Industry decarbonisation with process integration, electrification and district heating

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Sveučilište u Zagrebu
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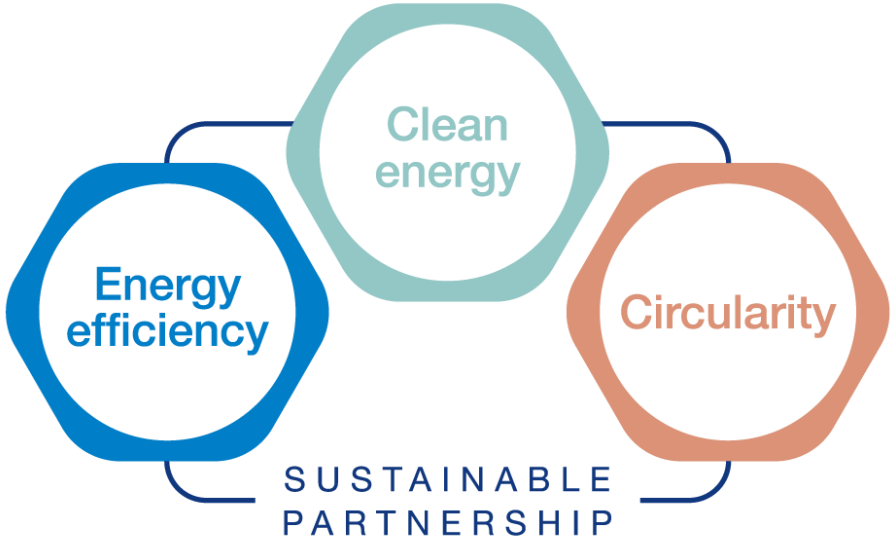
i brodogradnje

University of Zagreb
Faculty of Mechanical Engineering
and Naval Architecture

Agenda

- Introduction
- Energy partnering goals
- How to process with industry decarbonisation
  - Improving heat recovery
  - Electrification of process heat
  - Integration of district heating
- Case study of DH integration
- Summary
- Q&A session



General overview

Industry

- The industry sector in 2022 was directly responsible for emitting 9.0 Gt of CO_2, accounting for a quarter of global energy system CO_2 emissions[1].
- Annual emissions slightly declined in both 2020 and 2022, but not enough to align with the Net Zero Emissions by 2050 (NZE) Scenario, in which industrial emissions fall to about 7 Gt CO2 by 2030
- In 2021, the EU industry sector accounted for 25.6 % of the final energy consumption[2]

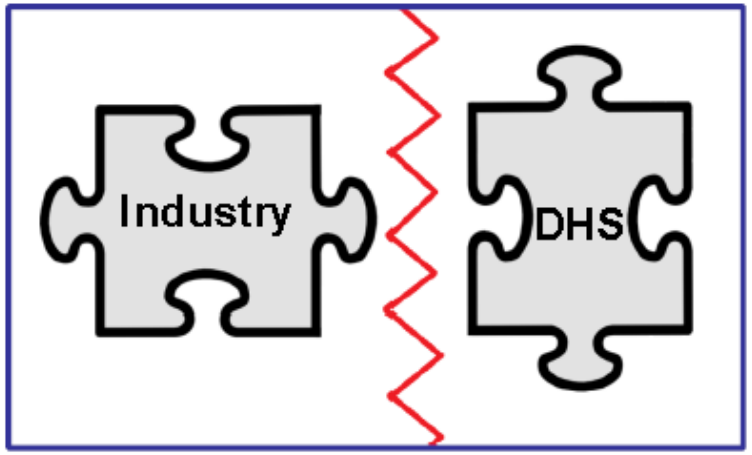
[1]*Tracking Clean Energy Progress 2023, IEA*
[2]*Eurostat*
[3]*IEA report*

District heating sector

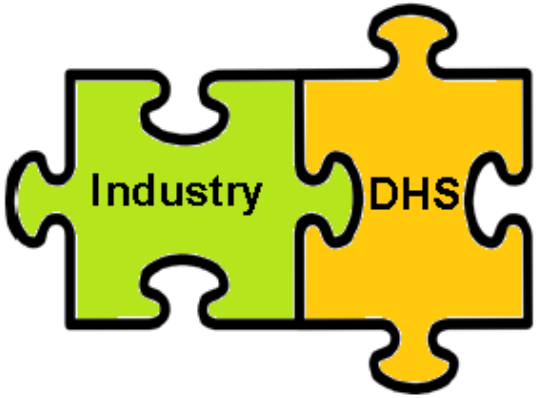
- The EU district heating sector accounts for around 30% of the overall energy demands
- Only 25% of DHSs are driven by renewable energy[3]
- EU forced the strategy for making heating and cooling more efficient and sustainable that presumes sector decarbonization
- Focus on Eastern Europe, where district heating is based mostly on fossil fuels.

The aim of energy partnering

Conventionally



Preferred

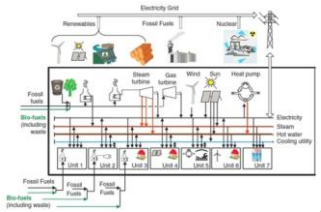


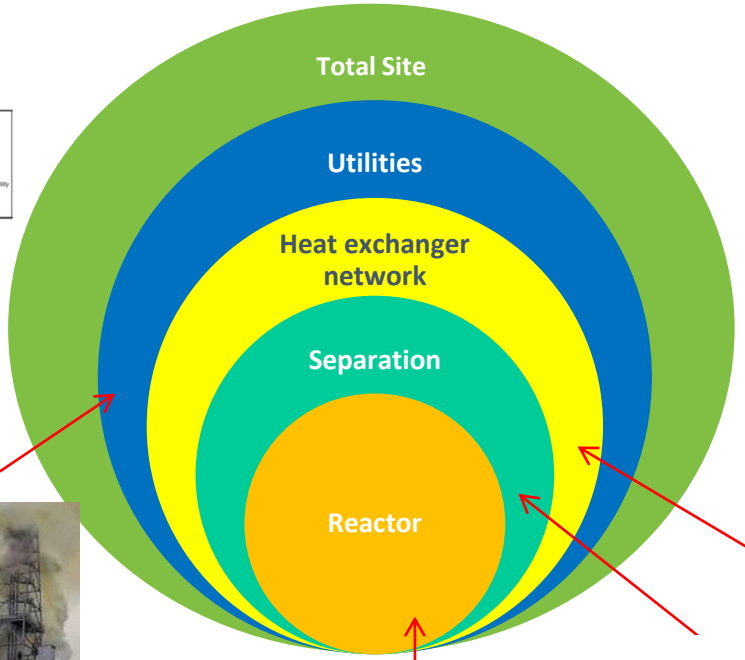
Benefits

- reduction in the final energy consumption & costs (direct)
- Pollution reduction
- Reduction of equipment size (energy generating)
- Reduction in auxiliary energy consumption (pumps, fans, etc.)

