Higher Heat Pump COP through better temperature match

HPT TCP Annex 48: Commercial and Industrial Heat Pump Application VI DK

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Content

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- DTI: short presentation
- Theoretical maximum Heat Pump COP
  A pre assesment tool for system integration?

- Gradually heating of water
  The ISEC project
- Split condensing
  The FOSCAP project
- Utilizing the glide of the working fluid
  The High Heat and the MiReHP projects

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- A world class research and technology company converting the newest knowledge and technology into value
- 111 Years old, +1.100 people, 71 laboratories
- +13.000 clients in 65 countries
- Expert in production, materials, life sceince, business, energy, agro technology, meat rescearch, robotics and more
- Revenue 150 m. EUR

Refrigeration and Heat pump technology

- 35 people
- +1.200 m^2 laboratories, up to 2 MW cap, 9 climate chambers

Industrial heat pump development at DTI

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- Flexible Energy Optimized Split Condenser Ammonia Heat Pump - Foscap
- Mixed Refrigerant Heat Pump – MiReHP
- Ultra-high temperature hybrid heat pump for process application – HighHeat (HighHeat)
- Gradually heating of water – ISEC
- Development of Rotrex turbocompressor for steam compression
- Experimantal Development of Electric Heat Pumps in Greater Copenhagen District Heating System – SVAF 2
- Direct contact heat exchangers (water vapor, heat uptake at freezing)

- Projects on COP optimization of heat pump cycles
- Heat pumps and storage (hot and/or cold)

Maximum HP COP
A generic first assessment tool

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Motivation

Postulate: *Heat pumps are just "nice to have"*

- *The only purpose is heat supply in a more appropriate way (like cost (incl. taxes), CO_2 foot print, CSR, …)*
- *They do not solve technical problems*

It is "all" about COP…
(….and first cost, maintenance…)

- Many heat pump solutions exists
- A way to first assessment is needed…????

Heat pump COP and system design calculations

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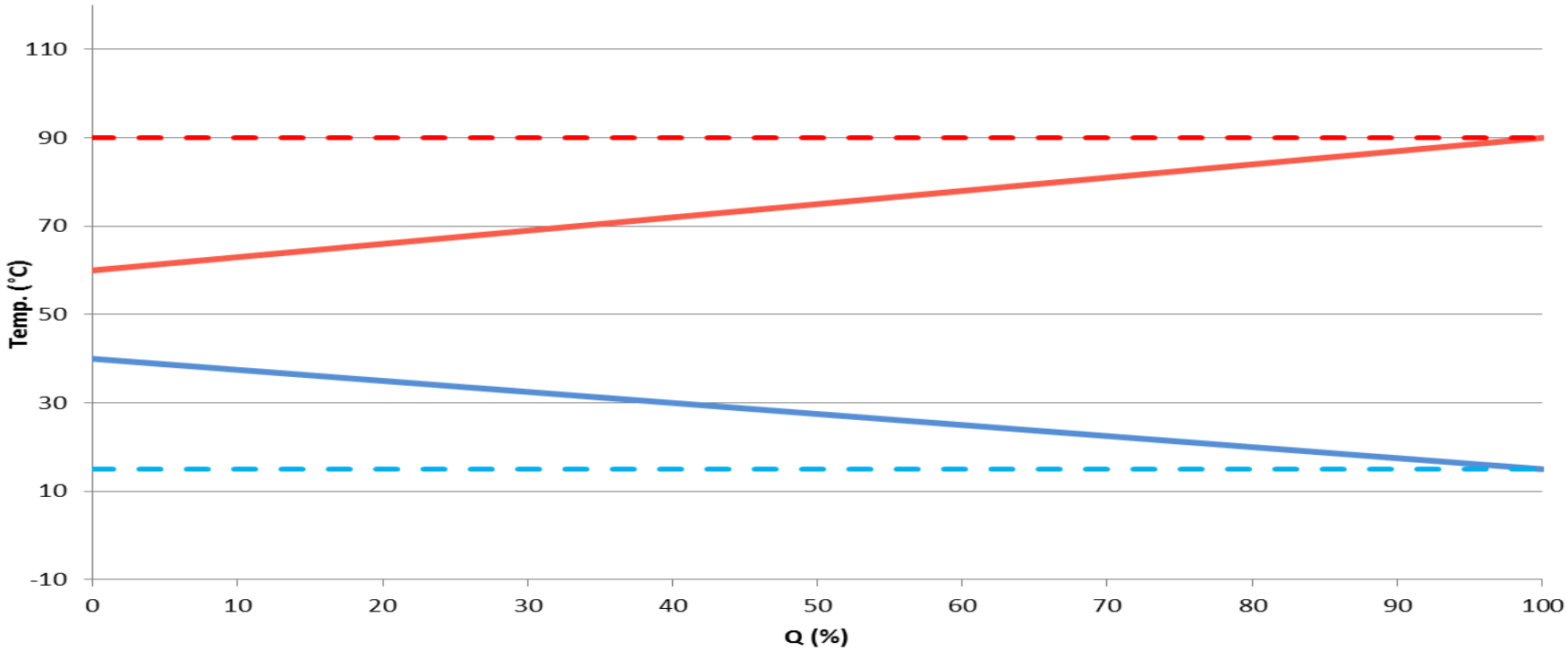
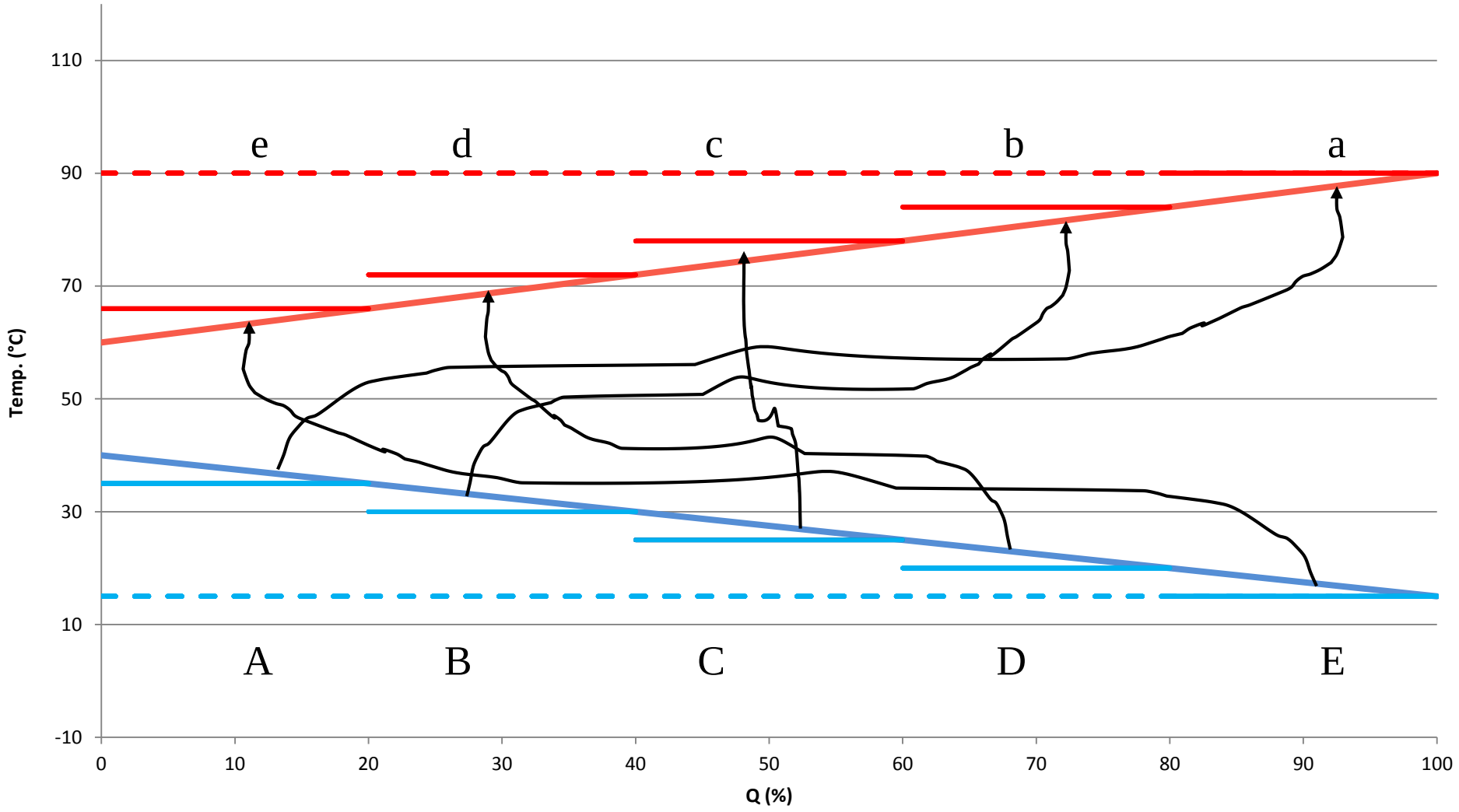
Theoretical limit: Carnot cycle

$$COP_{HP,Car} = \frac{T_H}{T_H - T_L}$$ (T in K)



Constant temperature source and sink: 15/90°C > COP_C = 4,84

Higher COP by splitting up



Higher COP by splitting up

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Process	T_L [°C]	T_H [°C]	$COP_{HP,Car}$ [-]	Q_H [kW]	P [kW]
A-a	35	90	6,60	1	0,1515
B-b	30	84	6,61	1	0,1513
C-c	25	78	6,62	1	0,1510
D-d	20	72	6,63	1	0,1507
E-e	15	66	6,65	1	0,1504
			Total	5	0,7549

COP = 6,62 (+37%)

