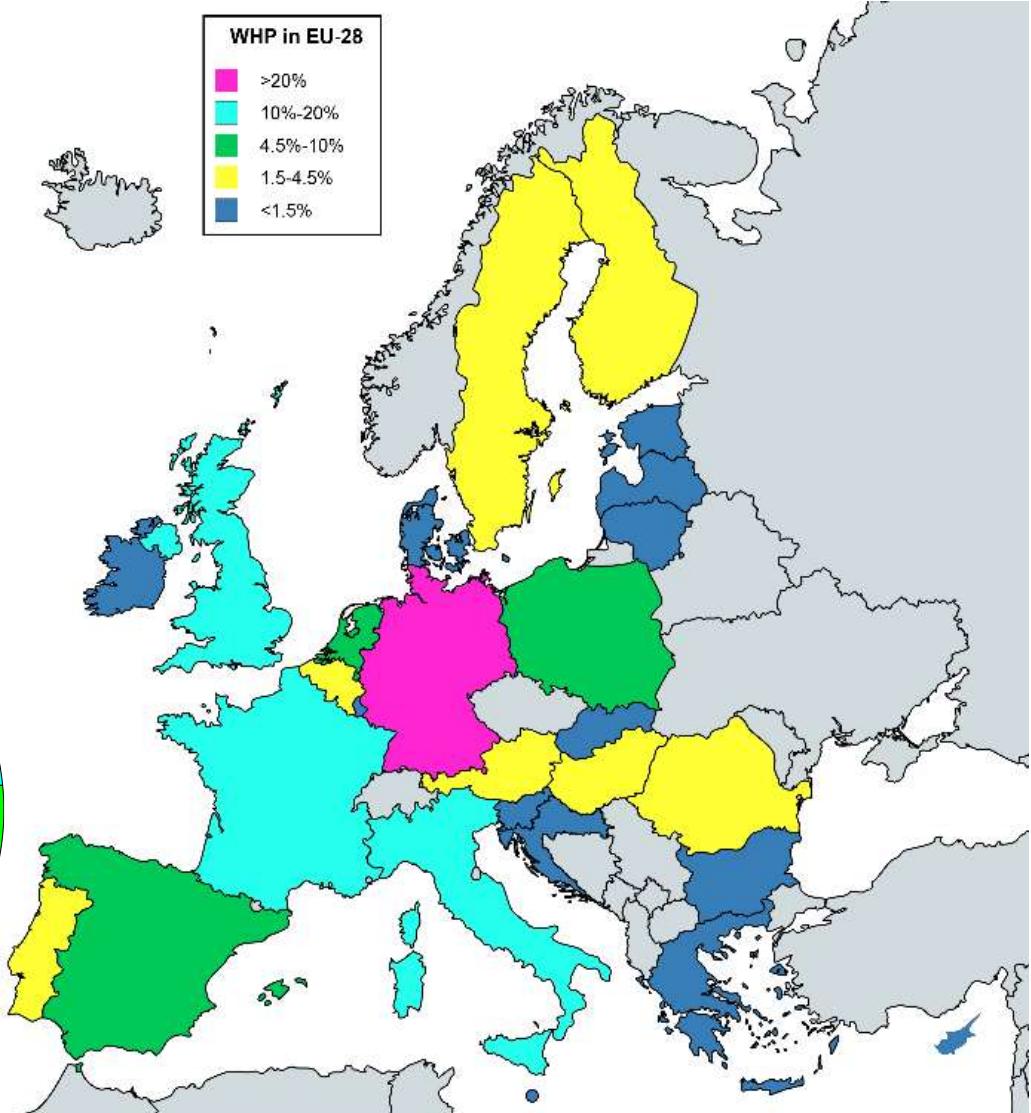
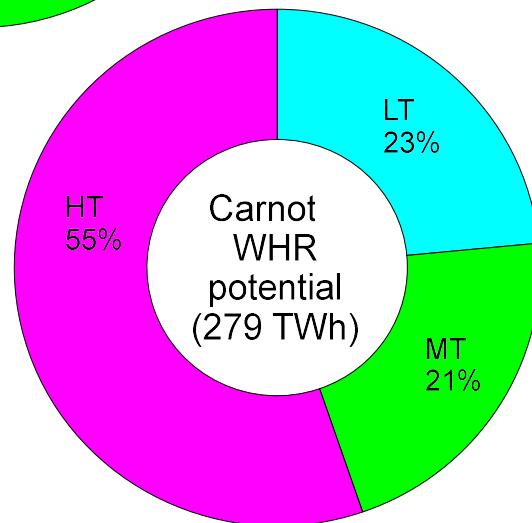
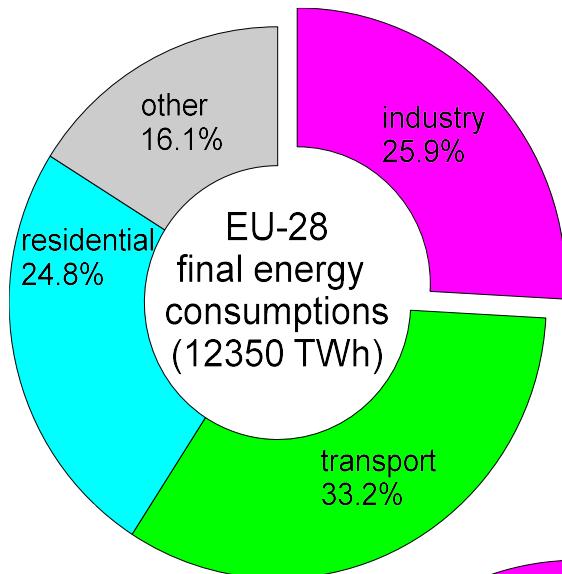


