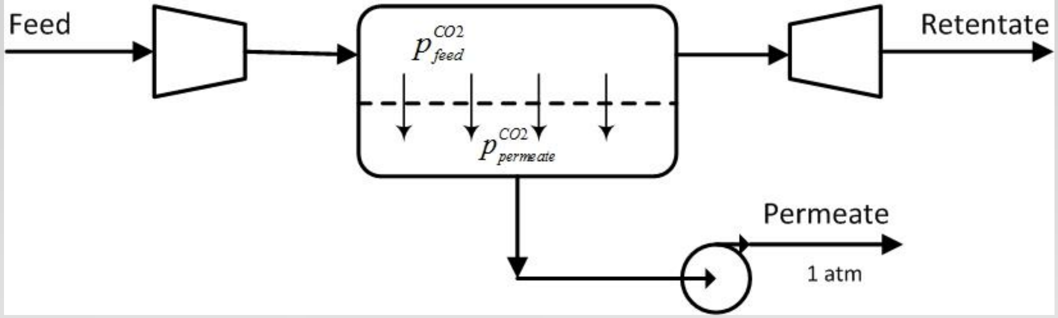
Pre-combustion capture from an IGCC using polymeric membranes

Rahul Anantharaman, SINTEF Energy Research
Brede Hagen, SINTEF Energy Research
Simon Roussanaly, SINTEF Energy Research

Backgound



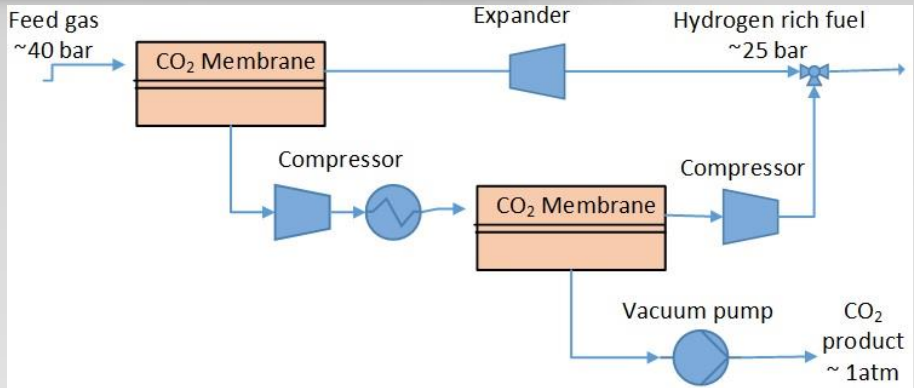
- Each membrane stage involves trade-off between product purity and capture rate.
  - Played out as a trade-off between driving force (compression work) and membrane area.
- Significant work in literature on “sensitivity” analysis to design single stage systems.
- For multi-stage process complexity increases further
- Identifying the "best" membrane configuration is not straightforward

