Booster Heat Pump with Zeotropic Mixtures

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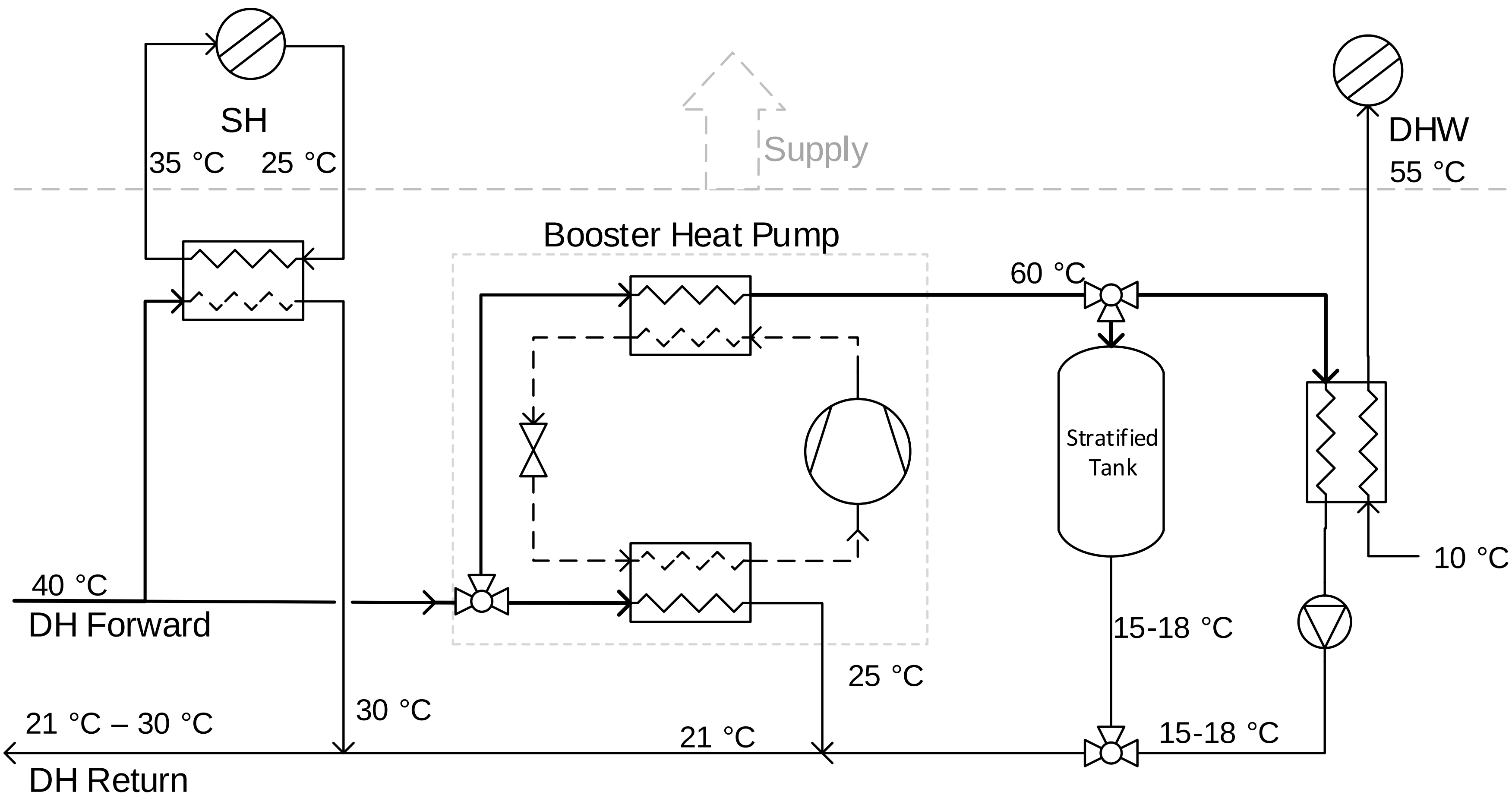
Agenda

- Introduction
- Motivation for using mixed working fluids
- Booster HP
  - Working fluid screening
  - Economic evaluation
- Ultra low temperature district heating mixtures
  - Off design analysis
  - System performance (incl. central HP with mixtures)
- Conclusions

