CO_2 CAPTURE BASED ON LOW-TEMPERATURE TECHNOLOGY

David Berstad
SINTEF Energy Research

Simon Roussanaly, Rahul Anantharaman, Petter Nekså, Jana P. Jakobsen
SINTEF Energy Research

CO2 CAPTURE AND STORAGE IN THE CONDITIONS OF THE CZECH REPUBLIC
"Cooperation of Czech republic and Norway"
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Outline

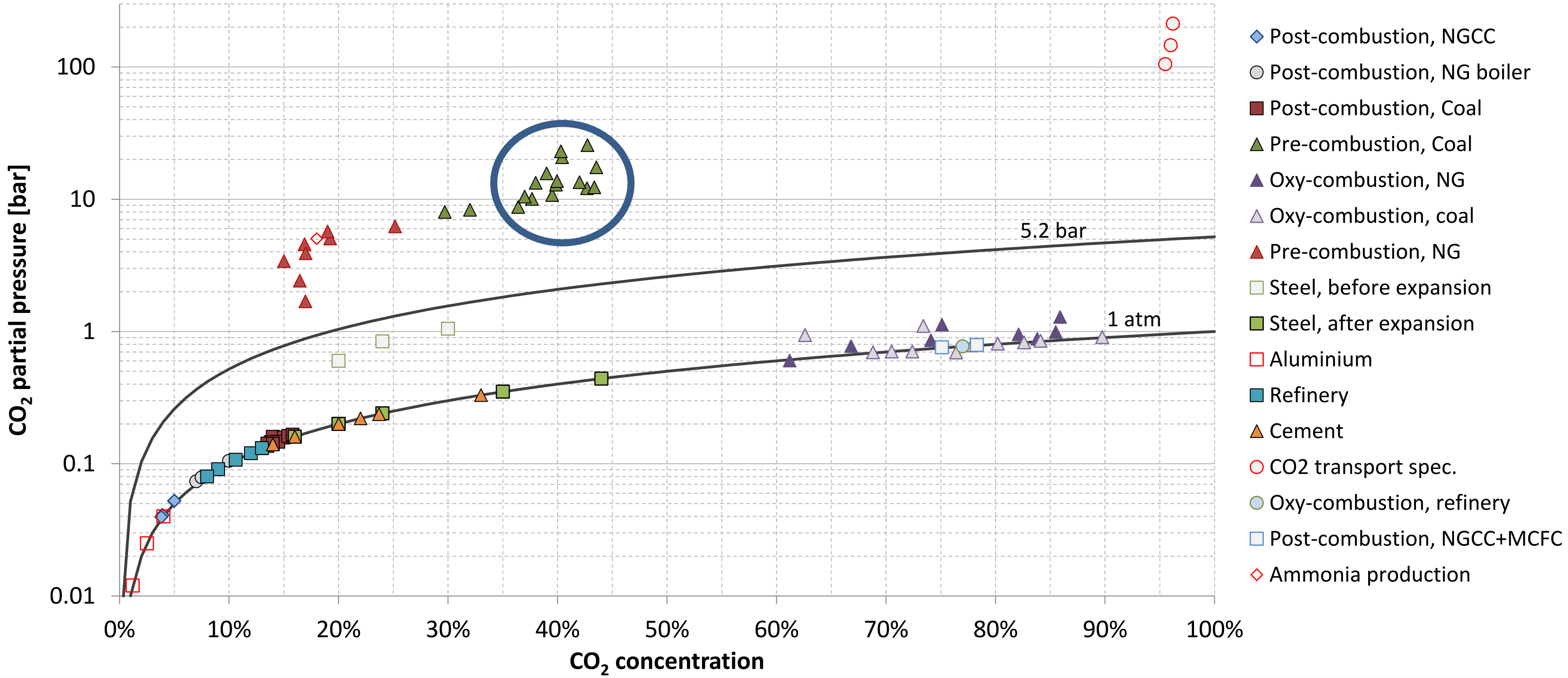
- Background and motivation
- CO_2 capture conditions – implications on capture technology
- Syngas data in consideration
- Process principles and design
- Energy results
- Concluding remarks, further work
- Prospective experimental activity

Background and motivation

- Generally: Different CO_2 separation technologies have different optimal operating conditions
  - Low CO_2 concentration: chemical sorption with high binding energy is generally the prevailing technology
  - High CO_2 concentration: bulk separation technologies such as e.g. condensation or membranes will become more efficient than solvents and sorbents
- Specifically: The high CO_2 concentration and partial pressure for typical IGCC syngas (shifted) can be utilised to achieve highly energy- and cost-efficient capture units by low-temperature condensation

