Development and Simulation of a High-Temperature Heat Pump based on the Reverse Brayton Cycle

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Overview

- Short introduction of the institute
- The High-Temperature Heat Pump (HTHP) „Pilot CoBra“
- Simulation and Pre-Design of HTHP
- Summary / Outlook

DLR Institute of Low-Carbon Industrial Processes

Challenge: CO_2-emissions from industry

- **Energy-related CO_2 emissions**
  - From the production of the electricity used
  - Use of fossil fuels to provide energy → process heat, steam, work
- **Direct process-related CO_2 emissions**
  - From non-energetic use of carbonaceous raw materials or from process-related release

Our mission

- Offering solutions in the field of energy research and energy system transformation for industry
- Reduction of CO_2 and pollutant emissions from industrial processes and power plants

Research Fields / Departments

High Temperature Heat Pumps

Simulation and Virtual Design

Low-Carbon Reducing Agents

Why High Temperature Heat Pumps ?

- **High demand for process-heat >100 °C in the industry**
  → process heat at 100 – 500 °C accounted for 30 % of total heating and cooling energy demand in Europe *
- **Key Component in Carnot Battery concepts**
  → improving round trip efficiency of Carnot Battery
- **Transformation of Coal Fired Power Plants in Lusatia region / Germany**

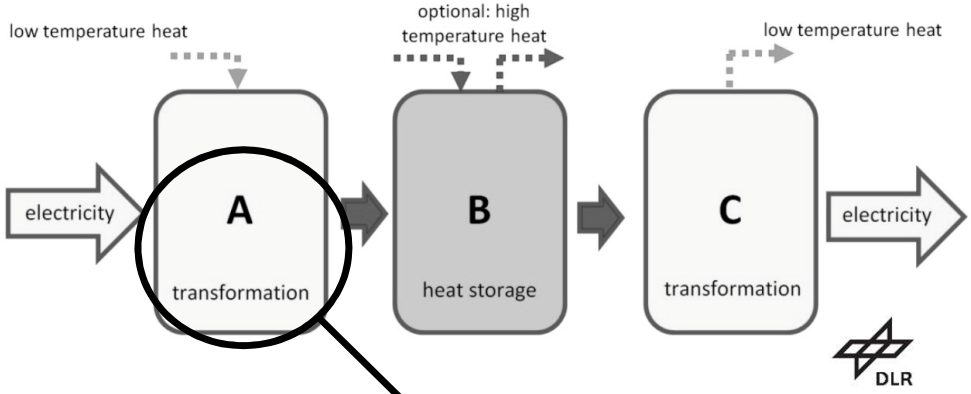
Goals of the institute

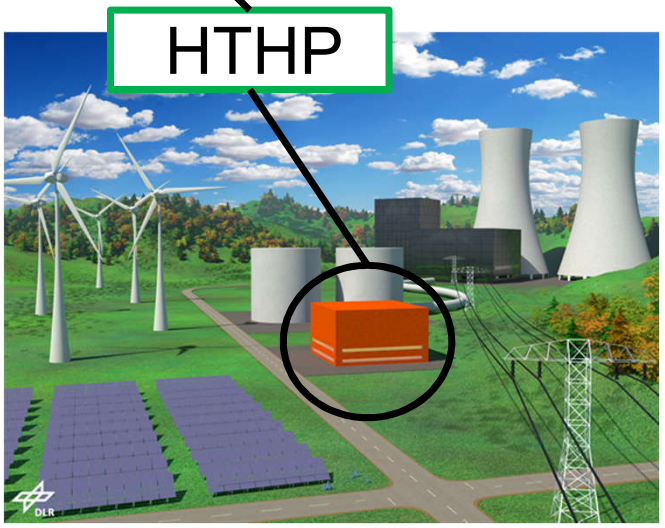
Midterm: Development of large scale HTHPs (>500 °C) based on Brayton and Rankine Cycle

First step: pilot scale HTHP “Pilot CoBra”