Booster HP System

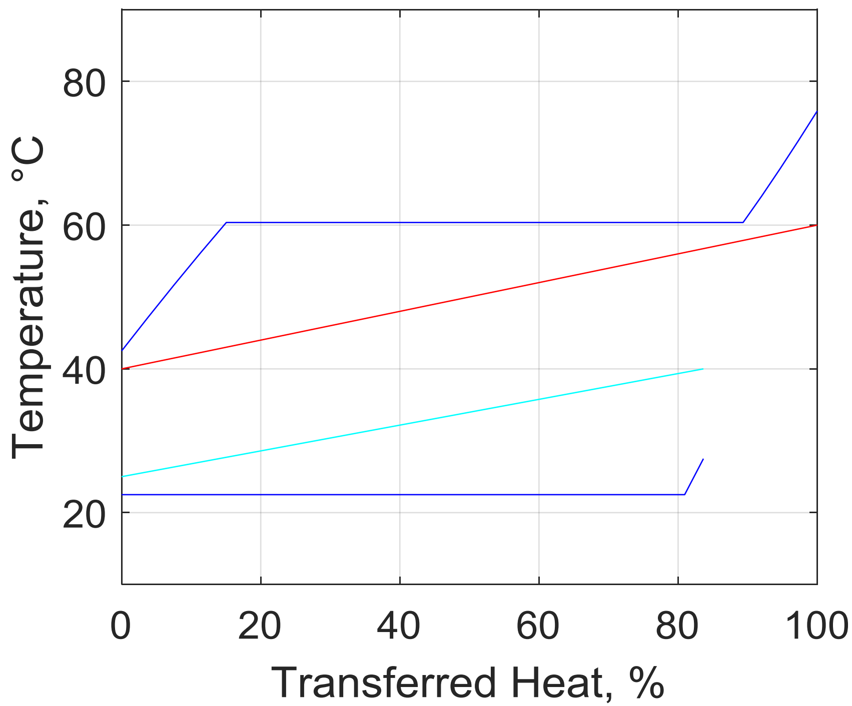


Motivation

<u>Heat Pump:</u>

Heat Source: 40 °C → 25 °C

Heat Sink: 40 °C → 60 °C



<u>R134a:</u>

COP = 6.11

$p_{\text{evap}} = 6.17\ \text{bar}, p_{\text{cond}} = 16.97\ \text{bar}$

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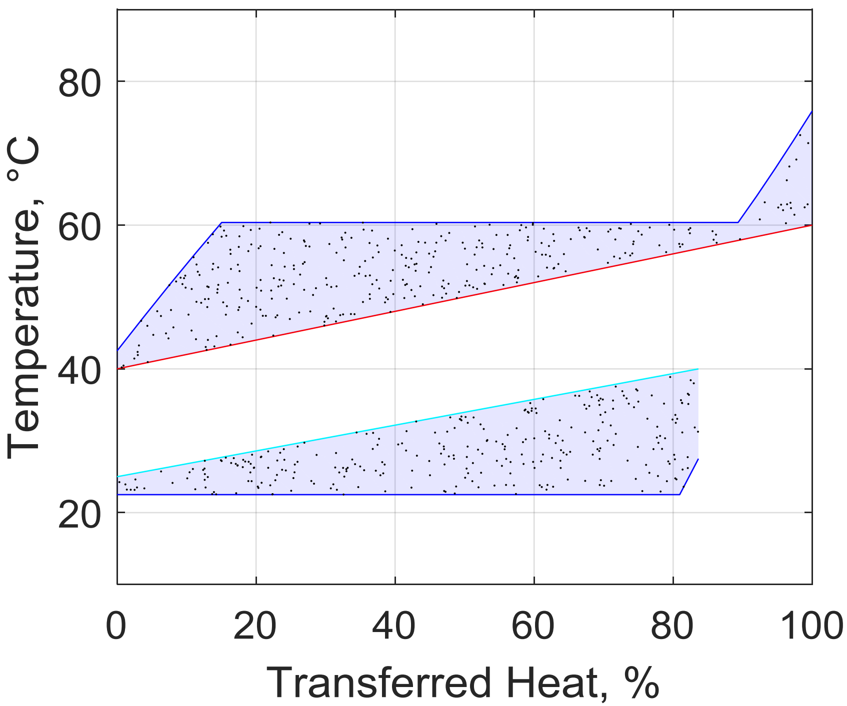

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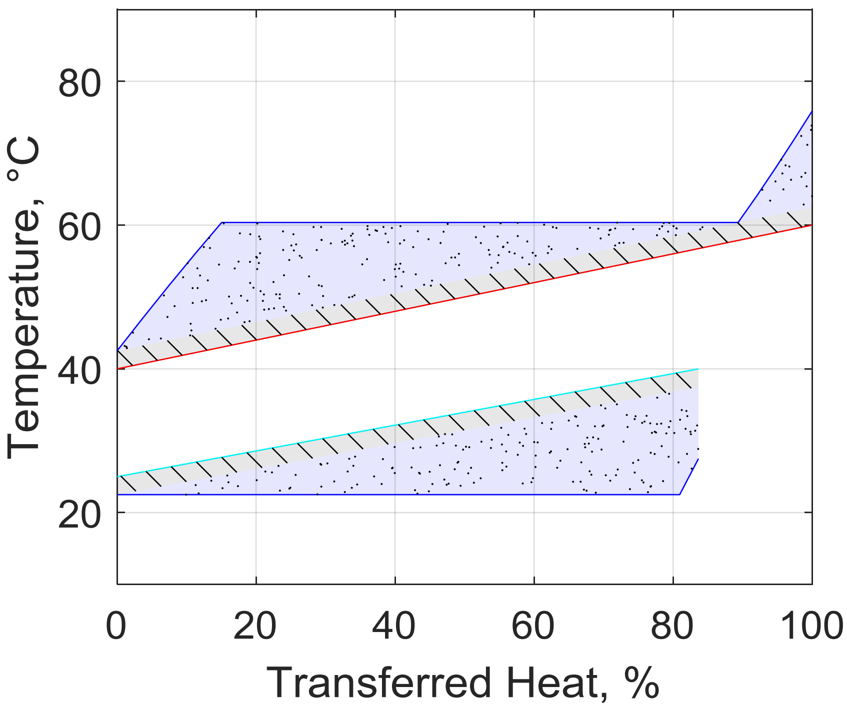