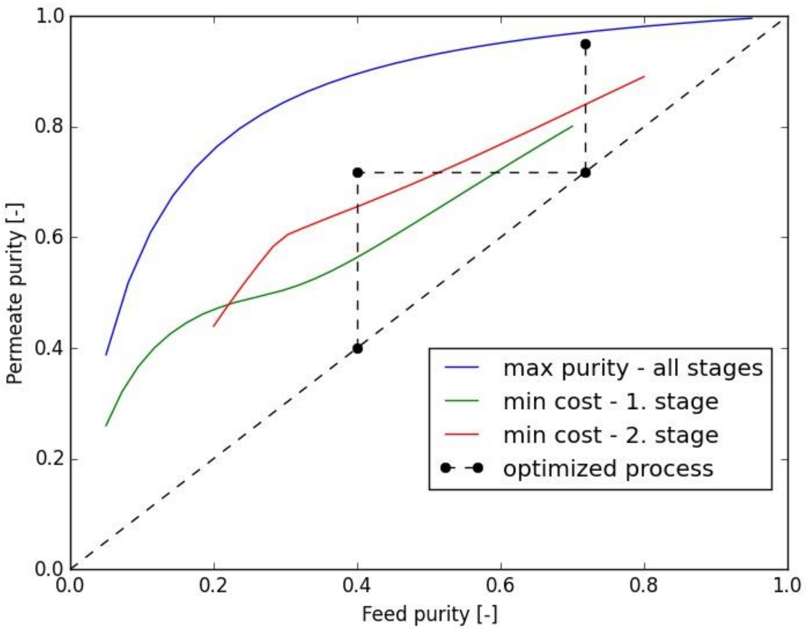
Attainable region approach

- A novel systematic methodology for design of stage-wise membrane captire has been designed at SINTEF Energy
- It is a simple visual method that allows consistent "optimal" design of membrane processes
- Also provides feedback to membrane developers
- The methodology has been implemented in Python to design membrane processes

Attainable region approach

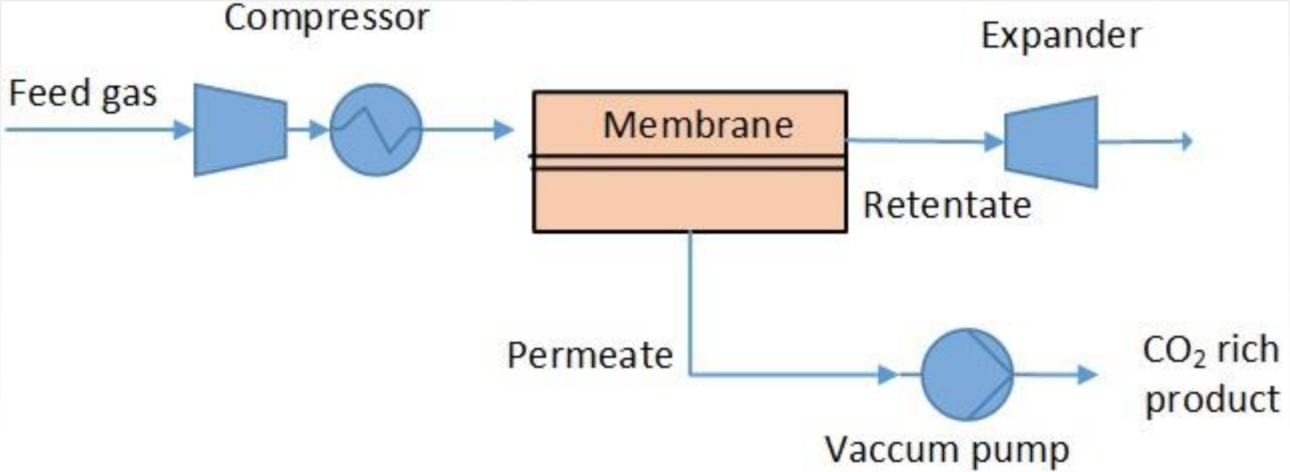
- **Visualization of an optimized 2-stage mambrane process**
  - Permeance = 10 m^3 (STP)/(m^2 h bar)
  - Selectivity = 40
  - Overall CCR = 90%
  - CO_2 product purity = 95%
  - Feed purity = 40%





