Technische Hochschule Ingolstadt
Institut für neue Energie-Systeme

Energetic Potential of Parallel Operation of Two Heat Sources in a Dual-Source Heat Pump

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Agenda

1. **Motivation and Background**
2. **Methodology**
3. **Results**
4. **Outlook**

1. Motivation and Background

Motivation

- **Dual-source heat pumps use two heat sources**
  - Energetic benefit by splitting the energy provided by each source
- **Why parallel operation of two heat sources / evaporators?**
  - Can reduce load on singular heat sources: smaller dimensioning / less noise emissions
  - Can increase flexibility between heat sources
  - Can increase efficiency compared to single source operation, especially at peak loads
- **How can you do parallel operation? Various ideas in literature:**

(1) One evaporator after the other on a similar pressure level

(2) Both evaporators in parallel on a similar pressure level

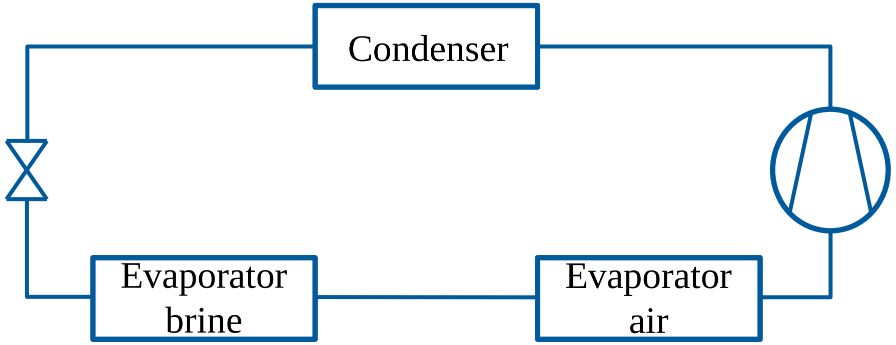
(3) One evaporator after the other on different pressure levels

(4) Both evaporators in parallel on different pressure levels

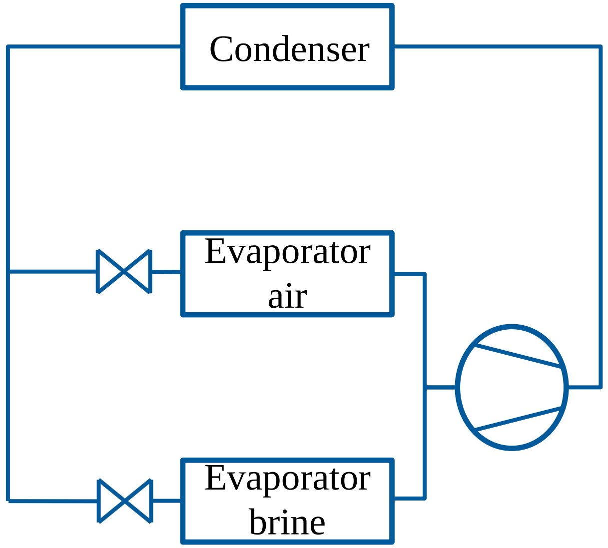
1. Motivation and Background

Background – investigated interconnections for parallel operation

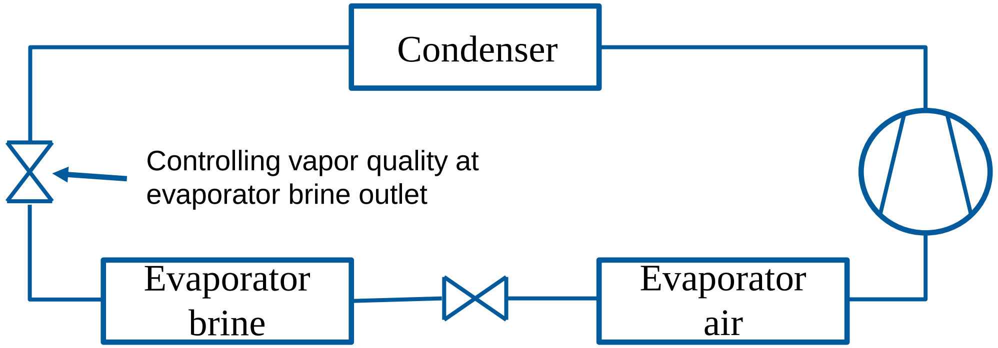
(1) One evaporator in series on a similar pressure level [1]



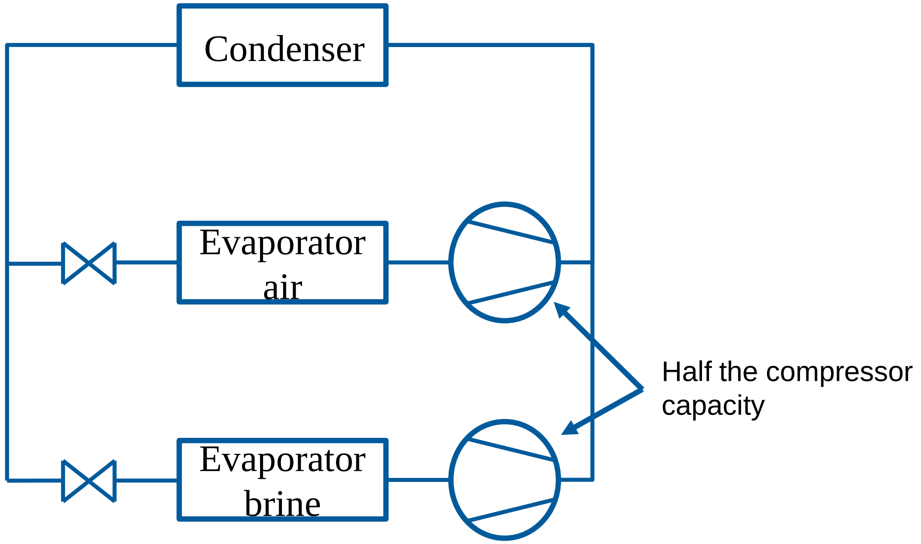
(2) Both evaporators in parallel on a similar pressure level [2]



(3) Both evaporators in series on different pressure levels (based on [3])



(4) Both evaporators in parallel on different pressure levels [4]



