Improving energy efficiency of carbon capture processes with heat pumps

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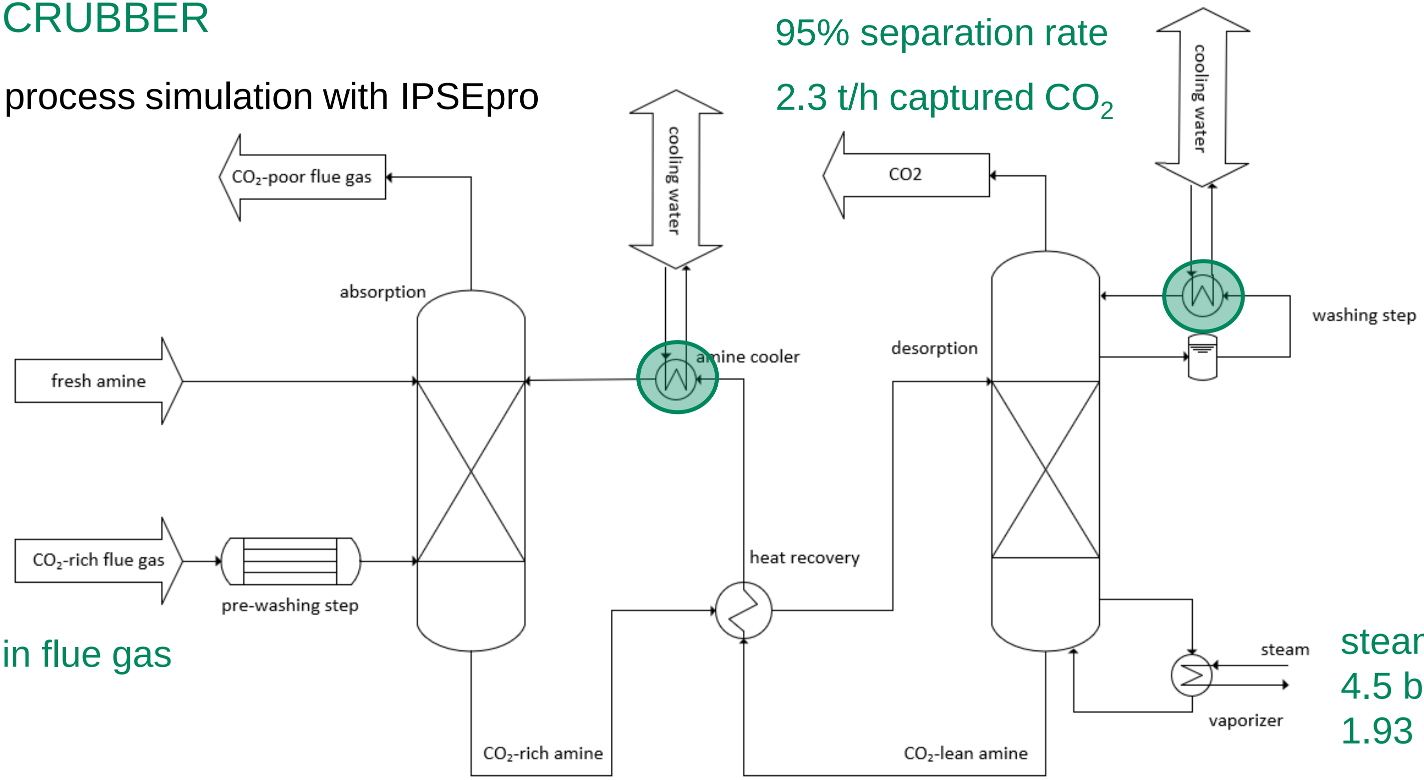
CARBON CAPTURE PROCESS

