Cost comparison of technologies for pre-combustion CO_2 capture from an lignite-fired IGCC

Simon Roussanaly[1,*], Monika Vitarova[2], Rahul Anantharaman[1], David Berstad[1], Brede Hagen[1], Jana Jakobsen[1], Vaclav Novotny[2] and Geir Skaugen[1]

[1] *SINTEF Energy Research, Sem Sælandsvei 11, NO-7465 Trondheim, Norway*

[2] *Czech Technical University in Prague, Faculty of Mechanical Engineering, Department of Energy Engineering, Czech Republic*

* *Corresponding author. E-mail address: simon.roussanaly@sintef.no*

Motivation

- Lignite represents around 10% of the total world coal production and is especially used in the power generation sector in Germany, United States, Russia and Eastern Europe due to its low price.
- While its consumption have been decreasing over the last decades. A pause in this decrease have been observed in 2015 and might compromise European emission target CCS is not integrated to lignite-fired power plant.
- Although solvent-based CO_2 capture is the most mature and demonstrated technologies for CO_2 capture, other emerging technologies are foreseen to have the potential to lower the capture cost
- However no systemic cost-comparison of CO_2 capture technologies from an lignite-fired IGCC have been investigated.

I. Methodology

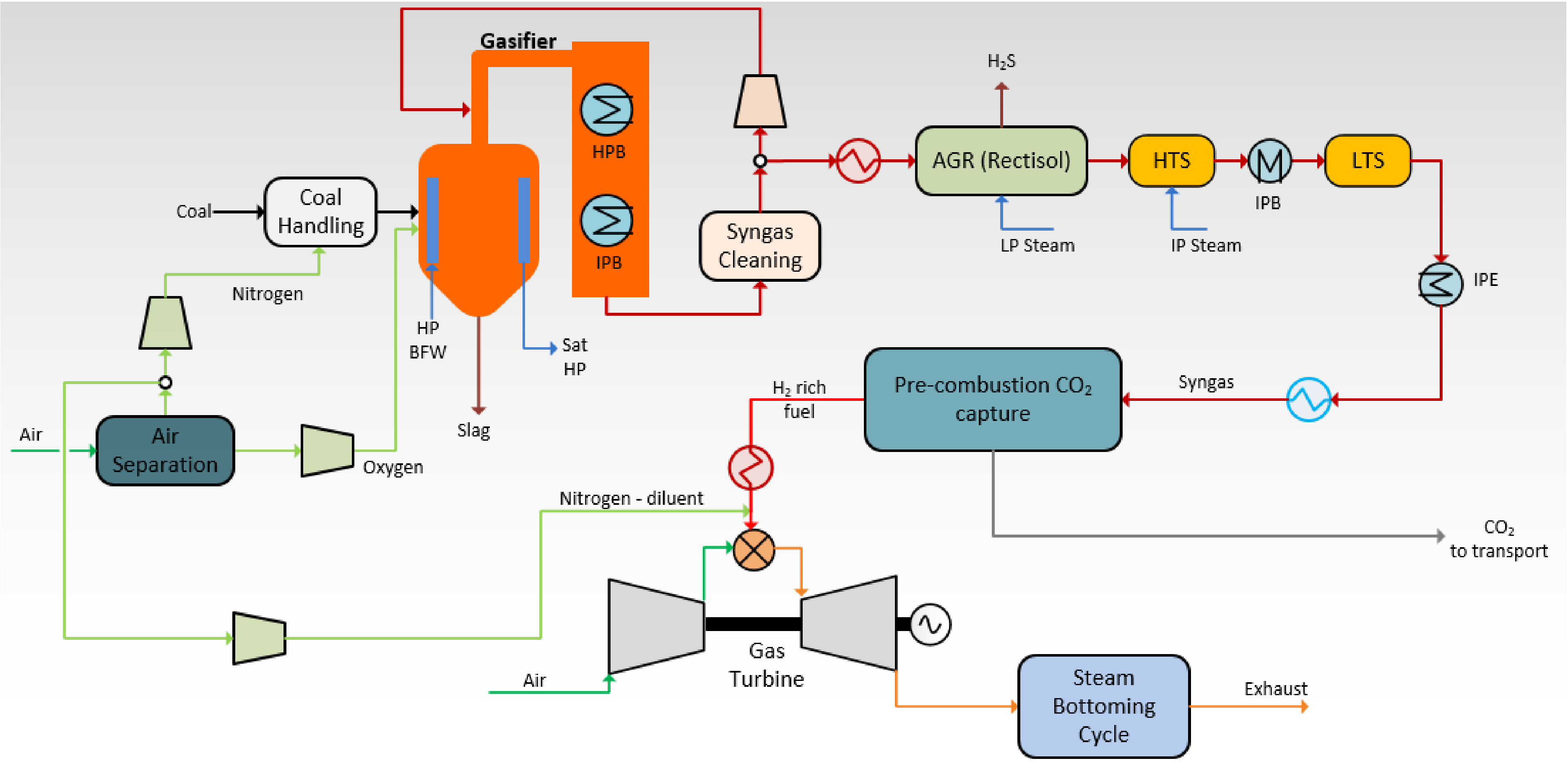
Concept presentation

- Lignite based IGCC
  - Located in Czech Republic
  - Lignite input 39 kg_{wet}/s leading to a NPO without CCS of 279 MW
  - CO_2 emissions without capture 1.57 $MtCO_2/y$
  - Syngas after WGS available at 28 bar and contain 29.2 $\%_{CO2,wet}$
  - Base case: 85% CO_2 Capture Ratio (CCR)

