sCO2 Supercritical CO_2 Power Cycles Symposium

CO2OLHEAT

Industrial waste heat recovery and its conversion in electricity via supercritical CO_2 cycles

Authors: CO2OLHEAT Consortium

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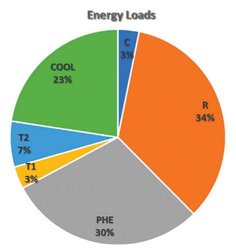
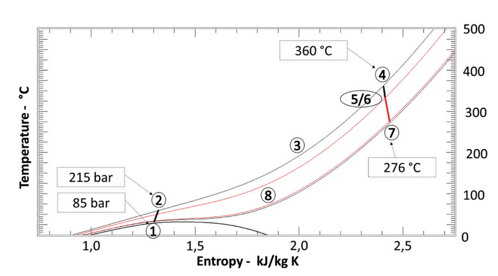
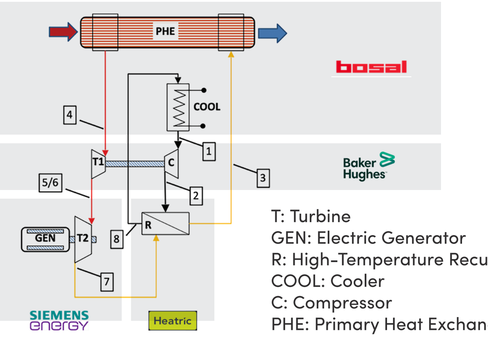
1 SCENARIO ANALYSIS AND REQUIREMENT DEFINITION

- Layout definition of the demo plant
- Analysis of the demo plant integration into the industrial site
- Thermodynamic and economic modelling and optimization of the selected demo cycle
- Off-design analysis of the selected demo cycle
- Definition of market scenarios for the WH2P plant in energy-intensive industries with a focus on cement considering the CEMEX demo site and definition of major boundary conditions
- Analysis of the interaction with the electric grid



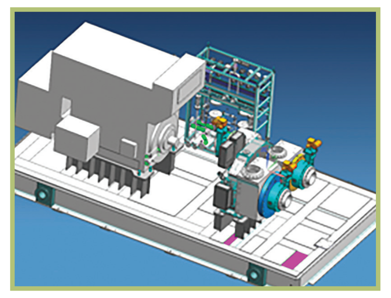


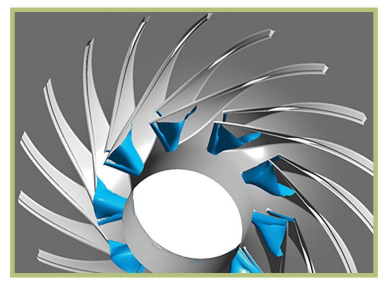


T: Turbine
GEN: Electric Generator
R: High-Temperature Recuperator
COOL: Cooler
C: Compressor
PHE: Primary Heat Exchanger

2 SCO_2 TURBOEXPANDER UNIT

- Design leveraging on the results got from sCO2flex project (funded by EU H2020) and STEP project (funded by DOE)
- Concept based on an integrated solution (two stages Compressor + Gearbox + two stages Expander)
- Equipment designed considering CAPEX optimization and footprint minimization
- Challenges:
  - Define a specific compressor fluid dynamic numerical model to keep in consideration local phase changes of the fluid that could impact the performance
  - Turbomachinery mechanical design and manufacturability process optimized to manage the small dimensions that could affect the performance
  - Turboexpander operability & controllability in all the operating conditions (transients included)

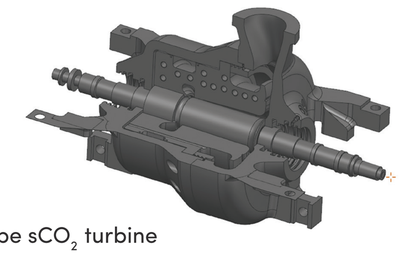




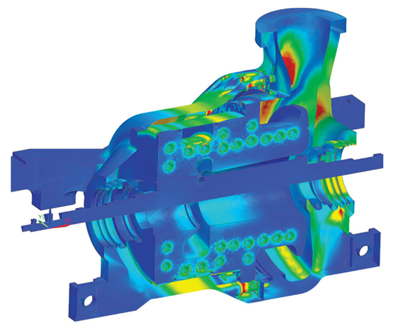
CFD model results showing the area with vapour formation on the first impeller of the compressor

3 SCO_2 POWER TURBINE

- Based on the results of the German R&D project Carbosola, a preliminary design concept of a demo turbine has been developed
- A barrel type turbine design with a circumferential split, allowing rotational-symmetrical design without local material build up even for high gas temperatures and pressures, thus minimizing unsymmetrical deformation and thermal loading
- Combining these results with UDE knowledge coming from previous sCO_2 EU-funded projects, this task will present a first sCO_2 turbine design considering the specific requirements at the demo-plant



