Technische Universität Dresden

Design and Investigation of a Heat Pump System for the Future Heat Supply at Nyhavna, Trondheim

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Background & Motivation

The increasing need to reduce CO_2 emissions and provide sustainable energy has intensified interest in efficient heating technologies. High-temperature heat pumps (HTHPs) are a promising solution for district heating (DH), as they can upgrade low-temperature heat sources to usable heat levels. In Trondheim, an existing district heating network is already in operation, while a new low-temperature heating grid is planned for the Nyhavna district. Both networks are intended to be supplied by a large seawater-based heat pump system.

This project therefore focuses on finding a suitable technical solution that enables the efficient and reliable integration of the heat pump into both the existing high-temperature network and the new low-temperature grid, ensuring a sustainable and future-proof heat supply.

Boundary conditions	DH Trondheim	DH Nyhavna	Seawater
Supply temperature	*95°C*	*45°C*	*6°C .. 8°C*
Return temperature	*45°C*	*30°C*	*2°C .. 4°C*
Heat load	*20MW .. 25MW*	*7,5MW*	-

System Design

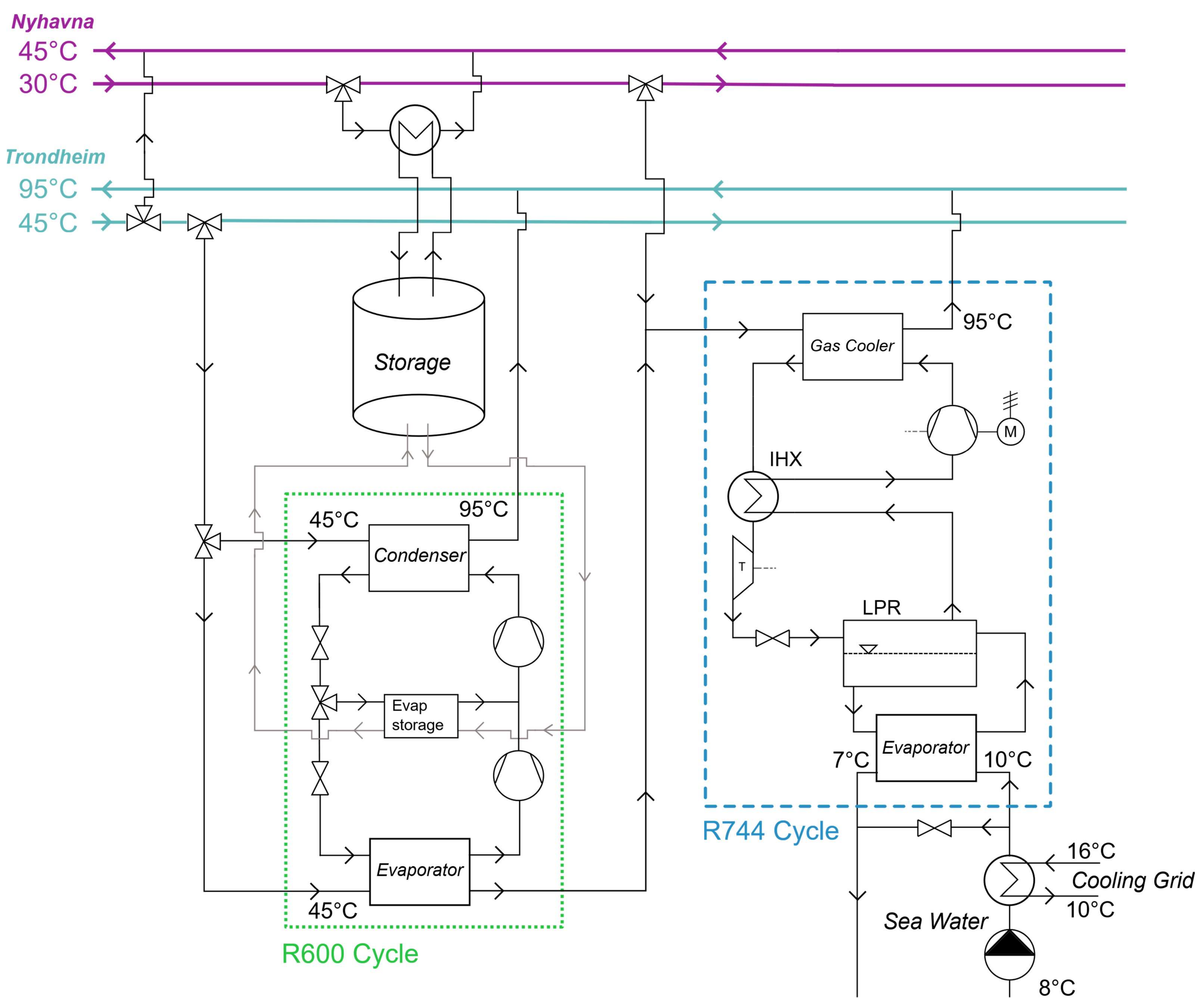

Fig. 1 System Design

A transcritical CO_2 heat pump system was developed and optimized to supply two district heating networks with different temperature levels. Starting from a basic four-component cycle, several efficiency measures were systematically evaluated and combined. The final design can be seen in Fig. 1.

Key optimizations include the use of an internal heat exchanger (IHX), and a turbine for expansion work recovery, although ejectors may also be viable. A low-pressure receiver (LPR) was found to improve operation but not efficiency. Borehole thermal energy storage (BTES) is included for seasonal operation. Additional efficiency gains are achieved by integrating a parallel butane heat pump to utilize low-temperature heat from the CO_2 gas cooler. The butane cycle ensures safe operation despite fluctuating return temperatures in the heating network.