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$y^*_{\text{D,source,Fluid}} = \mathbf{19}\ \%,\ y^*_{\text{D,sink,Fluid}} = \mathbf{19}\ \%$

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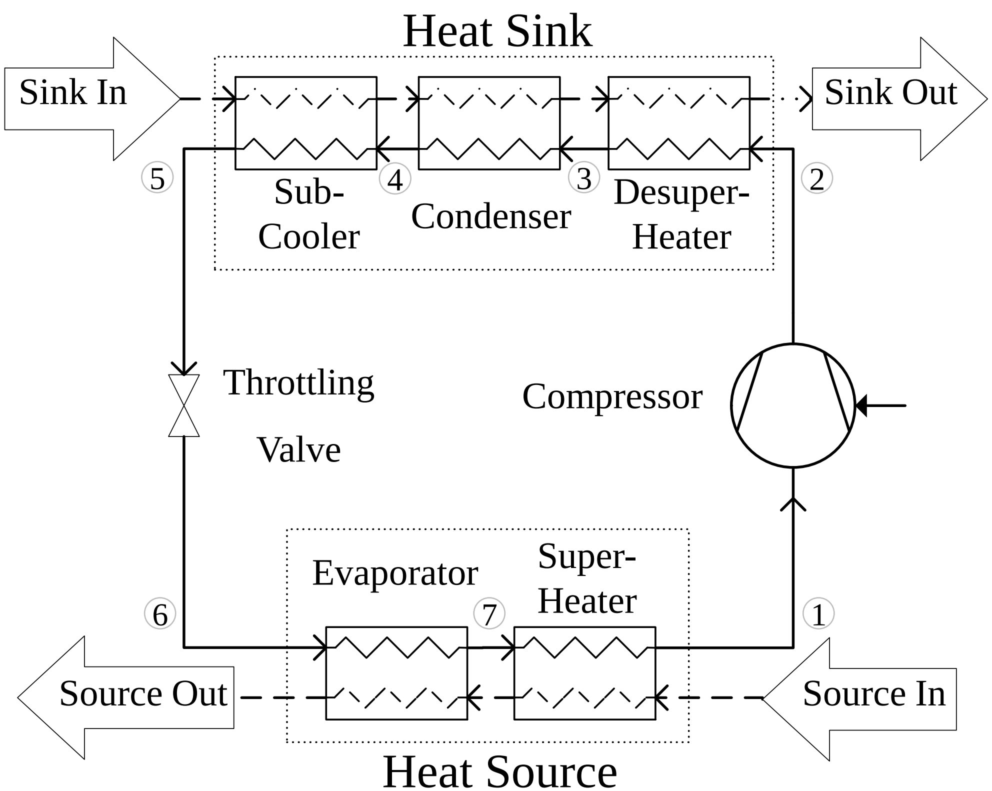
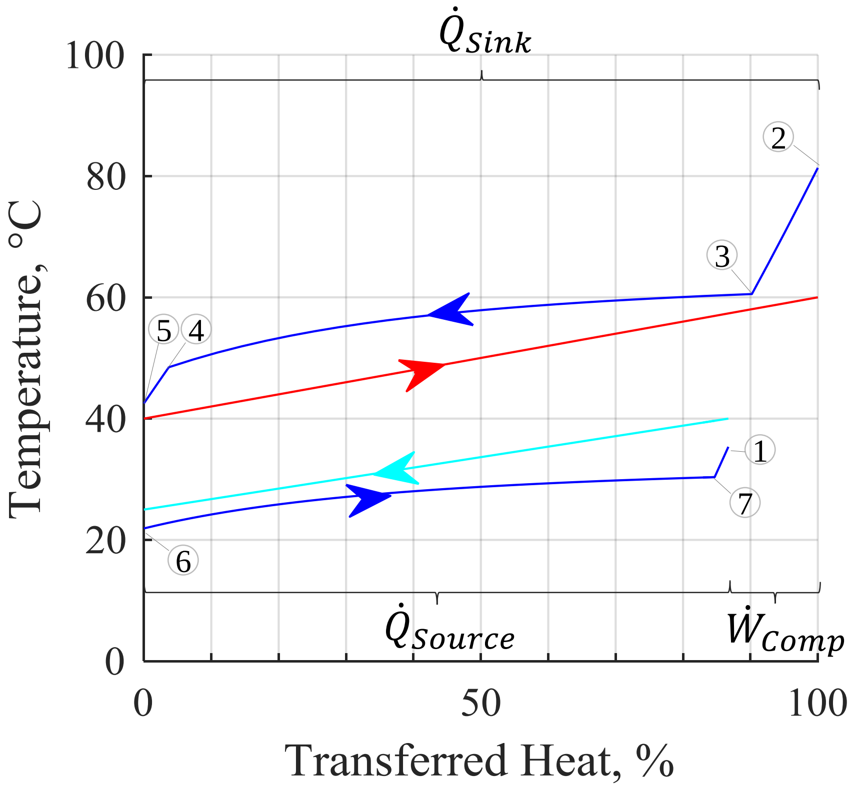
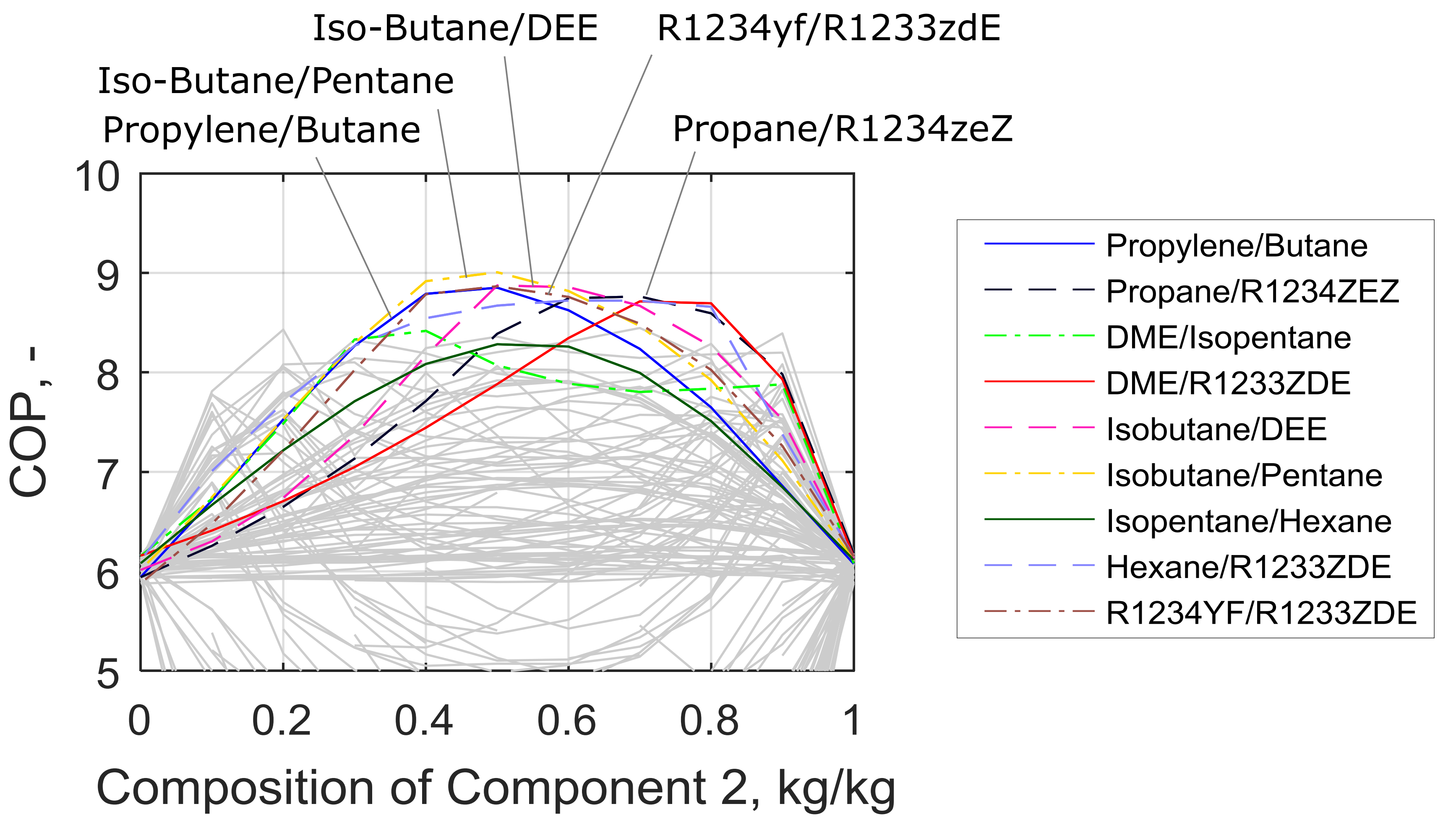
Working Fluid Screening: Thermodynamic Model