Uxbridge, 24/10/2017



Outline

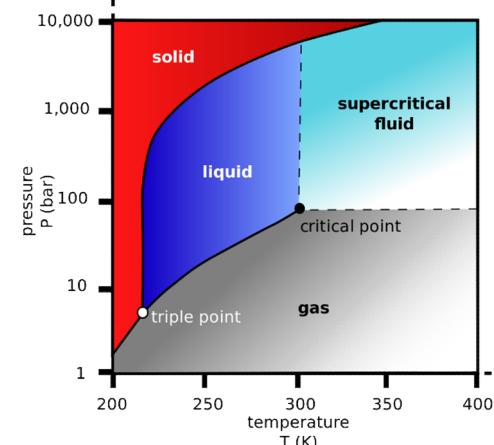
- High temperature waste heat recovery potential
- Fundamentals of sCO₂ systems
- I-ThERM sCO₂ demonstration application
- The Compressor-Generator-Turbine (CGT)
- Future work



- Iron & steel
- Non metallic minerals
- Food & tobacco

Why supercritical CO₂

- Not toxic
- Eco-friendly (GWP=1)
- High thermal stability
- High pressures (compactness)
- Near the critical point of CO₂ (30.98 °C, 73.8 bar)
 - Liquid-like density
 - Gas-like viscosity
 - Lower compression work
 - High cycle efficiency



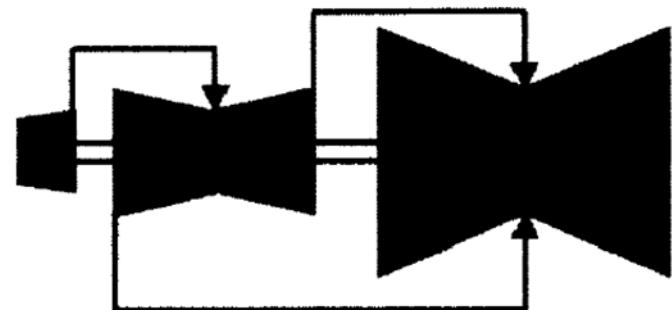
sCO₂ (300 MW)



He (300 MW)

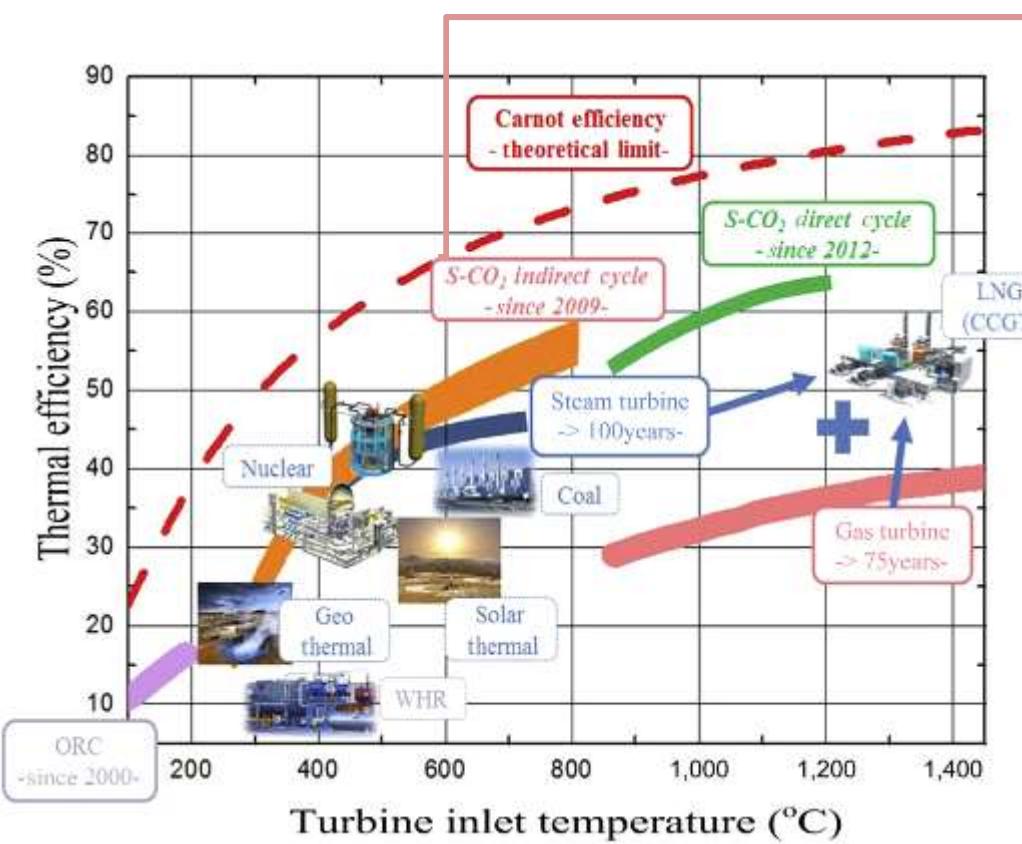


Steam (250 MW)