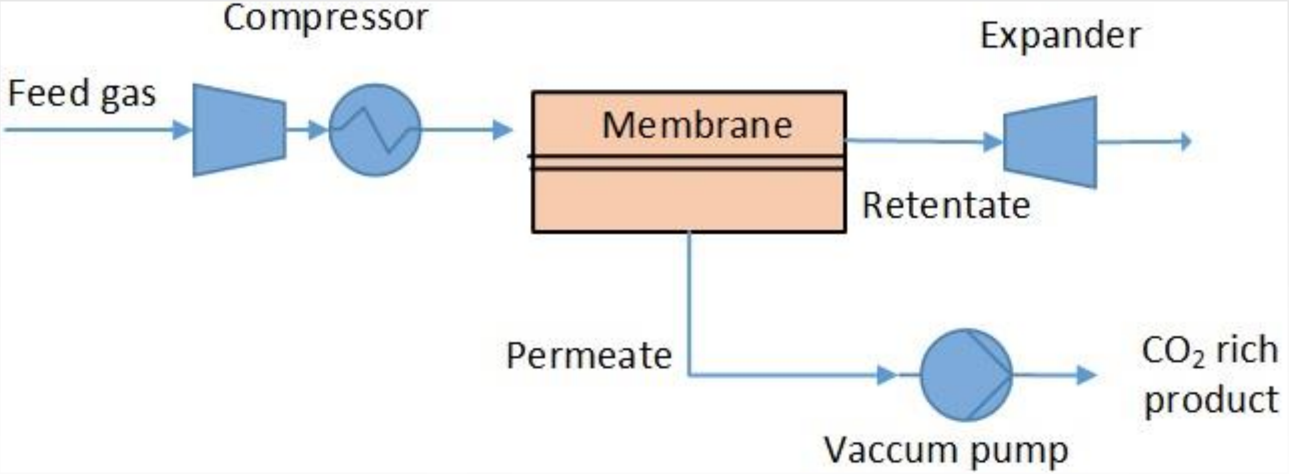
Membrane process model

- A simple but flexible membrane process model
  - Multicomponent ideal gas model for the feed gas
  - Constant isentropic efficiency models for rotational equipment
  - Constant heat transfer coefficient model for cooler(s)
  - Membrane model:
    - Two component gas
    - Constant permeance and selectivity
    - Cross flow model – variation in gas compostion along the membrane is taken into account
  - Flexible selection of rotational equipment

