Effects of process decarbonisation on future targets for excess heat delivery from an industrial process plant

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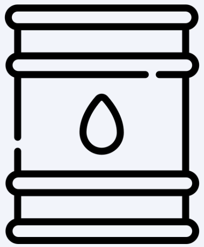
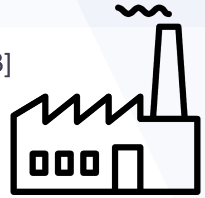
Industrial excess heat can contribute to decarbonising the heating sector

Residential heating accounts for more than 20 % of final energy consumption in EU28 [1]



> 70 % from fossil energy sources [4]

Industrial excess heat potential of 300 TWh/year [2],[3] -> 15 % of fossil energy demand for residential heating



[1] Mathiesen, B. V., Bertelsen, N., Schneider, N. C. A., García, L. S., Paardekooper, S., Thellufsen, J. Z., & Djørup, S. R. (2019). Towards a decarbonised heating and cooling sector in Europe: Unlocking the potential of energy efficiency and district energy. Aalborg Universitet.

[2] Papapetrou, M., Kosmadakis, G., Cipollina, A., La Commare, U., Micale, G. (2018). Industrial waste heat: Estimation of the technically available resource in the EU per industrial sector, temperature level and country. *Applied Thermal Engineering*, **138**, 207-216.

[3] Bianchi, G., Panayiotou, G.P., Aresti, L., Kalogirou, S.A., Florides, G.A., Tsamos, K., Tassou, S.A., Christodoulides, P. (2019). Estimating the waste heat recovery in the European Union Industry. *Energy, Ecology and Environment*, **4**, 211-221.

[4] Bertelsen, N. , Mathiesen, B. V. (2020). EU-28 Residential Heat Supply and Consumption: Historical Development and Status. *Energies*, **13**, 1894

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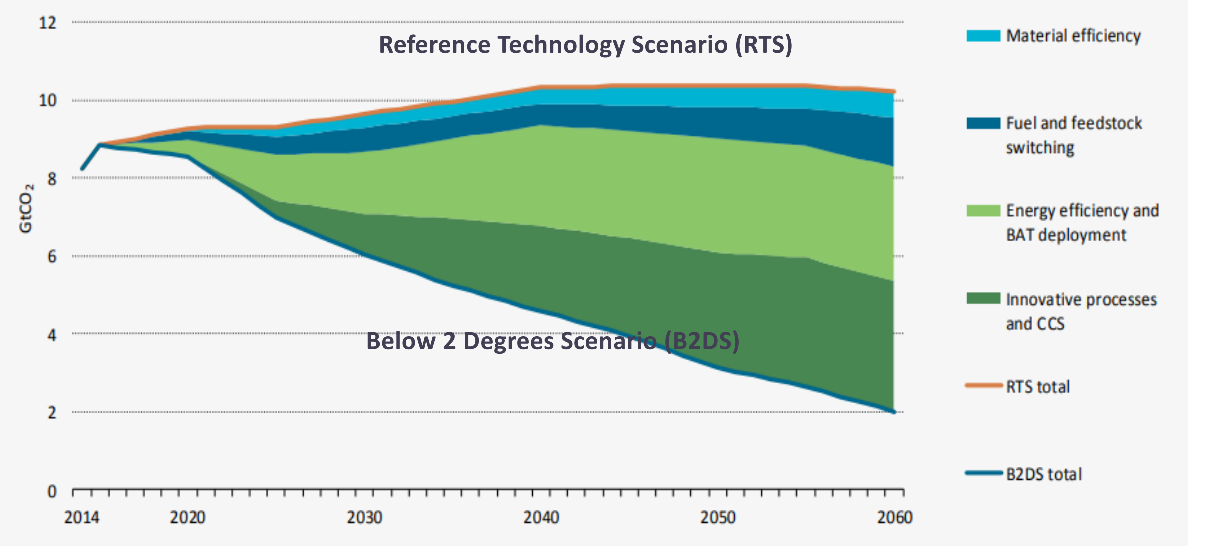
Industrial decarbonisation

"[…] decoupling expanding industrial production from CO_2 emissions require significant improvements in **material and energy efficiency**, […], shifts to **lower-carbon fuels and feedstocks**, and rapid deployment of innovative technologies, including **carbon capture and storage (CCS)**"

`IEA, Energy Technology Perspectives, 2017`

How will such industrial decarbonisation affect the potential for excess heat deliveries from industry?