Need to exploit the degrees of freedom within the system to produce energy efficiently that achieve the desired decarbonization goals

Hierarchy of Process System





Heat losses

Utility

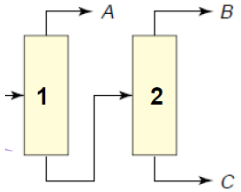
Emissions

Feedstock

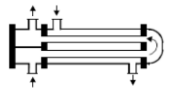
Wastes

$D + A \rightarrow C + B$

Product



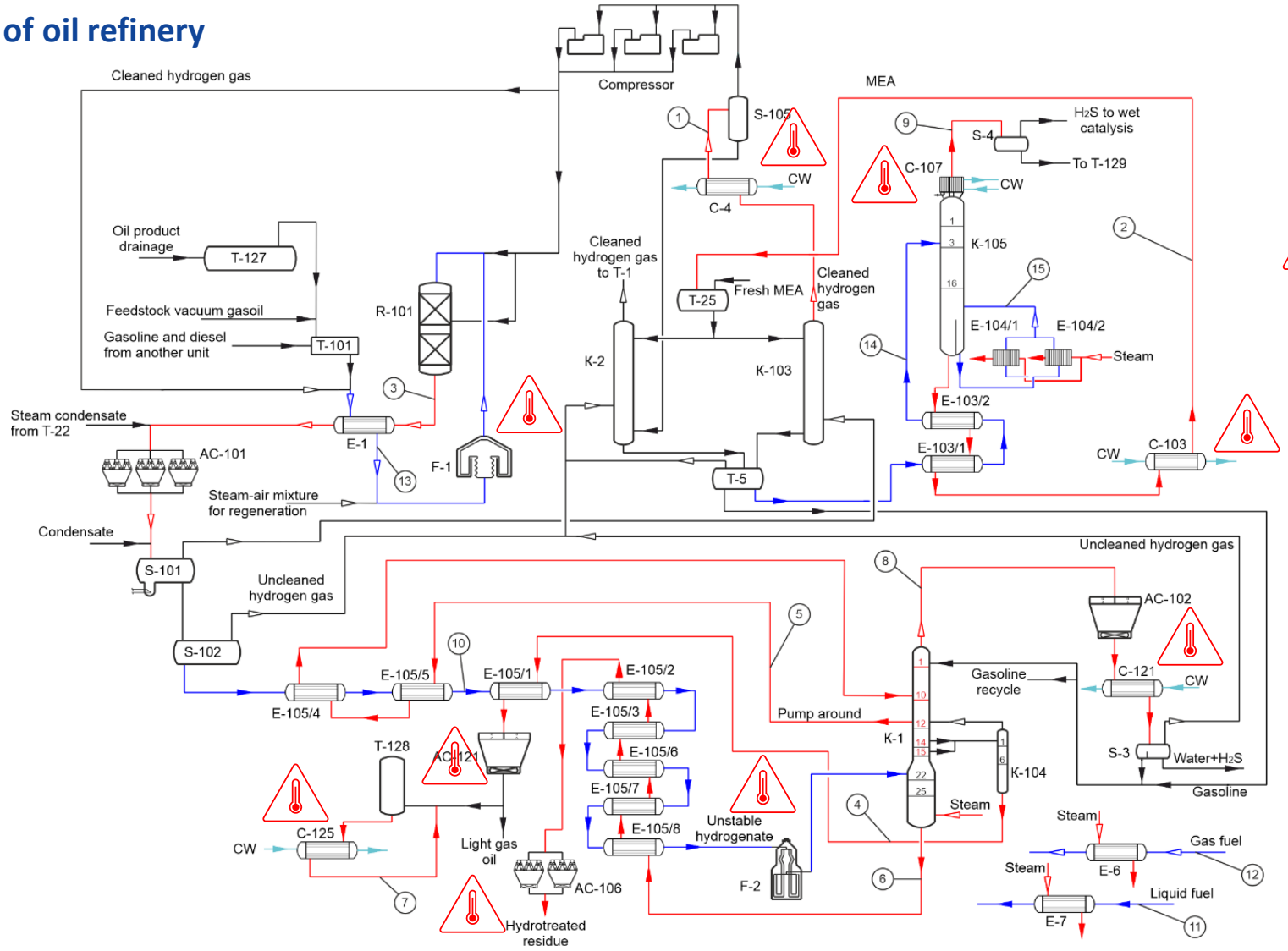
Separator



Heat exchanger

Example of real industrial process

Hydrotreater unit of oil refinery



Waste heat

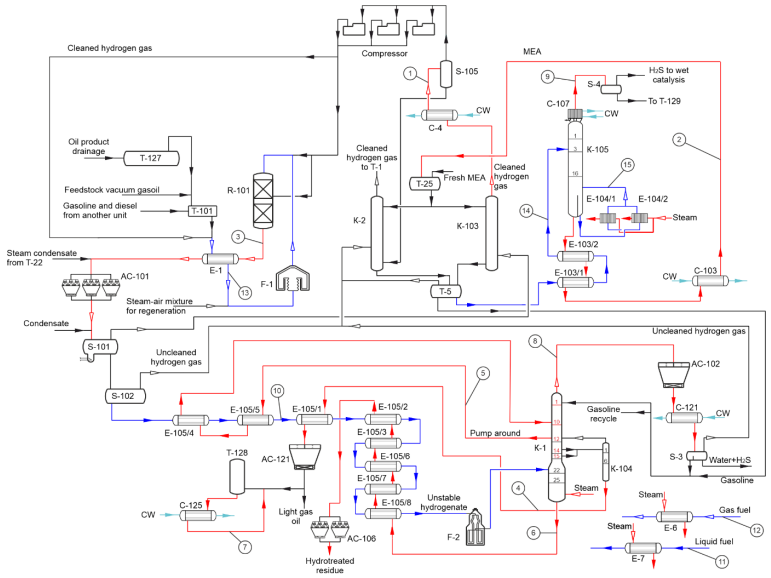
What is the potential of waste heat?