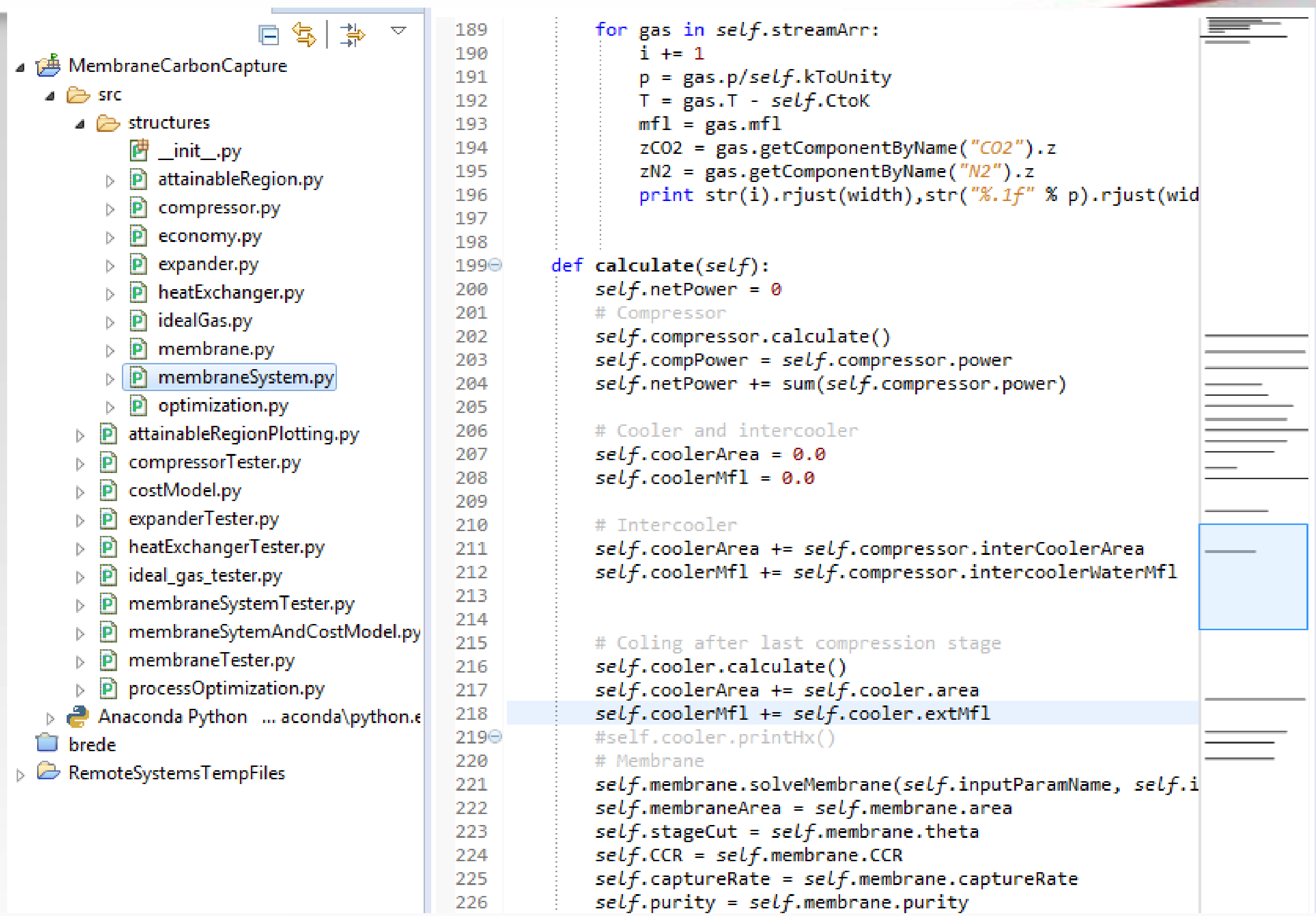


Membrane cost model

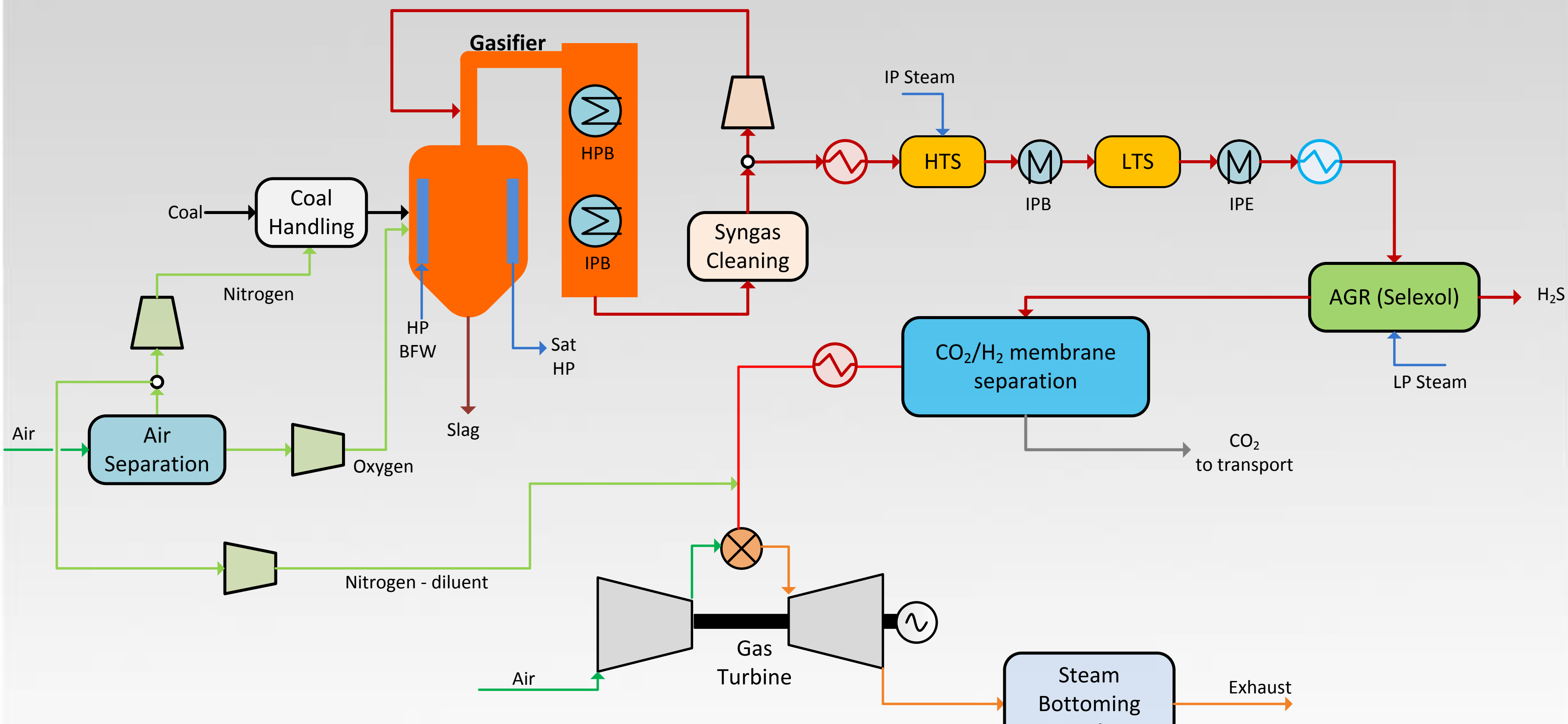
- A detailed life cycle cost model
  - Investment cost of all components
  - Cost of utilities such as
    - Net electricity consumption
    - Cooling water consumption for cooler(s)
    - Membrane module replacement
- Net present value (NPV) of cost and CO_2 capture cost are key performance indicators