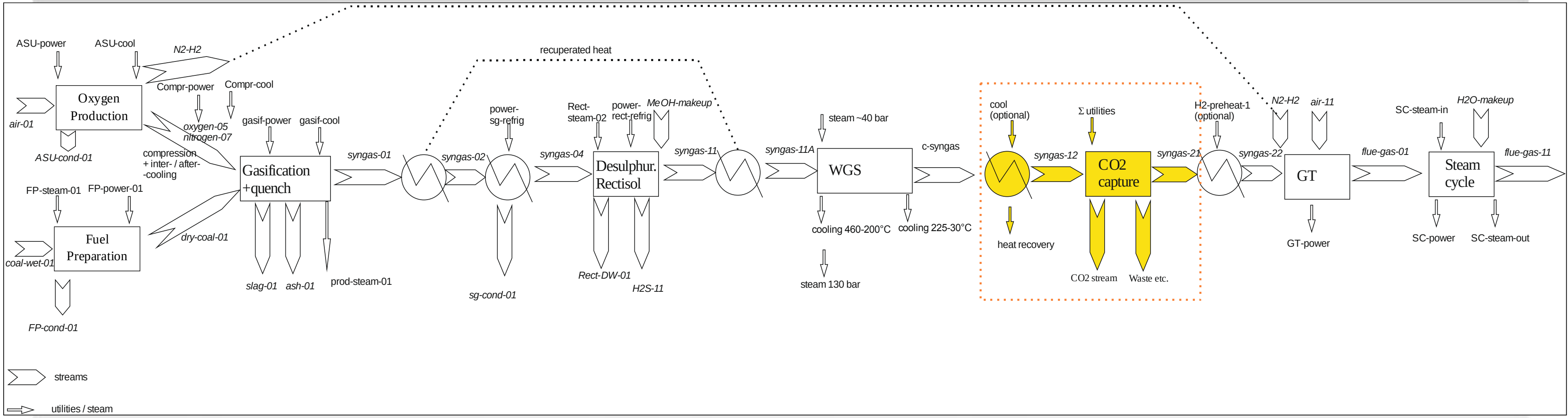
CO_2 capture conditions for IGCC

Figure: CO_2 capture conditions for large point sources



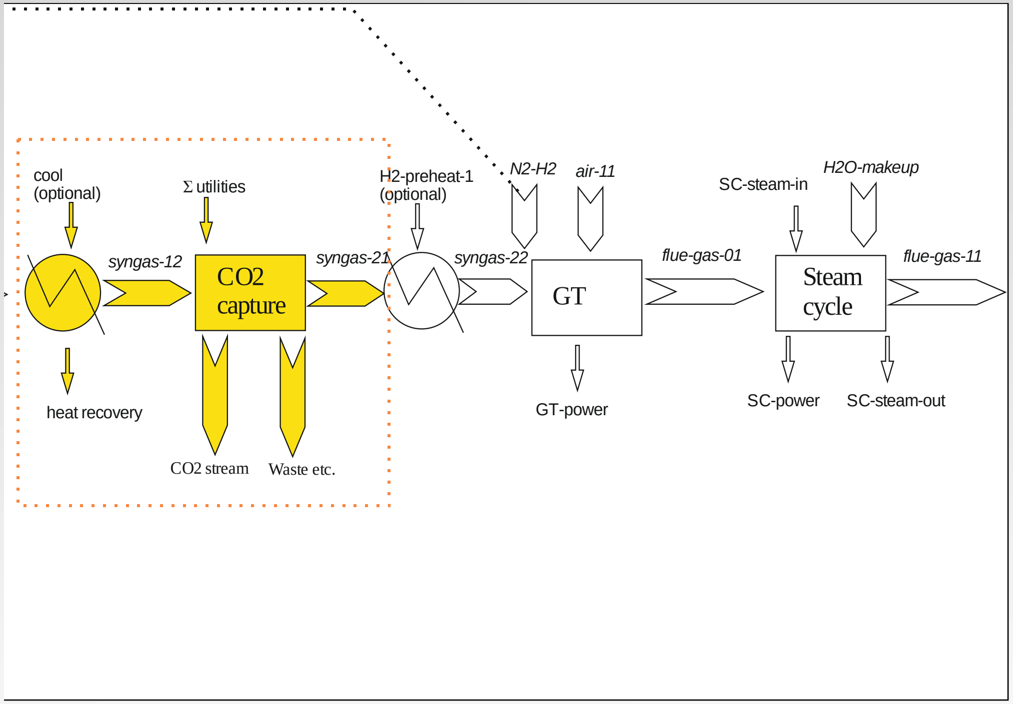
Based on: Berstad D., Anantharaman R., Nekså P. Low-temperature CO_2 capture technologies – Applications and potential. International Journal of Refrigeration, 36(5) 2013, 1403–1416

IGCC process



IGCC process

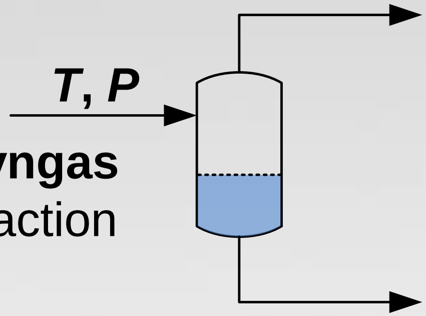
Syngas data	
T [°C]	30.0
P [bar]	28.0
m [kg/s]	68.0
CO_2	38.68 %
H_2	53.47 %
N_2	5.90 %
H_2S	0.00 %
CO	1.09 %
COS	0.01 %
H_2O	0.03 %
O_2	0.00 %
AR	0.80 %