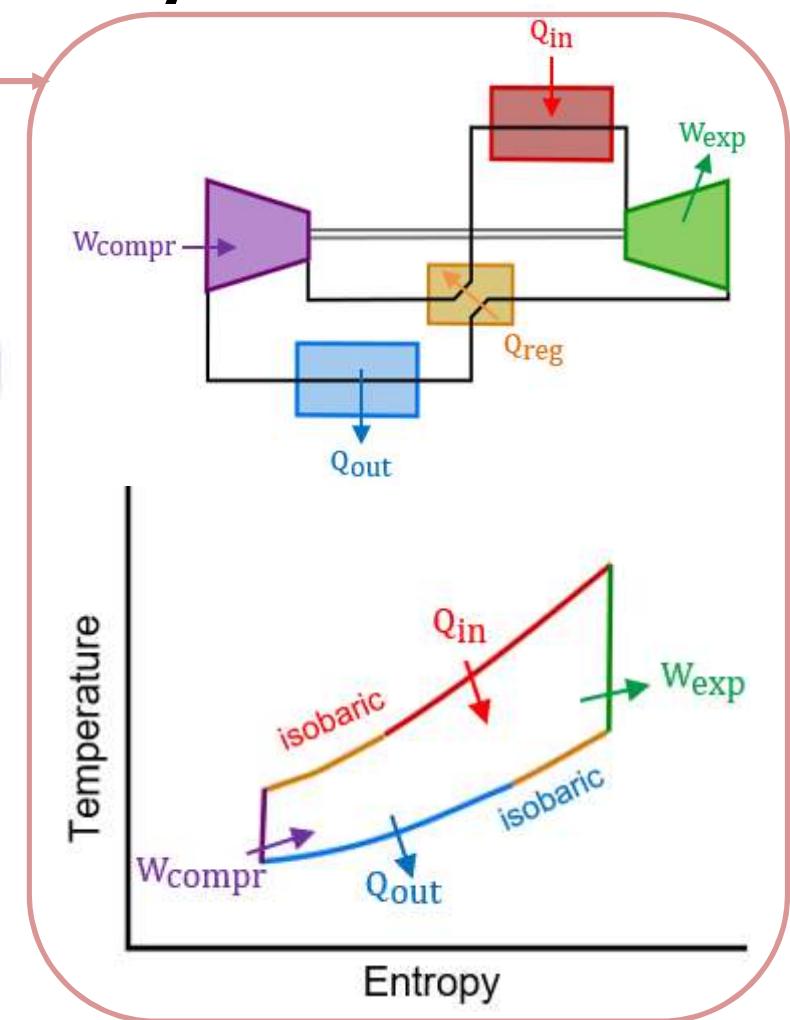


[Sandia National Laboratories, Technical report (2011)]