AMINE SCRUBBER

Stationary process simulation with IPSEpro

95% separation rate

2.3 t/h captured CO_2

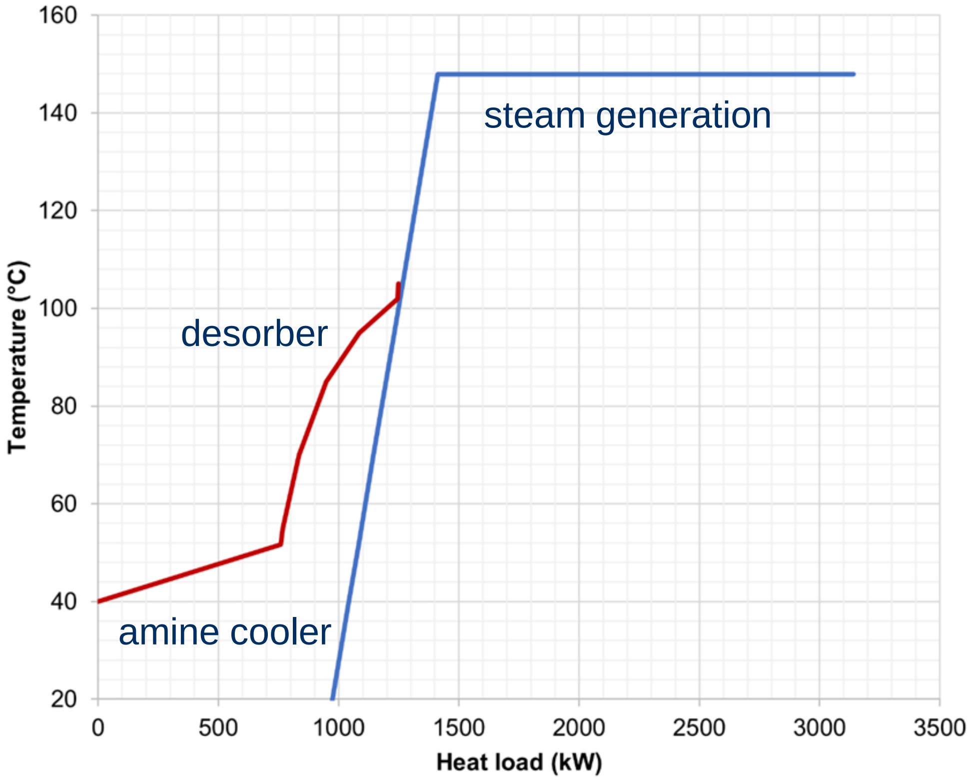


8.6% CO_2 in flue gas

steam:
4.5 bara/145°C
1.93 MW

HOT AND COLD STREAMS

NEW ENERGY FOR INDUSTRY

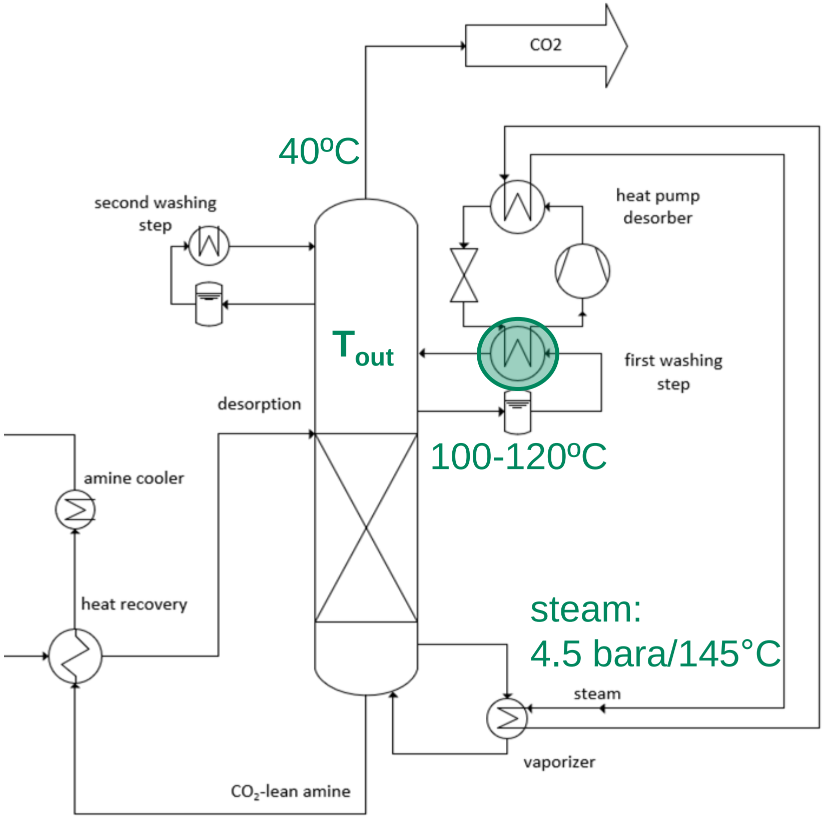


HEAT PUMP IN THE DESORBER

NEW ENERGY FOR INDUSTRY

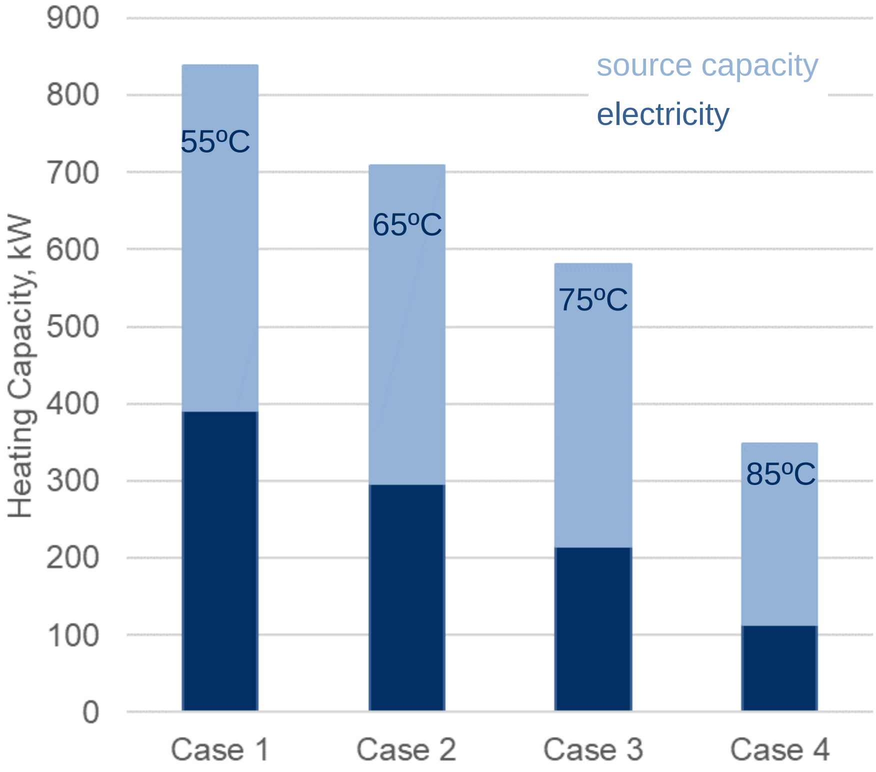
VARIATION OF COOLING TEMPERATURE

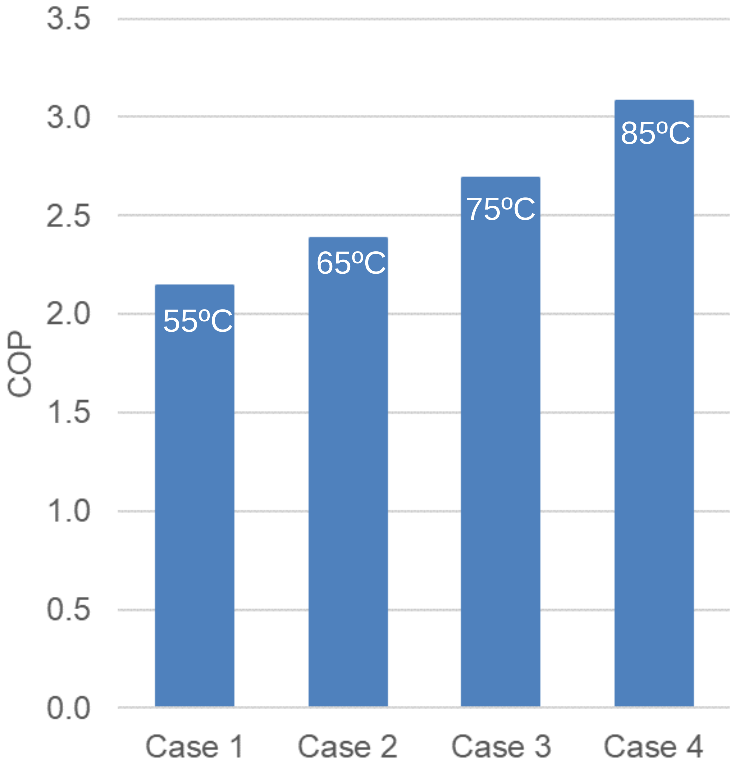
	Mass flow, t/h	T_{in}, °C	T_{out}, °C	Heat, kW
1	16.9	77.7	55	447
2	15.0	88.6	65	412
3	12.5	99.9	75	364
4	9.9	105.2	85	235