Vapour–liquid equilibrium for CO_2/H_2

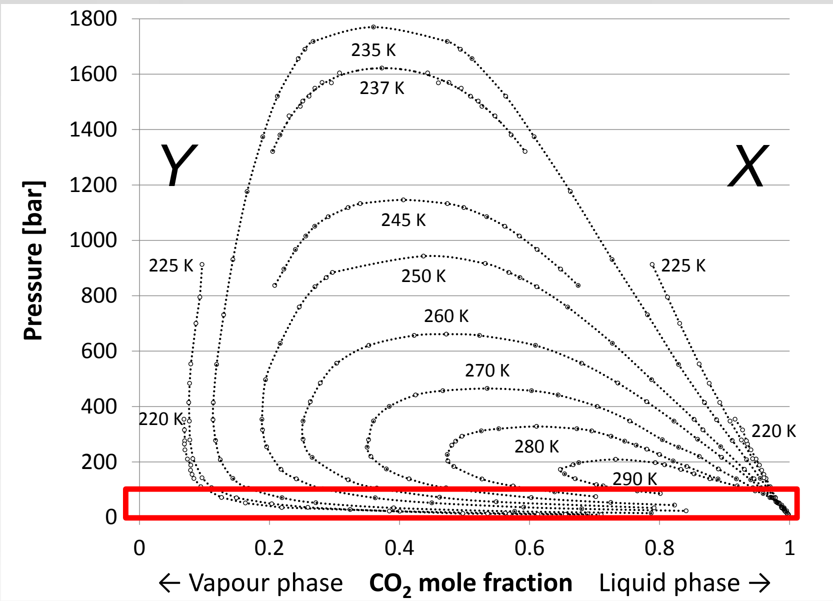
Hydrogen-rich fuel
Y (CO_2 fraction in vapour phase)

T*, *P



Shifted syngas
Y_0 (CO_2 fraction in feed)

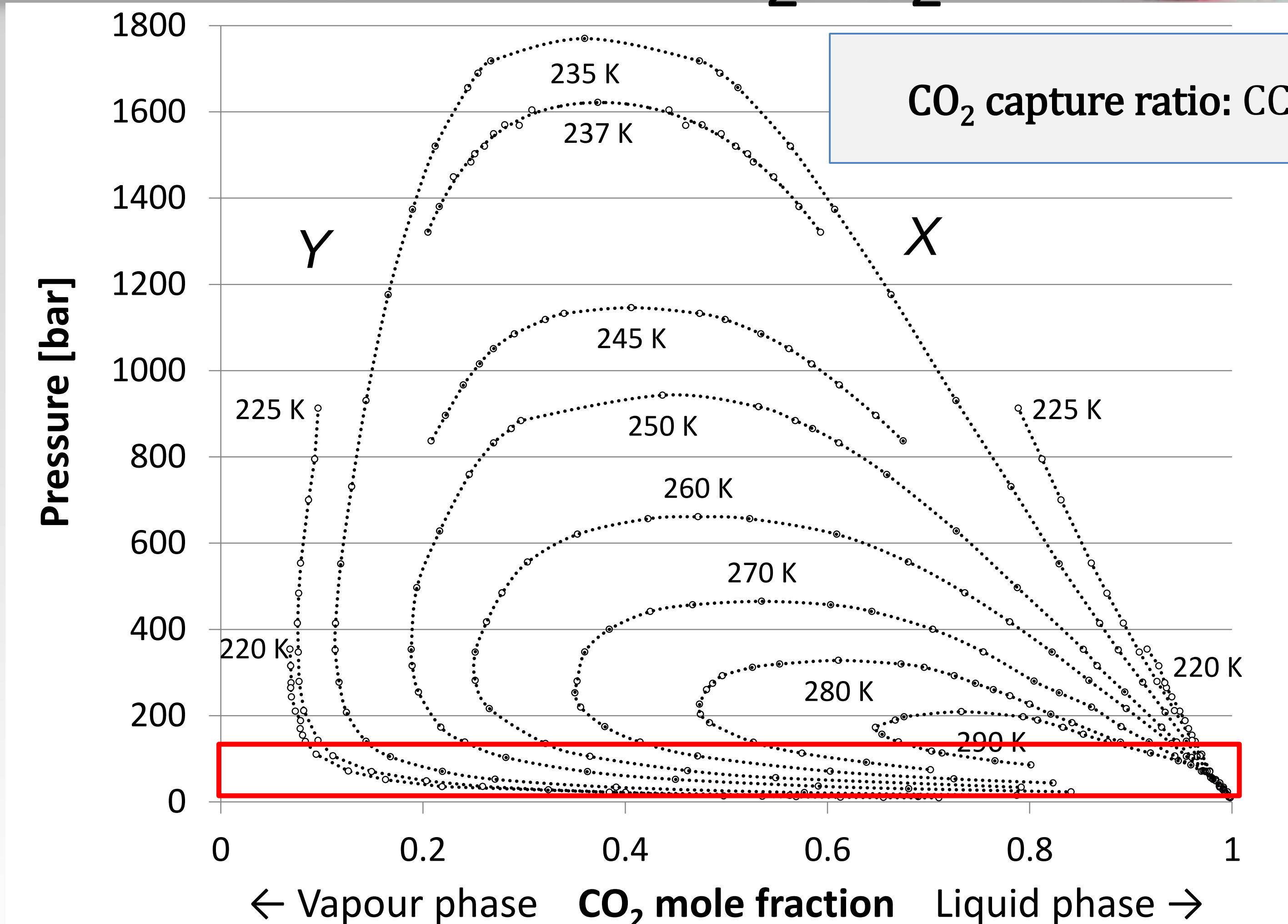
Liquid CO_2
X (CO_2 fraction in liquid phase)