2. Methodology

How to

- **Create refrigerant cycle simulation in MATLAB/Simscape:**
  - Standardized heat exchangers across all simulations (evaporators and condenser)
  - Isentropic compressor, mass flow based on data sheet (10 coefficient method)
  - Expansion valve controlling superheating at evaporator outlet
  - R454B was used as refrigerant
- **Compare simulations (sink temperature always 30 ^{o}C inlet):**

  a) At different temperature gradients: brine temperature was left constant at 5 ^{o}C, air temperature variations (-5, 5, 15 ^{o}C)

  b) Benchmarks: pure air / brine operation

  c) With each other

  → 4 interconnections, 3 temperature gradients, 4 benchmarks: 16 simulations

2. Methodology

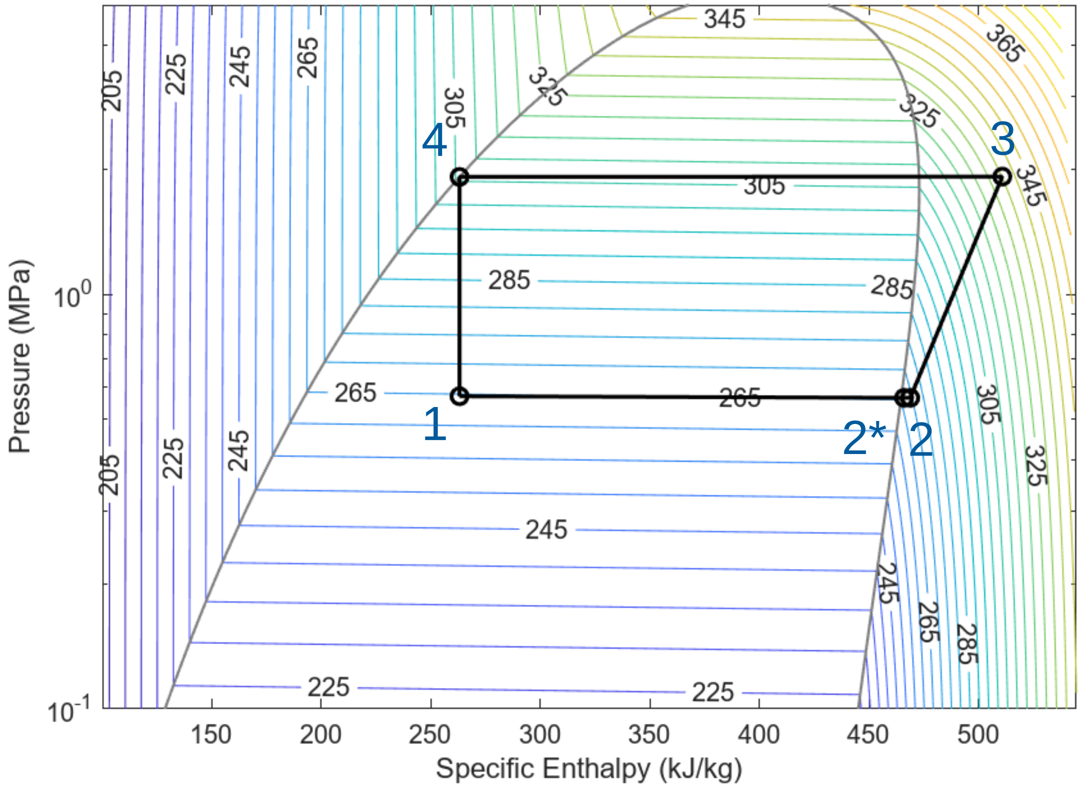
Evaluation

- **Credibility check with:**
  - Overheating and hot gas temperatures
  - Pressure-enthalpy diagram
- **Comparison parameters:**
  - COP
  - Evaporator powers $\dot{Q}_{evap}$ for brine evaporators (GSHX)

