sweet swiss energy research for the energy transition

DeCarbCH

Collaboration between

OST Ostschweizer Fachhochschule

IES Institute for Energy Systems

AHUORA CENTRE FOR SMART ENERGY SYSTEMS

THE UNIVERSITY OF WAIKATO Te Whare Wānanga o Waikato

Transcritical-Transcritical CO_2 High-Temperature Heat Pump Cycle for Dairy Spray Dryers

Riaan Engelbrecht[1], Cordin Arpagaus[1,*], Sidharth Paranjape[1], Frédéric Bless[1], Daniel Gstöhl[1], Lana Kong[2], Timothy Gordon Walmsley[2]

[1]OST – Eastern Switzerland University of Applied Sciences, Institute for Energy Systems (IES), Buchs, Switzerland, cordin.arpagaus@ost.ch

[2]AHUORA – Centre for Smart Energy Systems, School of Engineering, University of Waikato, Hamilton, New Zealand, tim.walmsley@waikato.ac.nz

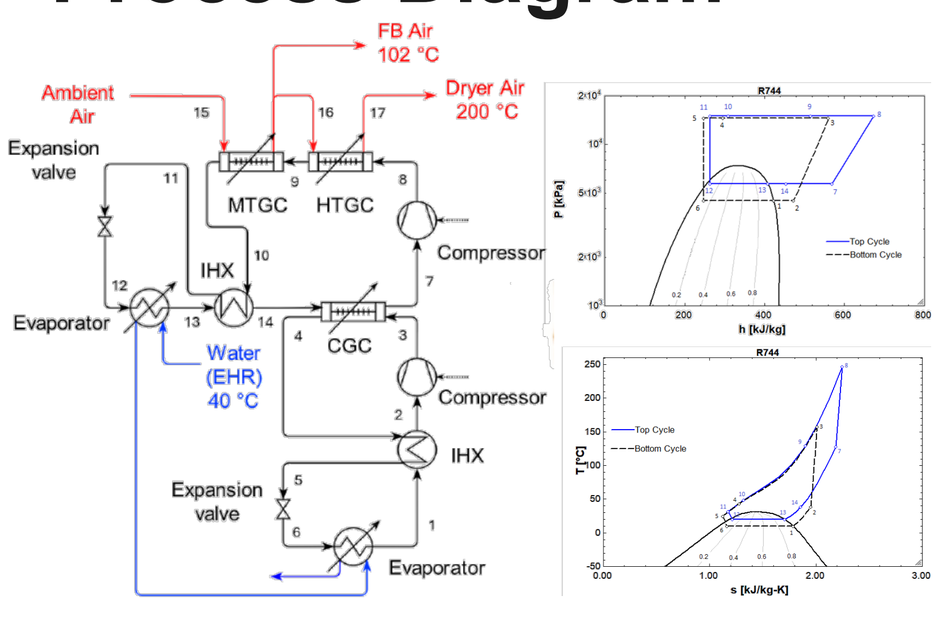
Goals

- Decarbonising industrial processes that require high-temperature air across a range of 15 °C to 200 °C
- Two-stage dairy spray dryers with fluid beds
- Achieve high temperatures at lower operating pressures than conventional multi-compression cycles
- Achieve better temperature profile matching on heat sink with two gas coolers
- Use of non-flammable, zero ODP and GWP refrigerants (e.g., CO2 = R744)

Process Data

- Heating Capacity: 470 kW and 360 kW
- COP: 2.55 (optimal) (see Results and Conclusions)
- Heat source temperature: 40 °C and 20 °C
- Heat sink air inlet temperature ($T_{air,in}$): 15 °C
- Heat sink air outlet temperature: 102 °C and 200 °C
- High pressure limit: 15 MPa (150 bar)