HEAT PUMP IN THE DESORBER

PRODUCTION OF 43% - 18% OF THE STEAM DEMAND



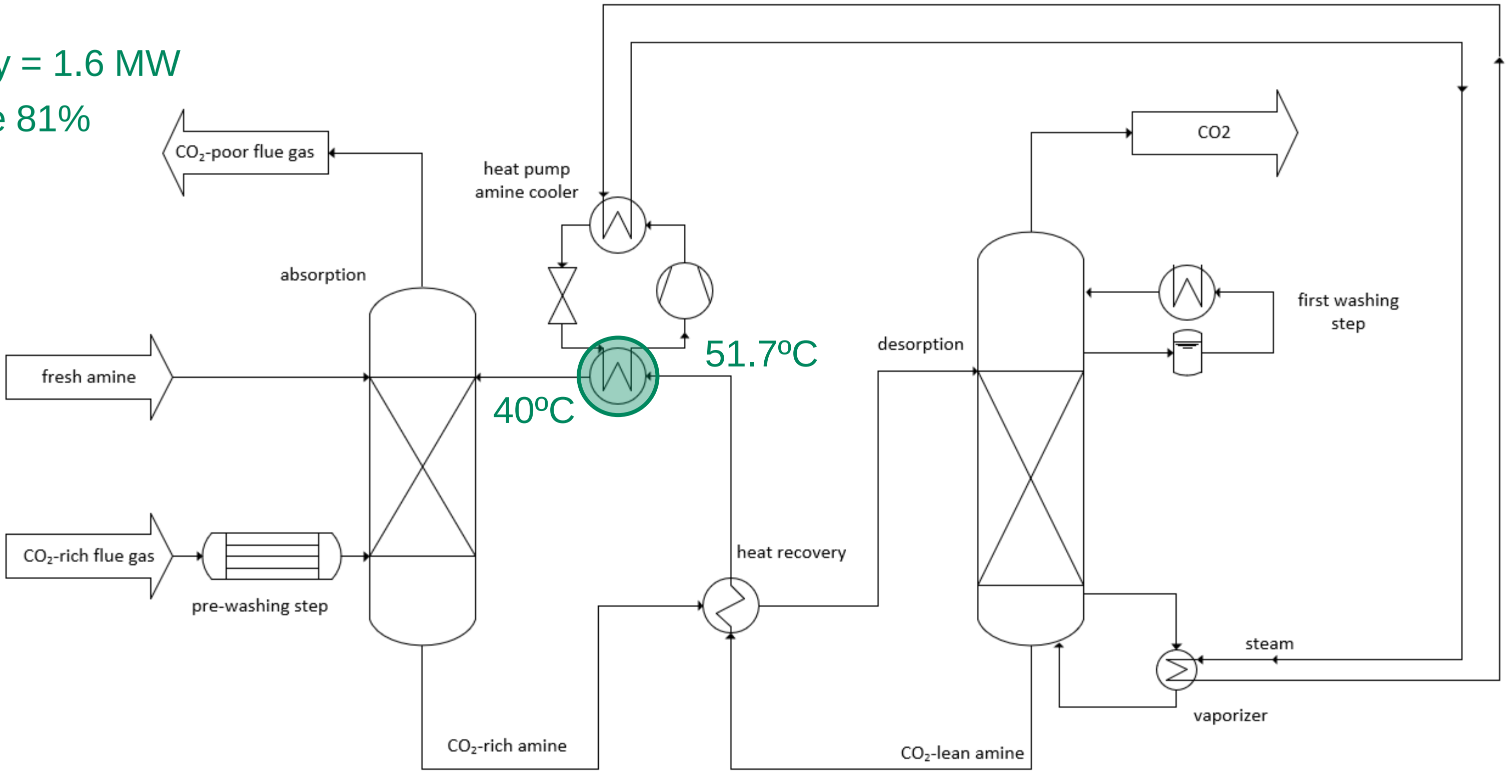


HEAT PUMP IN THE AMINE COOLER