- Comparison in term of energy and costs of three CO_2 capture technologies:
  - Rectisol based capture
  - Low-temperature based capture
  - Polymeric membrane based capture

- Impact of the CCRs on the capture technology comparison

IGCC plant with CO_2 capture

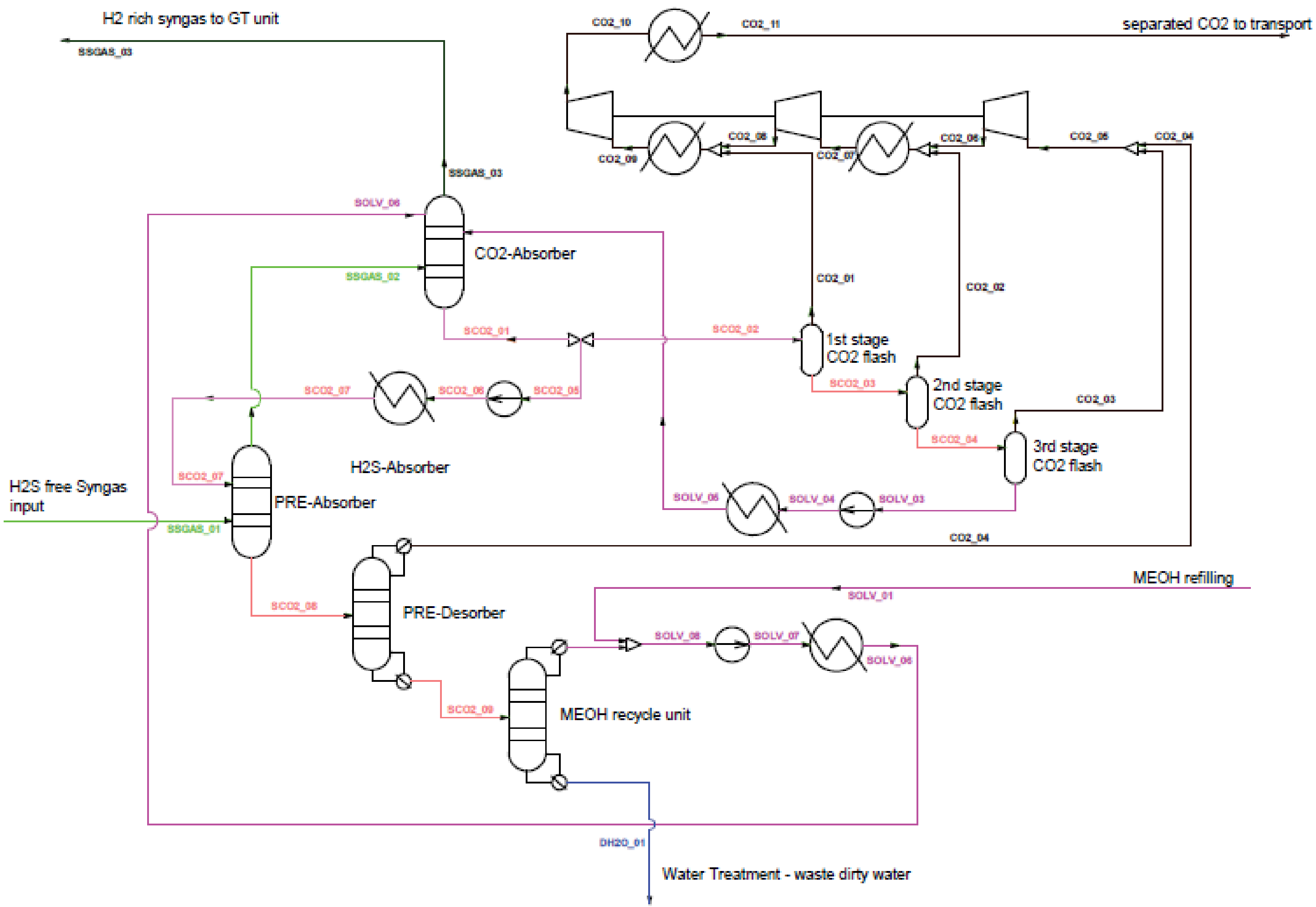


CT1: Rectisol based capture

- One of the most popular technologies for sour gas removal, especially in coal based on chemical processes
  - Used in the reference power plant for H_2S removal
  - Considered to suitable for high CO_2 partial pressure

- The Rectisol process is based on
  - Physical absorption by refrigerated methanol (-50ºC)
  - Multi-stages flashing for the regeneration