Vapour–liquid equilibria for the binary H_2/CO_2 system. Plot based on experimental data from Tsang and Streett (1981)

$$\textbf{CO}_2\ \textbf{capture ratio: } \mathrm{CCR} = \frac{X(Y_0 - Y)}{Y_0(X - Y)}$$

Vapour–liquid equilibrium for CO_2/H_2



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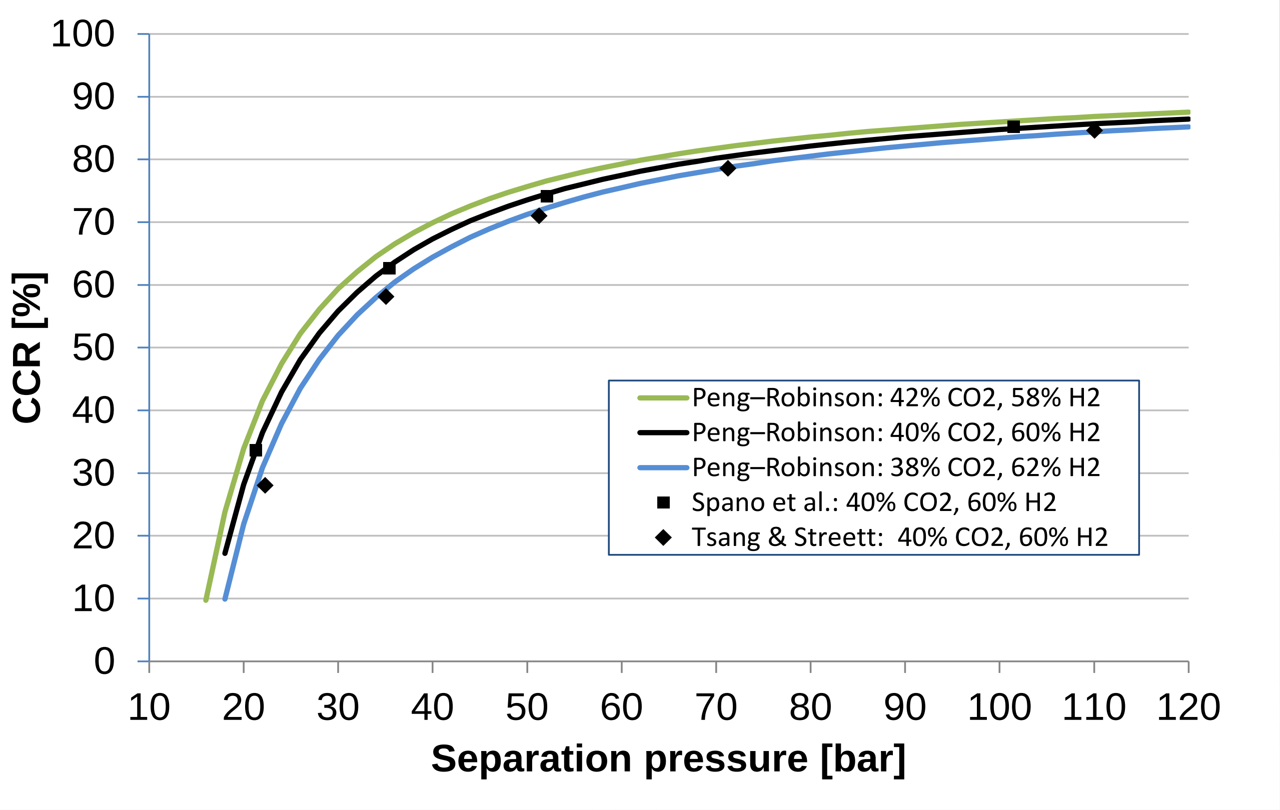
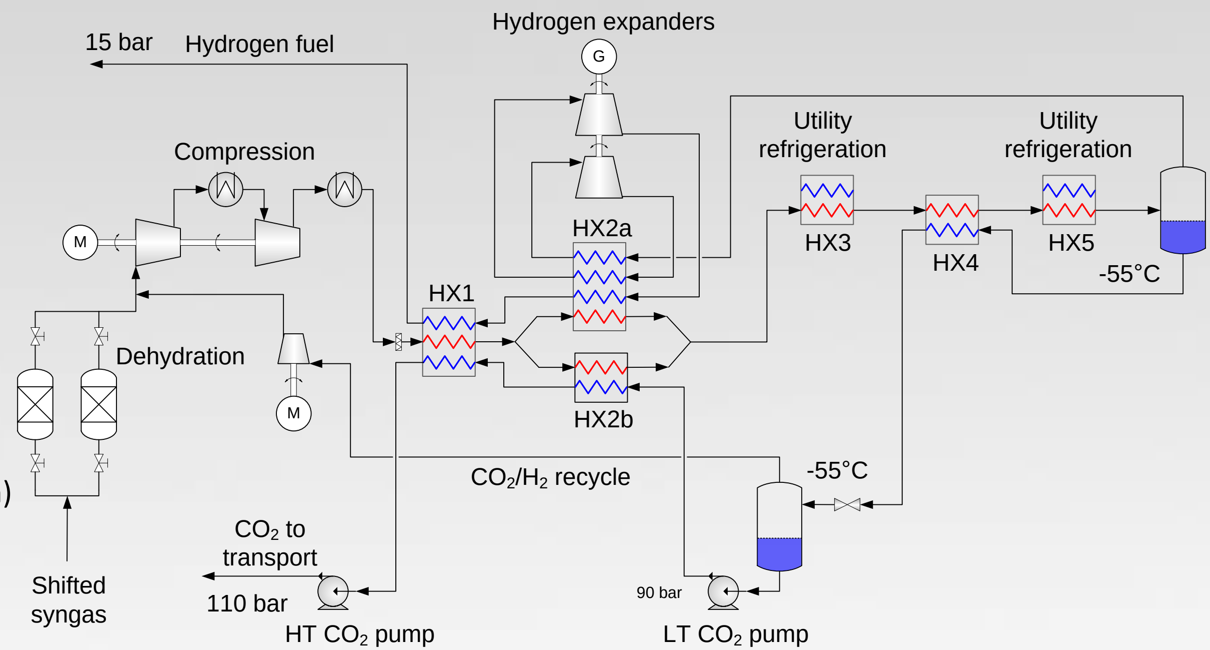