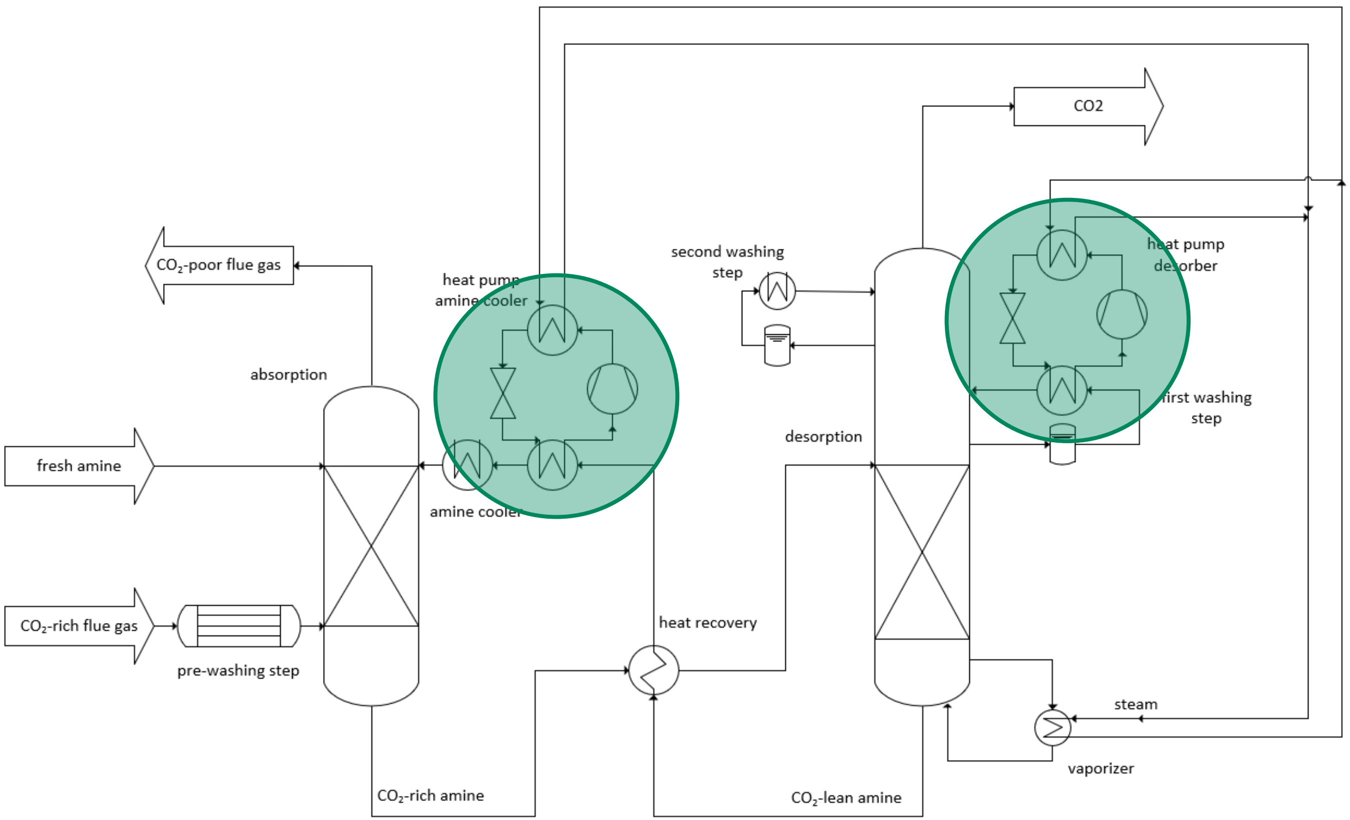
COP = 1.86

Heating capacity = 1.6 MW

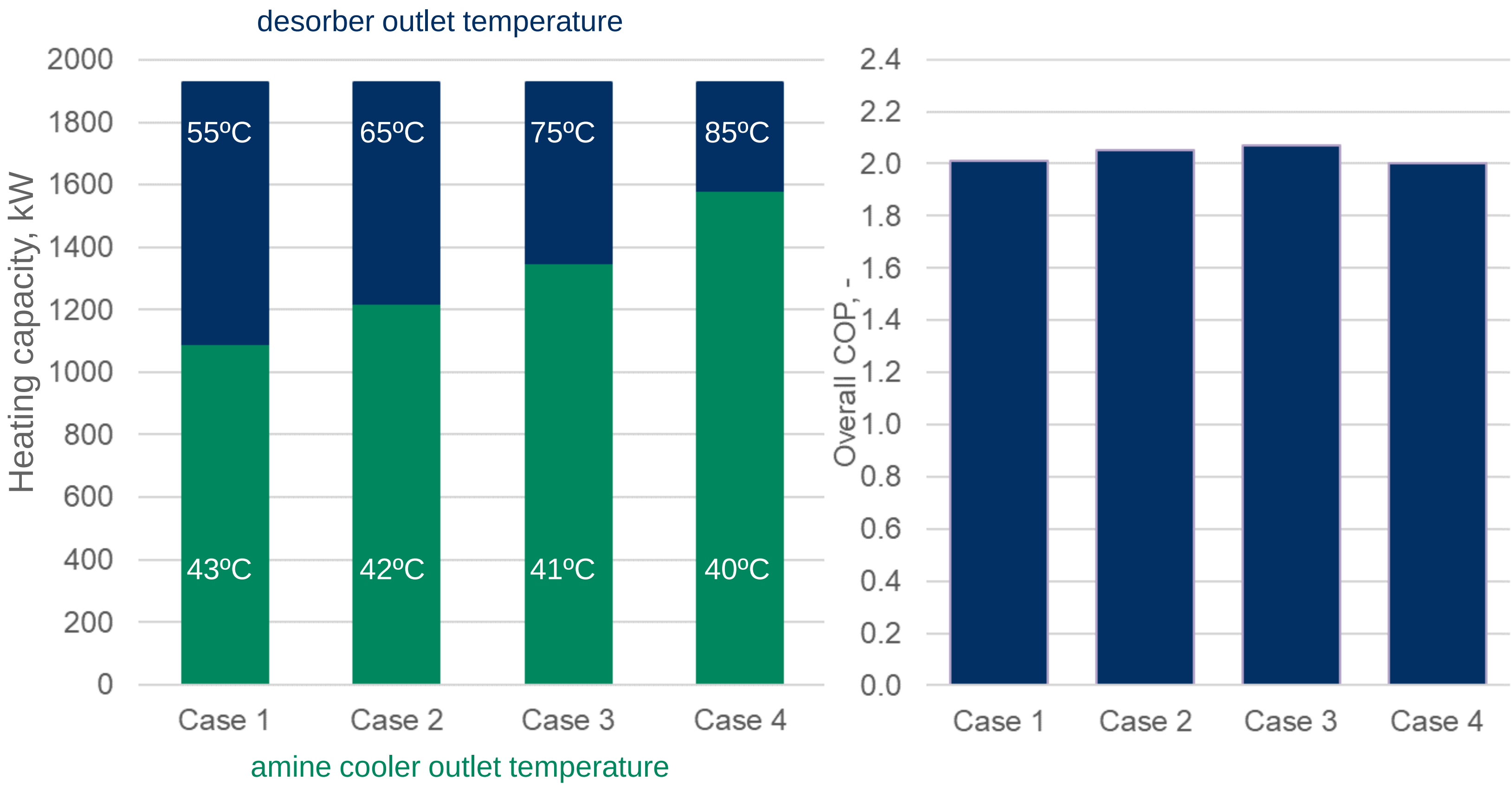
Steam coverage 81%