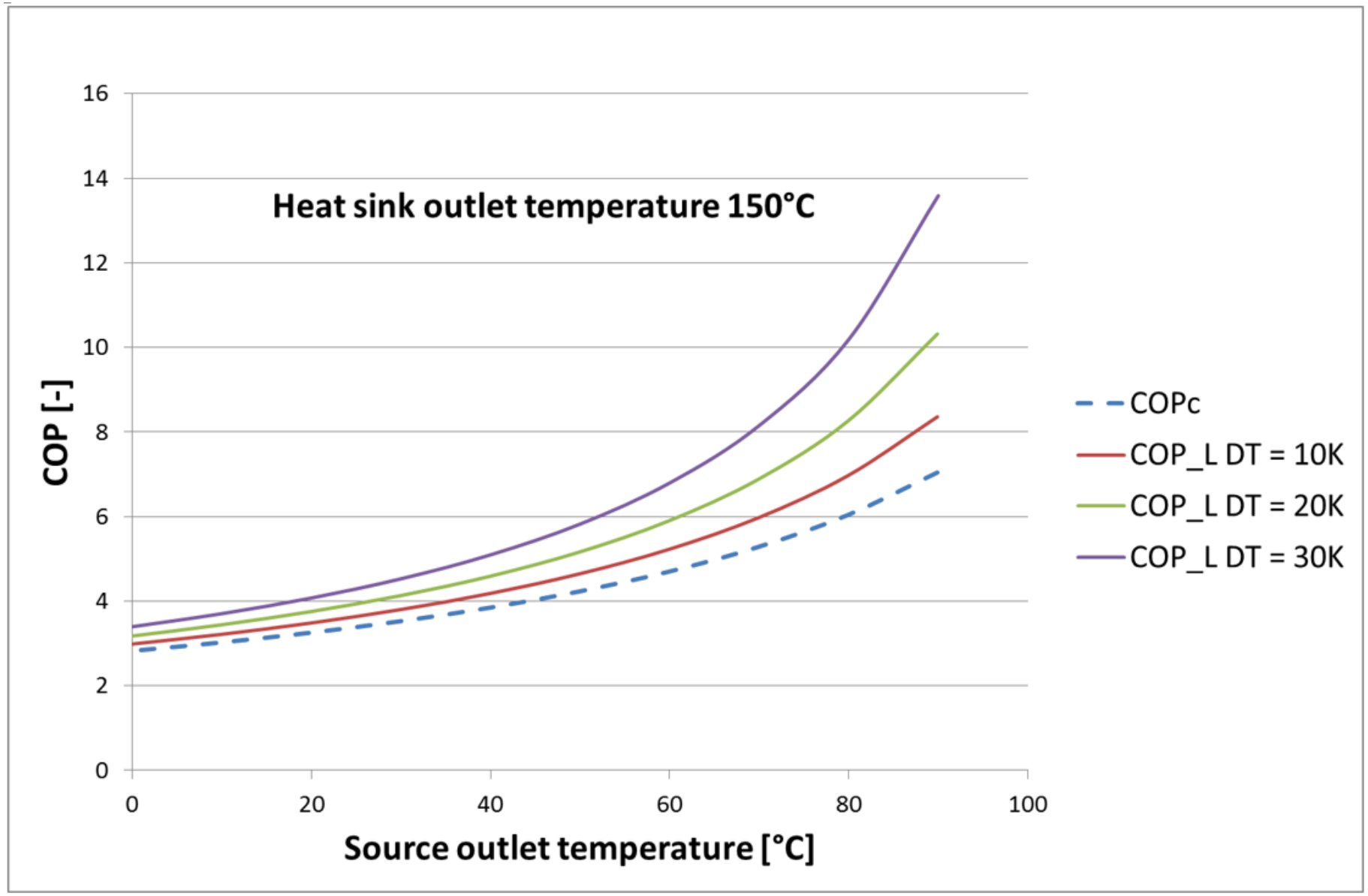
Lorenz COP

$$COP_{HP,Lor} = \frac{T_{lm,H}}{T_{lm,H} - T_{lm,L}}$$

No.	Heat source (°C)	Heat sink (°C)	COP_C	COP_L
Ex.	40 > 15	60 > 90	4,84	7,33
A	8 > 4	85 > 95	4	4,3
B	40 > 15	60 > 90	4,8	7,3
C	25 > 20	70 > 110	4,3	5,4
D	80 > 20	85 > 90	5,2	9,4

(+ 51%)

Theoretical maximum COP



(First) system design calculation

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Theoretical COP can be used for first assessment analysis of system design without knowing the heat pump technology.

Carnot and Lorenz efficiency:

- *How good a real heat pump system is compared to theoretical maximum*

$$\eta_{Car} = \frac{COP_{HP}}{COP_{HP,Car}}$$

$$\eta_{Lor} = \frac{COP_{HP}}{COP_{HP,Lor}}$$

(First) system design calculation

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- In the best industrial refrigeration systems 60% of COP_C have been realized, so high COP can also be expected by heat pumps…

$$COP_{HP} = COP_{HP,Lor}\eta_{Lor} \quad > \quad COP_{HP,Lor} = \frac{COP_{HP}}{\eta_{Lor}}$$

Example:

- System requirement to the heat supply: 150°C
- Based on the precalculations (energy cost etc.) COP = 3,0 is needed.
- Using η_{Lor} = 60% > $COP_{HP,Lor} = \frac{3,0}{0,6} = 5$

(First) system design calculation

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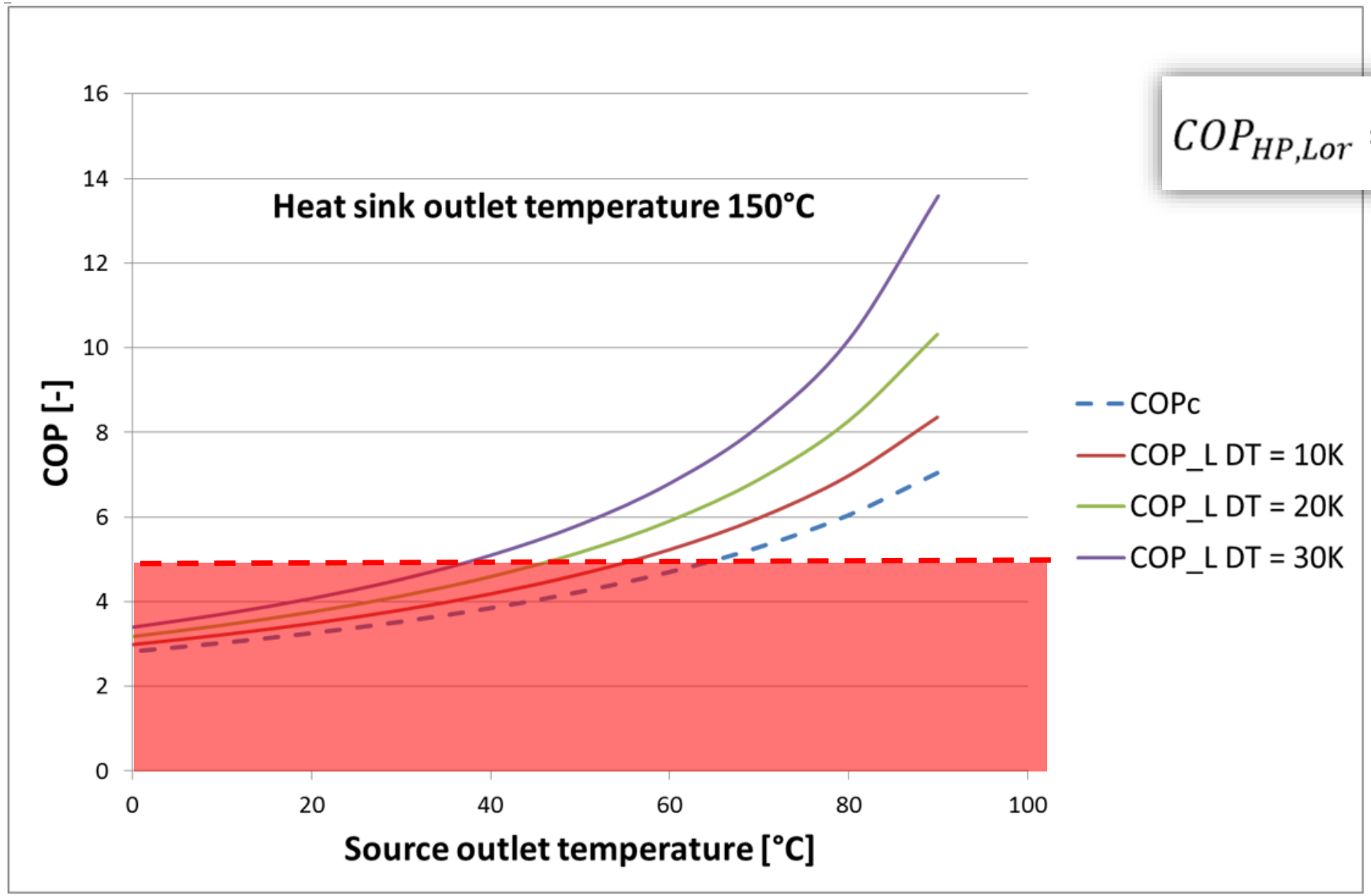


$$COP_{HP,Lor} = \frac{3{,}0}{0{,}6} = 5$$

Fundamental process analysis

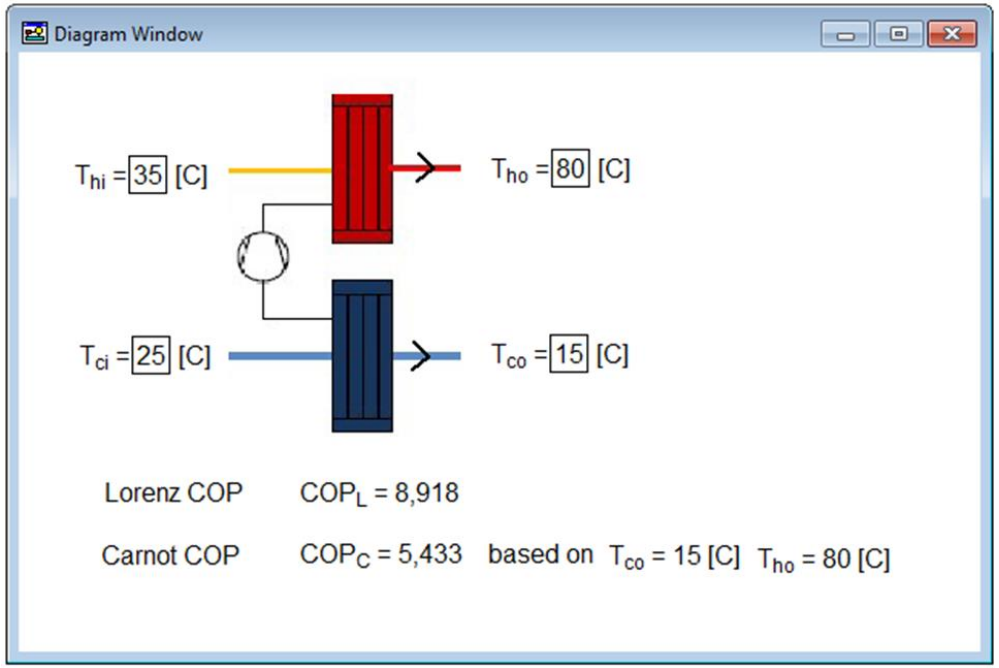
Case:

