High-Temperature Heat Pump Symposium

From Medium-Deep Geothermal to District Heating: Thermo-Economic Assessment of Different Heat Pump Configurations

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Motivation

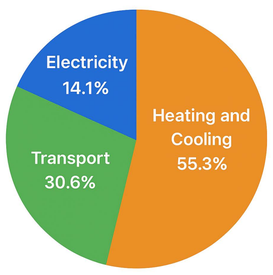

Figure 1: Energy consumption by sector in Germany in 2024[1]

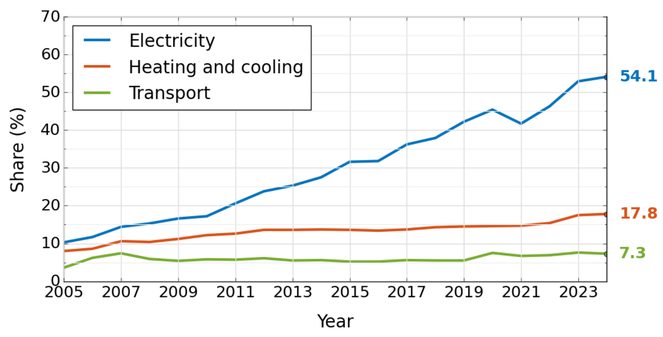

Figure 2: Share of renewable energy sources per sector in Germany[1]

- ❑ Heating and cooling sector dominates consumption
- ❑ Heating sector remains largely fossil-based
- ❑ High and growing share of renewables in electrcity

→ Decarbonizing Heating sector is of big interest
→ Electricity can be used to enhance this goal

➔ High promise to decarbonize district heating with large-scale heat pumps

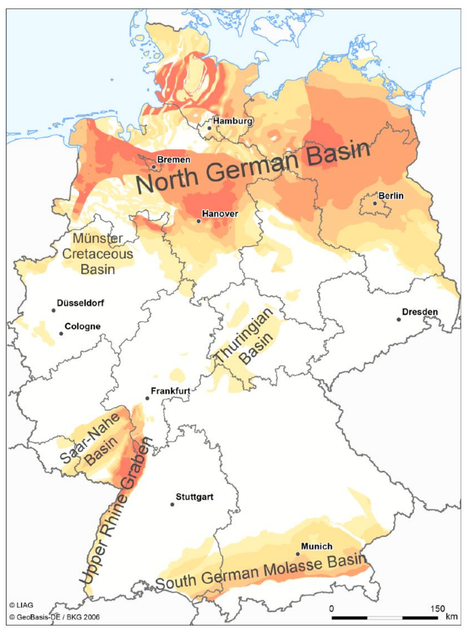

Figure 3: German regions with hydrothermal resources and associated temperature ranges[3]

- ❑ Deep-geothermal sources (>100°C) can be used directly for District Heating Systems(DHS)
  → potential limited to selected regions
- ❑ E.g. only 40% of Bavaria's heat demand could be covered with deep-geothermal-technologie[2]
- ❑ Significant medium-deep geothermal potential (<100°C) in Germany
- ❑ Large-scale heat pumps are required to utilize medium-deep resources for conventional DHS
- ❑ Optimal design and operational concepts are pivotal to achieve competitive economics

Research scope & evaluated concepts

Research Questions:

I) Which compression heat pump configuration performs best under varying project conditions?

II) How can the fluid selection for each stage further optimize the COP?

III) Which LCOH can medium-deep geothermal projects achieve?

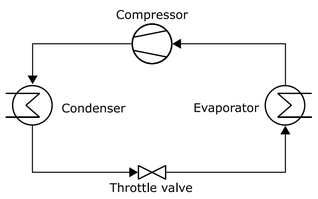

Figure 4: Single-stage compression heat pump

Single-stage HPs:

+ Lower CAPEX
+ Lower plant complexity
- Low COP; higher OPEX
- Strong off-design operation

Multi-stage cascade HPs:

+ Higher COP; lower OPEX
+ Optimal selection of refrigerants possible
- Higher CAPEX
- Higher plant complexity