Direct CO_2 emissions in industry by mitigation strategy in the B2DS compared with the RTS

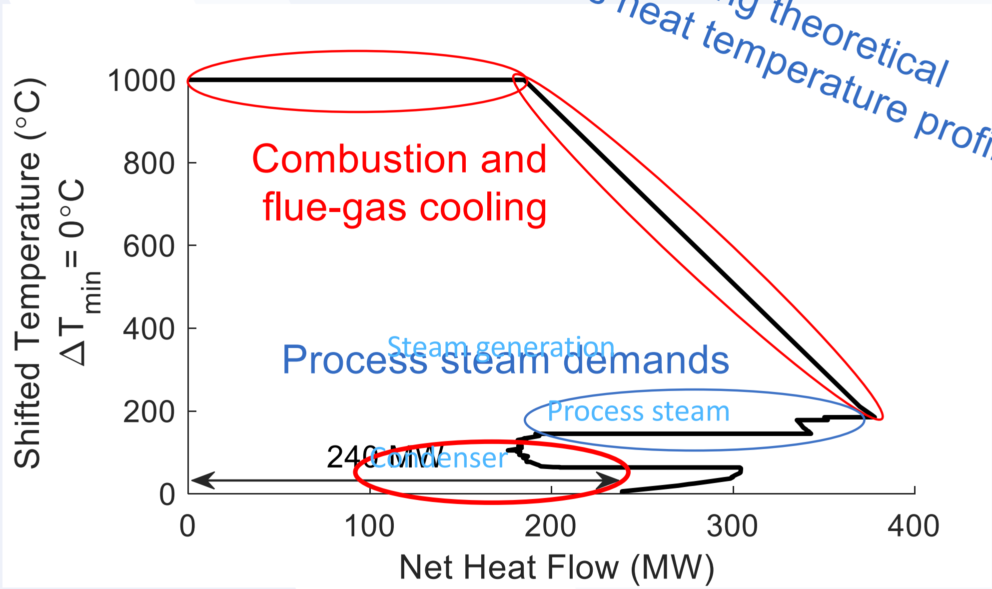


Excess heat assessment

Theoretical assumptions

1. Utilise all non-marketable fuel by-products on-site
2. Minimise heat production in utility boilers and furnaces (fired by purchased fuel)
3. Maximise co-generation in back-pressure steam turbines given process steam demands at existing steam levels
4. Maximise condensing power production
5. Maximise excess heat recovery for new purposes

Resulting theoretical excess heat temperature profile



Svensson, E., Morandin, M., & Harvey, S. (2019b). Characterization and visualization of industrial excess heat for different levels of on-site process heat recovery. International Journal of Energy Research, 43(14), 7988–8003.

Case Studies

PETROCHEMICAL

BIOBASED FEEDSTOCK

Olefins production: converting a steam cracker plant to production based on biomass

- Production of ethylene and propylene using the methanol-to-olefins process (MTO)
- Production of ethylene balance using the ethanol-to-ethylene process (E2E)
- Methanol and ethanol produced on-site from biomass

PULP AND PAPER

CCS (BECCS)