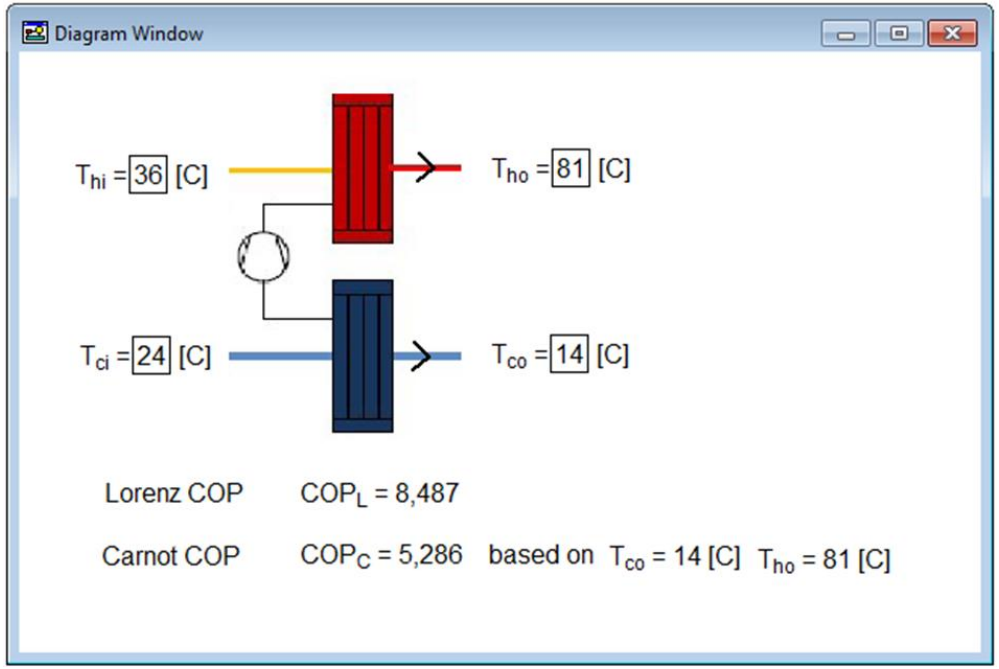
- Sink: Heating from 35 to 80°C
- Source: Cooling from 25 to 15°C

- COP_C = 5,4, COP_L = 8,9

Pinch temperature 1K

- COP_C = 5,3 > -2,7%
- COP_L = 8,5 > -4,8%





ISEC "Highly Efficient Thermodynamic Cycle with **I**solated **S**ystem **E**nergy **C**harging"

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- Traditionally full temperature increase in one step

Objective:

- up to 50 % better energy efficiency of heat pumps by optimum storage usage which reduces the average temperature level in the heat pump
- …For systems having high temperature change on hot (and/or cold) side

- Suppored by the Danish EUDPprogram (no. 64013-0110)
- Partners: Svedan, Innotek, Alfa Laval, Arla Foods, Bjerringbro DH, Metro Therm, DTU and DTI.

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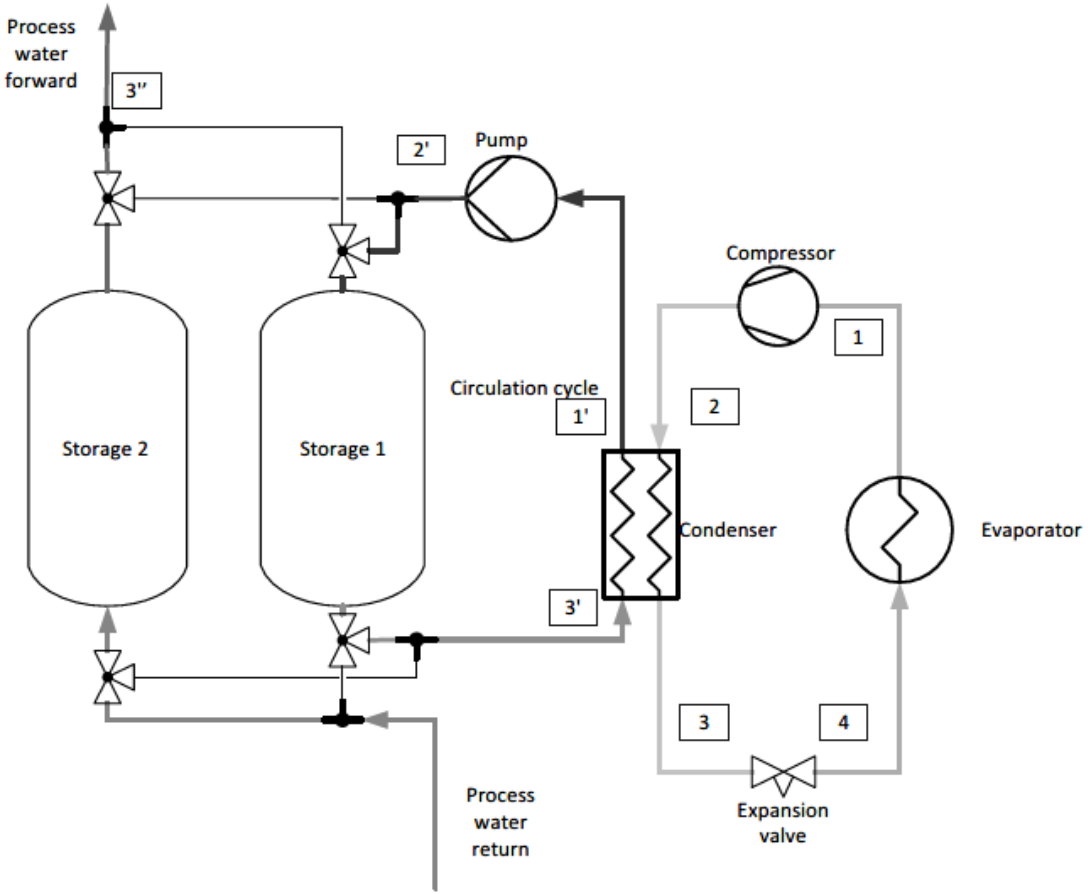

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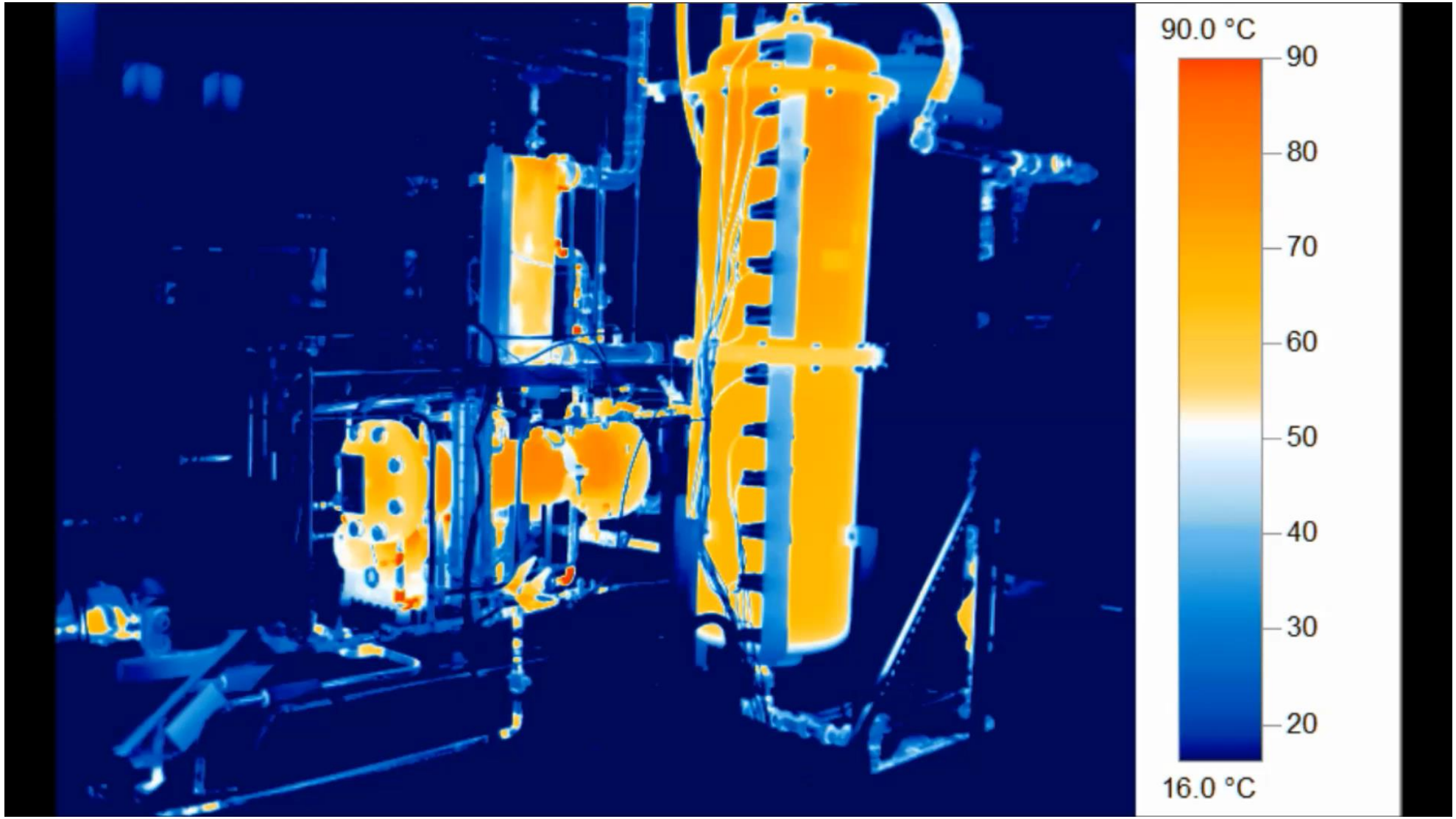