Estimated CCR for binary mixtures of H_2 and CO_2 separated at -53°C (Berstad et al., 2013)

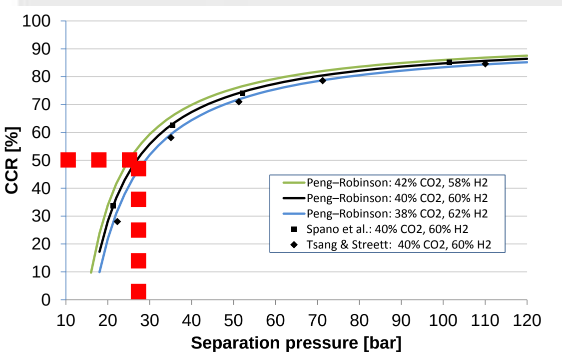
Process design principles – 84 % CCR

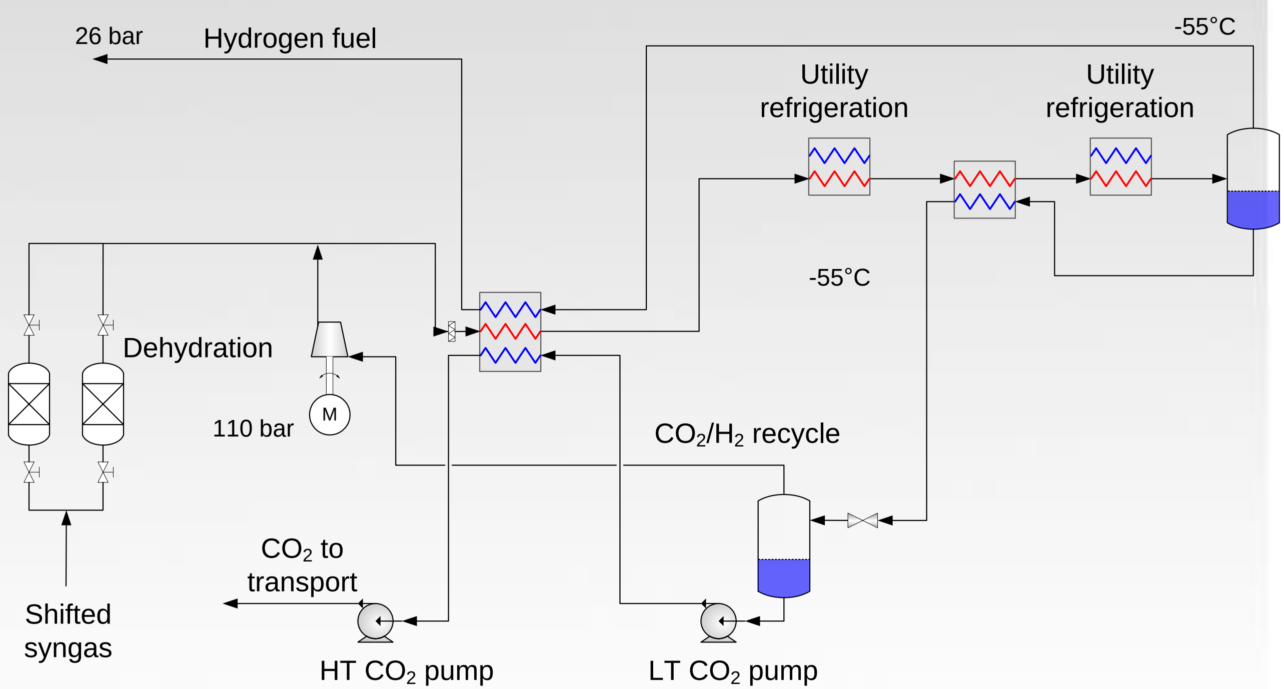
- Feed dehydration
- Syngas compression from 28 bar to 105 bar
- High- and low-pressure separation stages at -55°C
- Energy recuperation
  - Process-to-process heat recuperation
  - Gas expanders (power recovery and additional heat recuperation)
- Auxiliary refrigeration
- Liquid pumping of CO_2 to transport pressure