COMBINATION OF HEAT PUMPS



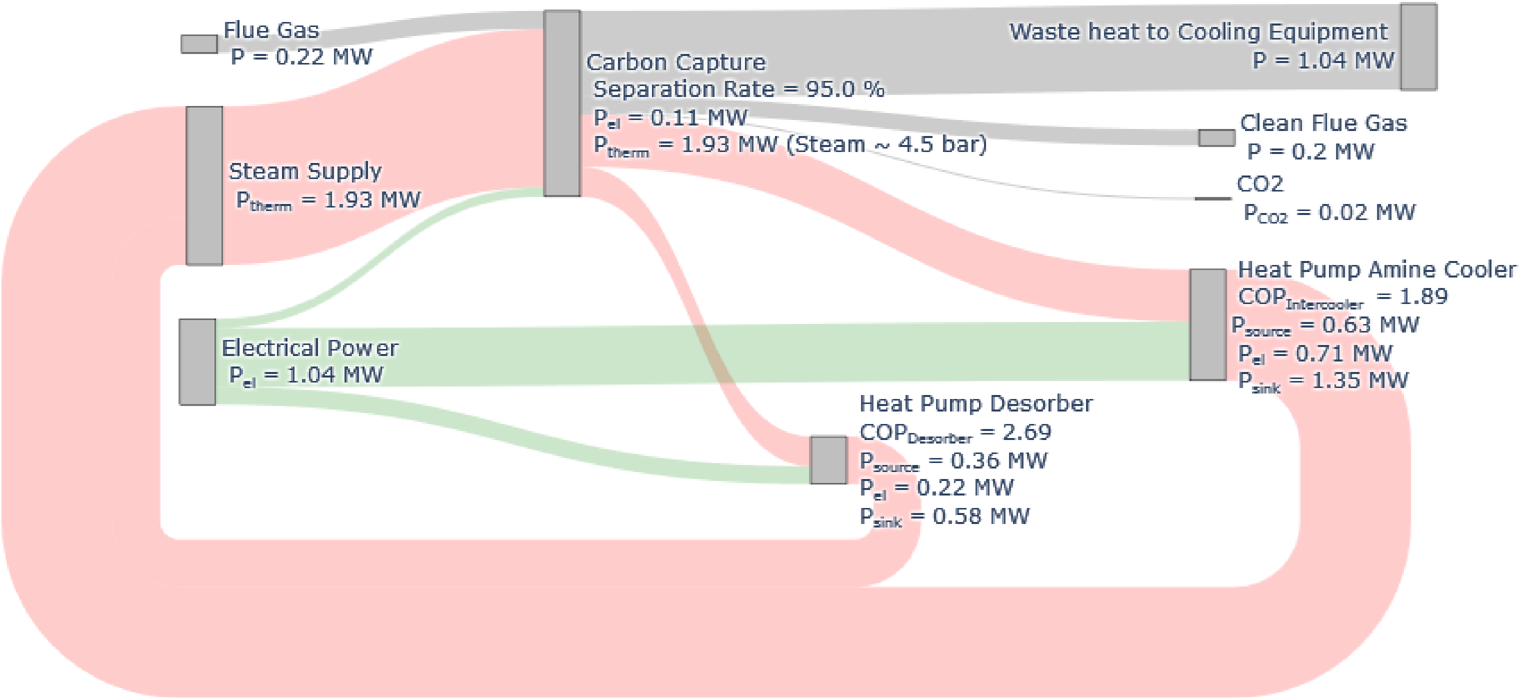
HEATING CAPACITY AND COP



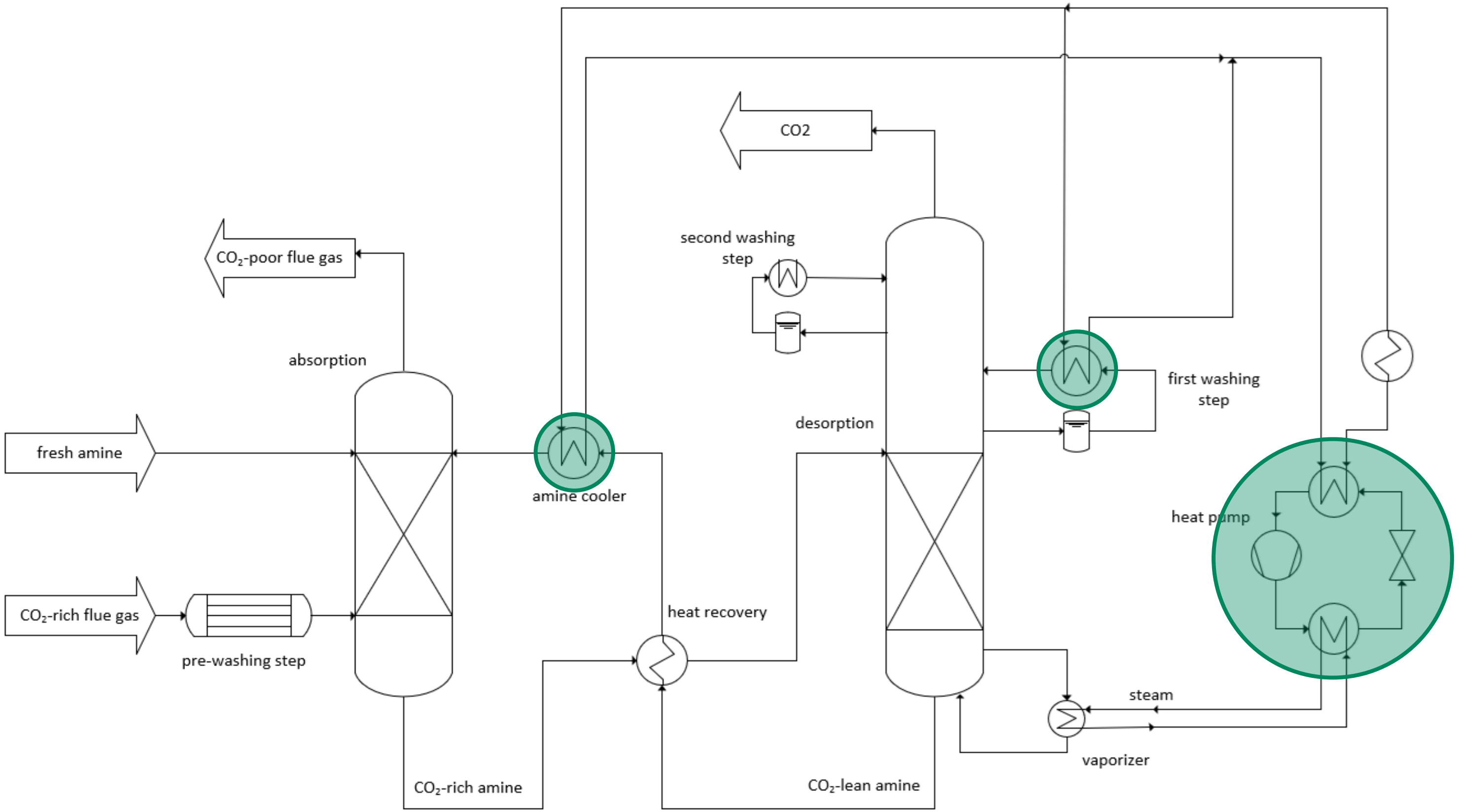
COMBINATION (CASE 3, 75°C)