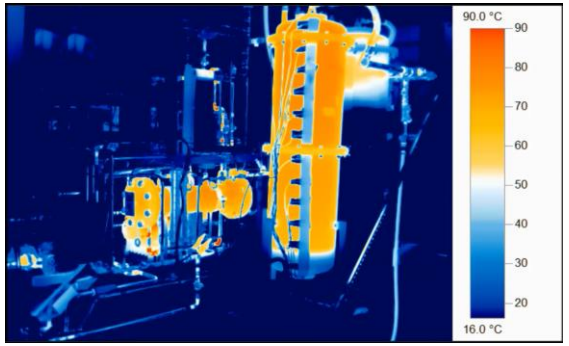

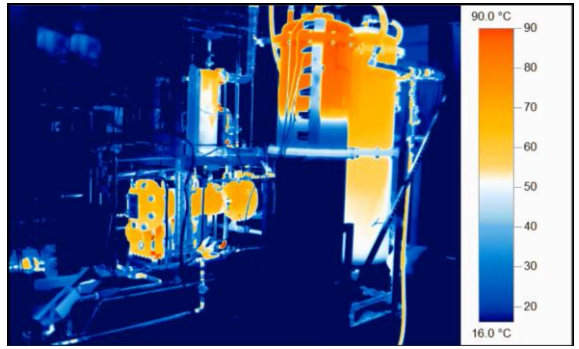

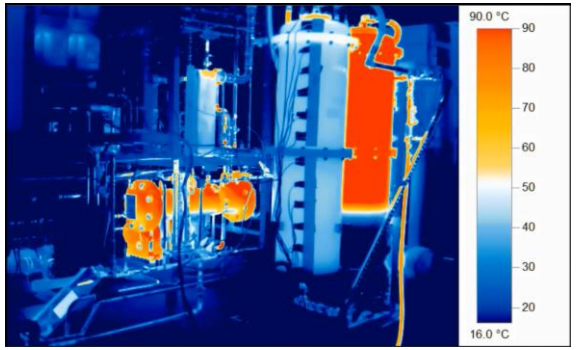

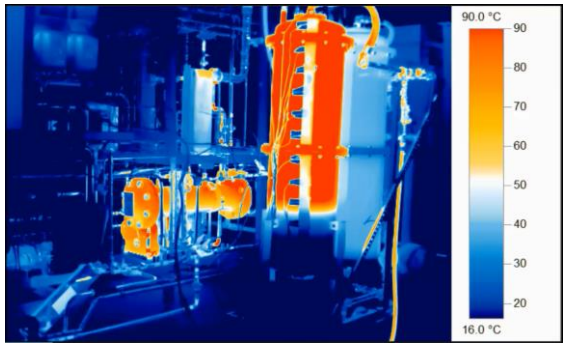

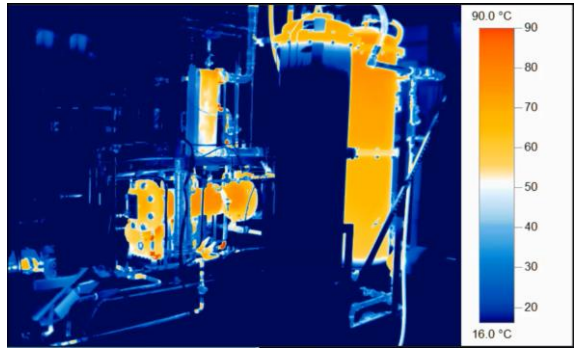

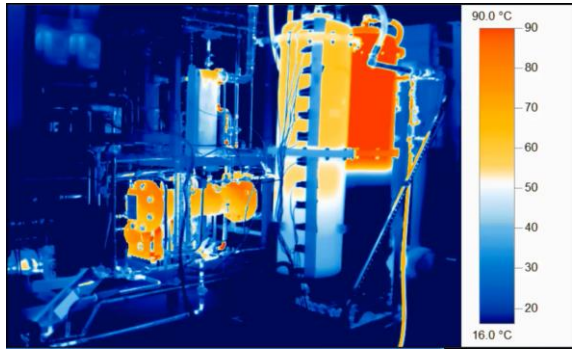

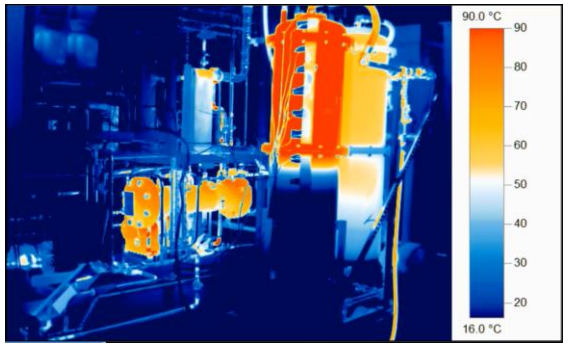

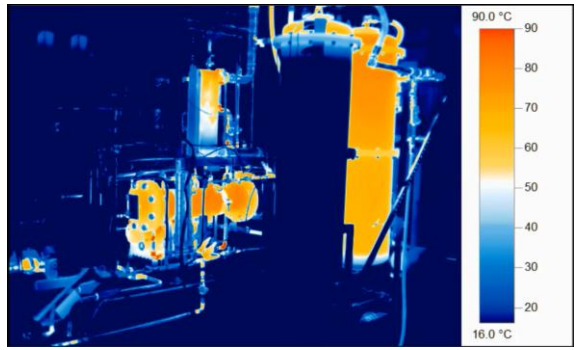

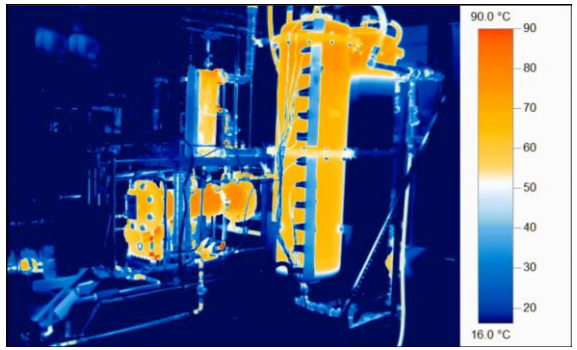

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FOSCAP "Flexible Energy Optimized Split Condenser Ammonia Heat Pump"

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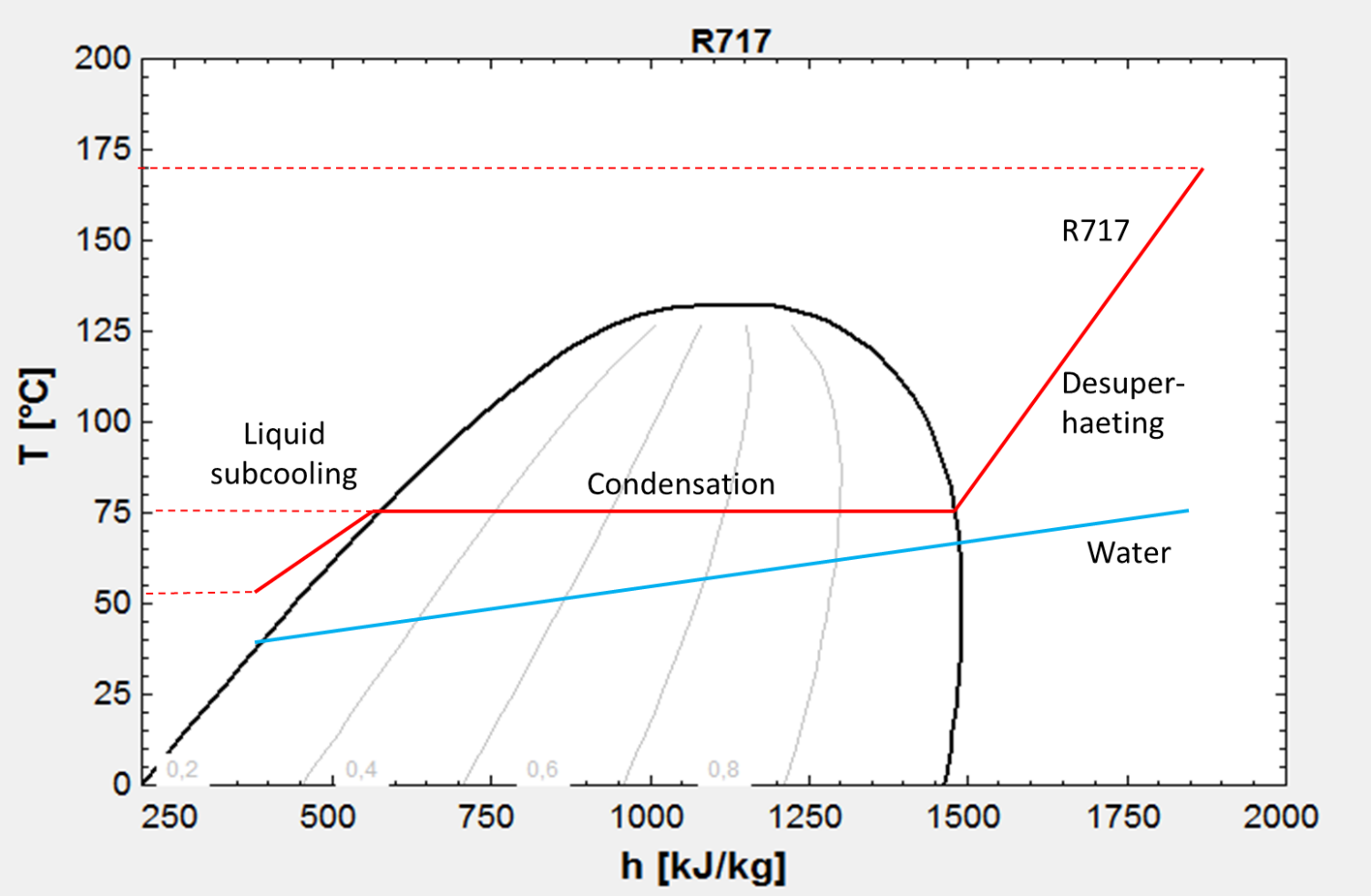
Objective: Improvement of performance and cost of HP´s by use of