Joule-Brayton cycle

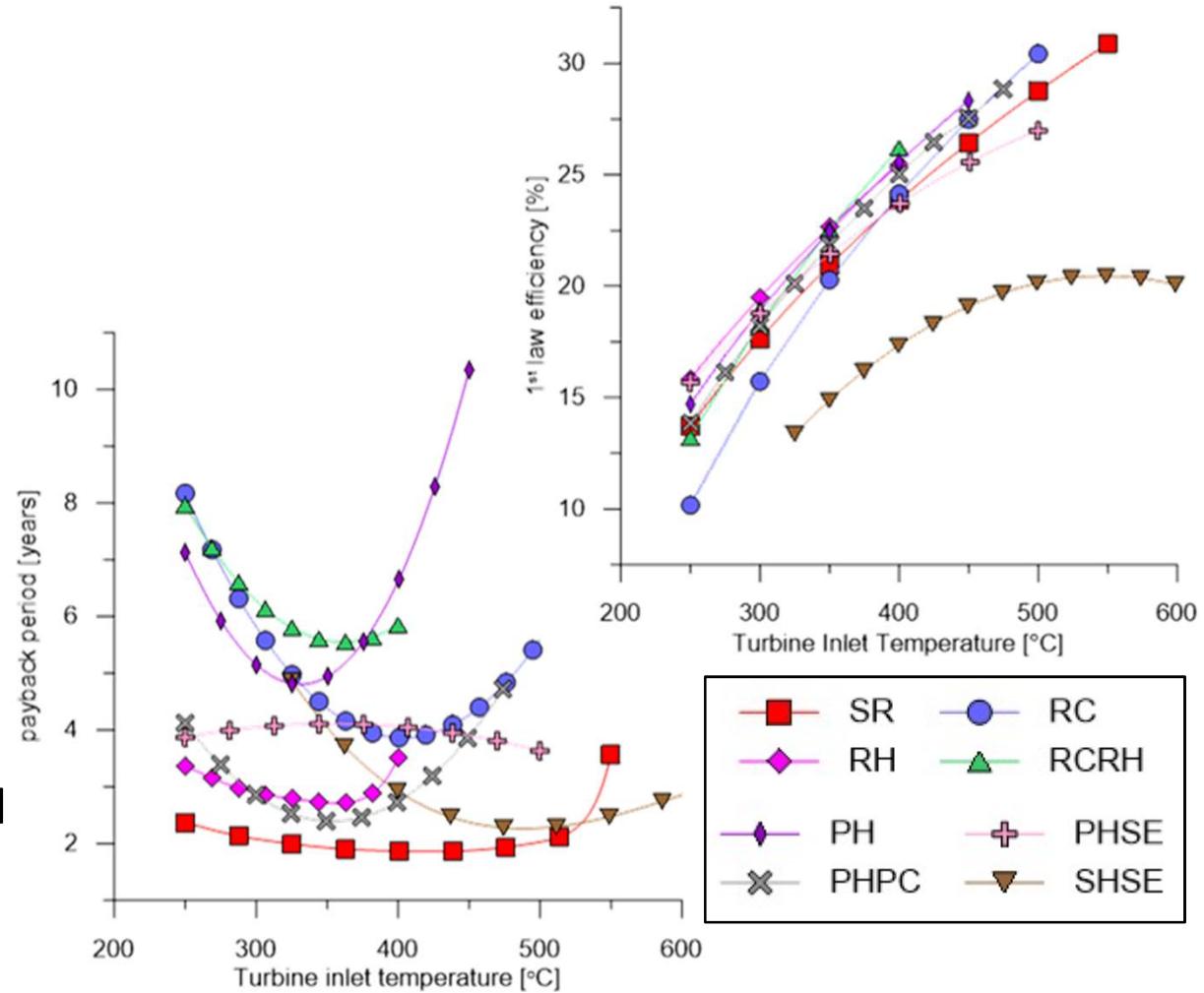


<https://doi.org/10.1016/j.net.2015.06.009>



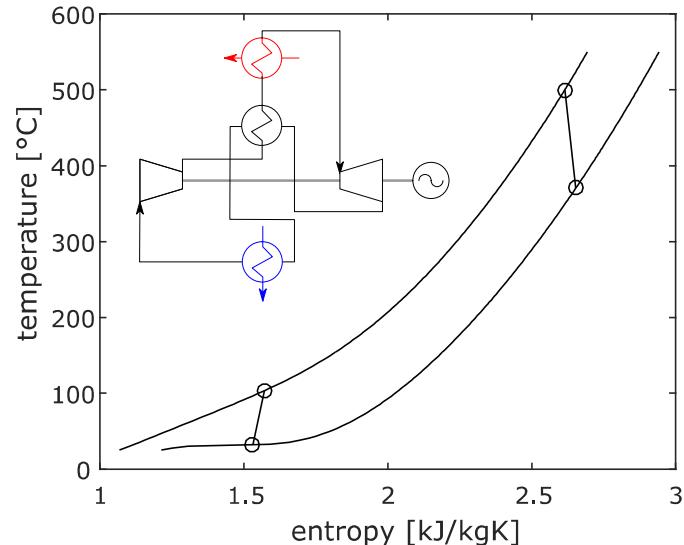
Modelling activities

- Techno-economic comparison of different sCO₂-based cycle architectures for high temperature WHR applications
- Design platform for the I-ThERM sCO₂ demonstration unit based on the Simple Regenerated (SR) configuration