Barrel type sCO_2 turbine

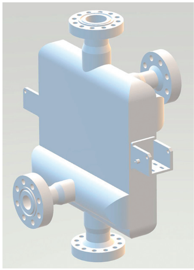


CAE supported design analysis & optimisation

4 CYCLE HEAT EXCHANGERS

Next work package stages:

- Recuperator part loads cycle optimization
- Predictive operational behaviour testing / control methodology within power block
- Modular skid base integration including replication cases
- Operational data to consolidate recuperator modelling



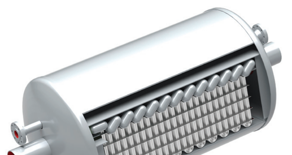
PCHE recuperator
Dimensions: 23.3 MW_{th}/m^3
2.24m x 1.4m x 1.52m – 5 tons

Modular design for the Cooler and the Primary Heat Exchanger:

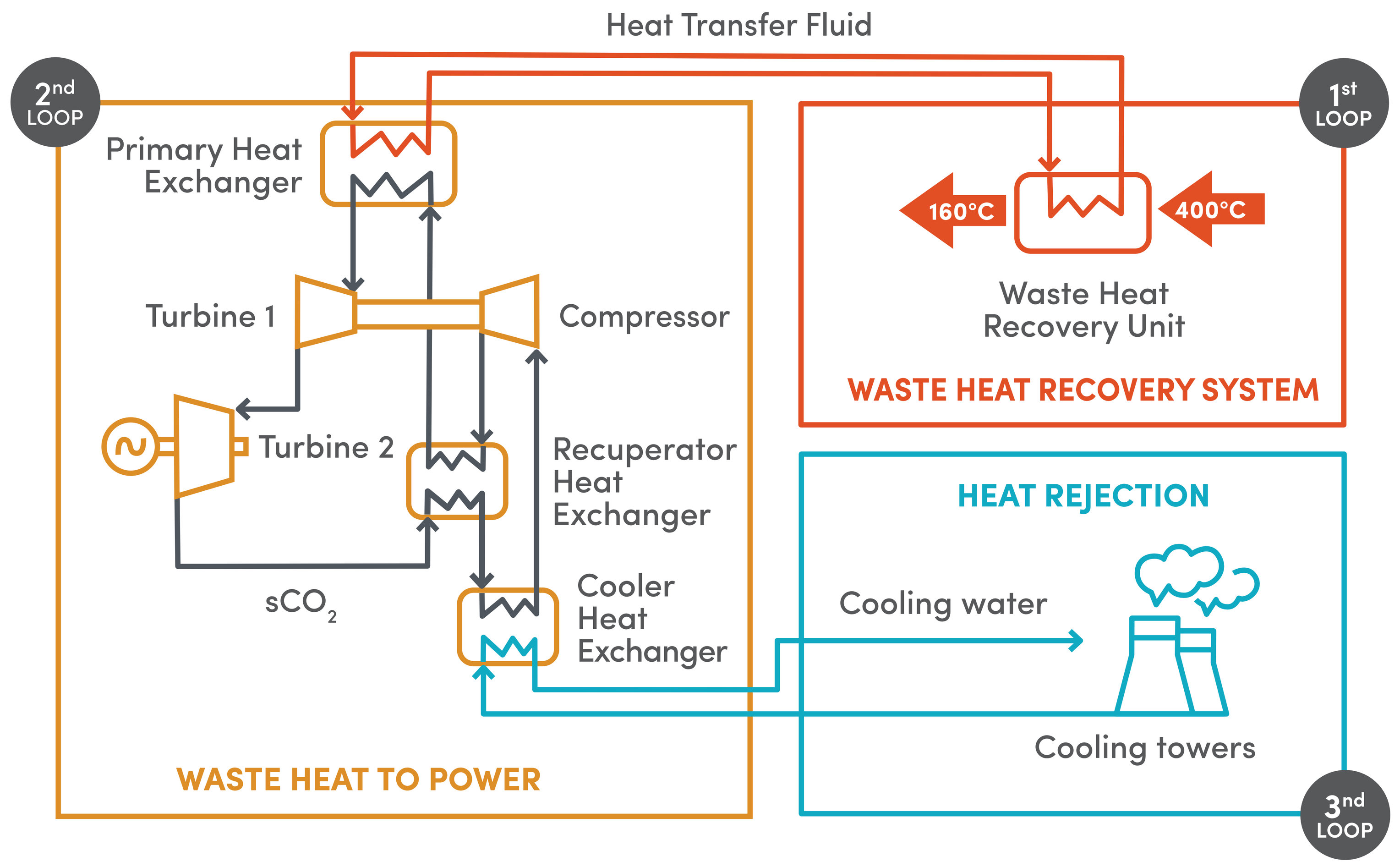
- A cell consisting of 320 U-tubes and two collectors form a standardized building block
- # of standard cells can be tuned for different applications (replicator sites)