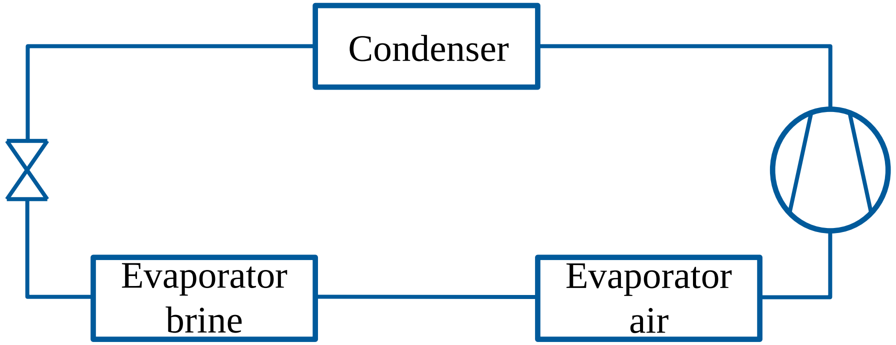
3. Results

Pressure-enthalpy diagrams: Parallel operation

(1) at A-5 and B5



*: Evaporator brine conditions

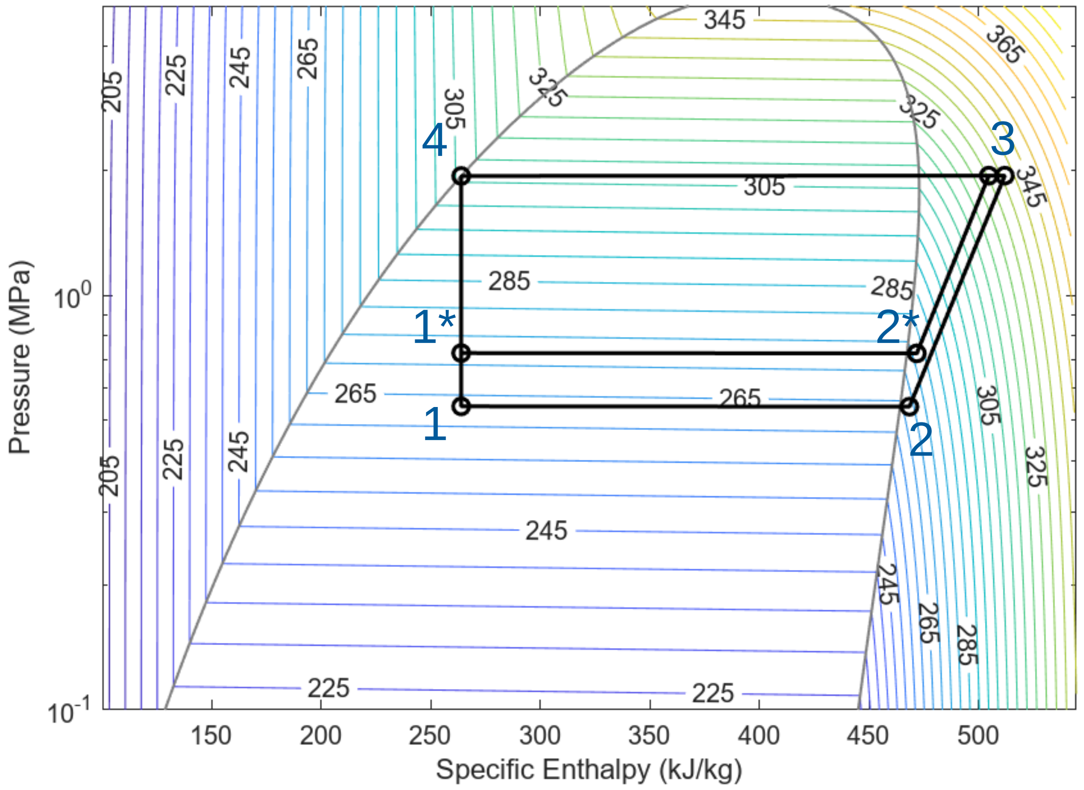


- **Example: brine evaporator, then air evaporator in series**
  - Low air temperature leads to barely any evaporation in air evaporator
  - Even reduced evaporation pressure compared to single brine operation

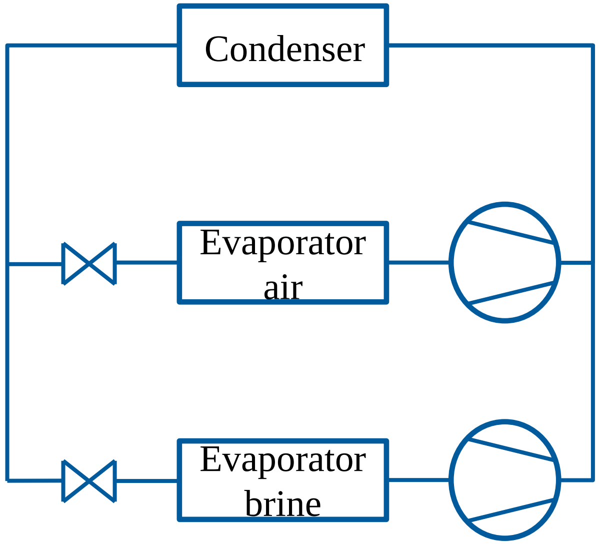
3. Results

Pressure-enthalpy diagrams: Parallel operation

(4) at A-5 and B5



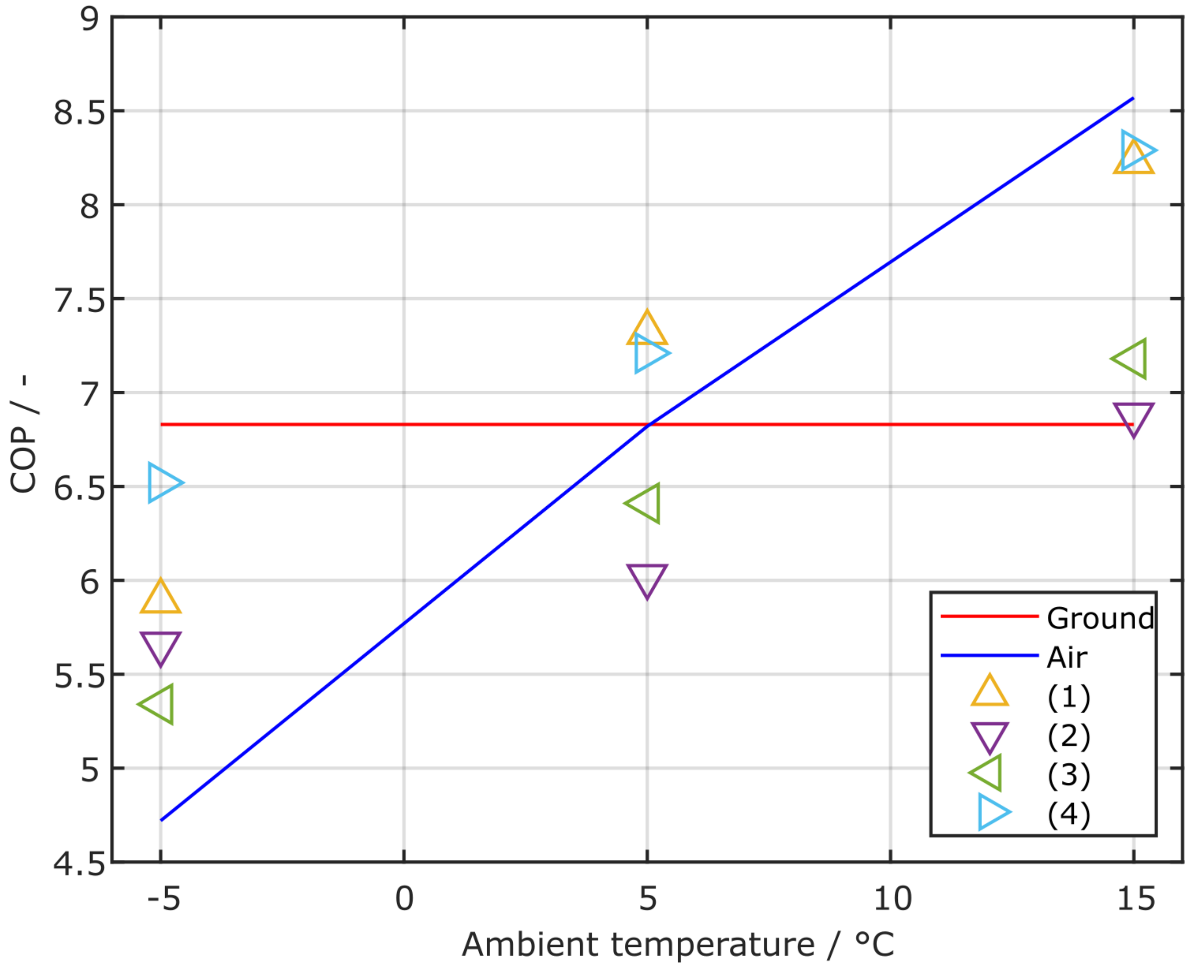
*: Evaporator brine conditions



- **Example: brine and air evaporator in series with separate compressors**
  - Stable and split evaporation pressures
  - Efficient ASO and GSO
  - Flexibility possible by adjusting compressor speeds