- Split condenser
- Optimized heat exchangers
- Higher outlet temperature



Single condenser:

ex. 300 plates

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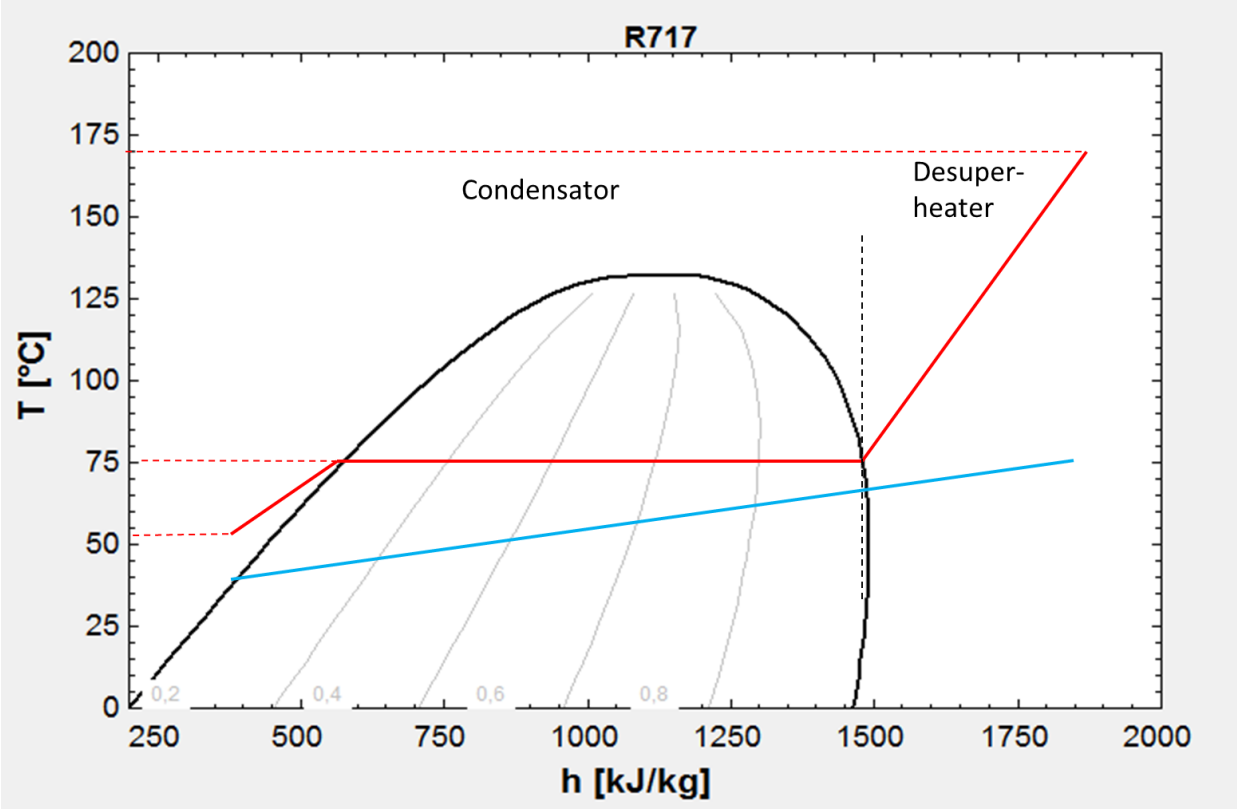
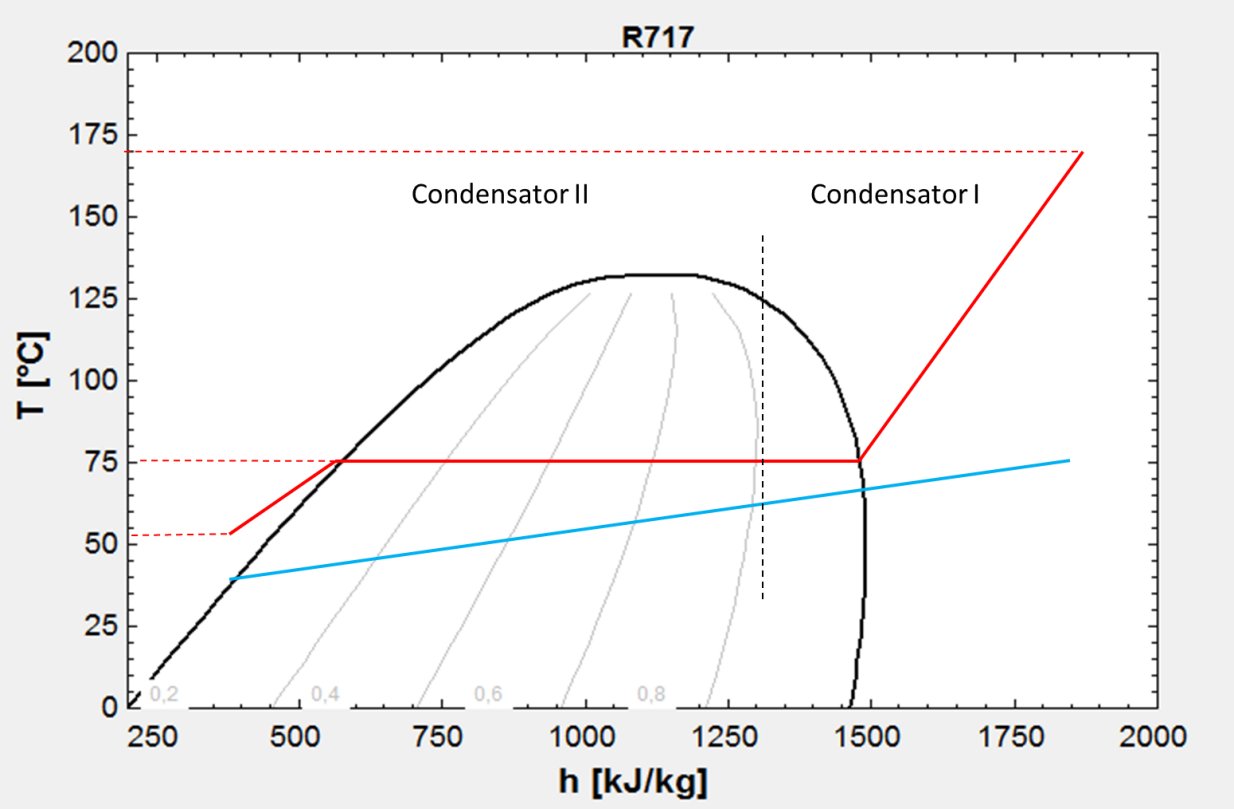
Two heat exchangers:

Desuperheater: 50 plates
Condenser: 200 plates (reduc. 17%)



Condenser I: 50 plates
Condenser II: 150 plates (reduc. 33%)



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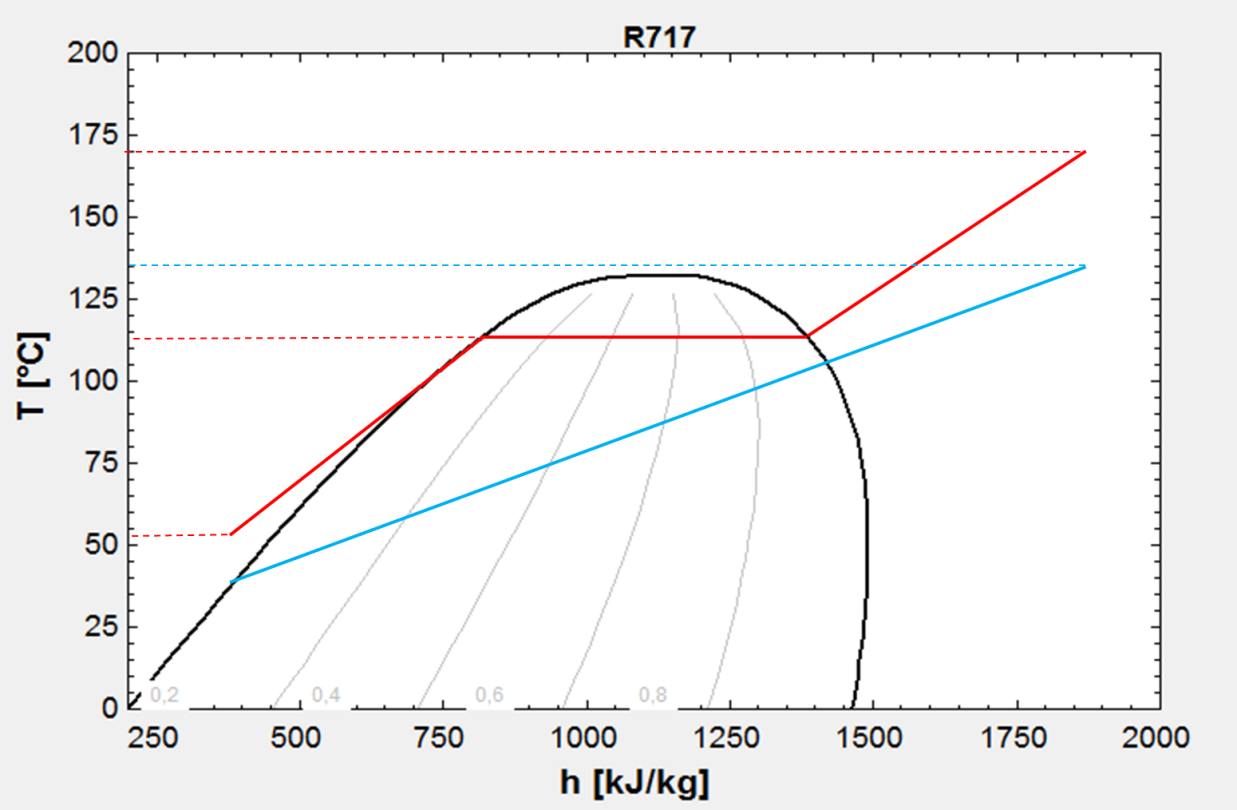
Higher outlet temperatures:

Higher condensing pressure =

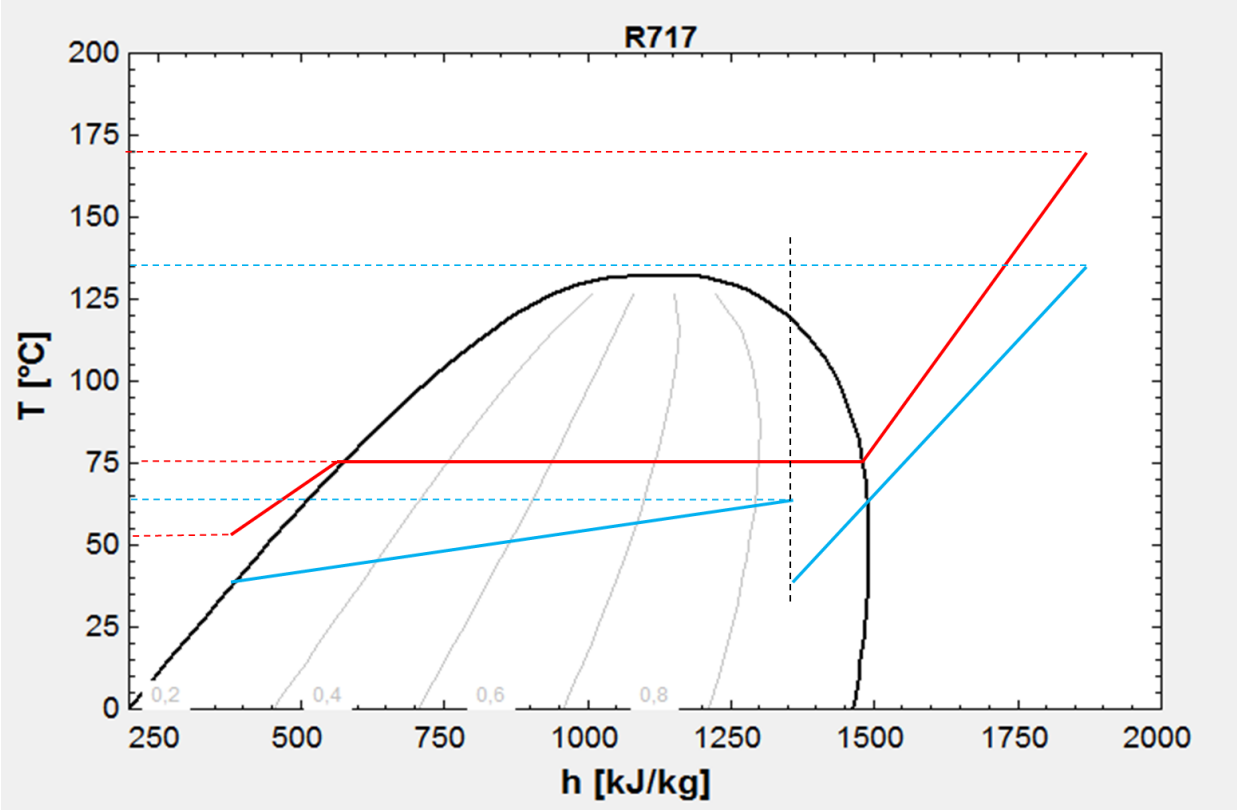
Lower COP



Split streams

Ex. 40% @ 130°C, 60% @ 65°C

Same COP



FOSCAP

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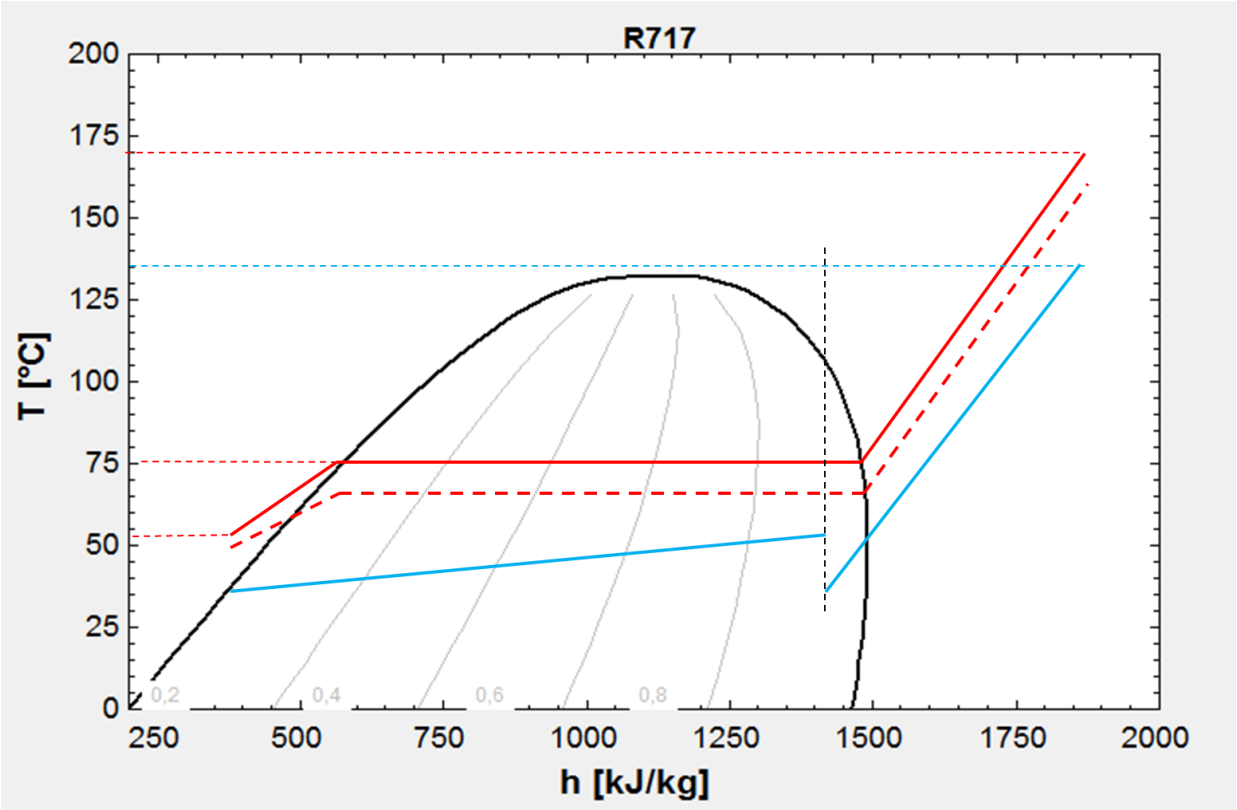
- In some cases: Reduction of condensing pressure possible = Higher COP



- Supported by the Danish PSO and EUDP program (no. 64013-0543)
- Partners: Svedan, Innotek, AlfaLaval, HOFOR, Mayekawa, Egaa S&M, Bjerringbro DH, DTU and Arla

HighHeat: Development of ultra-high temperature hybrid heat pump for process application

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Objective

- Increase the operating limits of the hybrid process by using the new standard components for higher pressures.
- Demonstrate efficient and reliable high capacity heat pump for high temperatures up to 130-145°C.
- Investigation of possible implementation into specific processes and the conduction of a general market survey.
- Lab (160-180°C) and full scale (>1 MW) demonstration.

Funded by the Danish EUDP program no. 64011-0351. Ends Dec. 2018.