* Heat Roadmap Europe 2015

Carnot Battery Technological Concept



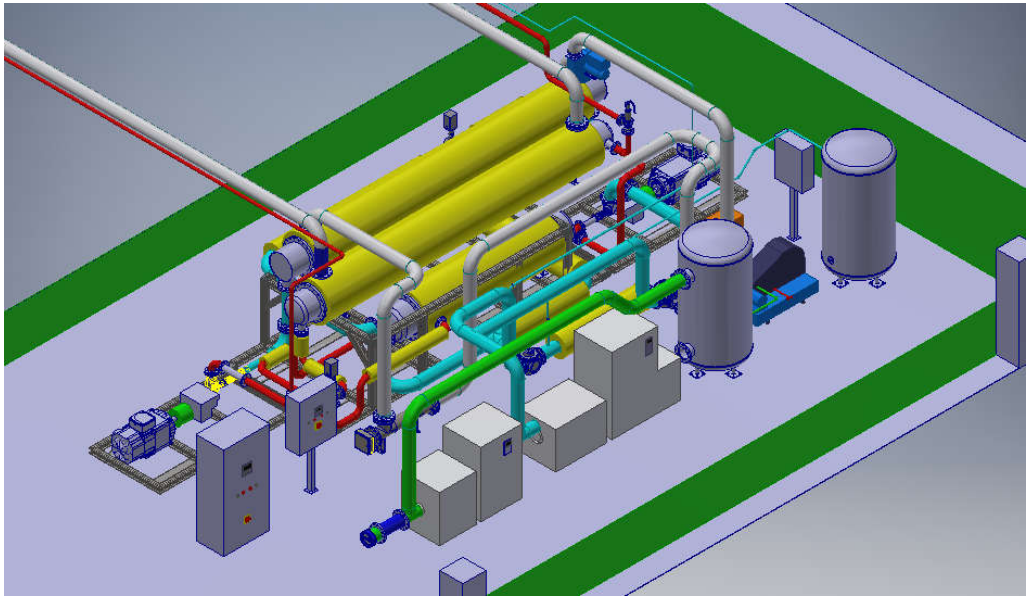


Third Life Coal-Fired Power Plant

Development of „Pilot CoBra“

Cottbus **Bra**yton

CAD model of Pilot CoBra



Concept for prototype

- Fully functional HTHP-System
- Reverse Brayton Cycle
- Modular design
- Extensive measurement and control equipment
- Pilot scale