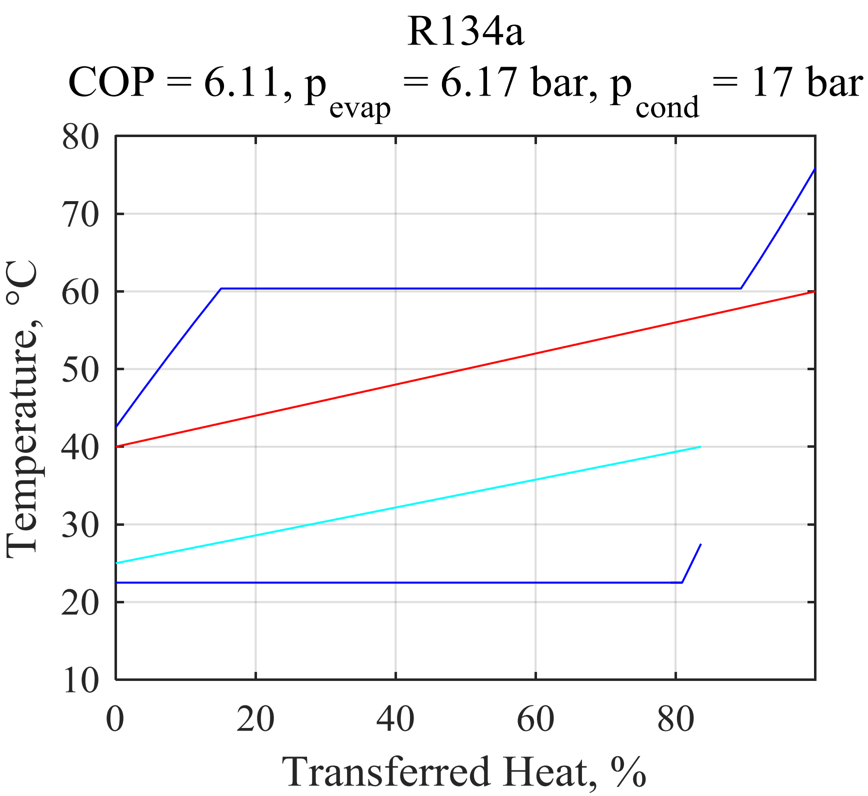


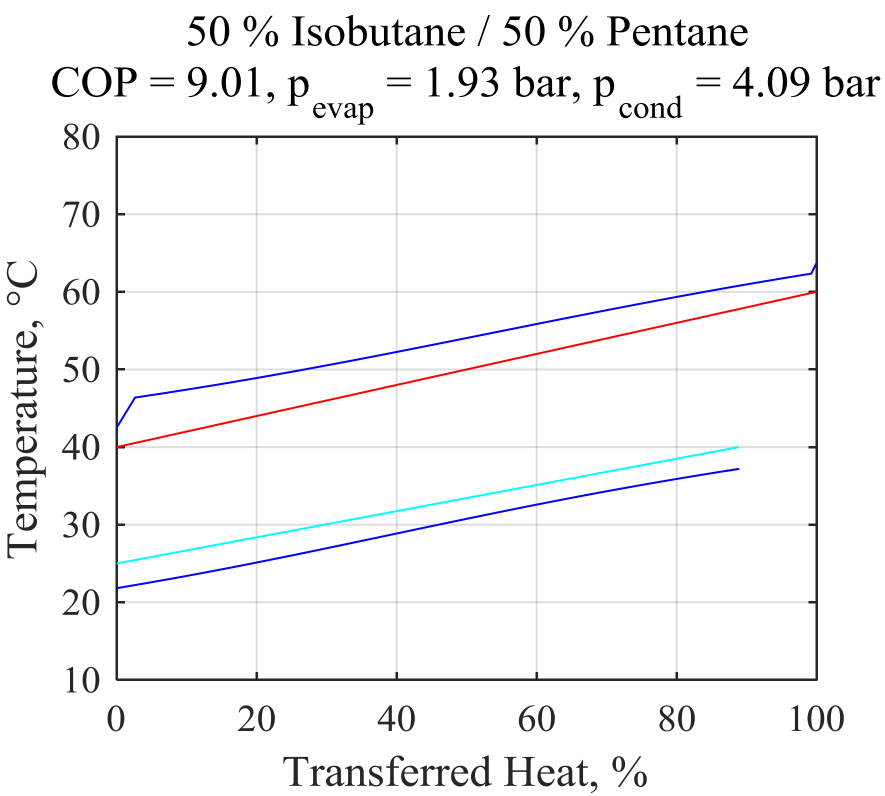
→ Simulation of all possible binary mixtures, considering 14 HCs + 4 HFOs

Working Fluid Screening: Results (0 K min. Super Heating)