How to decarbonize the process?

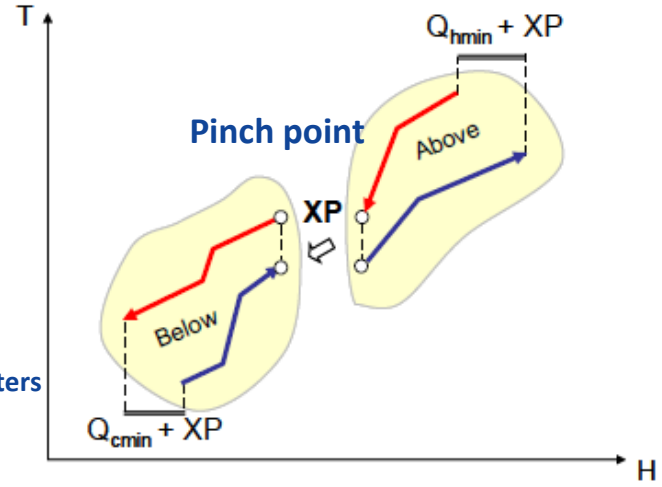
Boldyryev S., Gil T. Debottlenecking of existing hydrocracking unit by improved heat recovery for energy and carbon dioxide savings. Energy Conversion and Management. Vol. 238, 2021 114164.