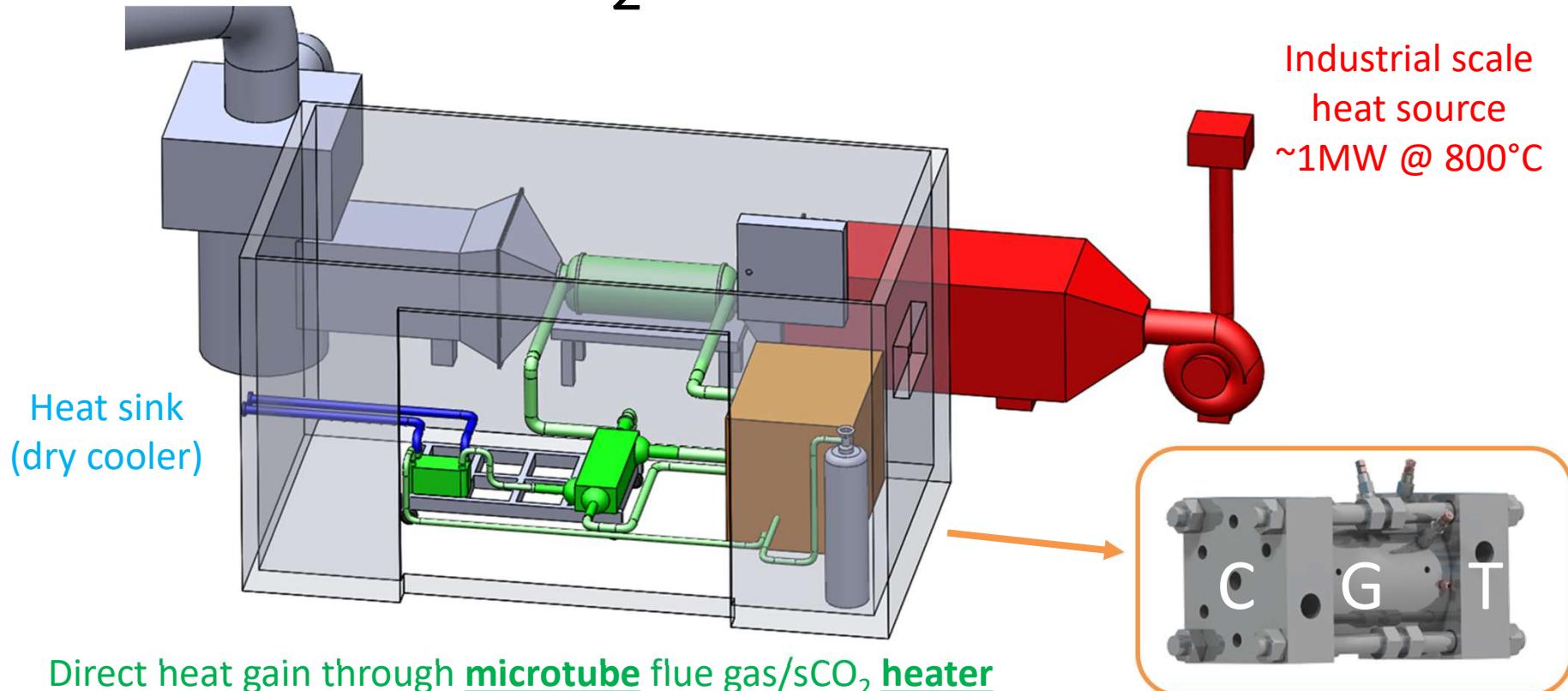


I-ThERM sCO₂ demonstration unit

- Site: BUL CSEF
- 1st experimental facility in EU
- 50-100 kWe power output
- Efficiency >15%
- Challenges:
 - BUL: design and control of heat source, heat exchanger, additional sCO₂ equipment, heat sink
 - ENO: design, manufacturing and preliminary testing of the sCO₂ compressor-generator-turbine unit (CGT)



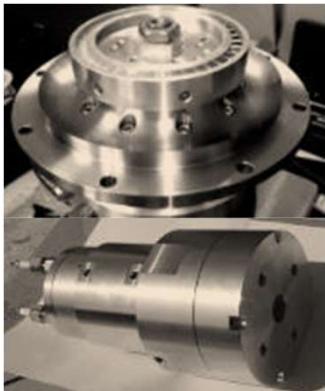
I-ThERM sCO₂ demonstration unit



- Direct heat gain through microtube flue gas/sCO₂ heater
- High efficiency through printed circuit recuperator
- Low investment cost through plate heat exchanger as cooler



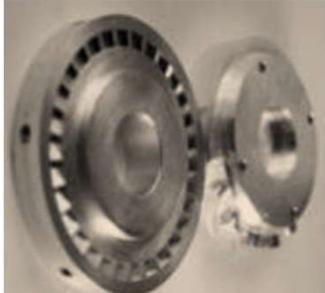
ENOGLA's turboexpander technology



Proprietary hermetic **high speed turboexpander** technology

Why the **kinetic turbogenerator** ?