Working Fluid Screening: Results

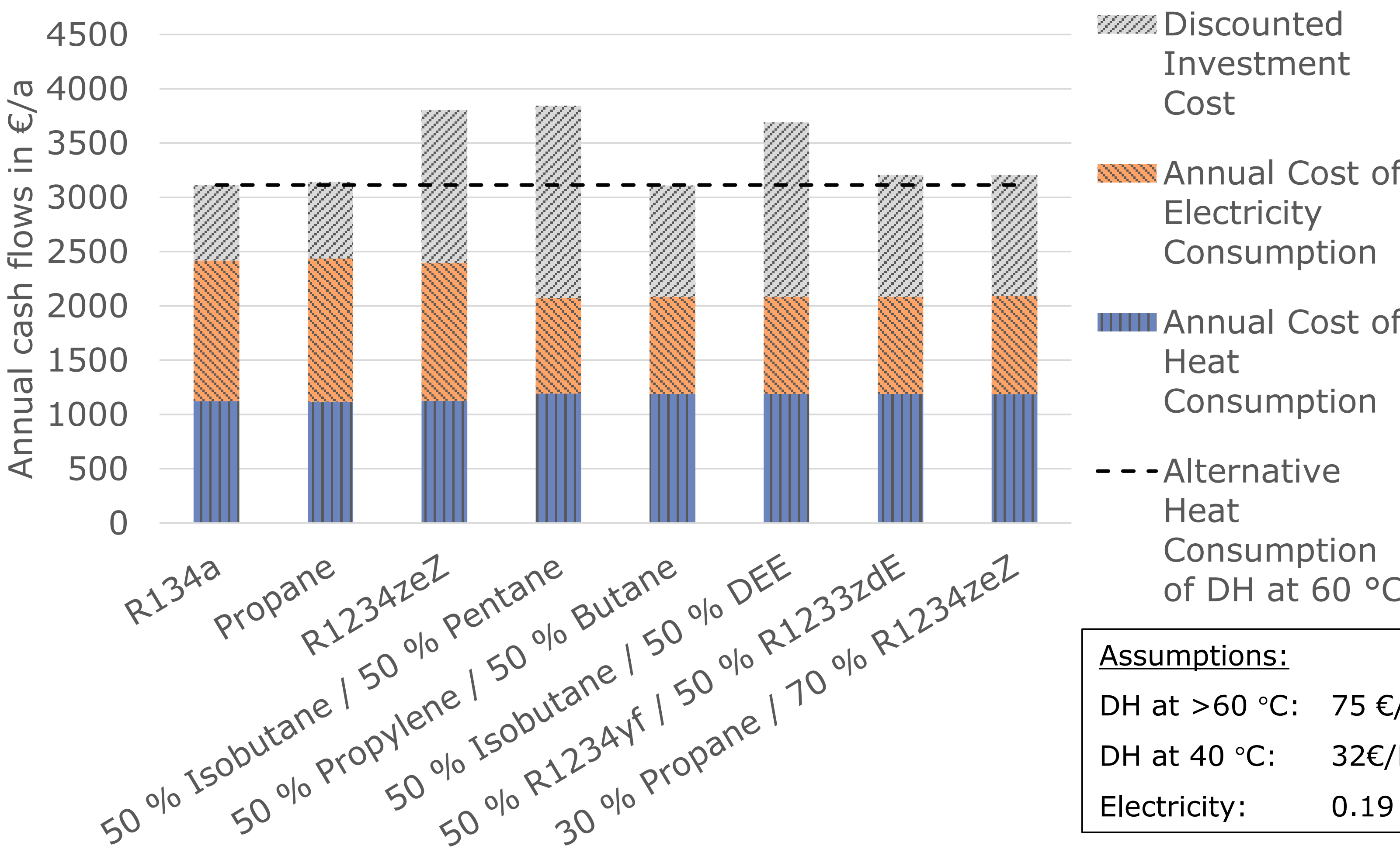




Booster HP: Investment Cost

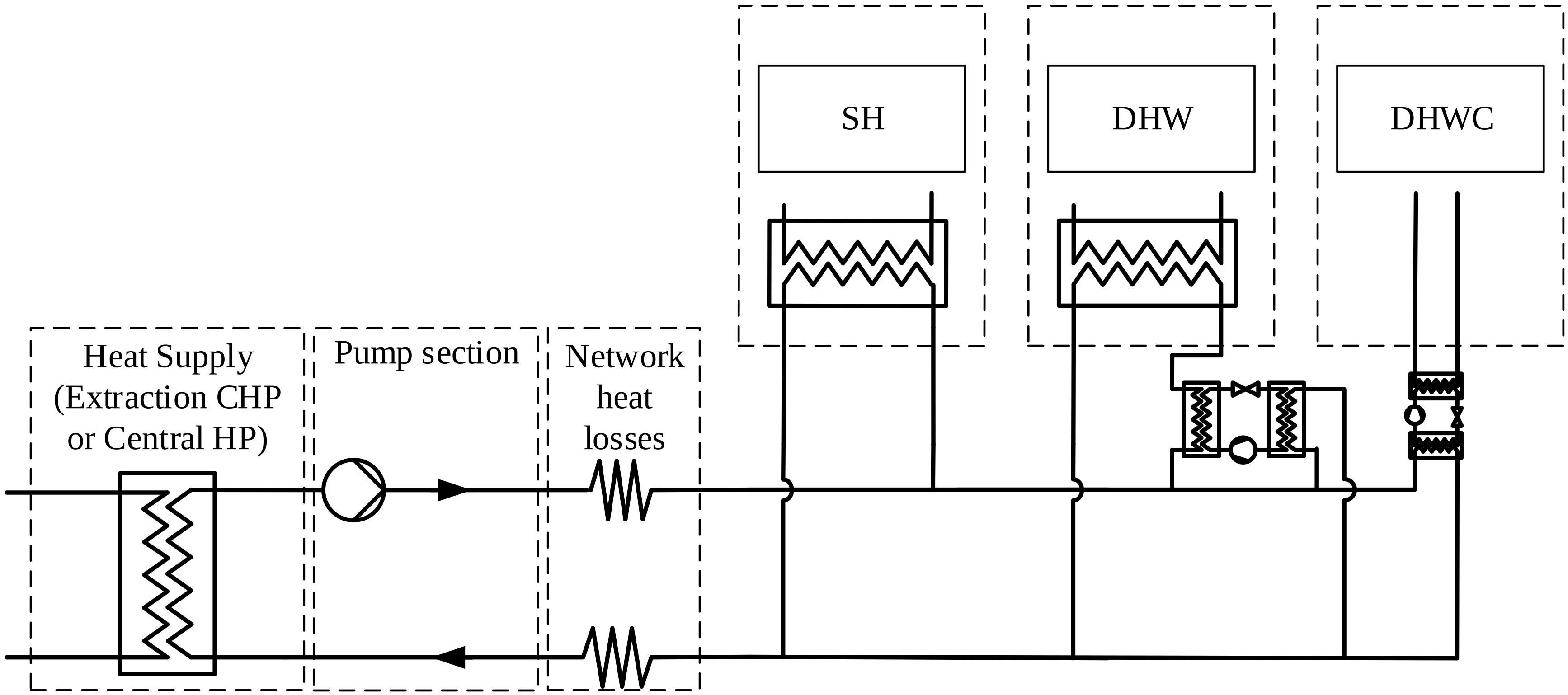
Working Fluid	COP $[-]$	A_{evap} $[m^2]$	A_{cond} $[m^2]$	$\dot{V}_{comp}$ $[m^3/h]$	PEC_{evap} [€]	PEC_{cond} [€]	PEC_{comp} [€]	PEC_{total} [€]	TCI_{total} [€]
R134a	6.11	1.52	2.11	9.21	289.01	350.88	1,525.83	2,165.71	8,662.86
Propane	6.01	1.52	2.13	7.56	288.54	353.80	1,564.14	2,206.49	8,825.94
50 % Propylene – 50 % Butane	8.85	5.09	4.28	9.92	668.31	582.06	1,943.18	3,193.55	12,774.20
30 % Propane – 70 % R1234zeZ	8.76	4.41	4.62	12.00	596.30	618.07	2,263.86	3,478.23	13,912.92

Booster HP:
Heat Generation Cost



Assumptions:	
DH at >60 °C:	75 €/MWh
DH at 40 °C:	32€/MWh
Electricity:	0.19 €/kWh

DH System: Layout



DH System: Off Design Analysis

Varying forward temperature:
$T_{forward} = (35 \dots \mathbf{40} \dots 45 \dots 50)$ °C