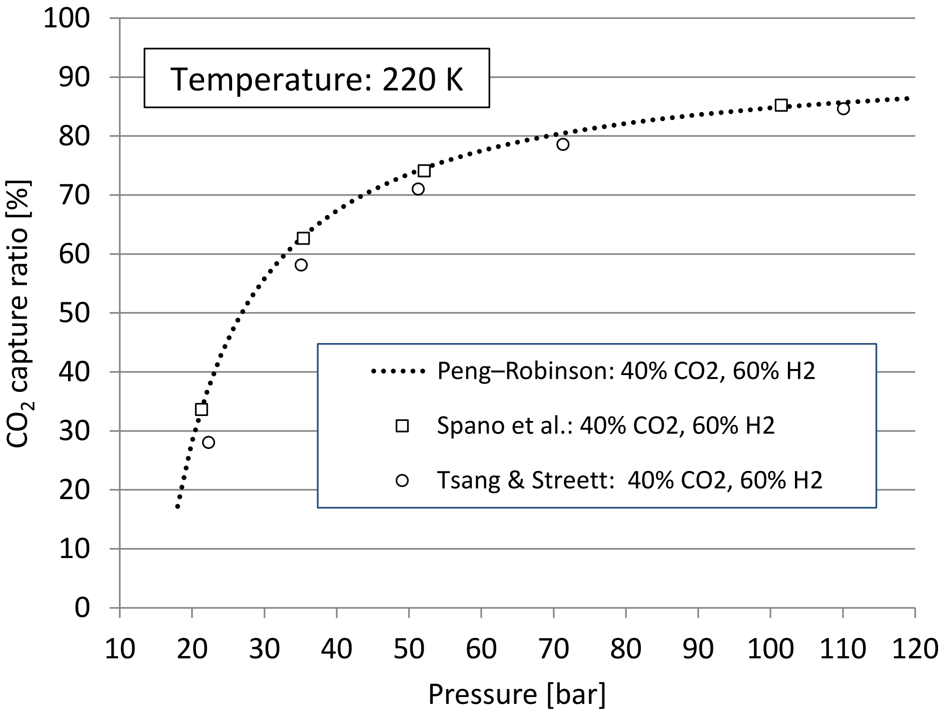
CT1: Rectisol based capture



CT2: Low-temperature based capture

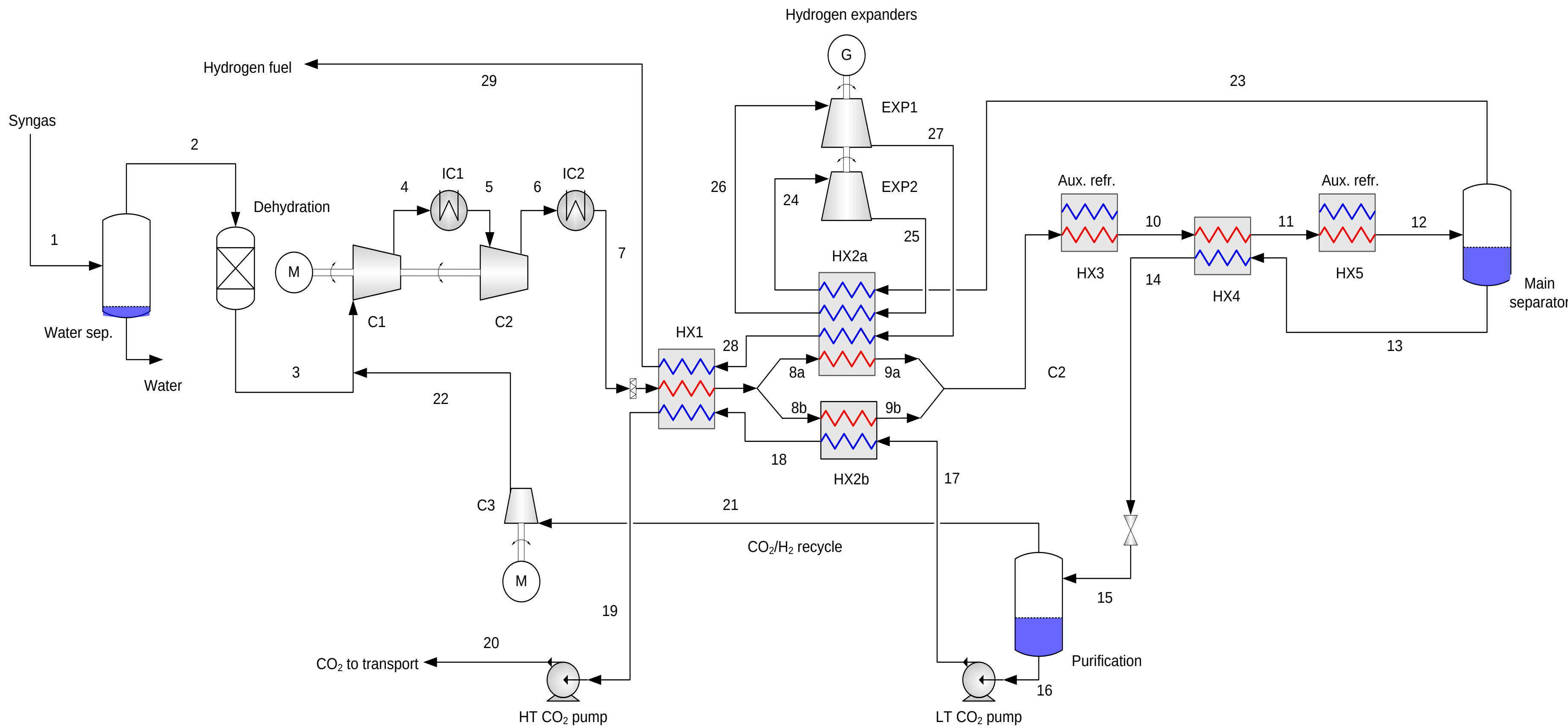
- Physical driven process
  - Process based on phase separation after partial liquefaction of the stream
  - Liquefaction achieved by compression and cooling