Bio-energy CCS (BECCS) at a chemical pulp mill

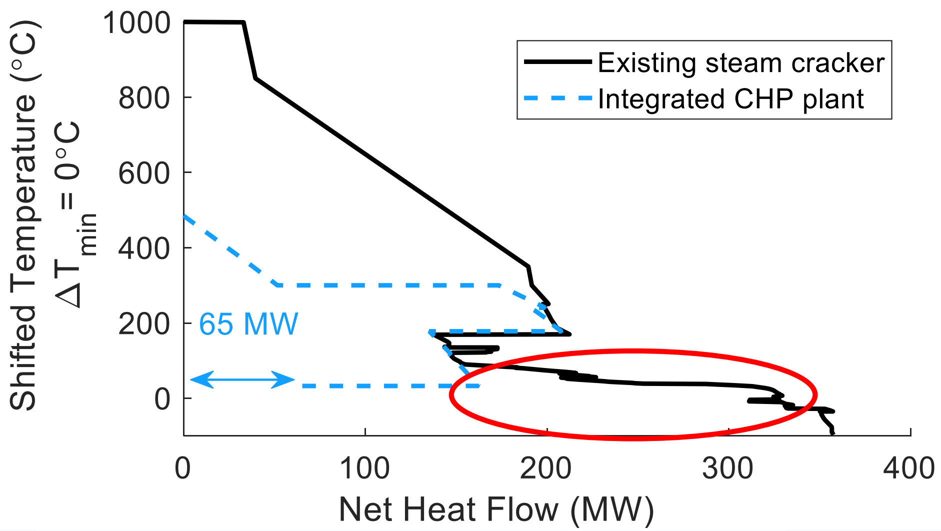
- Post-combustion capture of 90 % of the emissions from the mill's recovery boiler and lime kiln

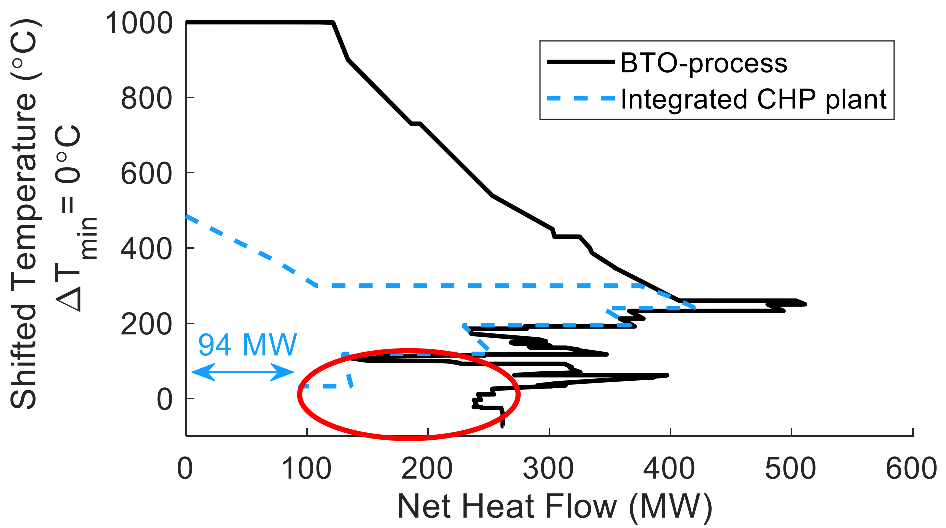
Data from **Chalmers Industrial Case Study Portfolio** [1]

A valuable resource for detailed data on process heat use in existing Swedish industrial plants

[1] Svensson, E., Bokinge, P., Harvey, S., & Normann, F. (2019a). Chalmers Industrial Case Study Portfolio - Contents, Structure and Example Applications, Göteborg, Sweden: Chalmers University of Technology. https://research.chalmers.se/publication/507813