3. Results

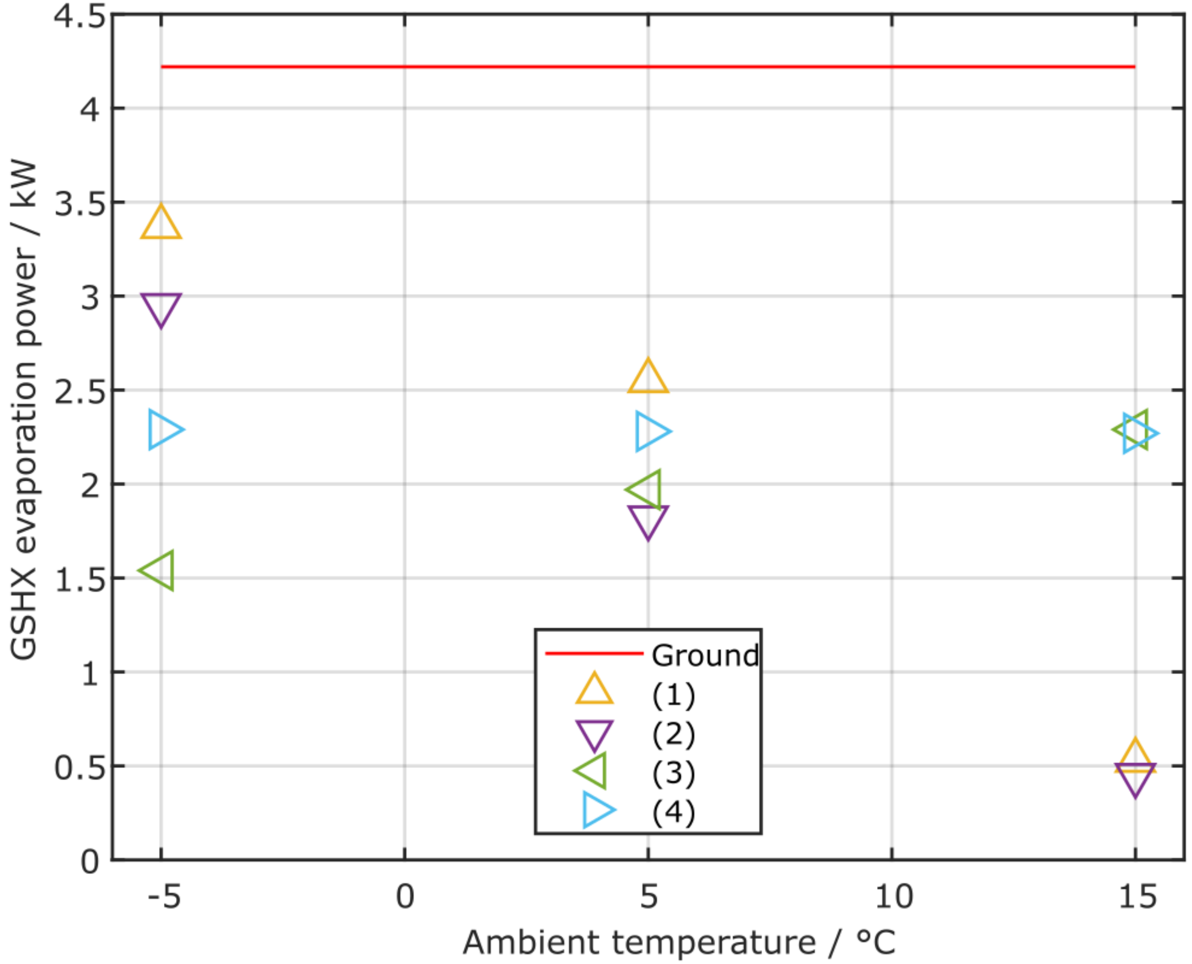
COP over ambient air temperature



- **Some details to note:**
  - At similar temperatures, only (1) and (4) improve COP
  - At high air temperature, (1) and (4) show almost Air COP
  - At low air temperature, (4) shows COP almost similar to Ground

3. Results

Brine / GSHX evaporation power over ambient air temperature



- **Some details to note:**
  - At similar temperatures, all interconnections show significant reduction in GSHX evaporation power
  - At high air temperature, (1) and (2) show almost no GSHX evaporation power
  - (4) shows similar GSHX evaporation power at any air temperature (controllable by compressor speed)
  - (3) shows negative gradient, lower GSHX evaporation power at low air temperature (dependent on specific control strategy)

4. Outlook

- **Refrigerant cycle simulation worked well with complex systems**
- **Temperature levels of the sources play a major role**
- **Each interconnection has their specific use case**
  - If the aim is to strictly improve COP: (1) and (4) are beneficial
  - If the aim is to strictly reduce GSHX evaporation power: (3) and (4) are beneficial
  - If the aim is maximum flexibility: (4) is beneficial
- **Especially (3) requires more involved expansion valve control**
- **Validation of components with experimental data**
- **Economic analysis must be conducted; especially (4) will need higher investment costs**

References

[1] W. Behrmann, "Hybridwärmepumpe," DE 10 2010 033 142 A1.

[2] G. Qiu, X. Wei, Z. Xu, and W. Cai, "A novel integrated heating system of solar energy and air source heat pumps and its optimal working condition range in cold regions," *Energy Conversion and Management*, vol. 174, pp. 922–931, 2018, doi: 10.1016/j.enconman.2018.08.072.