- The pressure after compression drives the CO_2 capture ratio



CT2: Low-temperature based capture

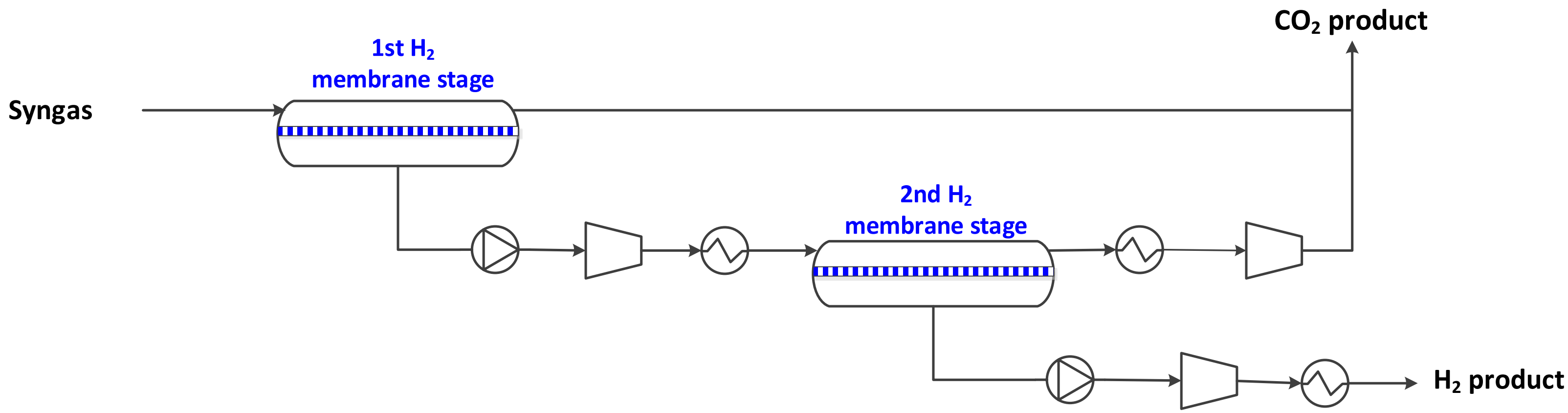
- Process flow diagram



CT3: Polymeric membrane based capture

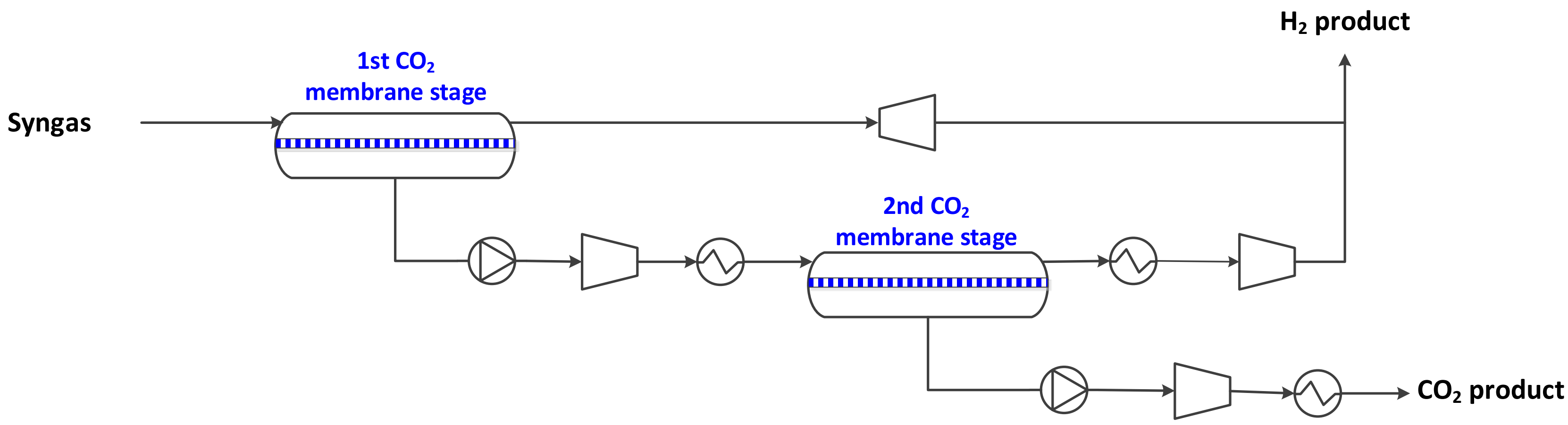
- CO_2 selective and H_2 selective membranes are considered
  - Cost optimisation of the membrane process within the power plant