Constant T_{return}:
$T_{return} = 25$ °C

Constant ΔT_{source}:
$\Delta T_{source} = 15$ K

<table>
<tr><td></td><td colspan="7">$T_{\text{forward}} = T_{sink,in}$</td></tr>
<tr><td></td><td colspan="2">35 °C</td><td>40 °C</td><td colspan="2">45 °C</td><td colspan="2">50 °C</td></tr>
<tr><td></td><td colspan="7">$T_{return} = T_{\text{source,out}}$</td></tr>
<tr><td></td><td>20 °C</td><td>25 °C</td><td>25 °C</td><td>30 °C</td><td>25 °C</td><td>35 °C</td><td>25 °C</td></tr>
<tr><td>Medium</td><td colspan="7">COSP [-]</td></tr>
<tr><td>R134a</td><td rowspan="8">- 7 %</td><td rowspan="8">- 13 %</td><td>4.18</td><td rowspan="8">± 0 %</td><td rowspan="8">± 0 %</td><td rowspan="3">- 2 %</td><td rowspan="3">- 3 %</td></tr>
<tr><td>R290</td><td>4.17</td></tr>
<tr><td>R1234zeZ</td><td>4.18</td></tr>
<tr><td>50 % IsoButane – 50 % Pentane</td><td>4.30</td><td rowspan="5">- 3 %</td><td rowspan="5">- 4 %</td></tr>
<tr><td>50 % Propylene – 50 % Butane</td><td>4.29</td></tr>
<tr><td>50 % IsoButane – 50 % DEE</td><td>4.29</td></tr>
<tr><td>50 % R1234yf – 50 % R1233zdE</td><td>4.29</td></tr>
<tr><td>30 % Propane – 70 % R1234zeZ</td><td>4.29</td></tr>
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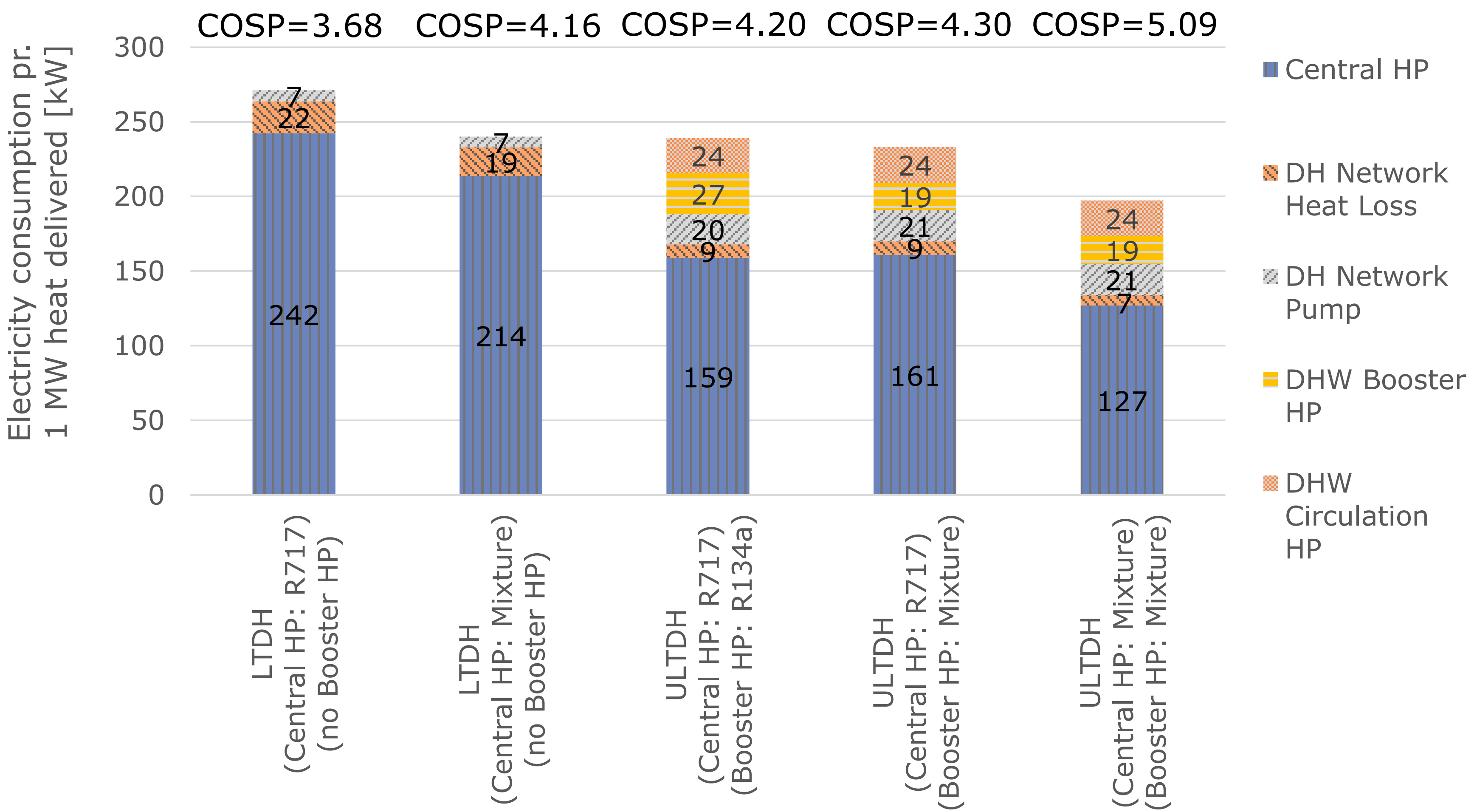
DH System: System Performance



Conclusions

- Thermodynamic performance of Booster HP:
  - R134a: COP = 6.11
  - 50 % Isobutane / 50 % Pentane: COP = 9.01 (+47 %)

- Economic performance of best mixtures similar to best pure fluid
  - Economic performance strongly dependent on boundary conditions
- Off Design of mixtures similar to pure fluids
- Temperature difference between forward and return should be maintained during off design
- Thermodynamic performance of DH System:

Working Fluid of HPs	Pure Fluid	Mixture	
LTDH	COSP=3.68	COSP=4.16	(+13 %)
ULTDH	COSP=4.20	COSP=5.09	(+21 %)
	(+14 %)	(+22 %)	