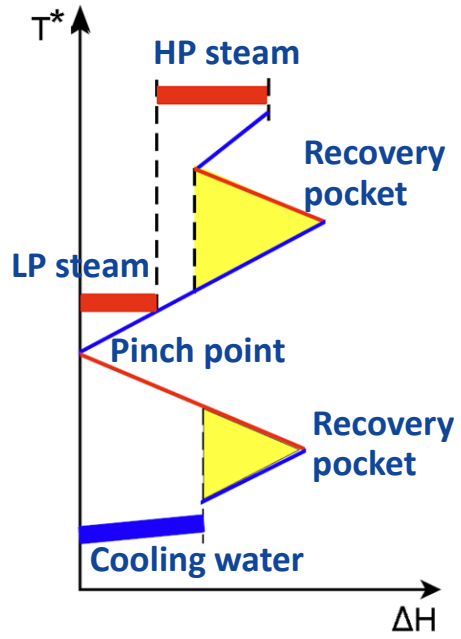
Energy targeting

Process integration approach



- ✓ Streams
- ✓ Properties
- ✓ Process parameters





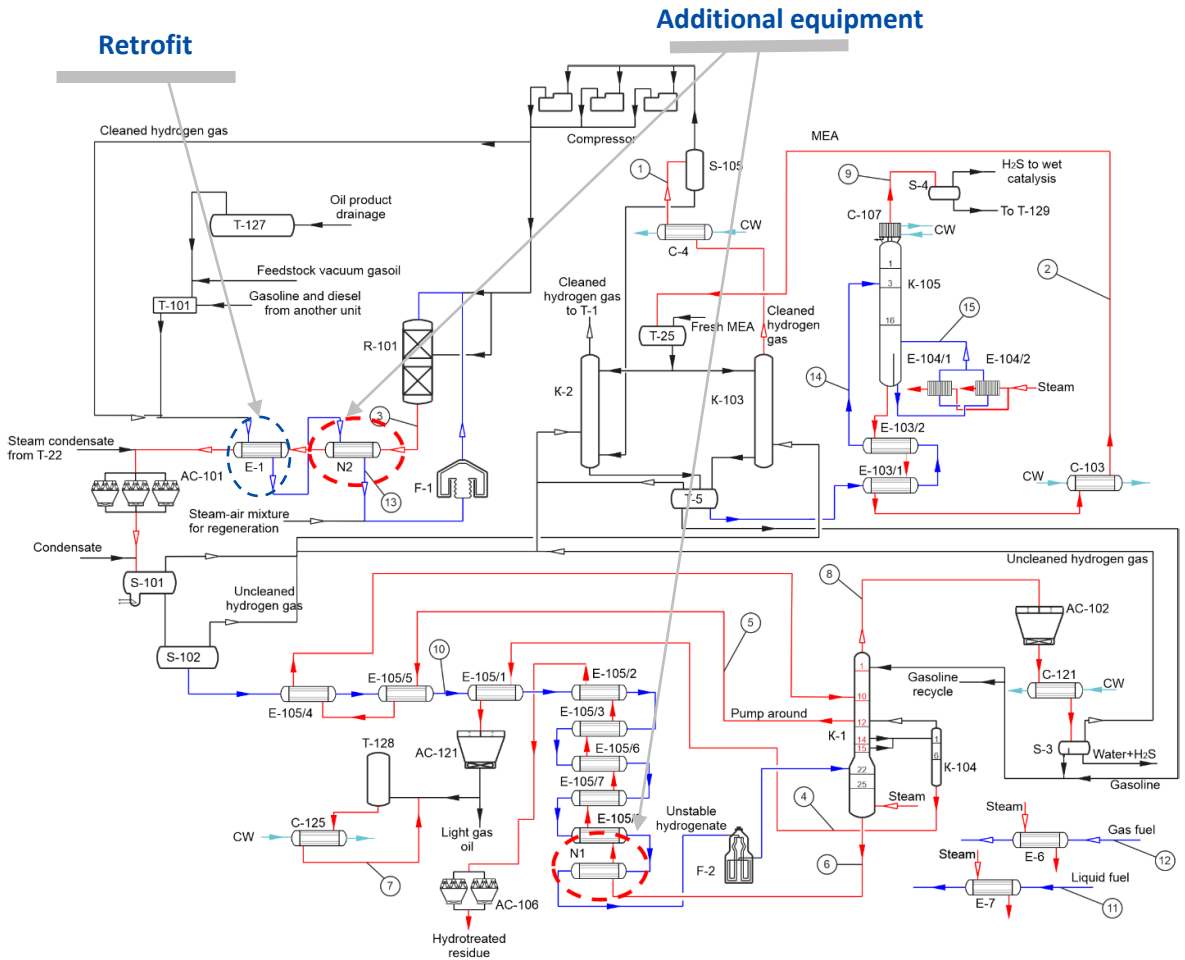
Flowsheet

Energy targets

Utility distribution

Improving the heat recovery

Hydrotreater unit of oil refinery



Energy saving measures

- Flowsheet upgrade
- Revamping of heat exchangers
- Economic efficiency

Results

- A **retrofit project** with improved heat recovery is proposed
- The reduction in **fuel gas** consumption in furnaces is **54%**
- The reduction in **electricity** consumption is **20%**
- Emissions reduction is **18.9 $ktCO_2/y$**

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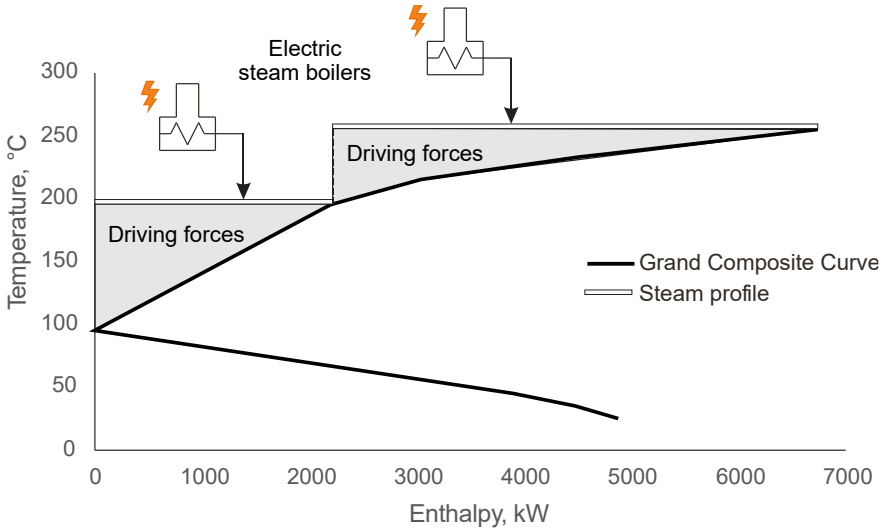
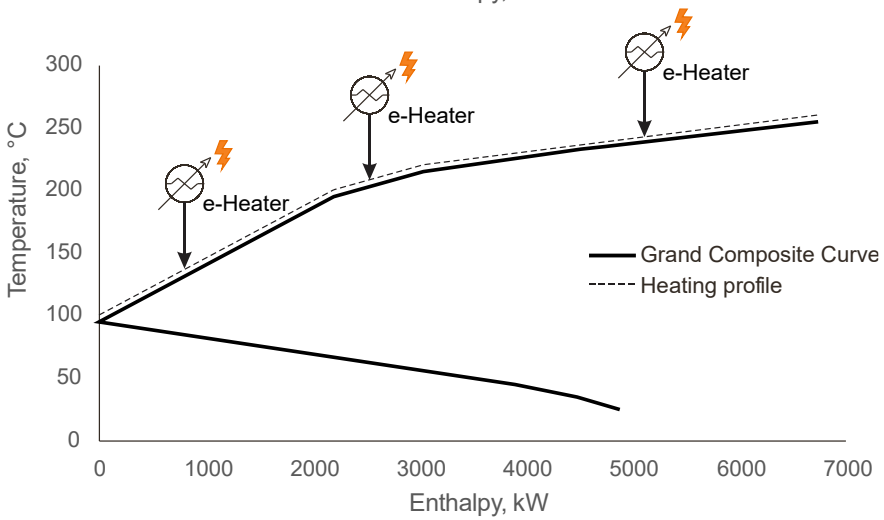
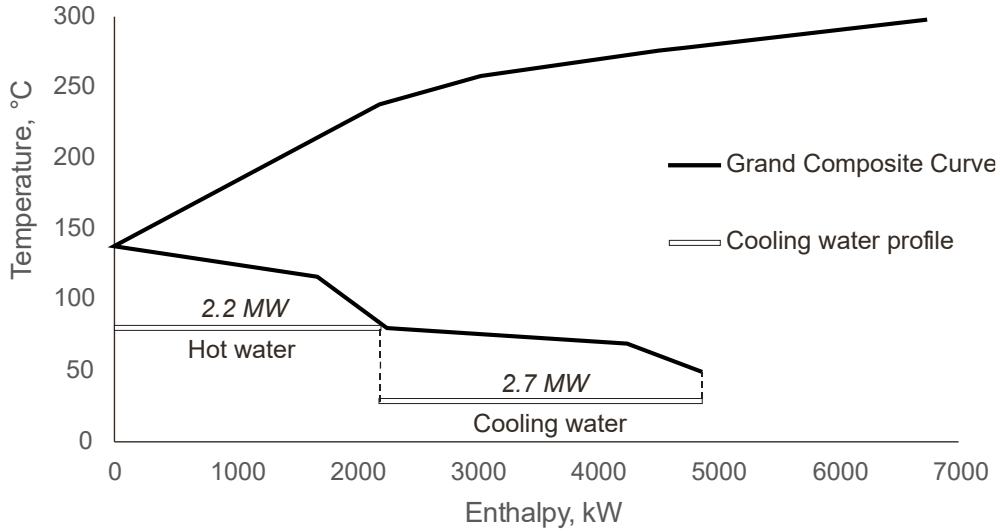
Electrification of process heat