Partners: Hybrid Energy, Innoterm, Process Engineering, Arla, Bigadan and SXP

Absoption compression heat pump process

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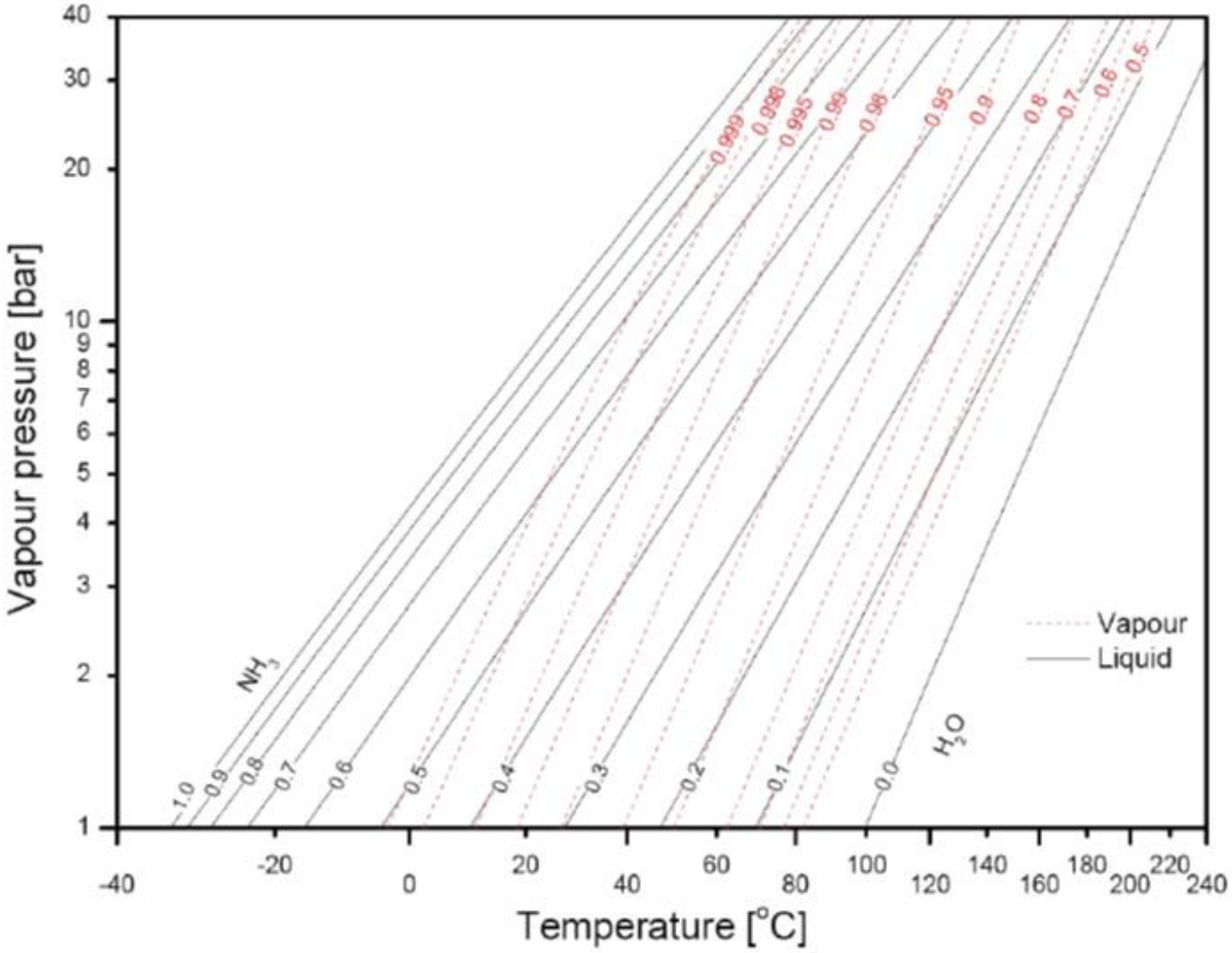

Absoption compression heat pump process

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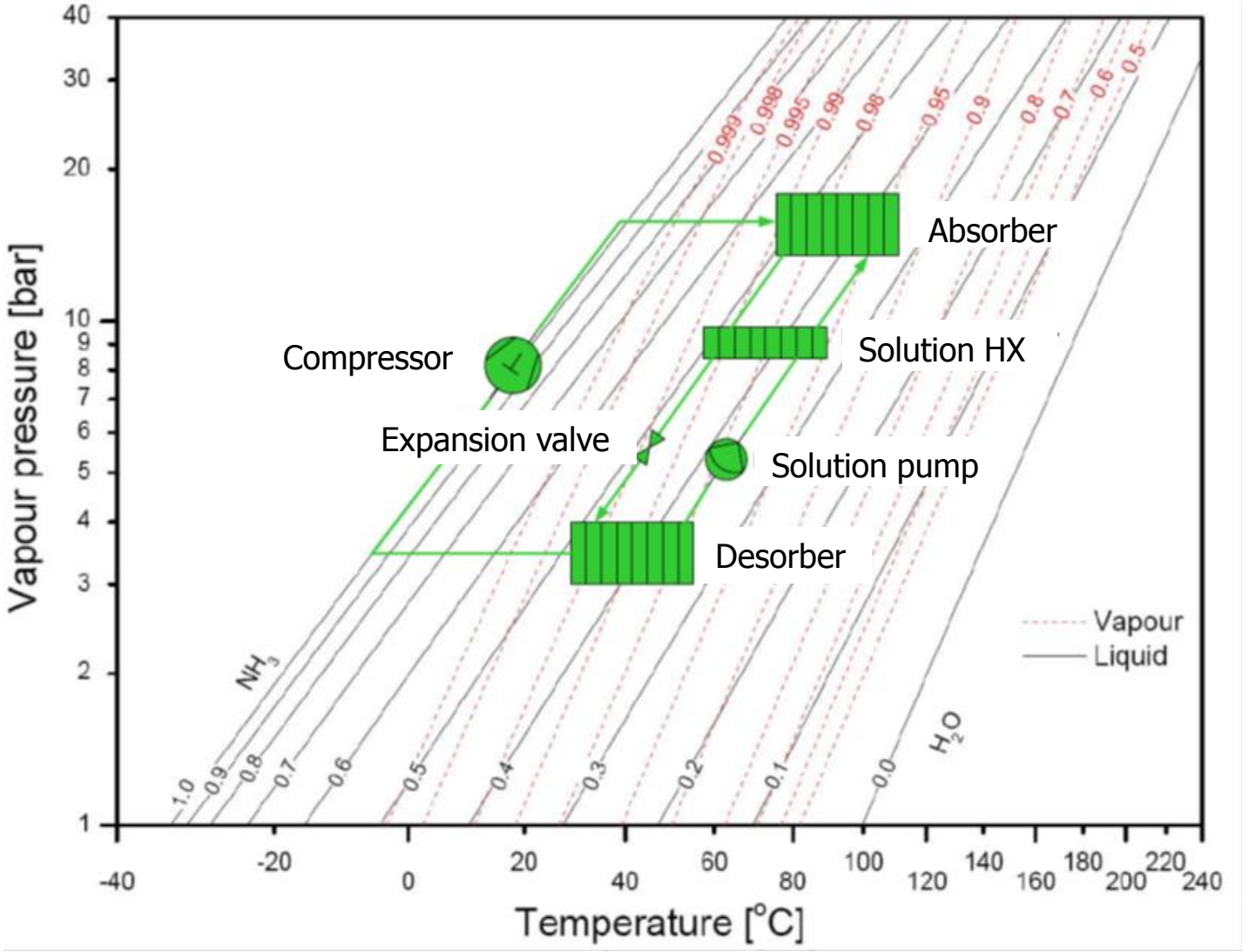

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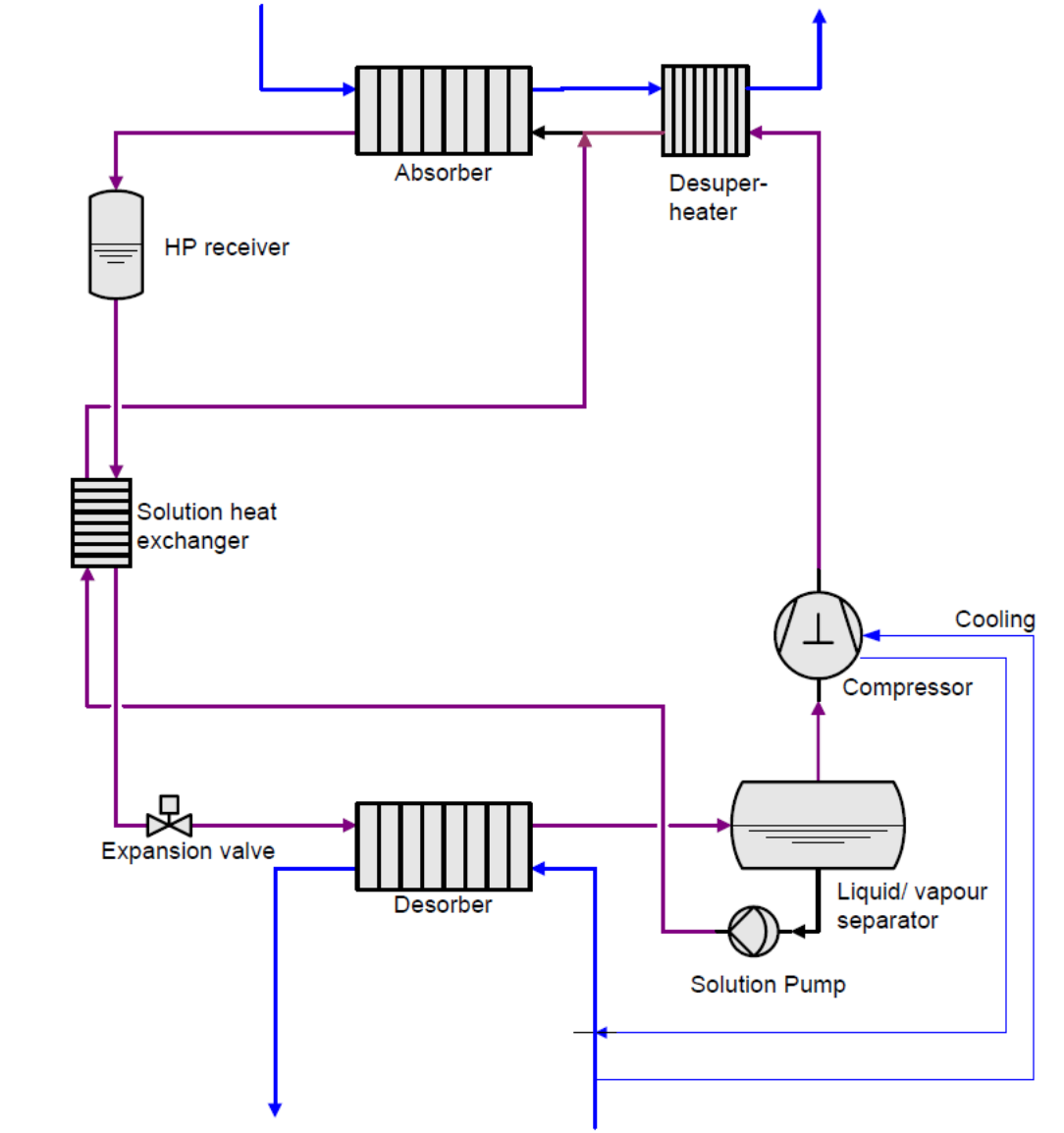