- → **Proven concept** on larger ORC units
- → **No friction**, no wear

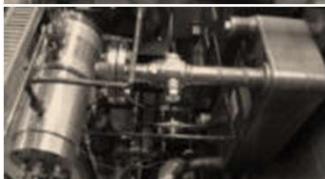


Hermetic turbogenerator with PMG generator inside

- → **No fluid leaking**
- → **Reduced** maintenance



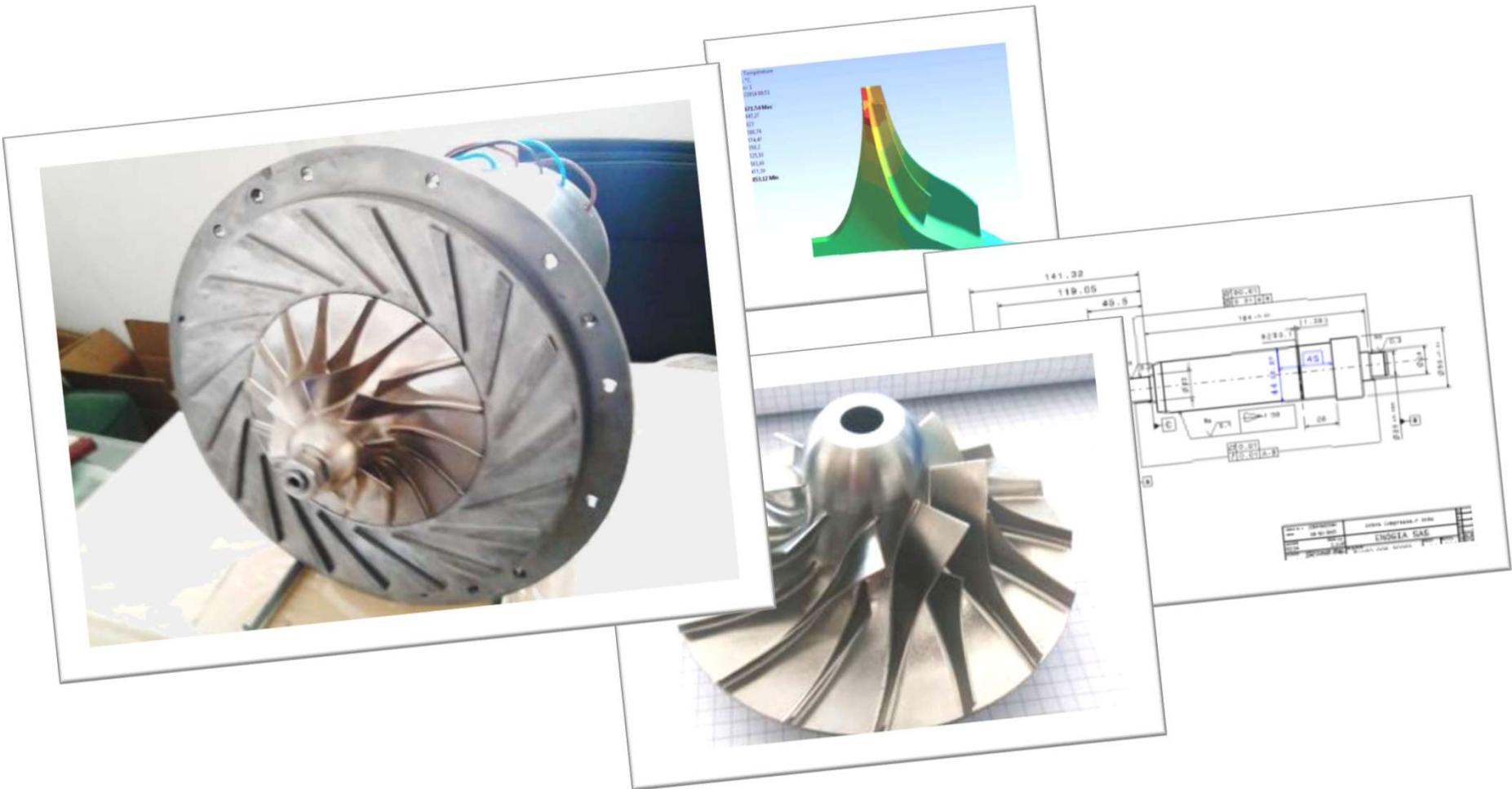
Extremely **Compact** units



Made in France with EU only components, in house assembly



Custom turbomachinery: from CFD to prototype



Which turbomachinery for sCO₂?