[3] S. Bertsch, M. Uhlmann, and A. Heldstab, "Heat Pump with Two Heat Sources on Different Temperature Levels," *International Refrigeration and Air Conditioning Conference*, 2014.

[4] T. Reum, T. Summ, M. Ehrenwirth, and T. Schrag, "Experimental Investigation of a Novel Hybrid Heat Pump," *EuroSun2022 Proceedings*, 2023, doi: 10.18086/eurosun.2022.08.11.

Thank you for the attention!

Any remarks? Any questions?

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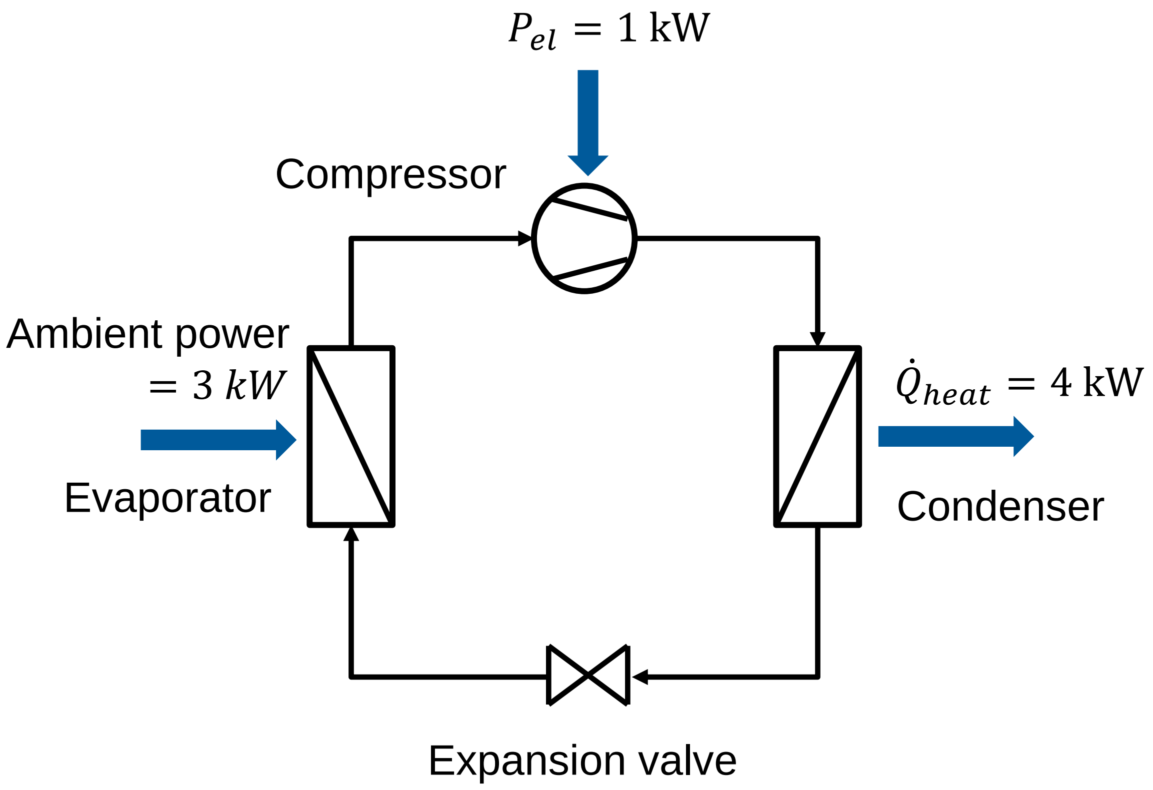
1. Motivation and Background

Motivation

- **Heat pump**
  - Converts ambient energy into heating energy using some electrical energy
  - Efficiency: $COP = \frac{\dot{Q}_{heat}}{P_{el}}$ increases with lower temperature difference between ambience and heating system
  - Ambient energy from:
    - Air with direct evaporation
    - Ground via brine cycle and GSHX
    - …
  - Dual-source heat pumps utilize two of these!