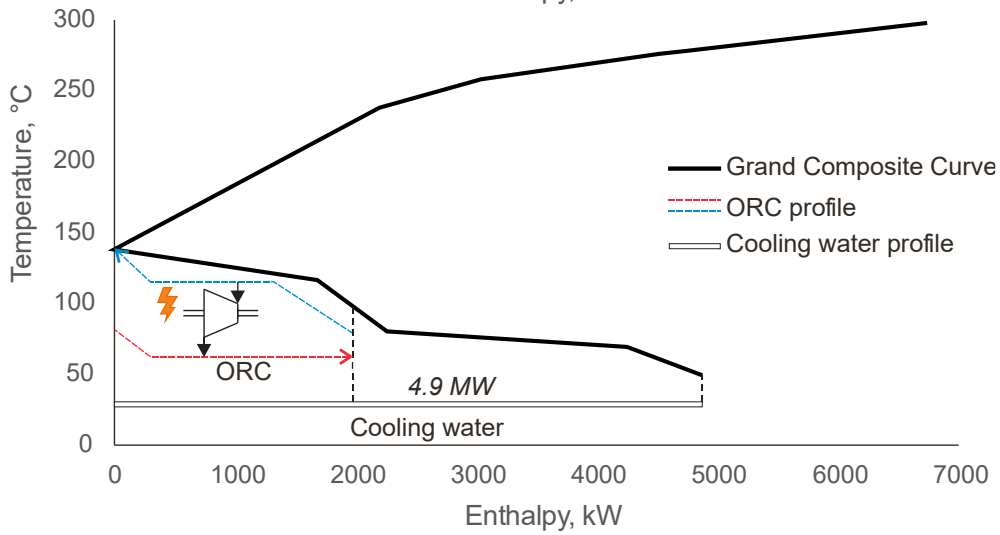
Heating the process





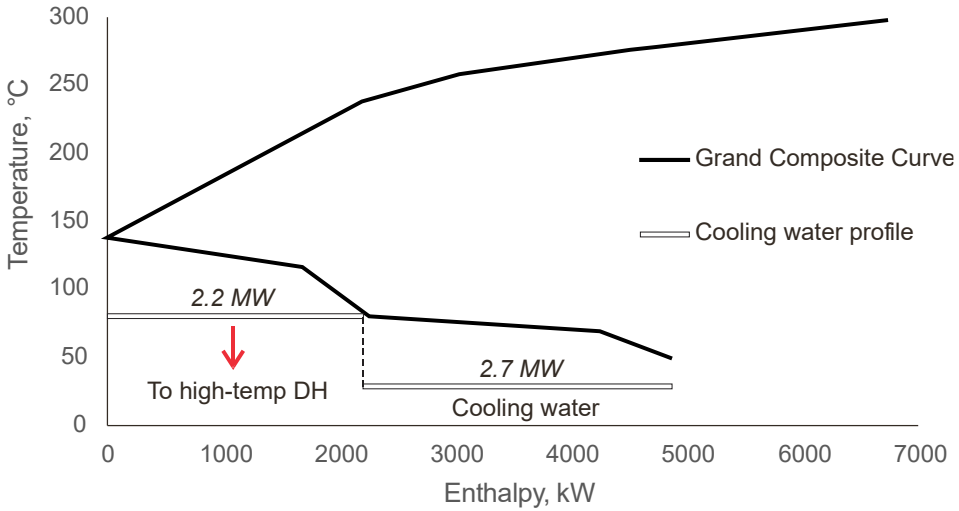
Cooling the process

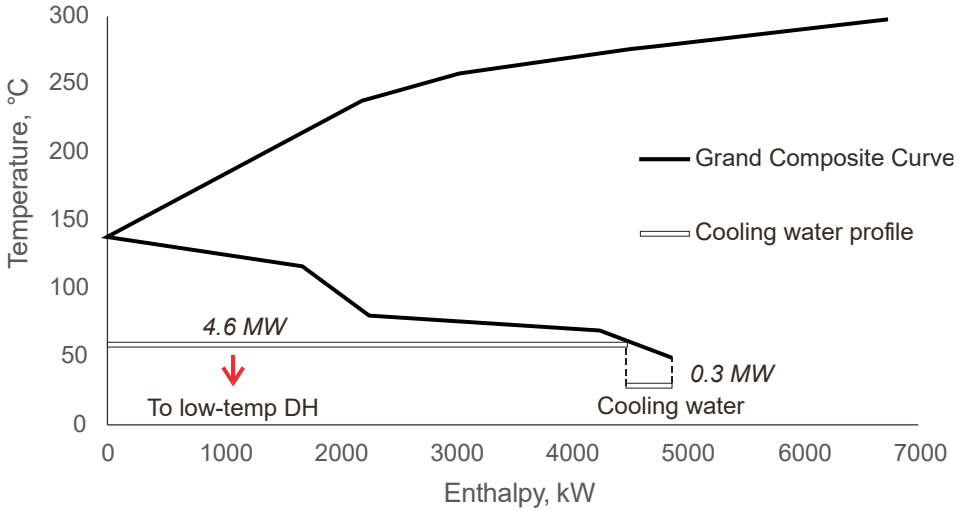




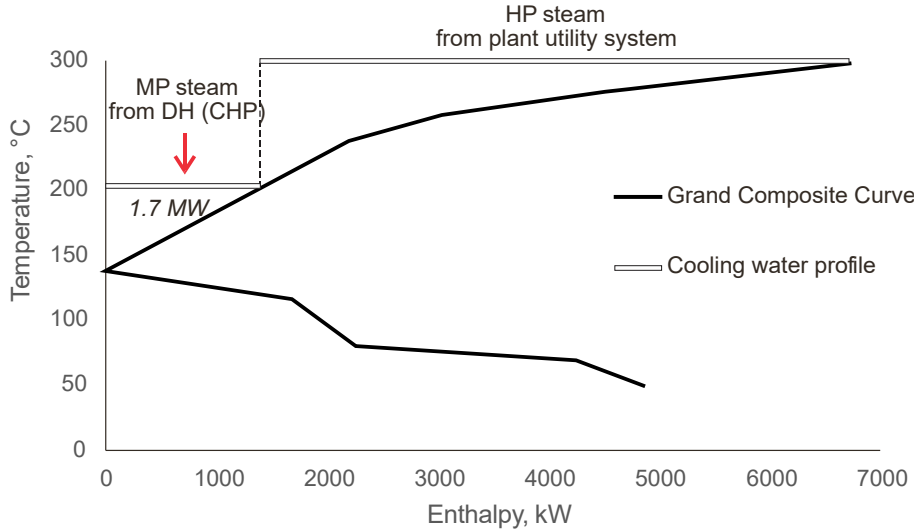
Integration of district heating