NEW ENERGY FOR INDUSTRY

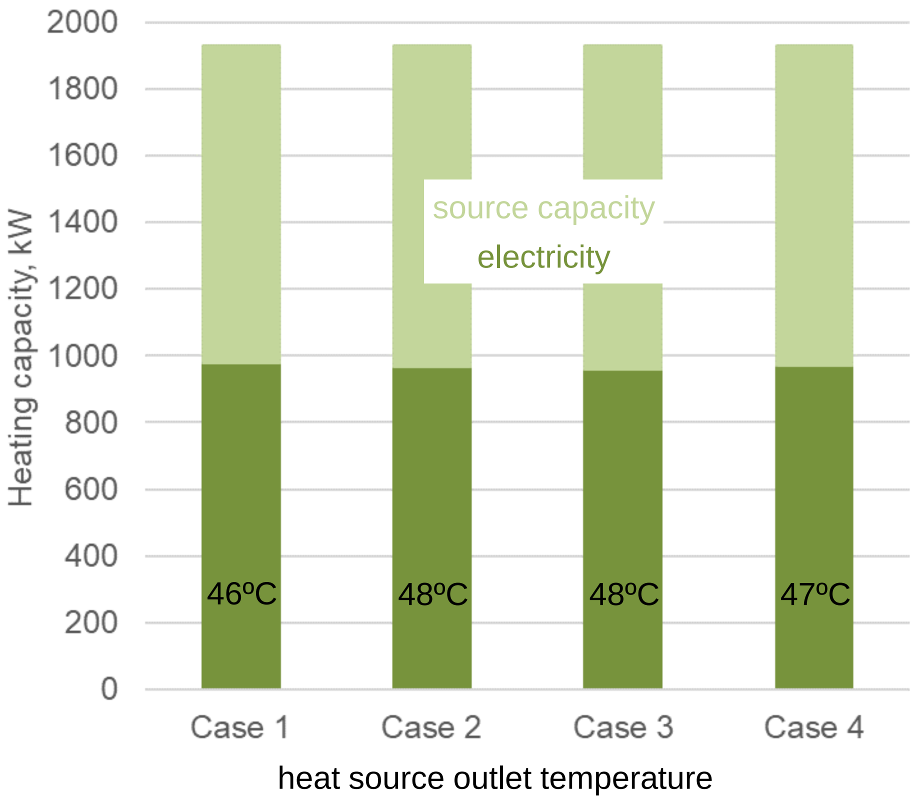
52% ENERGY SAVINGS (1.93 MW STEAM VS. 0.93 MW ELECTRICITY)