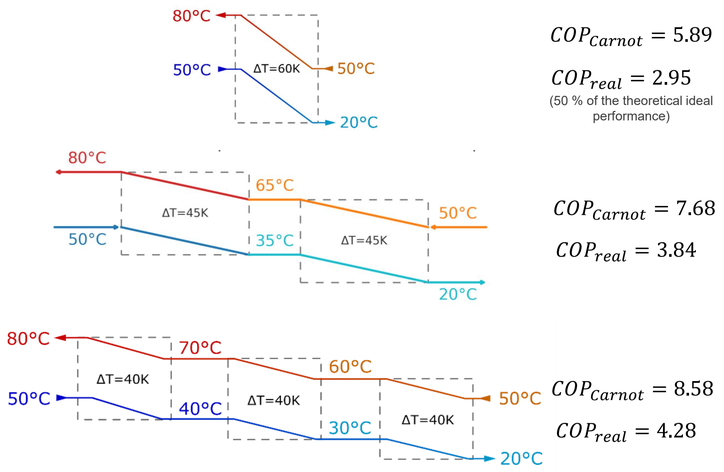

Figure 5: Distribution of temperature lift for different HP-concepts adapted from Mathes et al.(2022)[4]

Table 1: Key characteristics of some of the studied working fluids[5,6]

Name	Type	p_{crit} [bar]	T_{crit} [°C]	Safety Group	GWP	ODP	PFAS issue?
Propane	Natural (HC)	42.5	96.7	A3	3	0	No
Butane	Natural (HC)	37.0	152.0	A3	4	0	No
Pentane	Natural (HC)	33.7	196.6	A3	10–20	0	No
Ammonia	Natural (NH_3)	113.0	132.4	B2/B2L	0	0	No
R1224yd(Z)	HFO	33.4	155.5	A1	1	0.0002	Very high
R1233zd(E)	HFO	35.7	165.6	A1	1–4	0.0003	High

Methodology

Real Data

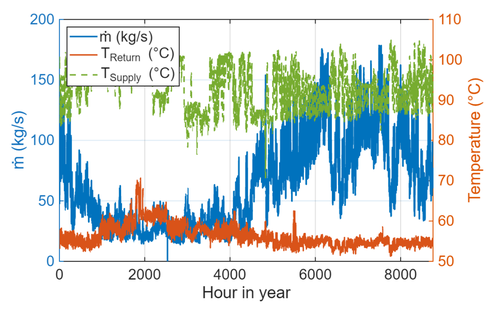

Figure 6: District Heating Network Data from geothermal plant in Pullach, Germany

- ❑ Using hourly demand data for realistic simulations
- ❑ Adapting the real data for various DHN and geothermal settings

Off-Design Simulation

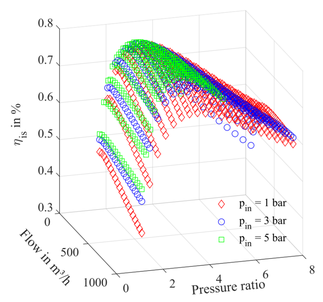

Figure 7: Performance map for the compressor simulation[7]

- ❑ Simulating different HP concepts and compressor sizes
- ❑ Design optimization based on thermodynamic constraints and real operational behaviour

Economic Evaluation

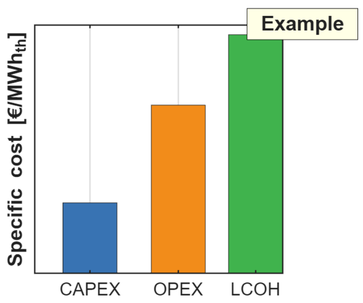

Figure 8: Conceptualization of the cost estimation method

- ❑ Using output data of HP-simulation to calculate investment and operational costs as well as LCOH

Recommendation

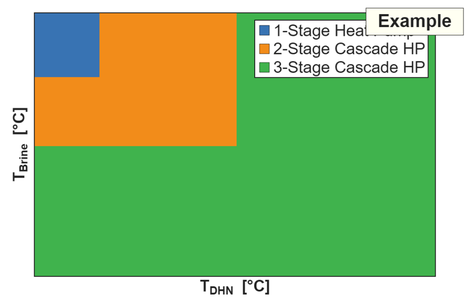

Figure 9: Conceptualization of the expected favourability map

- ❑ Determination of most favourable HP-setup based on geothermal conditions and DHN characteristic

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2. Technische Universität München, Munich School of Engineering, *Bewertung Masterplan Geothermie*, Gutachten im Auftrag des Bayerischen Staatsministeriums für Wirtschaft, Landesentwicklung und Energie, München, Germany, 2020.
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