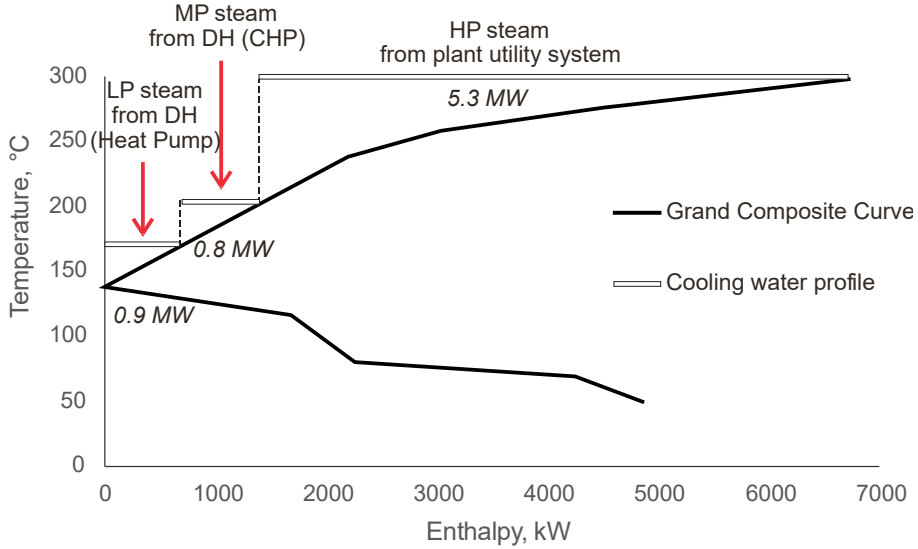
Heating the process





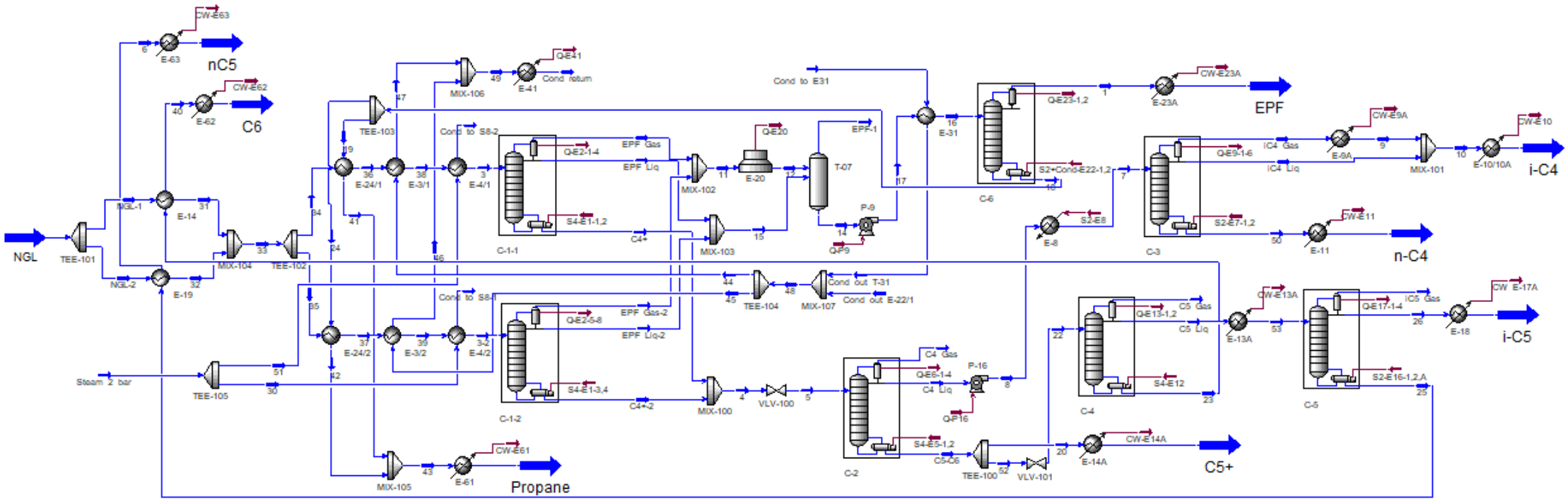
Cooling the process





Case study – DH integration

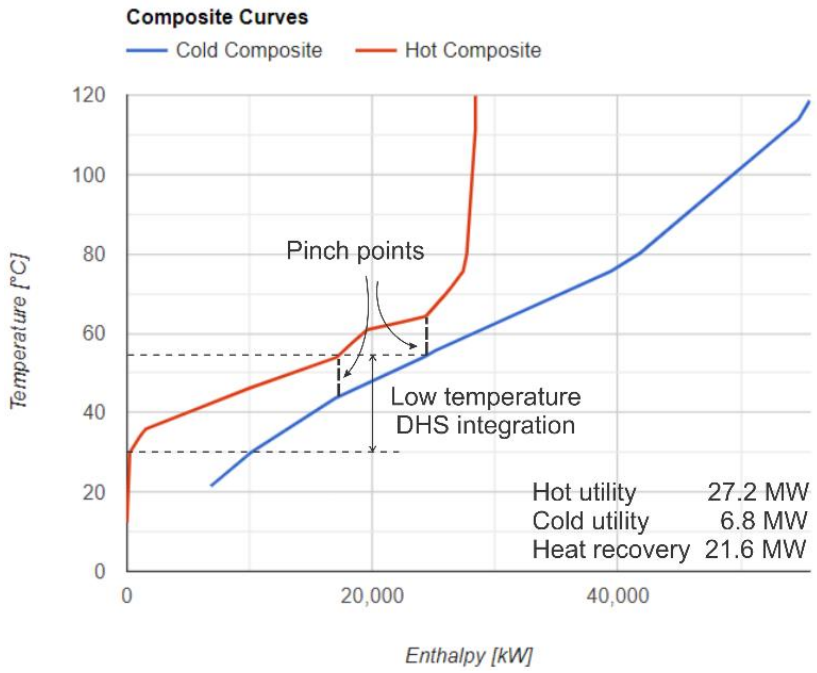
Gas fractioning plant (UniSim model)