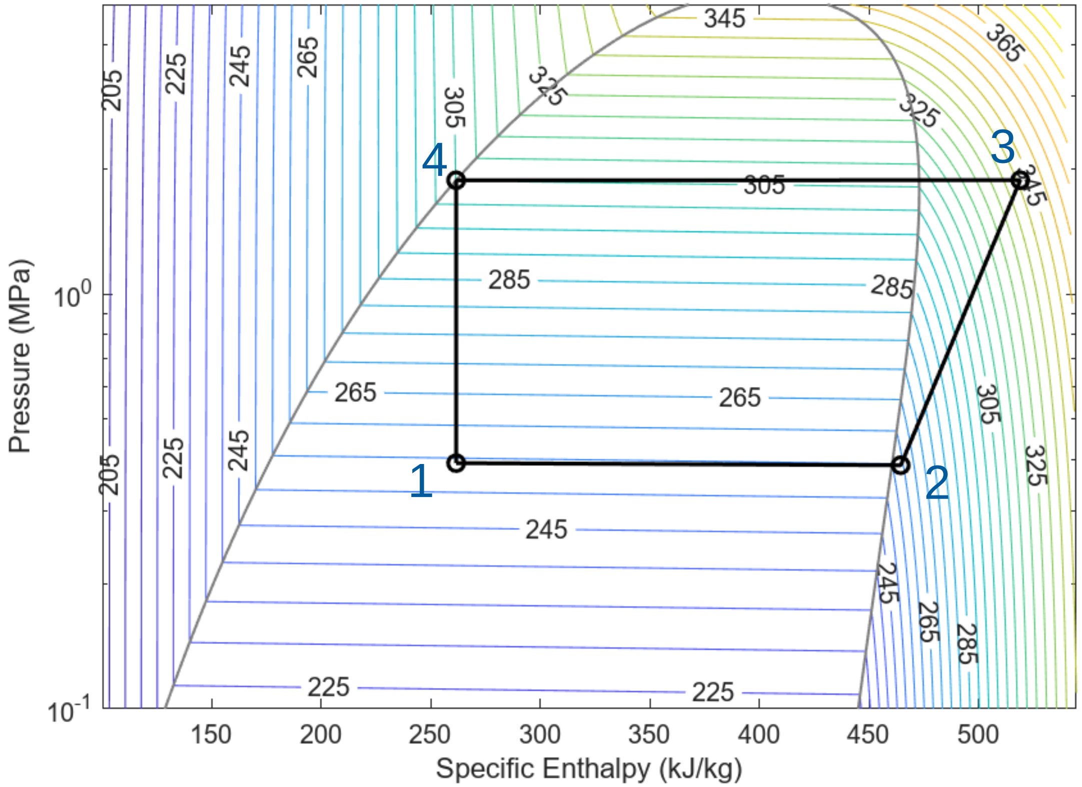
Appendix

Interconnection	T_{air}	COP	P_{heat}	P_{el}	$P_{evap,brine}$	$P_{evap,air}$
Air-source	-5	4,72	3,17	0,67	-	2,50
	5	6,82	4,94	0,72	-	4,21
	15	8,57	6,45	0,75	-	5,70
Ground-source	5	6,83	4,94	0,72	4,22	-
(1)	-5	5,89	4,12	0,70	3,37	0,05
	5	7,32	5,38	0,74	2,55	2,10
	15	8,23	6,166	0,75	0,53	4,89
(2)	-5	5,66	3,91	0,69	2,95	0,27
	5	6,02	4,23	0,70	1,82	1,71
	15	6,88	4,99	0,73	0,45	3,81
(3)	-5	5,34	3,69	0,69	1,54	1,47
	5	6,41	4,69	0,73	1,97	1,99
	15	7,18	5,65	0,79	2,29	2,58
(4)	-5	6,52	4,65	0,71	2,29	1,65
	5	7,21	5,29	0,73	2,28	2,27
	15	8,29	6,168	0,74	2,27	3,16