- Axial multi stage

Advantage

- Low rotation speed
- High efficiency for high pressure ratio

Disadvantage

- Very complex
- Suited for very large flow rate



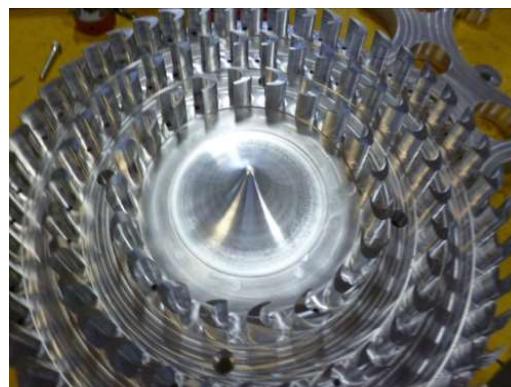
- Radial outflow

Advantage

- Low rotation speed

Disadvantage

- low efficiency
- High axial effort
- High bending stesses



- Radial inflow

Advantage

- High efficiency for low pressure ratio

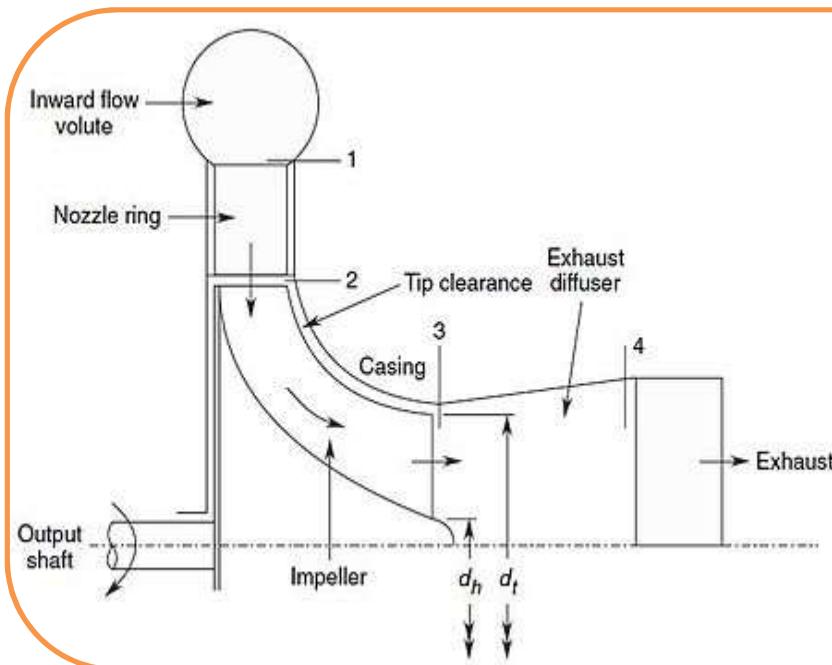
Disadvantage

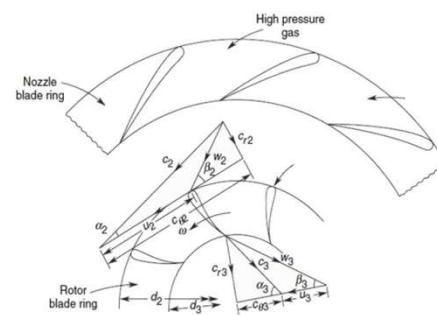
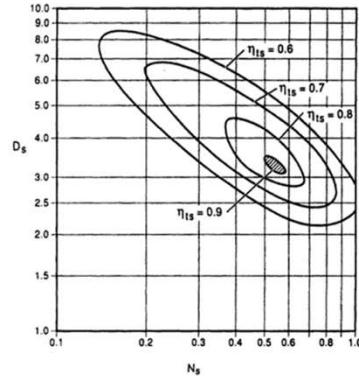
- High rotation speed
- High axial effort



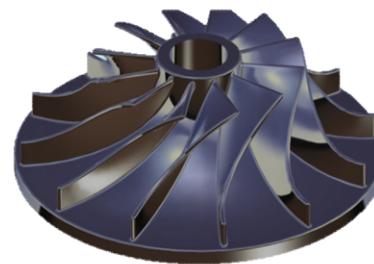
Which turbomachinery for sCO₂?

	Axial multistage	Radial outflow	Radial inflow
Efficiency	+++	+	++
Cost	----	-	-
Ranking	3	2	1