Next stages:

- Improve the fouling and abrasion resistance of the WHRU
- Guarantee the Cooler's operability & controllability for all seasons

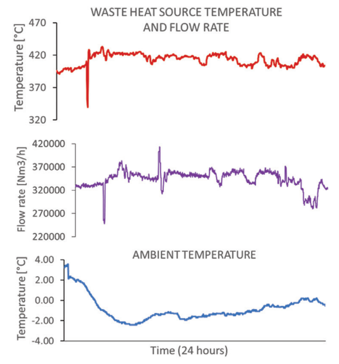


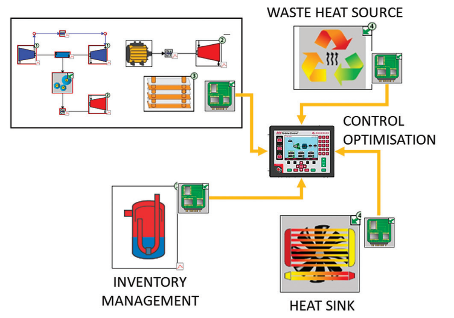
Integrated Tubular Cooler



5 DYNAMIC SIMULATION AND CONTROL OPTIMISATION

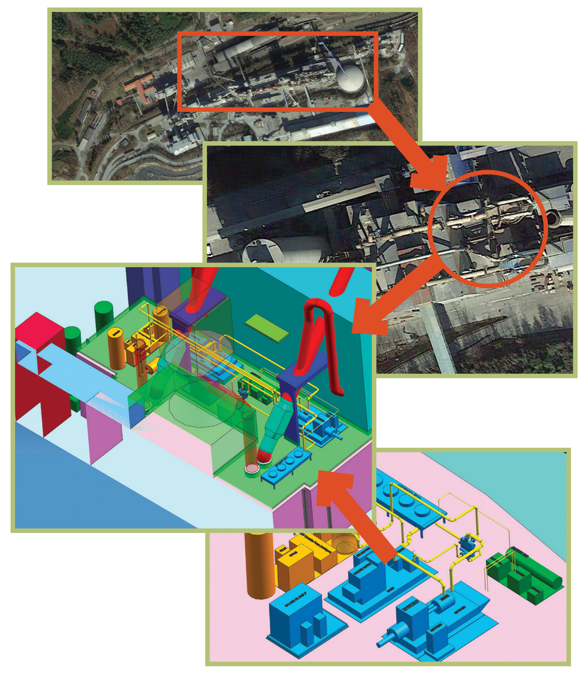
- Dynamic simulation of the integrated CO2OLHEAT system response (heat recovery, power block and heat rejection) to understand the challenges of control at start-up, shut down and fluctuations in waste heat source temperature and flowrate
- Control architecture that integrates individual turbomachinery and heat exchanger controls to optimise performance and ensure safe operation
- Control strategy that maintains turbine and compressor inlet temperatures close to design values over a range of waste heat conditions and ambient temperatures





6 PRACHOVICE DEMO CAMPAIGN

- Modular Design of the Power Cycle: single lift interconnected skid and modules composing the plant
- Maximization of pre-fabrication and pre-test @ workshops to minimize time length and extent of on-site activities
- Test at full scale in a real industrial environment the integration of the CO2OLHEAT concept – installation of the plant in CEMEX site in Prachovice (CZ)
- Take full advantage of installation flexibility, aiming to a plug and play approach applicable also to other potential replication sites



7 REPLICATION AND IMPACT ANALYSIS

- Current WHR systems experience significant gap in temperature range between 300 and 500°C and CO2OLHEAT can close it
- Demo will confirm this and replication studies will further develop this hypothesis
- They will also pave the way towards future R&D activities, identified during this process
- If only 5% of the EU available waste heat could be recovered, a CO2OLHEAT plant could produce 230 GWh_{el}/year, save 575 GWh/year of primary energy, and avoid more than 100.000 tCO_2/year

01.06.2021 | 02.2022 | 01.06.2022 | 01.06.2023 | 01.06.2024 | 31.05.2025

1 – Scenario analysis
2 & 3 – Turboexpander and Power turbine design and production
4 – Cycle heat exchangers
5 – Dynamic simulation and control optimisation
6 – Prachovice demo campaign
7 – Replication and impact analysis

EDF, SIEMENS energy, ENEA, Si Steme ROM, POLITECNICO MILANO 1863, Heatric, Brunel University London, ENGIE Laborelec, CEMEX, celsa barcelona, mas, Baker Hughes, MYTILINEOS, bosal, LEITAT, Open-Minded, ŞİŞECAM, ROMA TRE Università degli Studi, RINA, CERTH, ETN

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