Process design principles – 51% CCR (1)

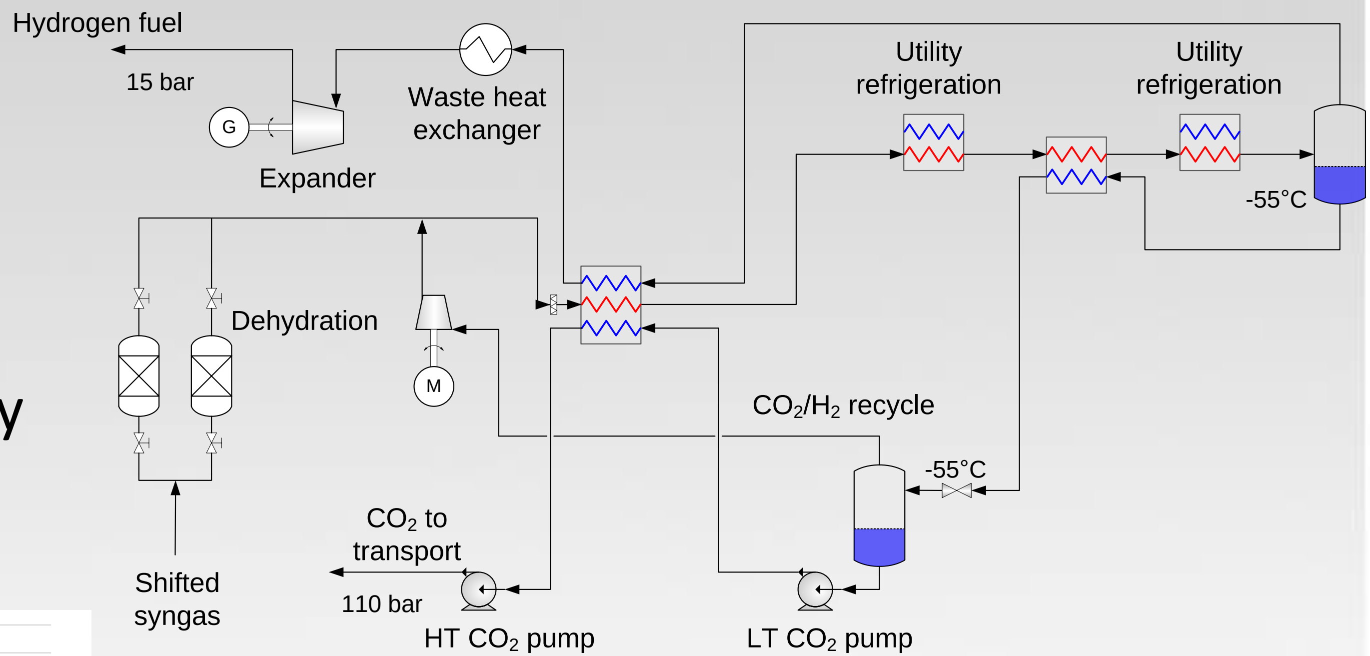
- No additional syngas compression
- No gas expander