HEAT PUMP IN COOLING WATER SYSTEM



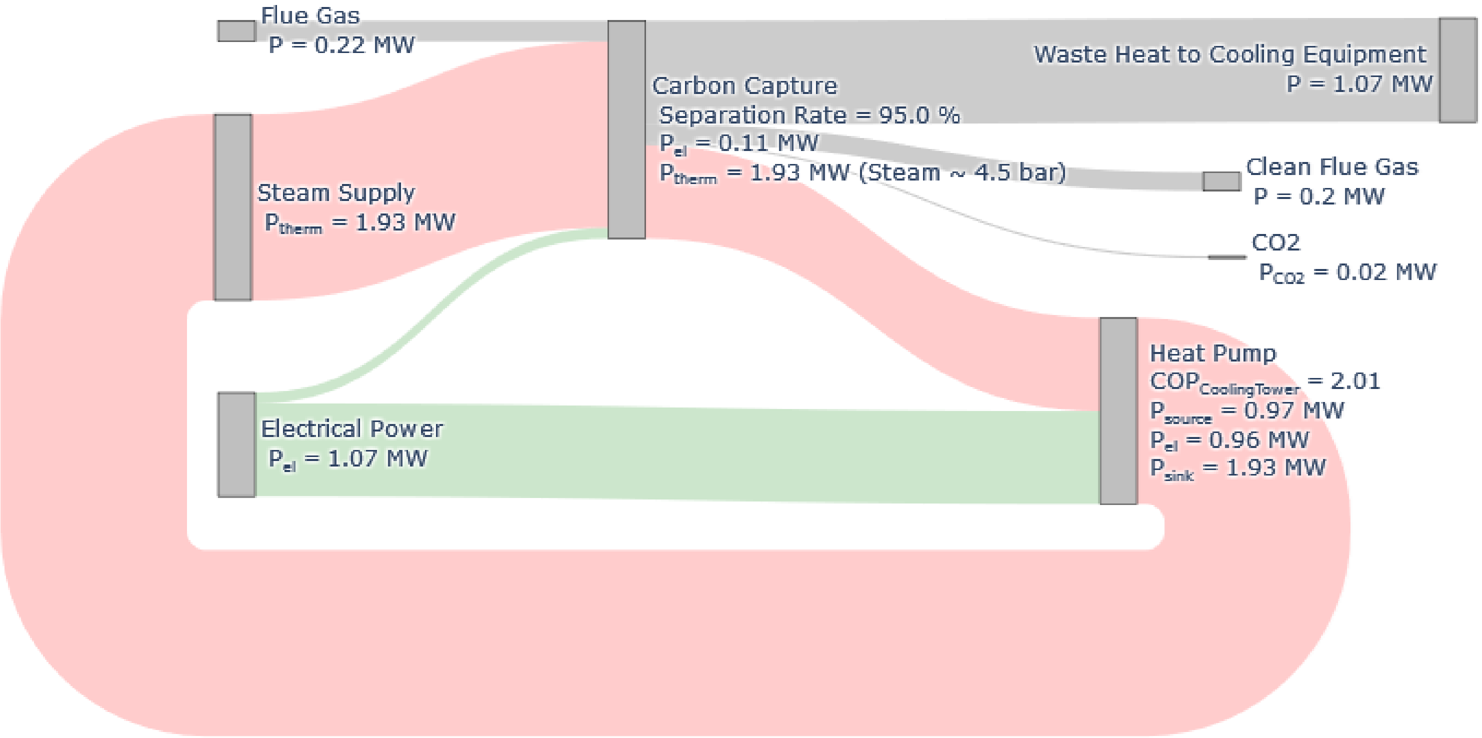
HEAT PUMP IN COOLING WATER SYSTEM



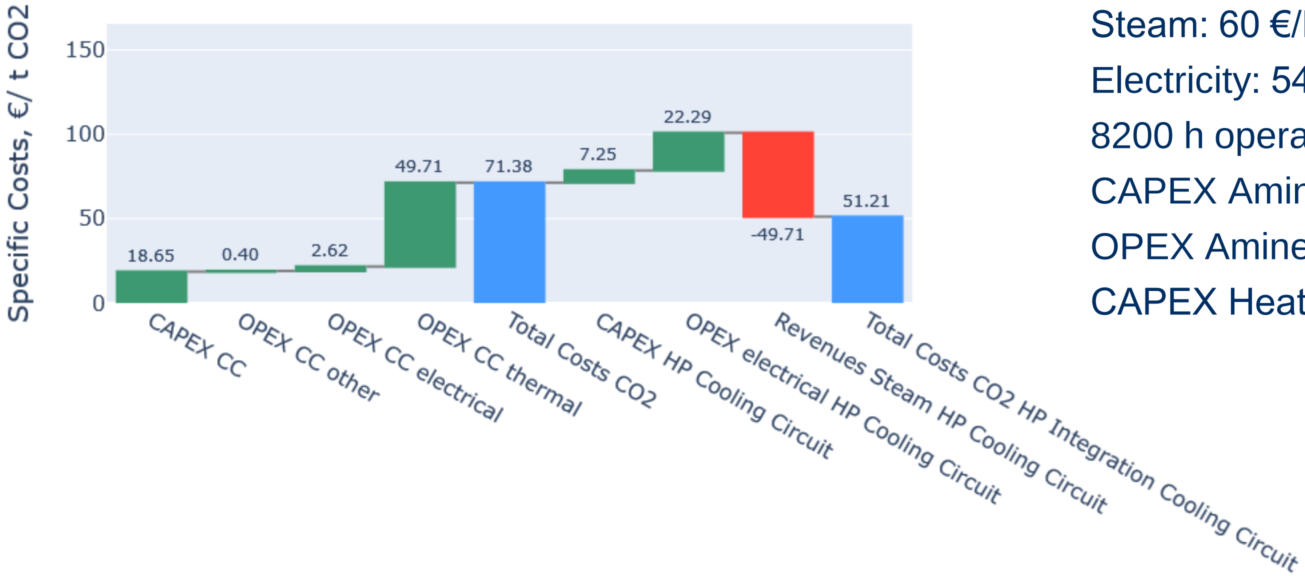
HEAT PUMP IN COOLING WATER SYSTEM

NEW ENERGY FOR INDUSTRY

50% ENERGY SAVINGS (1.93 MW STEAM VS. 0.96 MW ELECTRICITY)



COST ANALYSIS: HP IN COOLING SYSTEM



Steam: 60 €/MWh [1]

Electricity: 54 €/MWh [1]

8200 h operating hours for 20 years

CAPEX Amine Scrubber: 300 000 €/tCO2

OPEX Amine Scrubber: 8 €/t CO2 [2]

CAPEX Heat pump: 1400 €/kW

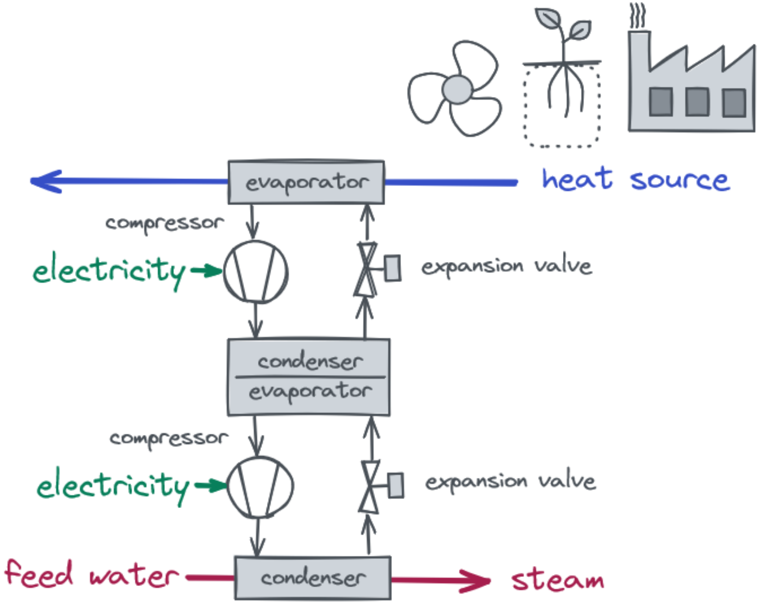
[1] S. Knöttner, R. Hofmann, "Assessment and conceptualization of industrial energy flexibility supply in mathematical optimization in a competitive and changing environment", Energy Conversion and Management, 304, 118205. 2024