Process Diagram

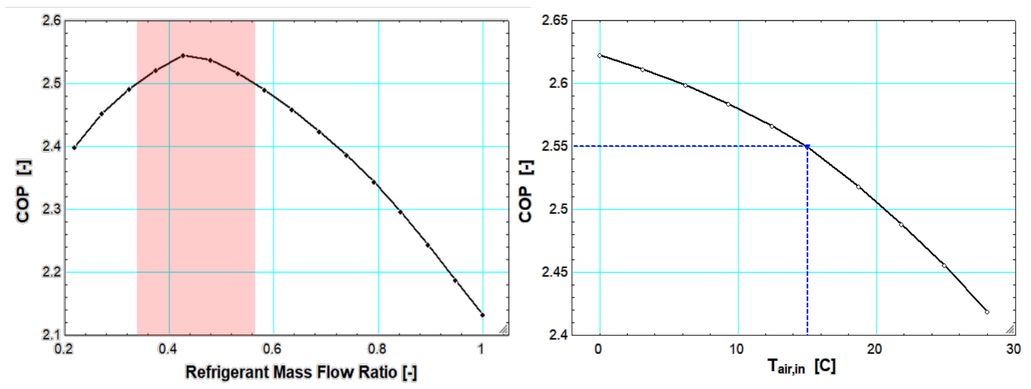


Method

- Develop a static model of two cascaded transcritical CO_2 cycles in EES software (Engineering Equation Solver, F-Chart) (see Process Diagram)
- Analyse the HTHP cycle through a parametric study
- Fixed parameters:
- heat source temperatures
- heat sink heating capacity and air outlet temperatures
- pinch point temperatures
- isentropic compressor efficiency
- refrigerant (CO_2)
- Solve the remaining parameters: e.g., refrigerant mass flow rates, pressure ratios, and COP
- Variation of mass flow ratios, heating capacity distribution, air inlet temperatures, and pressure ratios

Results and Conclusions

- The proposed cycle achieves supply temperatures above 200 °C at discharge pressures of 150 bar.
- CO_2 is well suited for achieving high supply temperatures.
- Careful compressor selection is critical, e.g., oil-free centrifugal CO_2 compressors for large-scale applications such as dairy spray dryers.
- Stable refrigerant mass flow ratios between the two compressors are required (some margin for manoeuvre).
- Having two gas coolers on the heat sink provides two air streams at different temperature levels simultaneously (as required in dairy spray dryers with fluidized beds).
- Altering the heating capacity ratio between the two gas coolers significantly affects the pinch points of both heat exchangers.
- The cycle is resistant to changes in supply air temperature and thus largely season-independent in moderate climates.



[1] Kong et al. (2025): Advances in High-Temperature Heat Pump Technologies for Industrial Process Applications with Large Temperature Glides: Assessing the potential for carbon dioxide as a refrigerant, Energy Conversion and Management, 350, 2026, 120933, https://doi.org/10.1016/j.enconman.2025.120933

Core partners

UNIVERSITÉ DE GENÈVE · HSLU Hochschule Luzern · OST Ostschweizer Fachhochschule · ETH zürich · zhaw School of Engineering · Empa Materials Science and Technology

Associate partners

Scuola universitaria professionale della Svizzera italiana SUPSI · HEIG VD · cem · INDP

Cooperative partners:

SWISSOLAR · Weisskopf Partner GmbH · AMSTEIN+WALTHERT · BELIMO · BASF We create chemistry · JURA CEMENT A CRH COMPANY · Energie aus Abfall · gaz energie · VBSA ASED ASIR · SIG · fernwärme Die Komfort-Energie · SBB CFF FFS · Emmi · SEFAR · BUILDING TRUST · Abicht Gebäudetechnik zukunftssicher planen · anex · energienetz GSG AG · CASALE · MIGROS · e+p · ENGINEERING TOMORROW · FELDSCHLÖSSCHEN Part of the Carlsberg Group · ENERGIE-AGENTUR DER WIRTSCHAFT EnAW · Stadt Winterthur · viteos · ewb · Nestlé · energie-cluster.ch