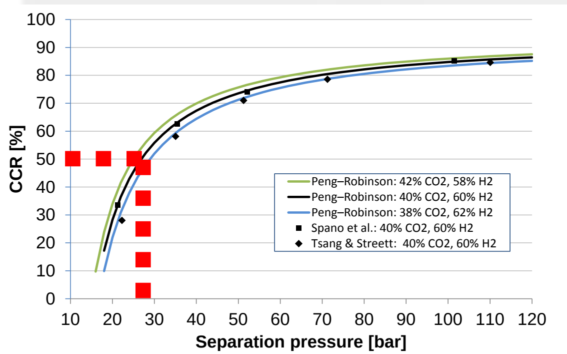




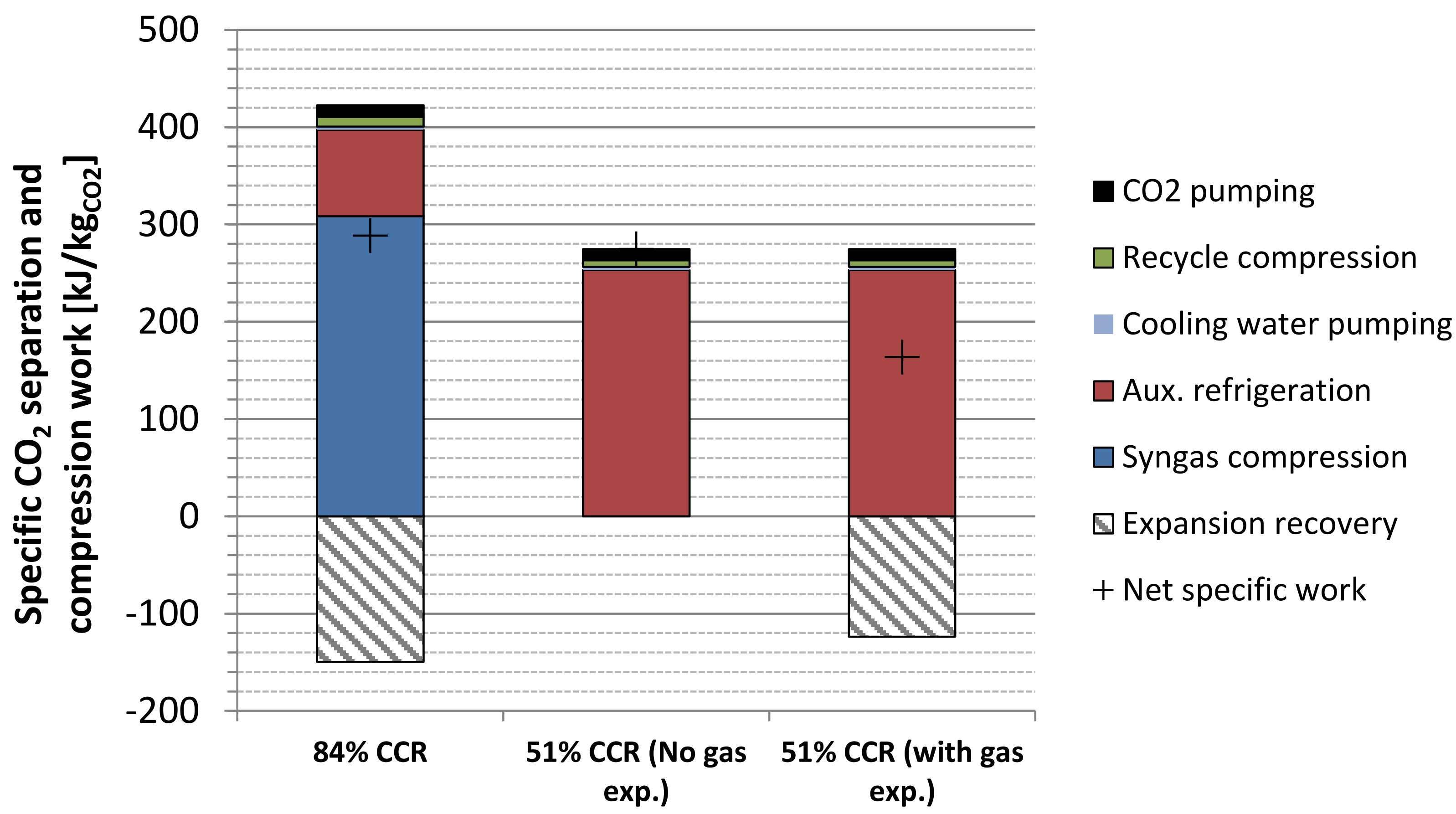
Process design principles – 51% CCR (2)