- The plant capacity is 4 Mt/y (feed)
- Hot utility is a steam (4 and 2 bar)
- Cold utility are cooling water and air coolers
- Low-temperature district heating (30→60 °C)

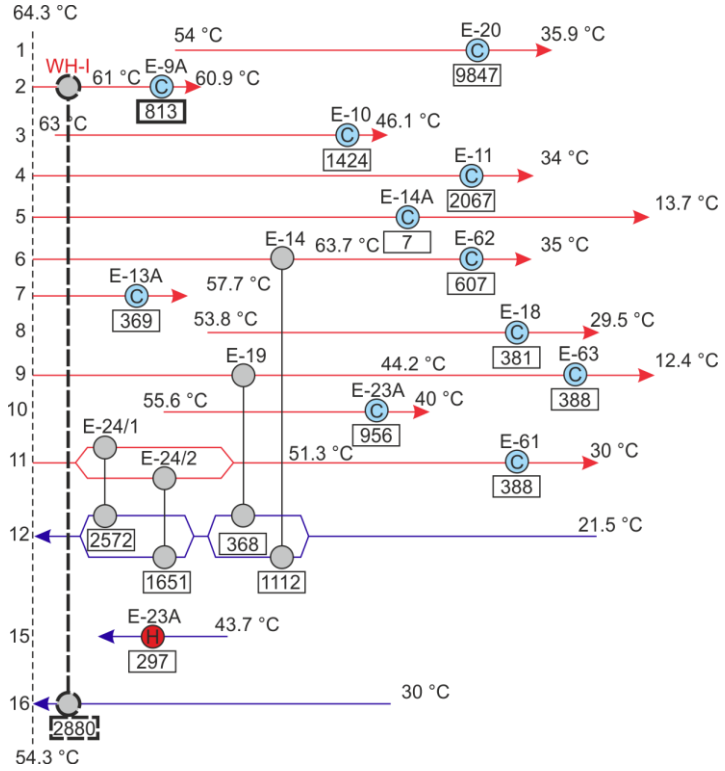
Case study – DH integration

Energy targeting



- DH water can be heated 30→54 °C
- Max hot water flow rate 103.1 t/h
- The process cooling in the range of 30-50 °C is performed by air coolers

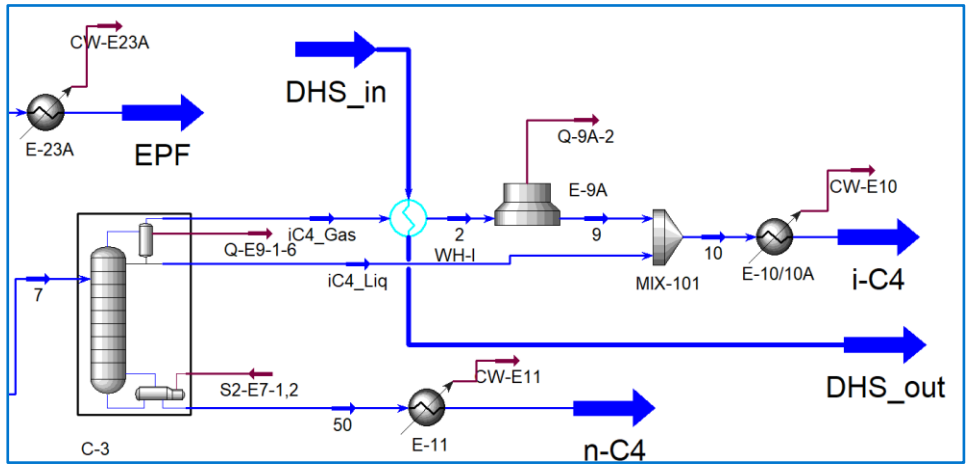
Exchanger network design



- 1 additional heat exchanger (WH-I)
- Placement at the top of debutanizer
- Process condenser duty decreased by 2,880 kW
- Electricity consumption reduced by 33.75 MW

Case study – DH integration

Final plant design (UniSim model)



Heat exchanger design

TEMA Style Summary

1 Diam/Length(mm) 590.5/ 6096.0 TypeAEL , HORIZONTAL 1 Exchgrs connected 1 series x 1 para. Selection Basis: COST
2 Surface areas m2 - total 124.77 - /shell 124.77 - heat transfer 122.93 STE cost 3861