Results – Case Study 1





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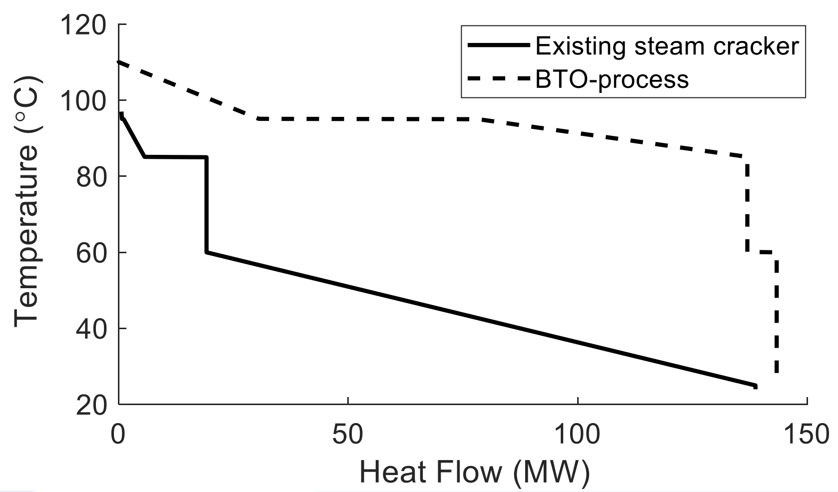
BIOBASED FEEDSTOCK

Results – Case Study 1

Heat		
Excess heat (≥ 85 °C)	+118 MW	+620 %
Excess heat (≥ 25 °C)	+4 MW	+3 %
Power		
Power generation target	+29 MW	+45 %
Power consumption	+141 MW	+270 %
Power import	+112 MW	+560 %



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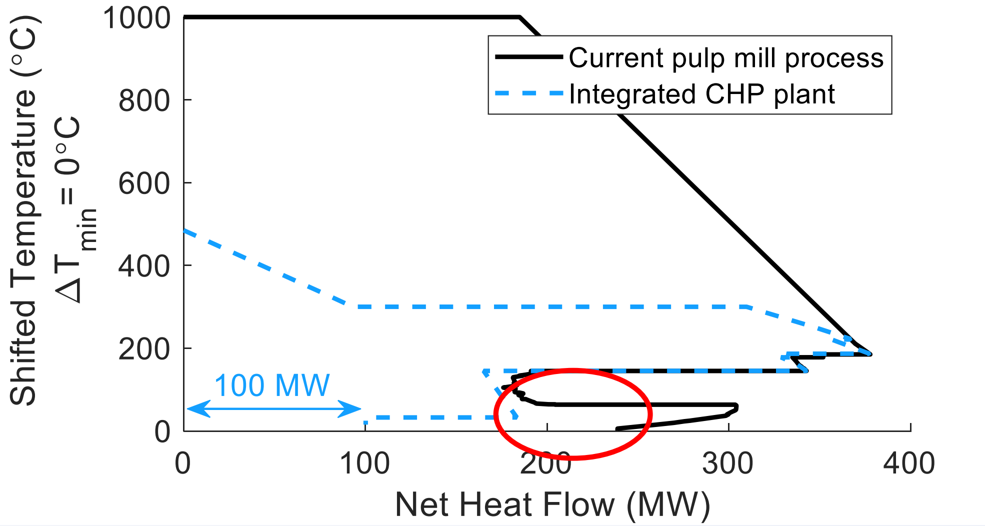
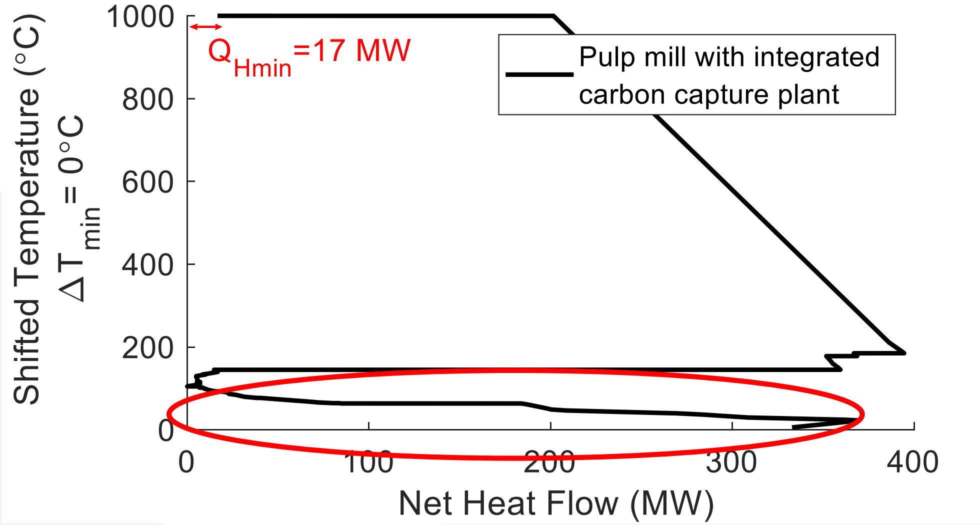
BIOBASED FEEDSTOCK