- No additional syngas compression
- Gas expander for max energy recovery





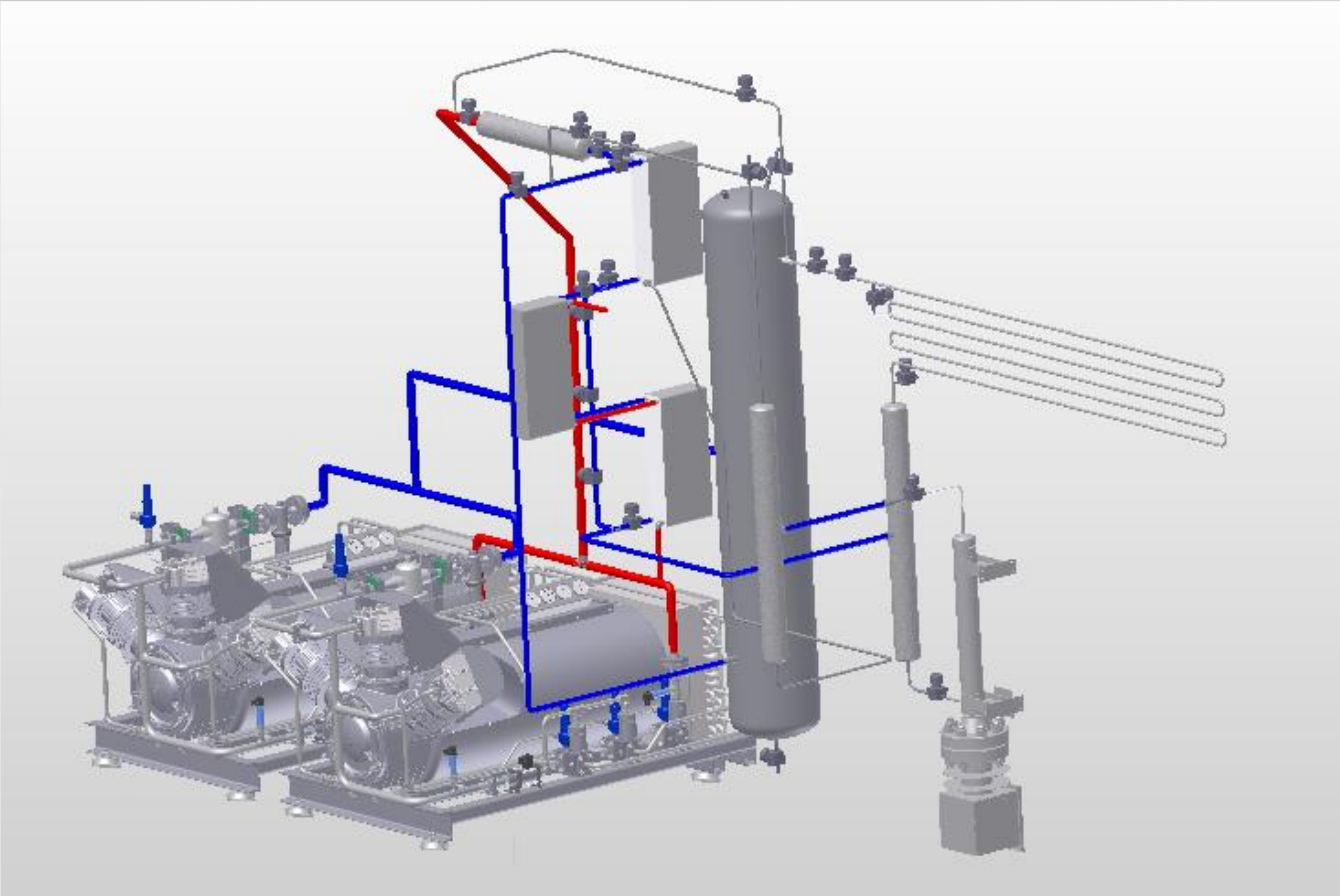
Energy results – decomposed



Concluding remarks and further work

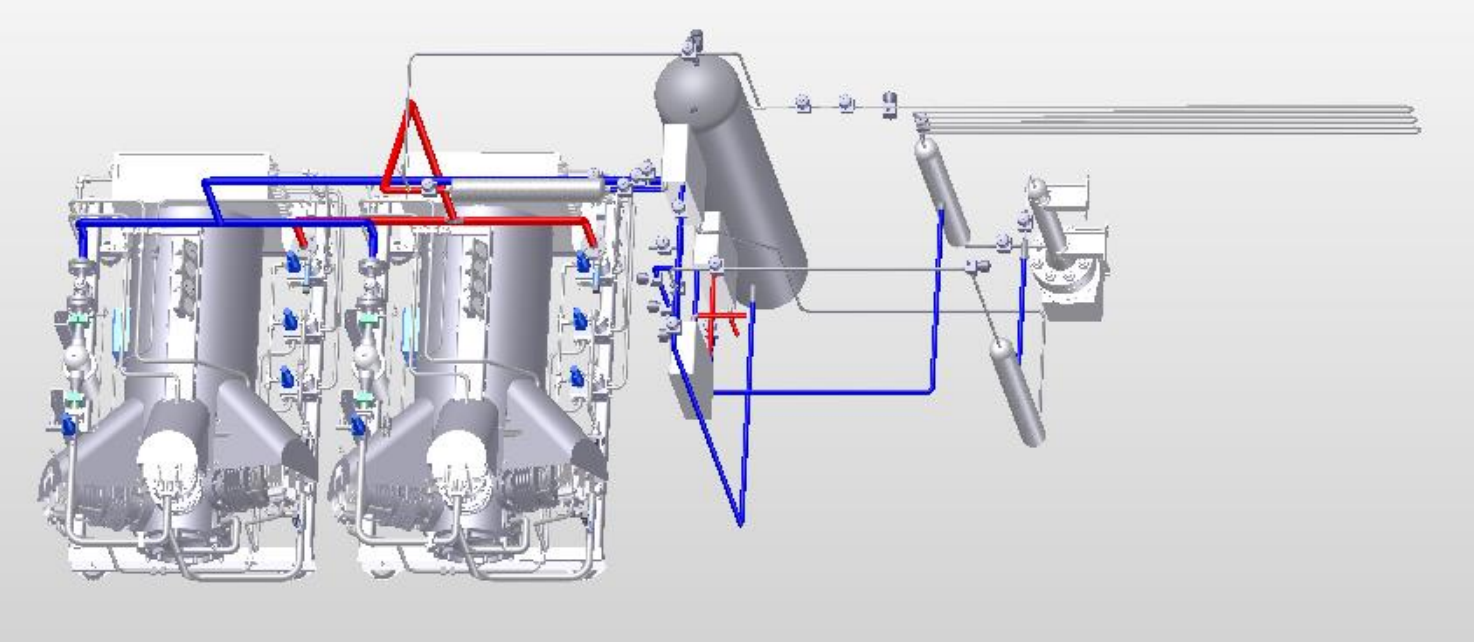
- High CO_2 concentration and pressure is favourable for CO_2 separation processes by liquefaction and phase separation
- CO_2 capture ratio in the range of 85% can be obtained for shifted syngas with around 40% CO_2 concentration – this requires further compression of the syngas (up to around 100 bar)
- Lower capture ratios ("partial capture") can be achieved with lower investment and power requirement without syngas compression prior to cooling and condensation
- Further work includes lab pilot testing of the technology

Prospective experimental activity



Prospective experimental activity

- Closed loop lab pilot rig
- 5–10 ton CO_2 per day
- 120 bar max. operating pressure
- Engineering phase and investment phase currently ongoing
- First experiments: N_2/CO_2 separation
- Succeeding experiments: H_2/CO_2 separation



Acknowledgements

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