- H_2 selective membrane:



CT3: Polymeric membrane based capture

- CO_2 selective membrane



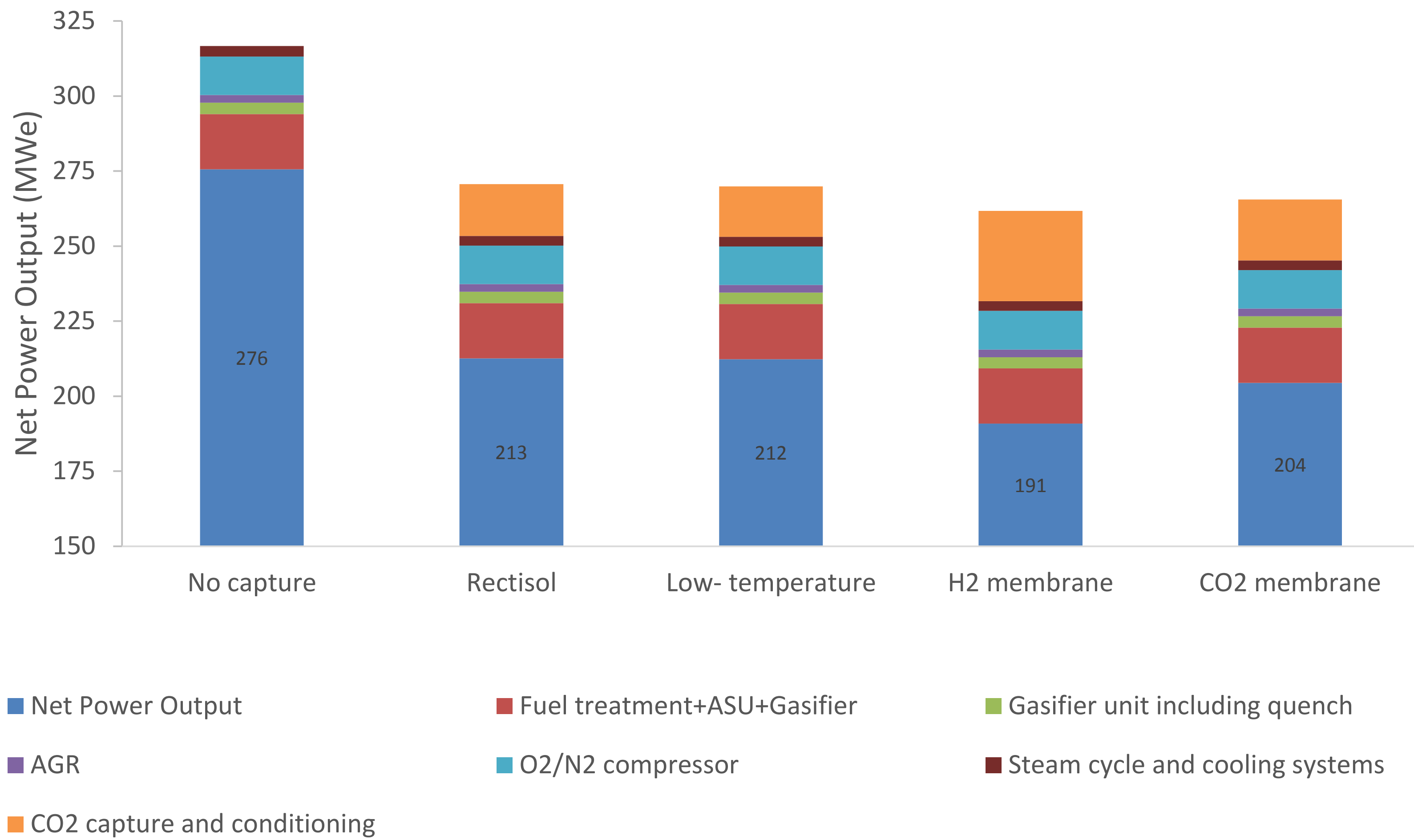
- **H_2 selective membrane**
  - $P = 0.18\ m^3_{(STP)} m^{-2} bar^{-1} h^{-1}$
  - $\alpha = 30$
- **CO_2 selective membrane**
  - $P = 0.18\ m^3_{(STP)} m^{-2} bar^{-1} h^{-1}$
  - $\alpha = 37.2$

Cost assessment

- Bottom up approach
  - Developed to be consistent between capture technologies
  - Taking into account maturity differences between technologies
- Cost of the power plant are based on the EBTF (European Benchmarking Task Force)
  - Adjusted to reflect cost representative of Czech Republic
- KPIs: Levelized Cost of Electricity and CO_2 avoided cost