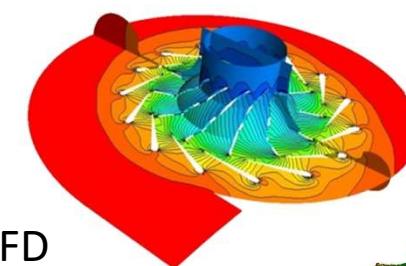




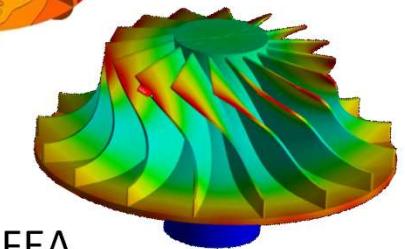
Velocity triangles



CAD



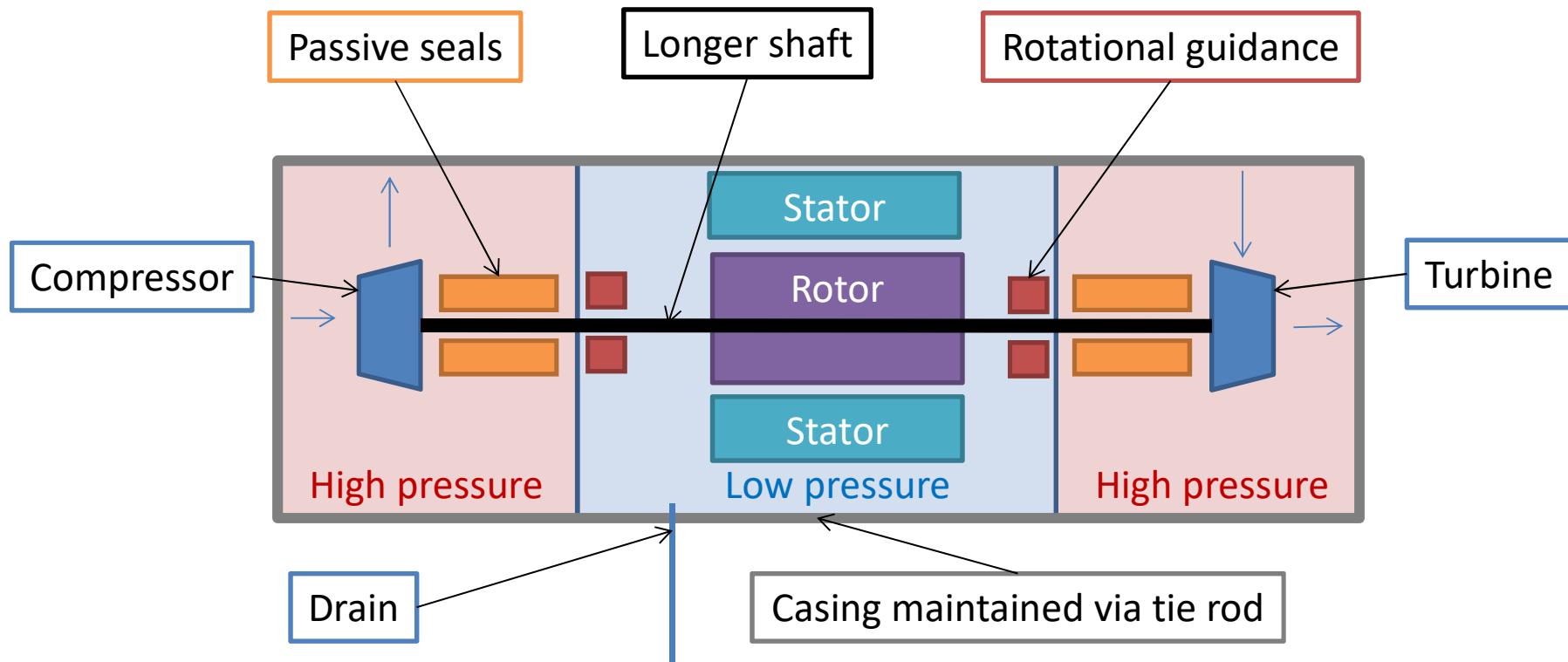
CFD



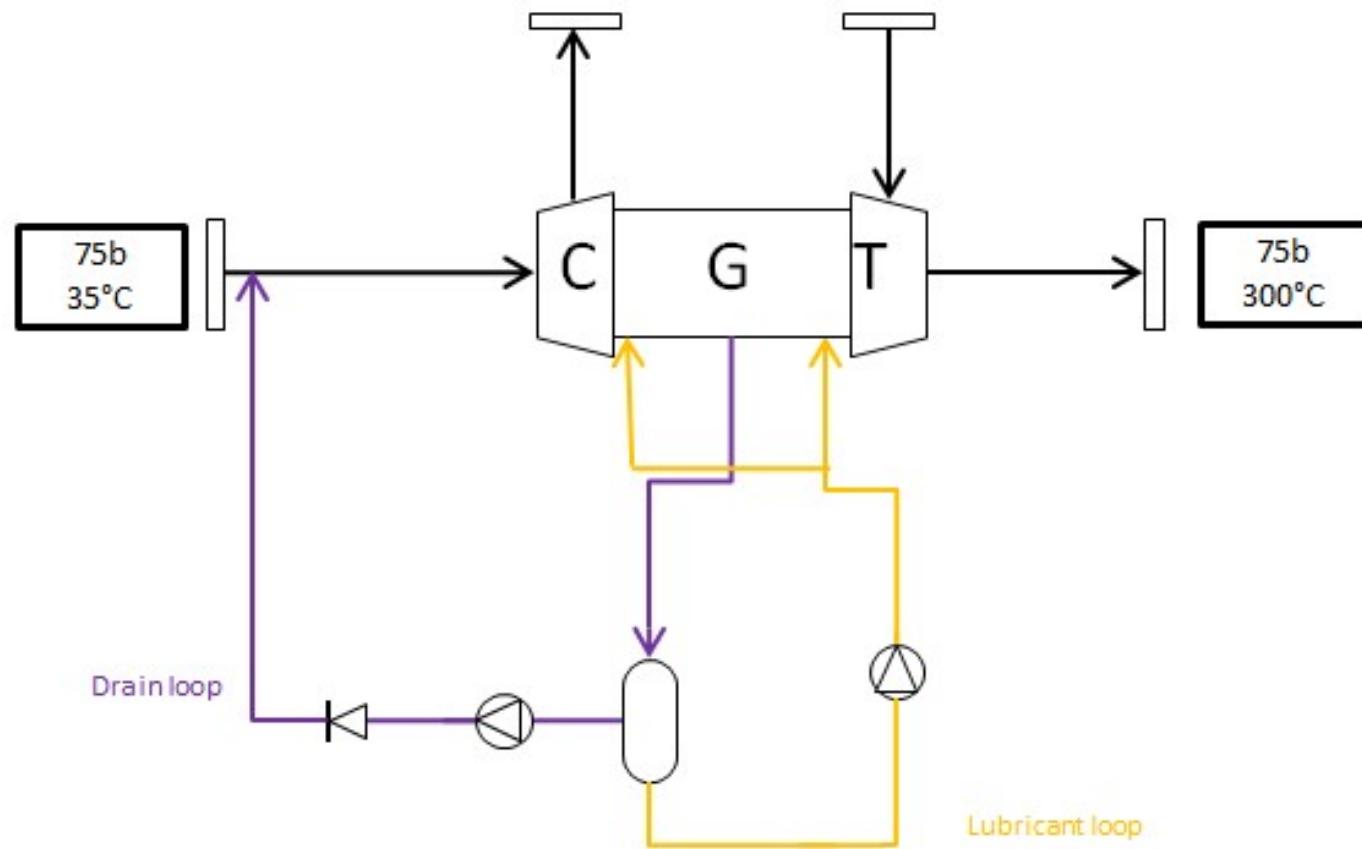
FEA

Turbomachinery Design

CGT overall architecture



Ancillary loops





Ongoing and Future work

Short term (<3M)

- CGT manufacturing and preliminary testing

Medium term (<6M)

- Construction of the sCO₂ facility
- Installation and commissioning of the CGT

Long term (>6M)

- Experimental campaign
- Online monitoring and control



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BUL's team

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- Nicolas Goubet
- Gabriel Henry
- William Derue