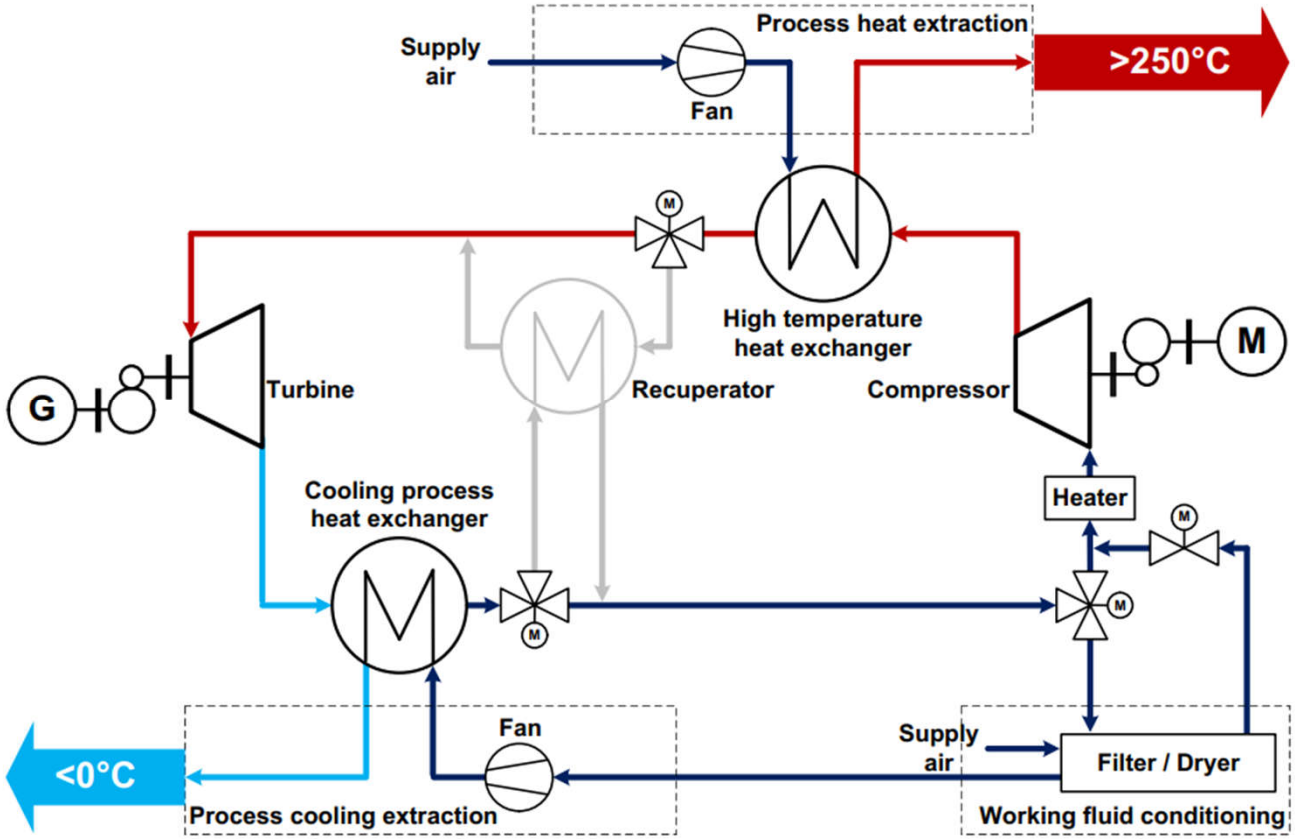
Focus on Know-How and How-To

- Controlling overall HTHP process
- Part-load and transient operation
- Testing of various types of components

→ Prototype
→ Experimental tool
→ Preparation for large scale plant

Pilot CoBra – Design

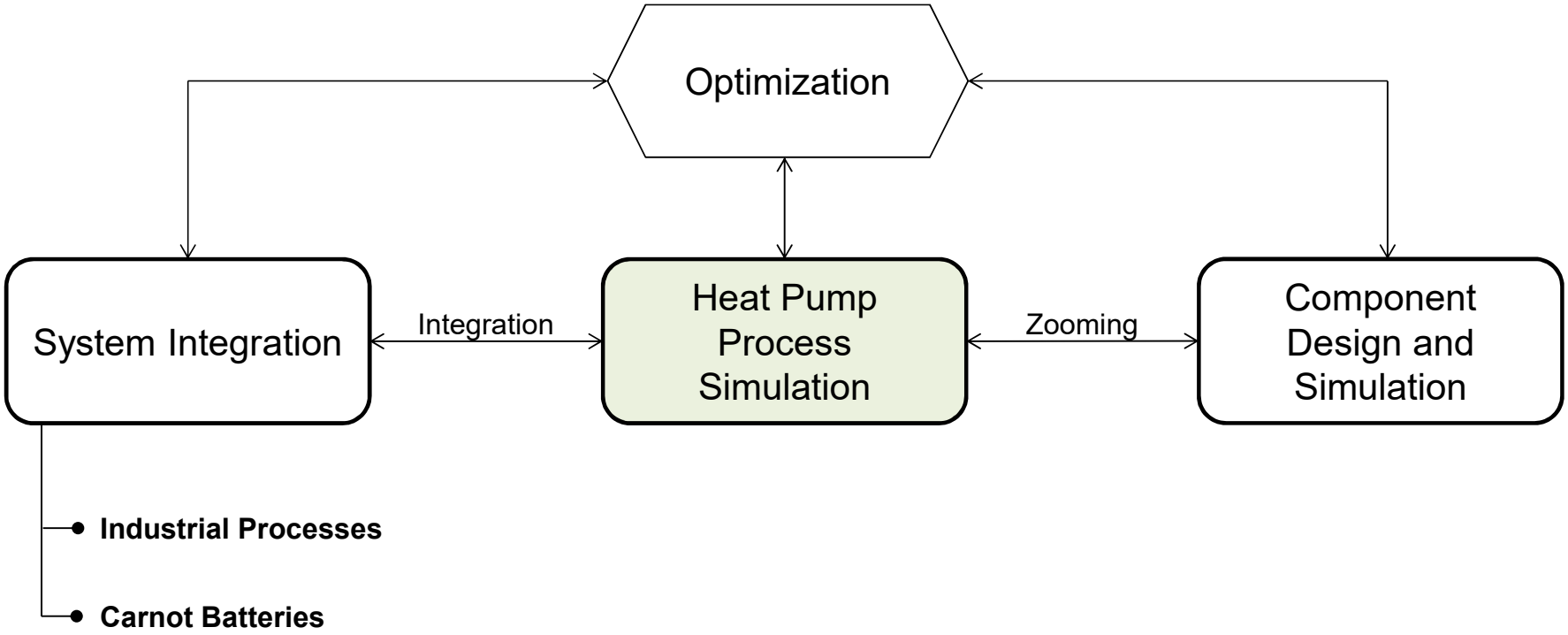
- **Initial working fluid: Air**
- **Main components**
  - Axial compressor
    - Pressure ratio = 6 to 7
    - Power consumption: 200 kW
  - Heat exchangers
  - Turbine
    - Power recovery: - 80 kW
  - Recuperator