Influence of Return Temperature on the System

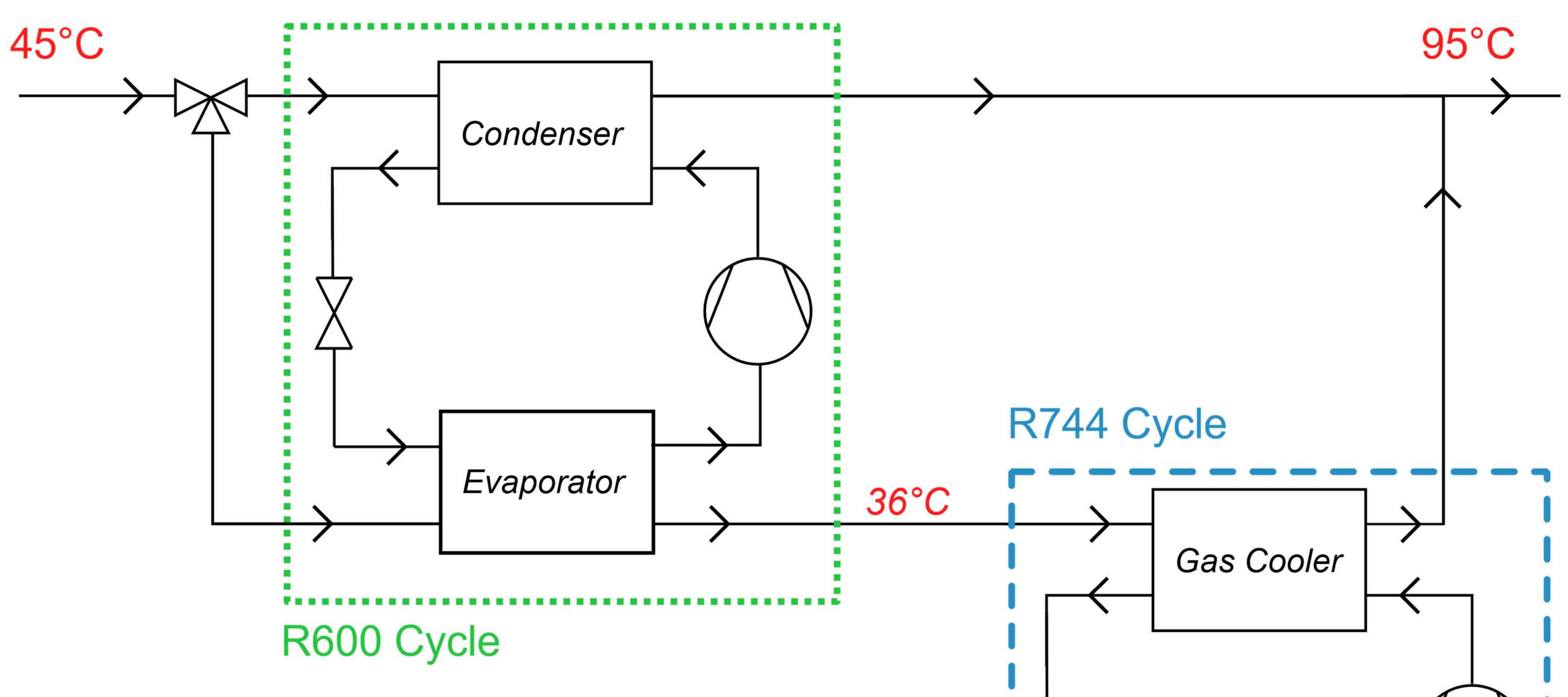

Fig. 2 Optimazation with Additional Butane Cycle

The transcritical R744 cycle works best at low return temperatures, so the additional butane cycle cools the flow for the CO_2 cycle to an intermediate temperature.

The lower the intermediate temperature, the better the CO_2 cycle and the worse the butane cycle operates. Thus, an ideal intermediate cooling temperature must exist.