Results – Case Study 2



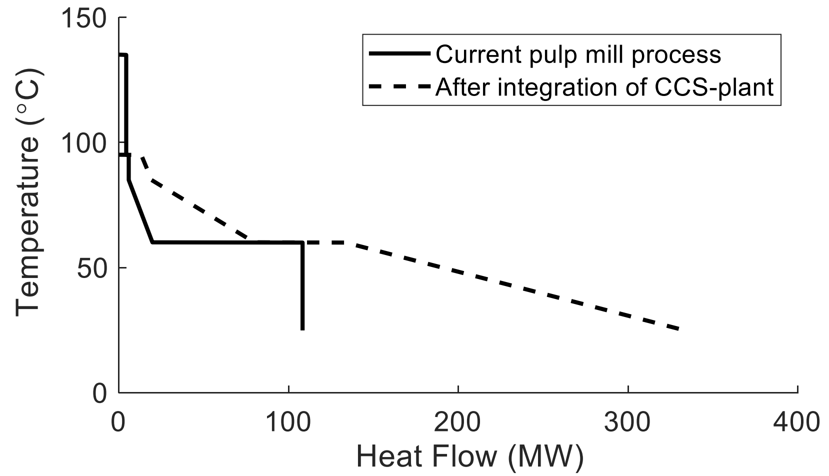


PULP AND PAPER

CCS (BECCS)

Results – Case Study 2

Heat		
Excess heat (≥ 60 °C)	+26 MW	+24 %
Excess heat (≥ 25 °C)	+224 MW	+207 %
Power		
Power generation target	-100 MW	-100 %
Power consumption	+20 MW	+36 %
(Net) power import	+120 MW	N/A



PULP AND PAPER

CCS (BECCS)

Summary and Conclusions

- Decarbonisation may significantly change potential excess heat availability, and power generation targets.
- Important to account for future process development when estimating industrial excess heat potentials
- Systematic energy targeting – basis for further bottom-up assessments of sector-wide potentials for future industrial excess heat

Sneak peak into further work

	Theoretical excess heat			Potential steam turbine power generation	
	Total > 25 °C	> 60 °C	>= 85 °C	Back-pressure	Condensing
Iron and steel mill					
HYBRIT	↗	↑	↓	↓	↓
HYBRIT with off-gas heat recovery	↗	↑	↓	↓	↓
Steam cracker plant					
BTO process	→	↑	↑	↑	↓
MTO/ETE process	↘	↑	↑	↓	↓
Oil refinery					
Full-scale carbon capture	→	↑	→	→	↓
Low-temp electro-HPU & carbon capture	↗	↑	→	↘	↘
High-temp electro-HPU & carbon capture	→	↑	→	→	↓
Pulp mill					
Lignin extraction	↘	→	→	→	↓
Carbon capture	↑	↑	↑	↓	↓