Topics to be addressed

- **Development** of innovative heat pump concepts
- **Optimization** of the heat pump process and its components
- **Integration** of HTHPs in large scale industrial processes and Carnot Batteries

Integrated Simulation Framework

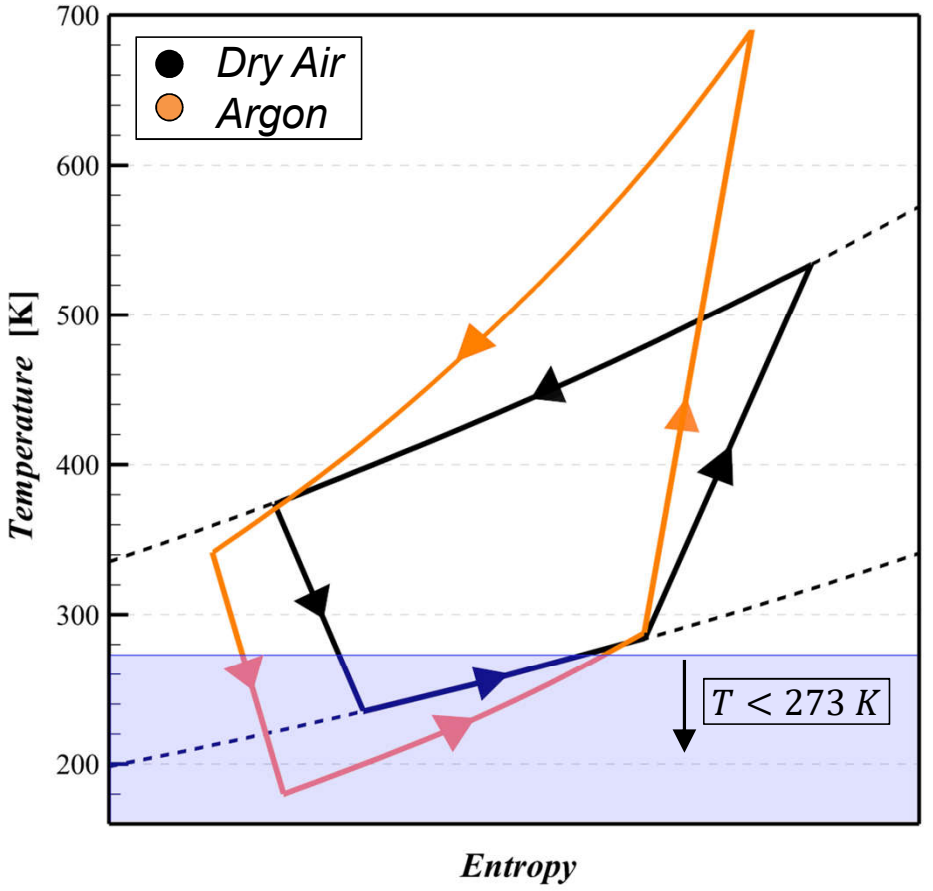


Process-level simulation

Preliminary results of working fluid analysis

- Performance simulation of inverted brayton cycles with dry air and argon as working fluids
- Higher temperature differences when argon is used
- Low temperatures for cooling processes achievable
- → Argon should be considered for future heat pump applications e.g. for Carnot Batteries

Inverted Brayton cycles for air and argon



Summary / Outlook

- Establishment of the institute: summer 2019
  - Institute is developing well – almost 50 % of desired number of employees reached
- Pilot CoBra:
  - → Reached „design freeze“
  - → Main components are being procured
- Scientific work started in all research fields / departments