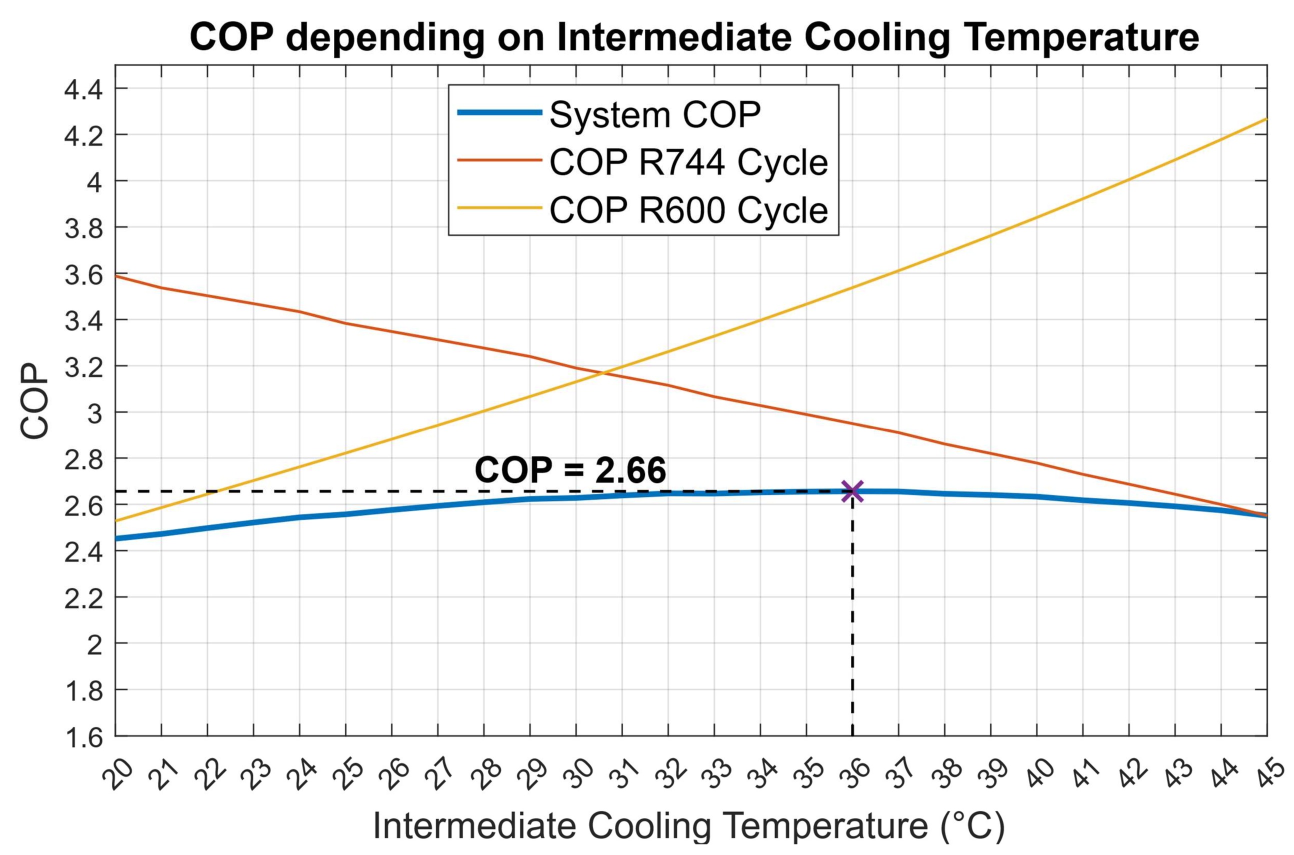

Fig. 3 Determination of the Optimal Intermediate Temperature

The log(p)-h and T-s diagram reveals the advantage of lower return temperatures for the CO_2 system.

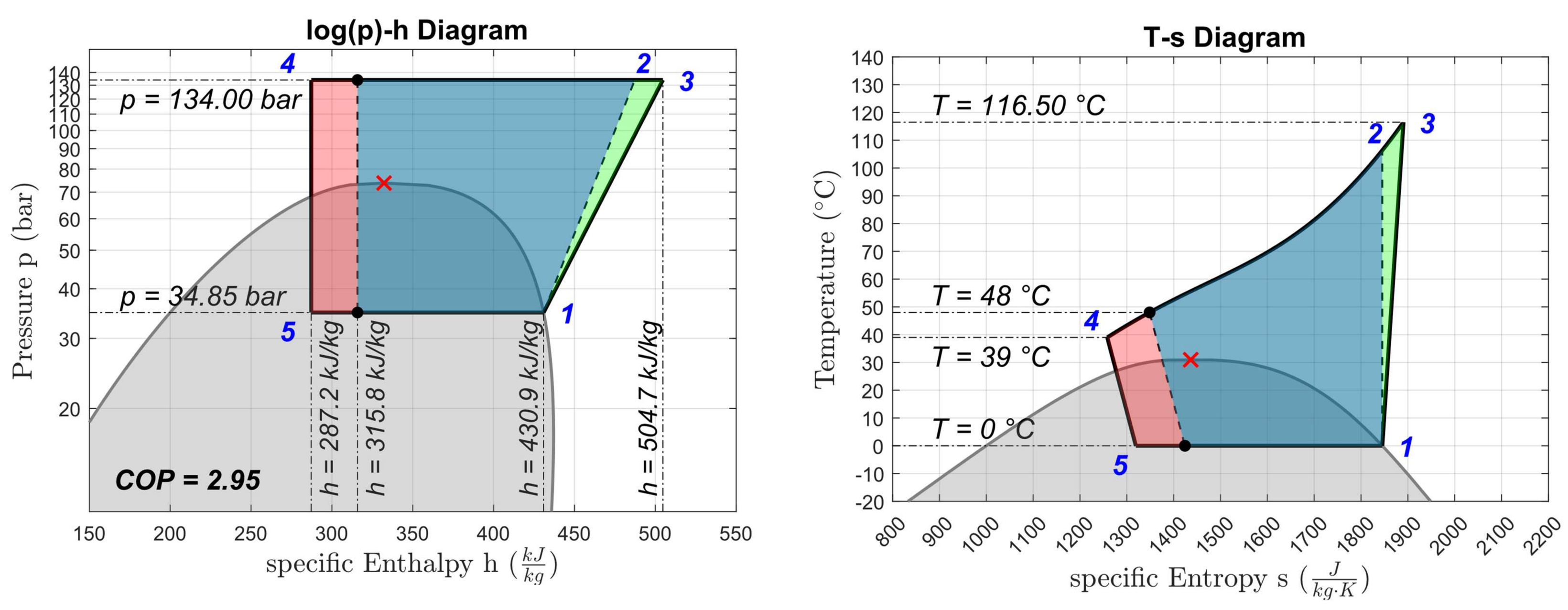

Fig. 4 Cycle Diagrams for the CO_2 System

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High-Temperature Heat Pump Symposium

Die TUD ist Gründungspartnerin der Forschungsallianz DRESDEN-concept e.V.

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