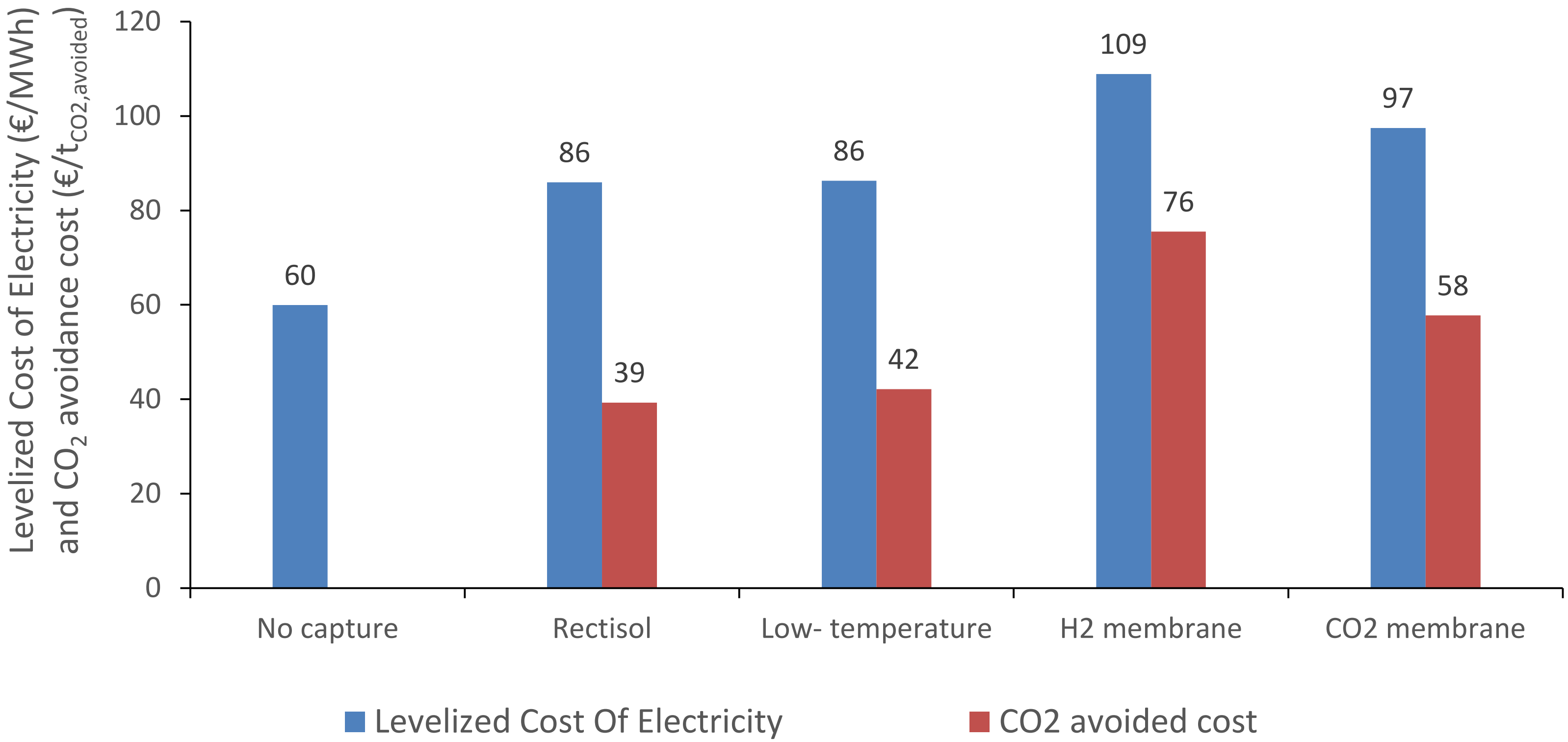
II. Results

Energy performances



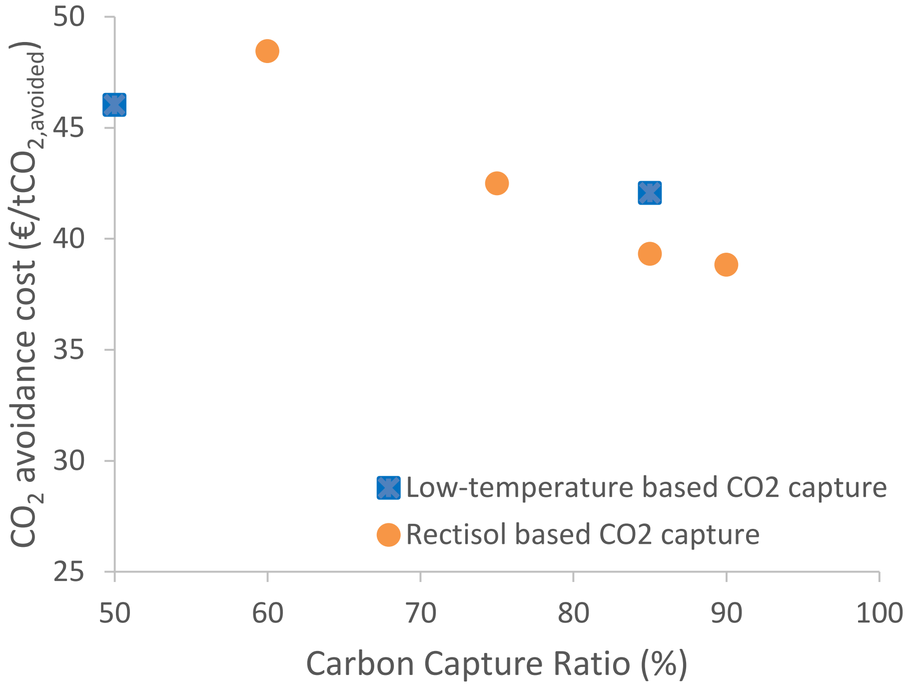
Cost performances (CCR ~85%)