Absoption compression heat pump process

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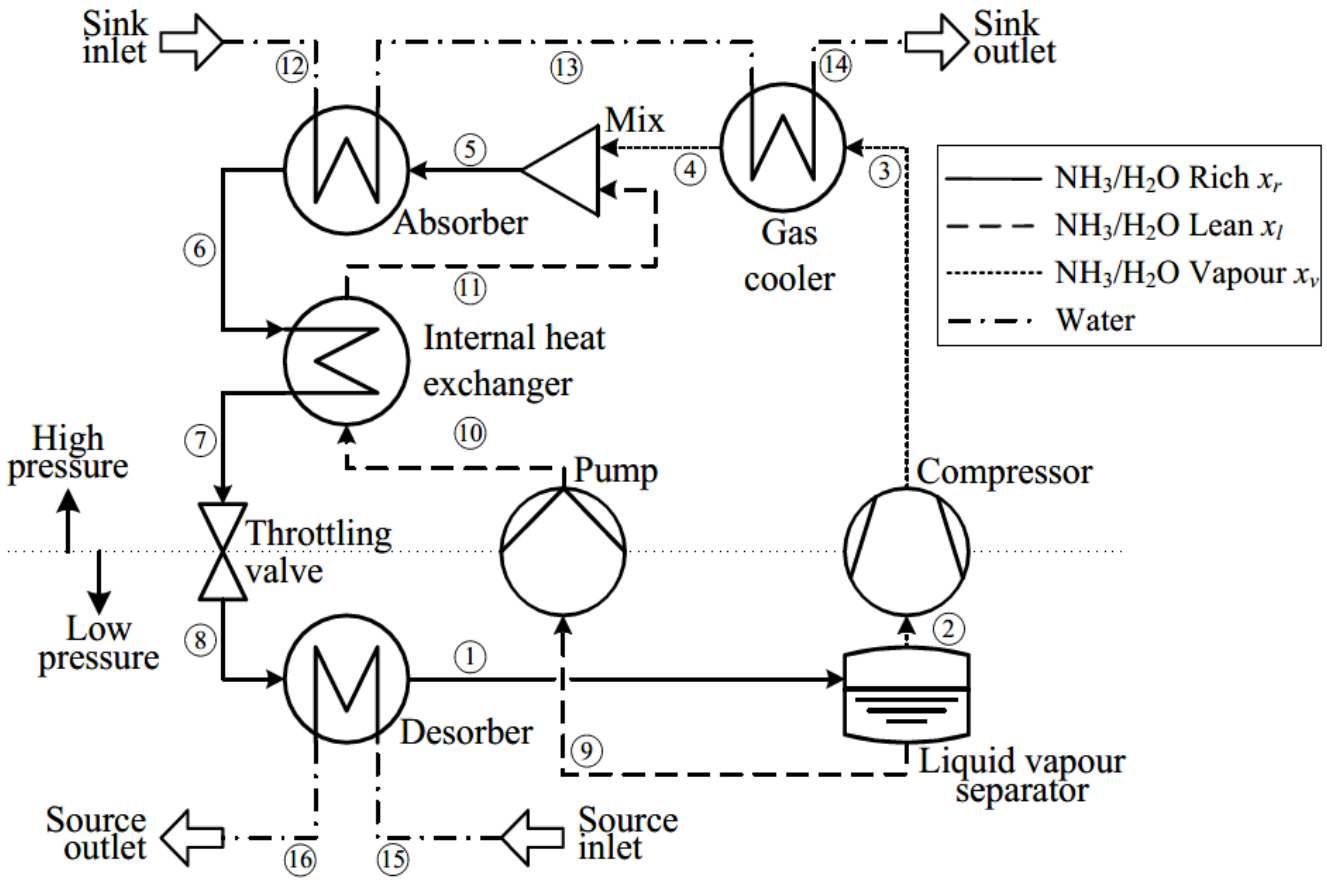

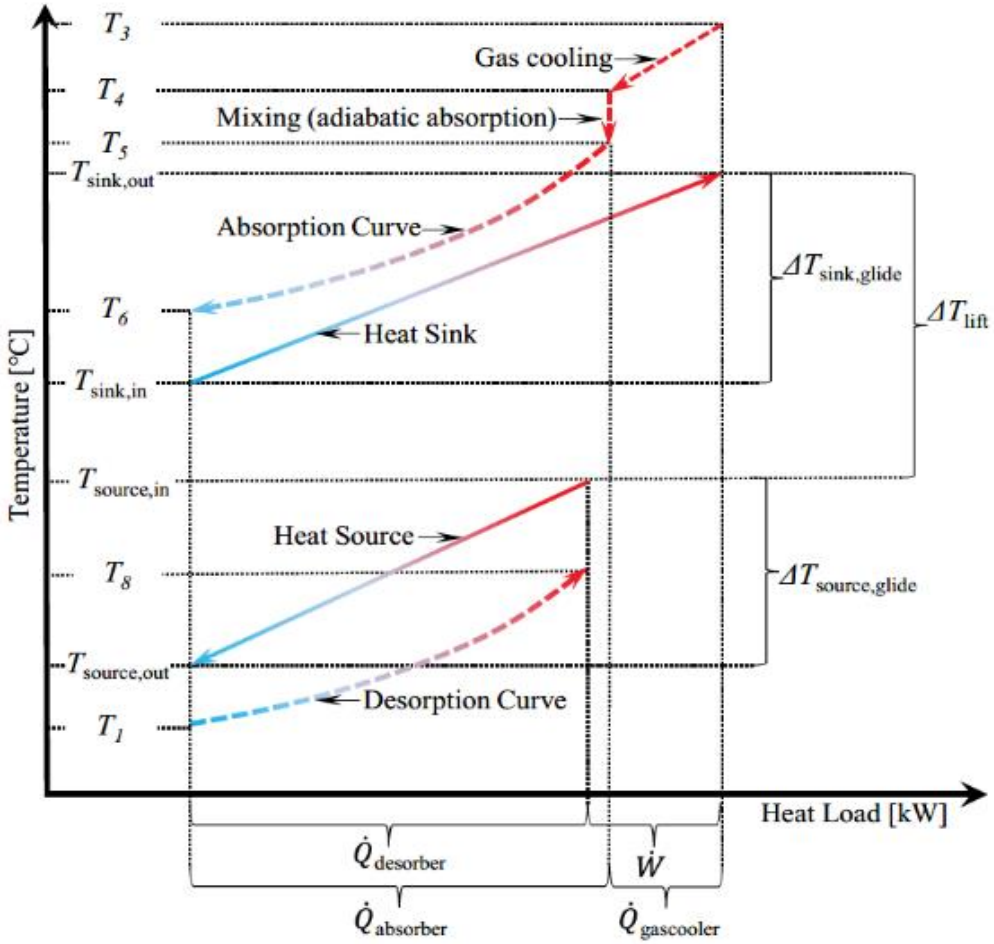

800kW three-stage system in sewage treatment plant

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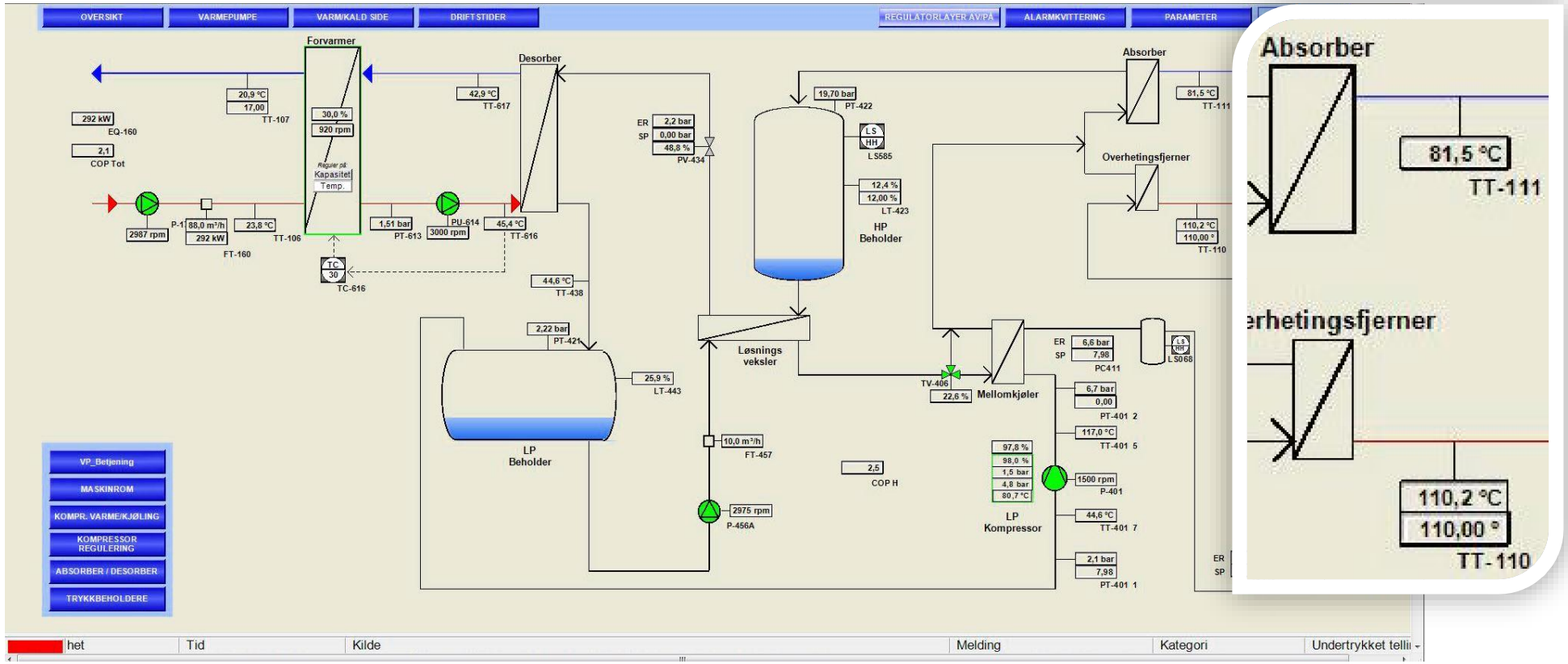

$T_{L,i}$ = 22.5°C, $T_{L,o}$ = 19.4°C, $T_{H,i}$ = 79.1°C, $T_{H,o}$ = 108.4°C,
Q_H = 540 kW, P_{tot} = 198 kW.
COP_{HP} = 2.72, η_{Car} = 63%, η_{Lor} = 54%

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Thank you

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