			HOT SHELLSIDE INLET	HOT SHELLSIDE OUTLET	COLD TUBESIDE INLET	COLD TUBESIDE OUTLET
	FLOWRATES	UNITS	iC4_Gas->2		DHS_in->DHS_out	
3	Total Fluid Flowing	kg/h	43708.1		100138.4	
4	Total Vapour + Gas	kg/h	43708.1	9632.6	0.0	0.0
5	Total Liquid	kg/h	0.0	34075.4	100138.4	100138.4
6	Steam/Water	kg/h		0.0		0.0
7	Non-Condensables	kg/h		0.0		0.0
8	Condensed/Evaporated	kg/h		34075.4		0.0
	LIQUID PROPERTIES					
9	Density	kg/m3	0.0	505.7	1003.7	985.2
10	Viscosity	centipoise	0.0000	0.1150	0.7972	0.5091
11	Specific Heat	kJ/kg K	0.0000	2.8172	4.3132	4.3240
12	Conductivity	W/m K	0.0000	0.0752	0.6182	0.6475
13	Molecular Weight		0.00	70.06	0.00	0.00
	VAPOUR PROPERTIES					
14	Density	kg/m3	22.5467	22.1011	0.0000	0.0000
15	Viscosity	centipoise	0.0090	0.0090	0.0000	0.0000
16	Specific Heat	kJ/kg K	2.0322	2.0165	0.0000	0.0000
17	Conductivity	W/m K	0.0205	0.0203	0.0000	0.0000
18	Molecular weight		69.75	68.57	0.00	0.00
	2-PHASE PROPERTIES					
19	Latent heat	kJ/kg	295.52	296.37	0.00	0.00
	TEMPERATURES AND PRESSURES					
20	Stream	C	64.34	61.48	30.00	54.00
21	Bulk Average / Skin	C	62.91	50.98	44.36	49.94
22	Pressure In/Out	bar	9.070 /	8.983	3.000 /	2.775
23	DP Calc./Estimated	bar	0.0870 /	0.1000	0.2251 /	1.0000
	(Frictional/Accelerational)		0.0762 /	-0.0040	0.1068 /	0.0000
	(Nozzles+Turns/Gravitational)		0.0148 /	0.0000	0.1183 /	0.0000
	HT. TRANS. COEFF/RESIST					
24	Stream	W/m2 K	1983. / .0005043		4301. / .0002325	
25	Fouling	W/m2 K	0. / .0000000		0. / .0000000	
26	Wall	W/m2 K		21678. / .0000461		
27	Overall Clean	W/m2 K		1277. / .0007829		
28	Overall Dirty	W/m2 K		1277. / .0007829		

	CLEARANCES ETC.			
1	Tube/Baffle (Diametric)	mm	0.39690	
2	Bundle/Shell (Diametric)	mm	12.700	
3	Baffle/Shell (Diametric)	mm	4.76250	
4	Baffle Thickness	mm	9.52500	
	PERCENTAGE OF TOTAL PRESSURE DROP			
5	Shell X-Flow 28.9	Tube	Straight	47.5
6	Window 35.3		Return	5.3
7	Ends 18.8			
8	Nozzle 17.0		Nozzle	47.3
	DIMENSIONLESS NUMBERS	Shell	Tube	
9	Reynolds In Gas/Vapour	186474.	0.	
10	Out Gas/Vapour	41217.	0.	
11	In Liquid	0.	17514.	
12	Out Liquid	11380.	27426.	
13	Prandtl In Gas/Vapour	0.8921	0.0000	
14	Out Gas/Vapour	0.8901	0.0000	
15	In Liquid	0.000	5.562	
16	Out Liquid	4.306	3.400	
	HEAT LOADS	Shell	Tube	
19	Gas/Vapour kW	1.	0.	
20	Cond./Evap. kW	2879.	0.	
21	Liquid kW	0.	2880.	
22	Wet Wall Desuperheat. YES: HTC Fact. NO			
23	Vap.Shear Enhancement YES: User HTC NO			
	*Veloc./Momentum Flux	m/s /	kg/m s2	
24	Shell-Nozzle Inlet	6.05 /	826.1	
25	Outlet	1.92 /	319.1	
26	Inter	0.00 /	0.0	
27	X-Flow Highest	3.91 /	344.5	
28	Window Highest	7.09 /	1132.1	
29	Tube -Nozzle Inlet	3.37 /	11429.0	

Heat exchanger summary

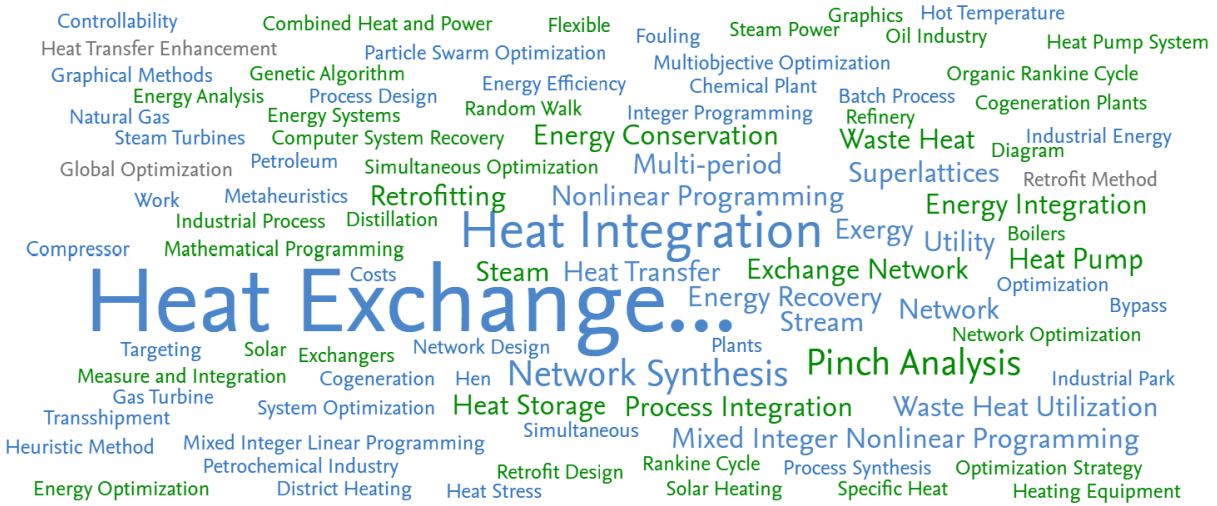
- Heat duty: 2880 kW
- Heat transfer area is 122.93 m^2
- Heat transfer coefficient 1277.27 W/m^2 K
- Type: shell-and-tube
- Length/diameter: 6096/254 mm
- Material: carbon steel

Summary

- Systematic approach plays pivotal role in industry-DH integration
- Finding a real potential important to get more benefits
- Process integration allows effectively decarbonise process industry with
  - Heat recovery improvement
  - Electrification of process heat
  - Effectively use of District Heating for process heating and cooling
- Economic trade-off and KPI can be estimated before redesign the process
  - Energy saving
  - Emission saving
  - CAPEX, OPEX
  - NPV, IRR, PI
- Further steps with final process design, scheduling, process safety are recommended

Thank you for your attention!

Q&A session



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