- Best options: Rectisol, low-temperature
- The considered CO_2 and H_2 membranes do not appear as a good option for the membrane properties and process configuration considered
- LCOE increase of at least 43% with CCS



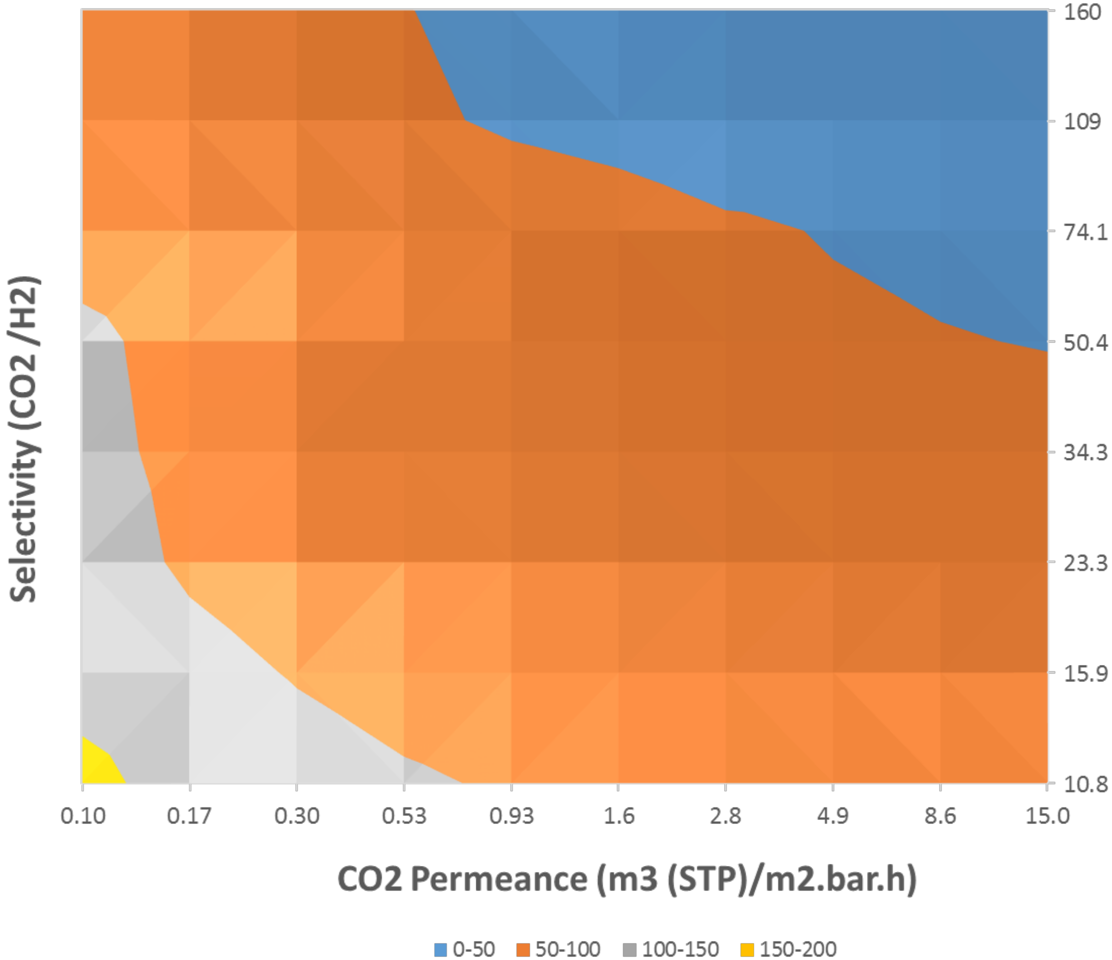
Impact of lower CCRs

- Rectisol
  - 39 €/t at 90% CCR
  - 49 €/t at 60% CCR
  - Non-linear evolution
- Low-temperature
  - 42 €/t at 90% CCR
  - 46 €/t at 50%CCR
  - Not very sensitive to CCR
- It appears that there is a CCR under which the low-temperature become the optimal technology
- Membrane not evaluated yet
  - From experience in post-combustion capture, CO_2 avoided cost can decrease with lower CCR
- Syngas pressure is another parameter intersting to investigate