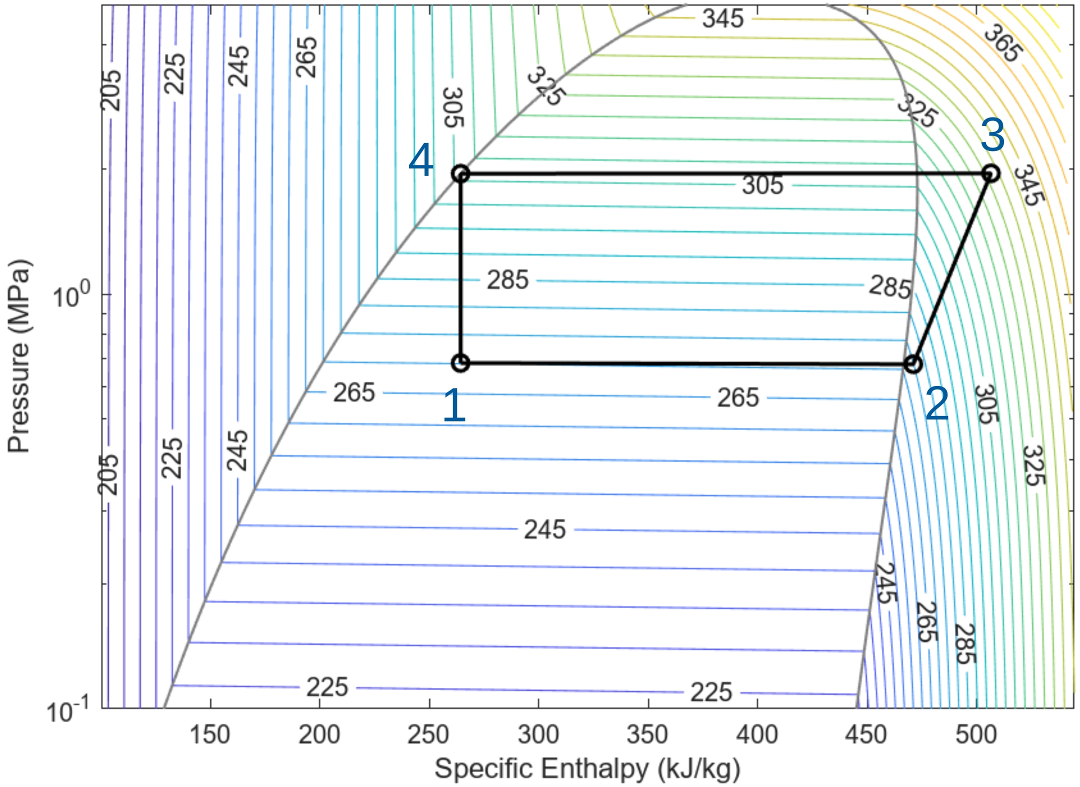
3. Results

Pressure-enthalpy diagrams: Air and Ground

Air at -5 °C



Ground at +5 °C

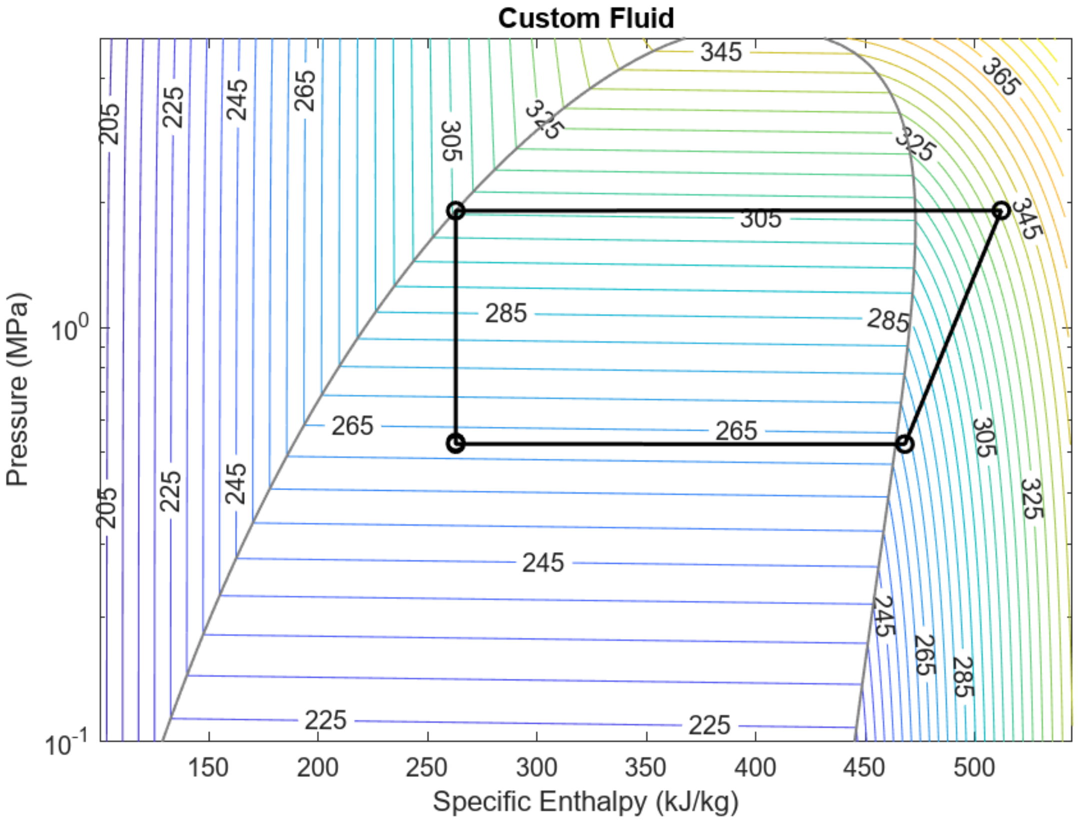


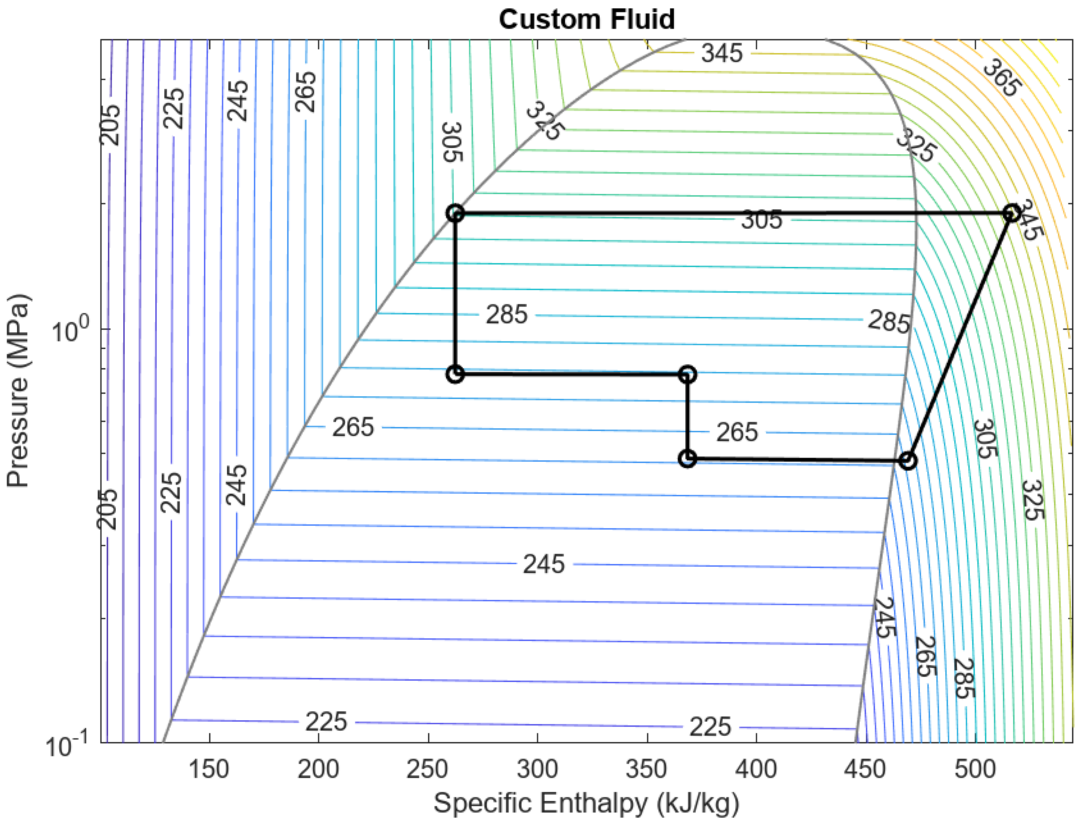
→ Rather low evaporation pressure, indicating small evaporator sizes