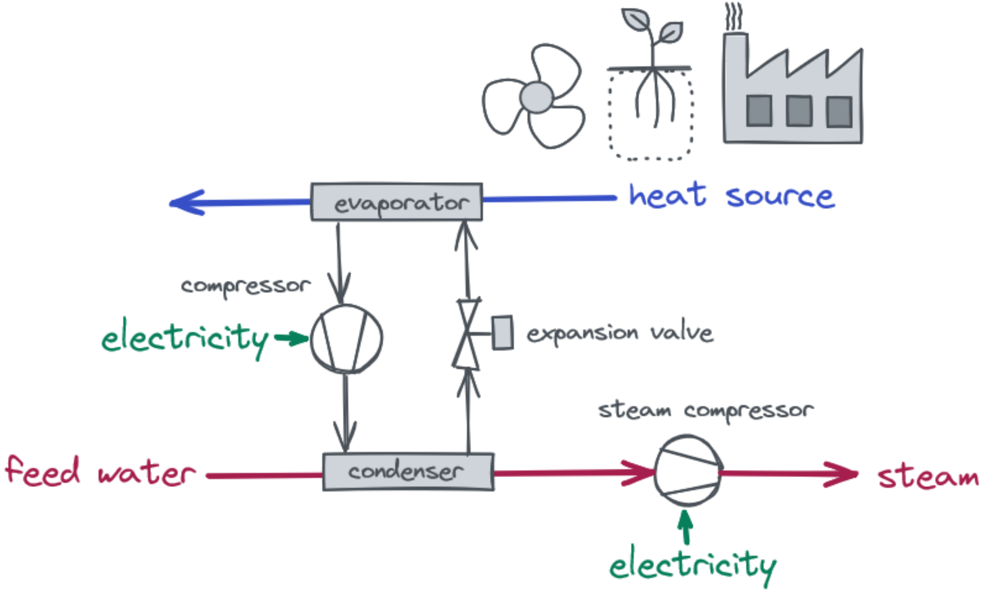
[2] J. Husebye, A.L. Brunsvold, S. Roussanaly, X. Zhang, "Techno economic evaluation of amine based CO2 capture: impact of CO2 concentration and steam supply", Energy Proce-dia, Volume 23, 381-390, 2012

HEAT PUMP SOLUTIONS

NEW ENERGY FOR INDUSTRY

HEAT SOURCE: < 60°C, HEAT SINK: 145°C, HEATING CAPACITY: 1.9 MW

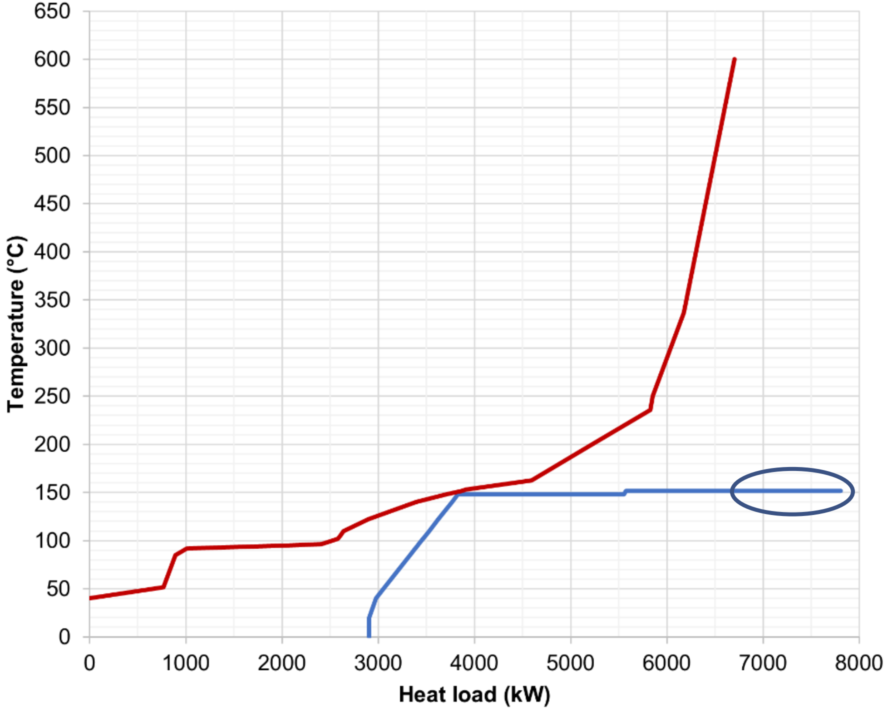




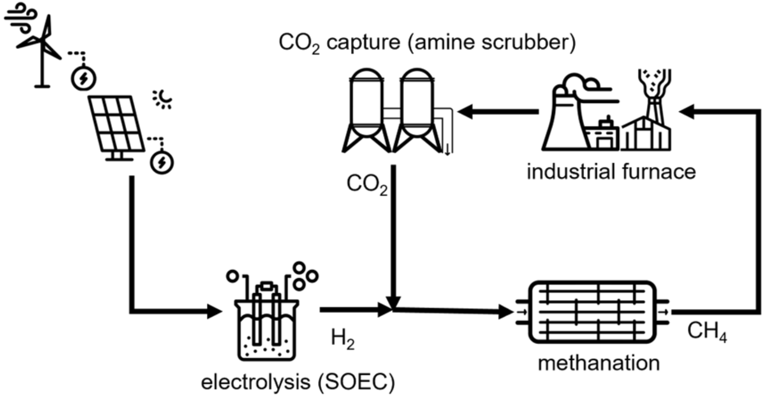
DECARBONIZED INDUSTRIAL FURNACE

NEW ENERGY FOR INDUSTRY

CARBON CAPTURE, ELECTROLYSIS AND METHANATION



D. Leibetseder, P. Moser, C. Zauner, M. Schwaiger, “Renewable fuels for decarbonizing industrial furnaces: A techno-economic assessment of different Power-to-X concepts”, INFUB-14, 2024.



Remaining heat demand = 1.1 MW

CONCLUSIONS

NEW ENERGY FOR INDUSTRY

Heat recovery with heat pumps

- decreases energy demand of CC by 50%
- decreases cooling need by 50%
- steam costs are important cost drivers in CC units

Suitable heat pumps are available on the market but not yet demonstrated

- cascaded system: two stage closed loop heat pump
- combination of closed loop heat pump and steam compressors (MVR)

Process chain decisive for waste heat recovery potential

NEW ENERGY FOR INDUSTRY

Thank you!

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AUSTRIAN INSTITUTE OF TECHNOLOGY

voestalpine ONE STEP AHEAD.

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TOTAL COSTS FOR CO_2

NEW ENERGY FOR INDUSTRY