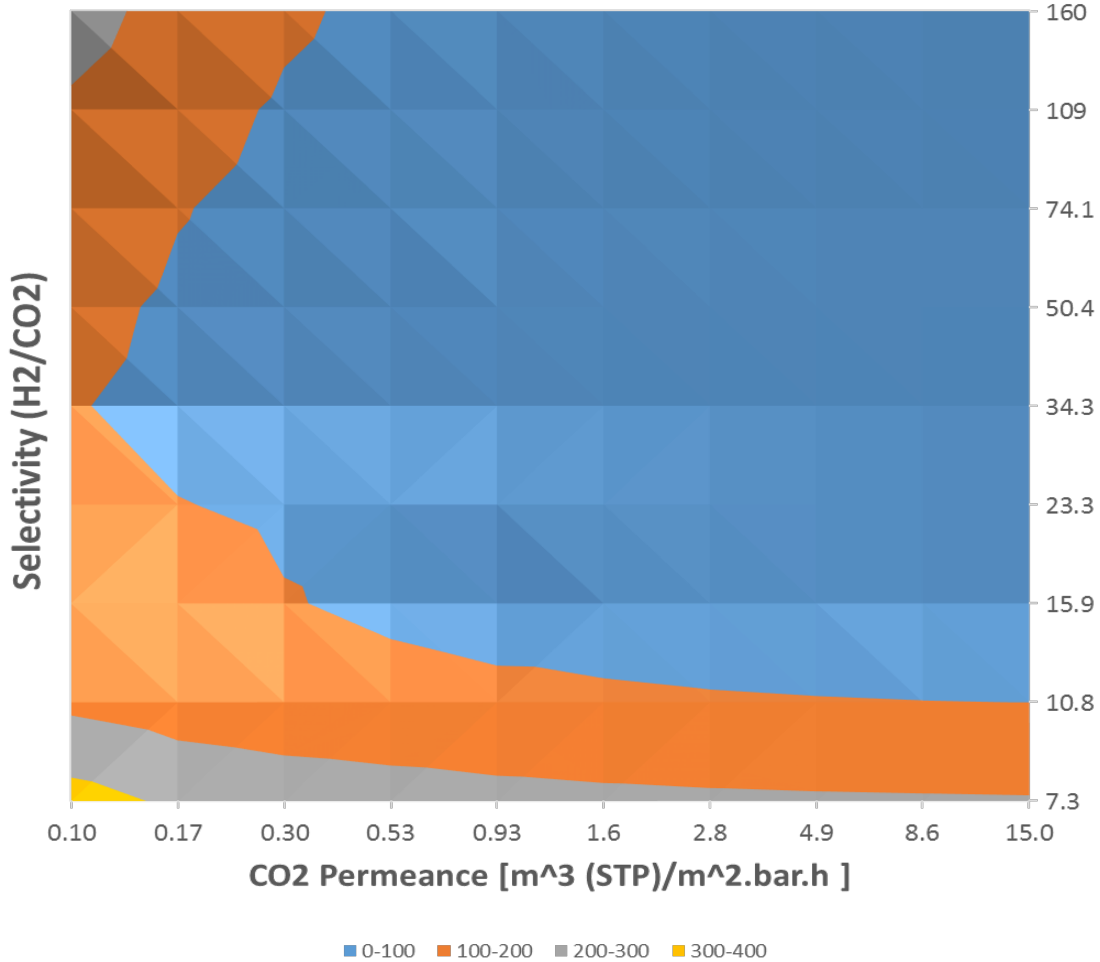
What properties for membrane based capture?

- CO_2 selective membranes



What properties for membrane based capture?

- H_2 selective membranes



III. Conclusions and future work

Conclusions and future work

- Conclusions
  - Investigation three capture technologies for a lignite based IGCC
  - Rectisol and low-temperature appear to be the best options in term of energy and cost
  - Rectisol is better for higher CCRs while low-temperature is more efficient for lower ones
  - The selected CO_2 and H_2 membranes are not competitive in the base case with the process configurations and CCR considered

- Future work
  - Investigate the impact of lower CCRs and high syngas pressure on the bechmark of the capture technolgies
  - Perform full-chain evaluation to include the impact of impurities in CO_2 stream

Acknowledgements

This publication has been produced as part of the PilotCCS project with support from the Norway grants, as part of the project NF-CZ08-OV-1-003-2015

Cost comparison of technologies for pre-combustion CO_2 capture from an lignite-fired IGCC

Simon Roussanaly[1,*], Monika Vitarova[2], Rahul Anantharaman[1], David Berstad[1], Brede Hagen[1], Jana Jakobsen[1], Vaclav Novotny[2] and Geir Skaugen[1]

[1] SINTEF Energy Research, Sem Sælandsvei 11, NO-7465 Trondheim, Norway

[2] Czech Technical University in Prague, Faculty of Mechanical Engineering, Department of Energy Engineering, Czech Republic

** Corresponding author. E-mail address: simon.roussanaly@sintef.no*