→ Altogether reasonable results

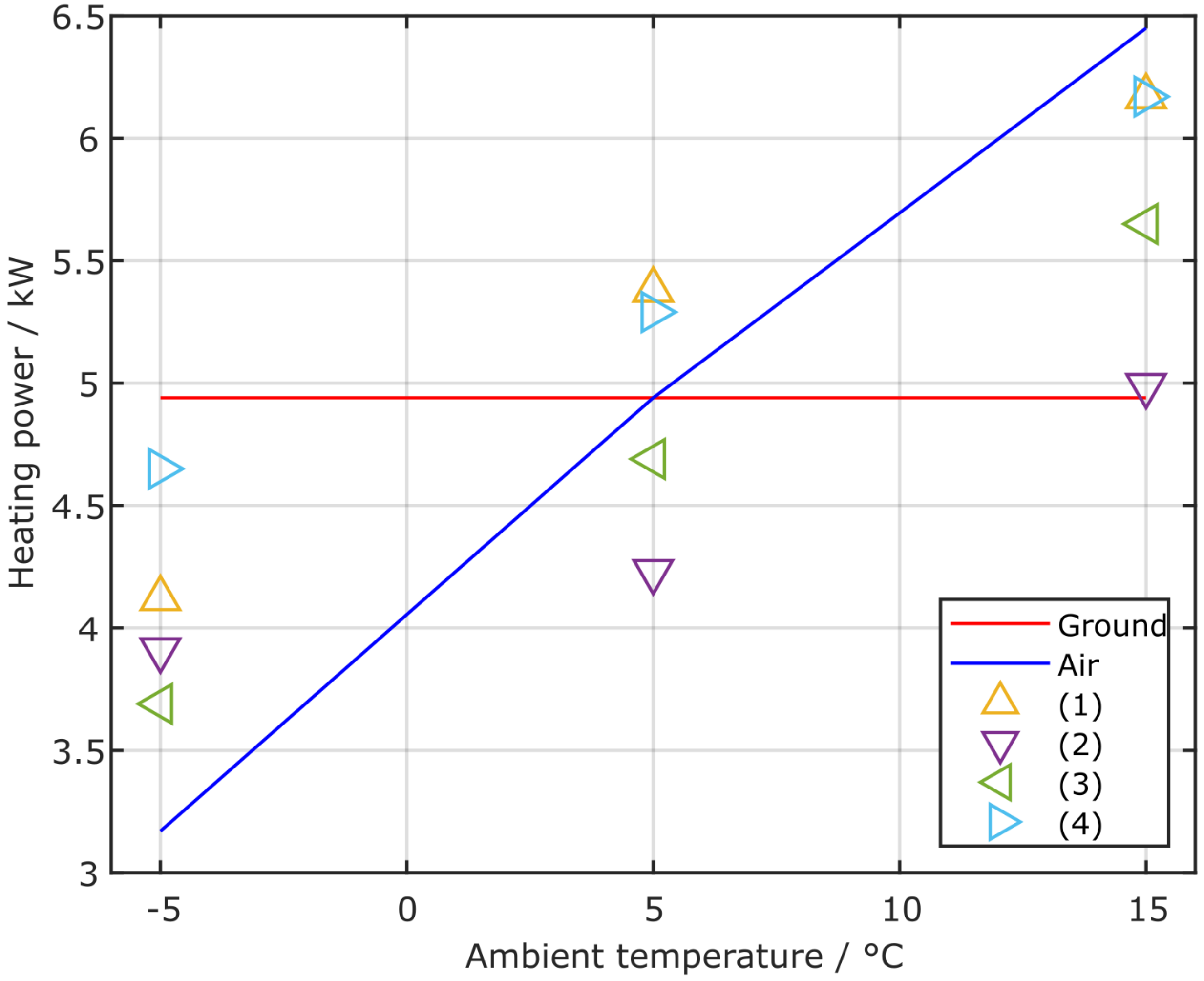
3. Results

Pressure-enthalpy diagrams: Air and Ground



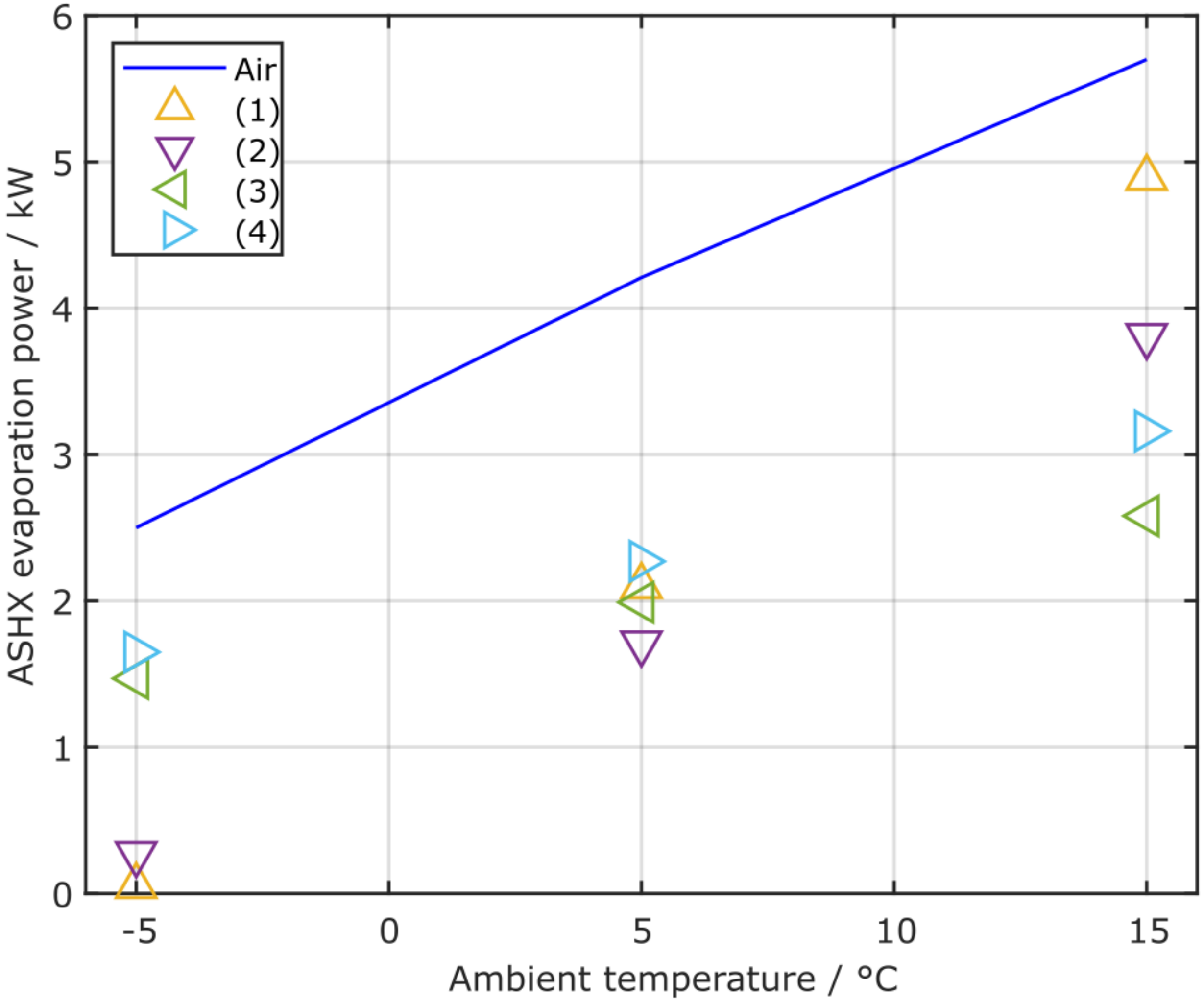


Appendix



6.5
6
5.5
5
4.5
4
3.5
3
Heating power / kW
-5
0
5
10
15
Ambient temperature / °C
Ground
Air
(1)
(2)
(3)
(4)

Appendix



Air
(1)
(2)
(3)
(4)
ASHX evaporation power / kW
Ambient temperature / °C
0
1
2
3
4
5
6
-5
0
5
10
15