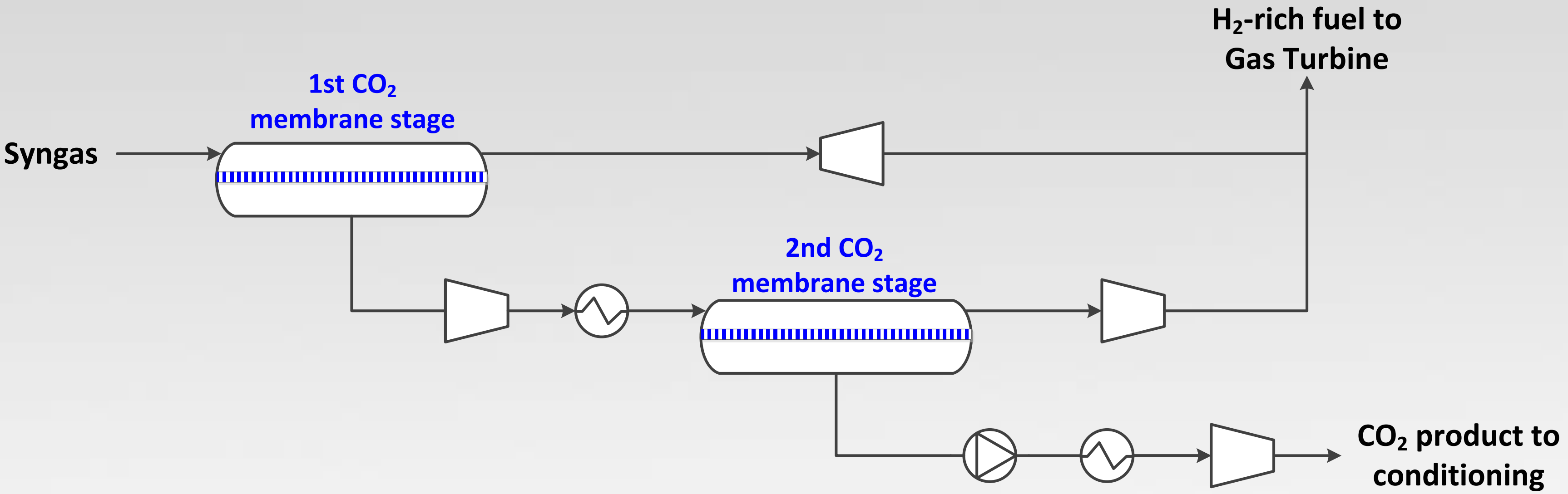
Screen shot of the model



Conceptual process diagram



CO_2 membrane



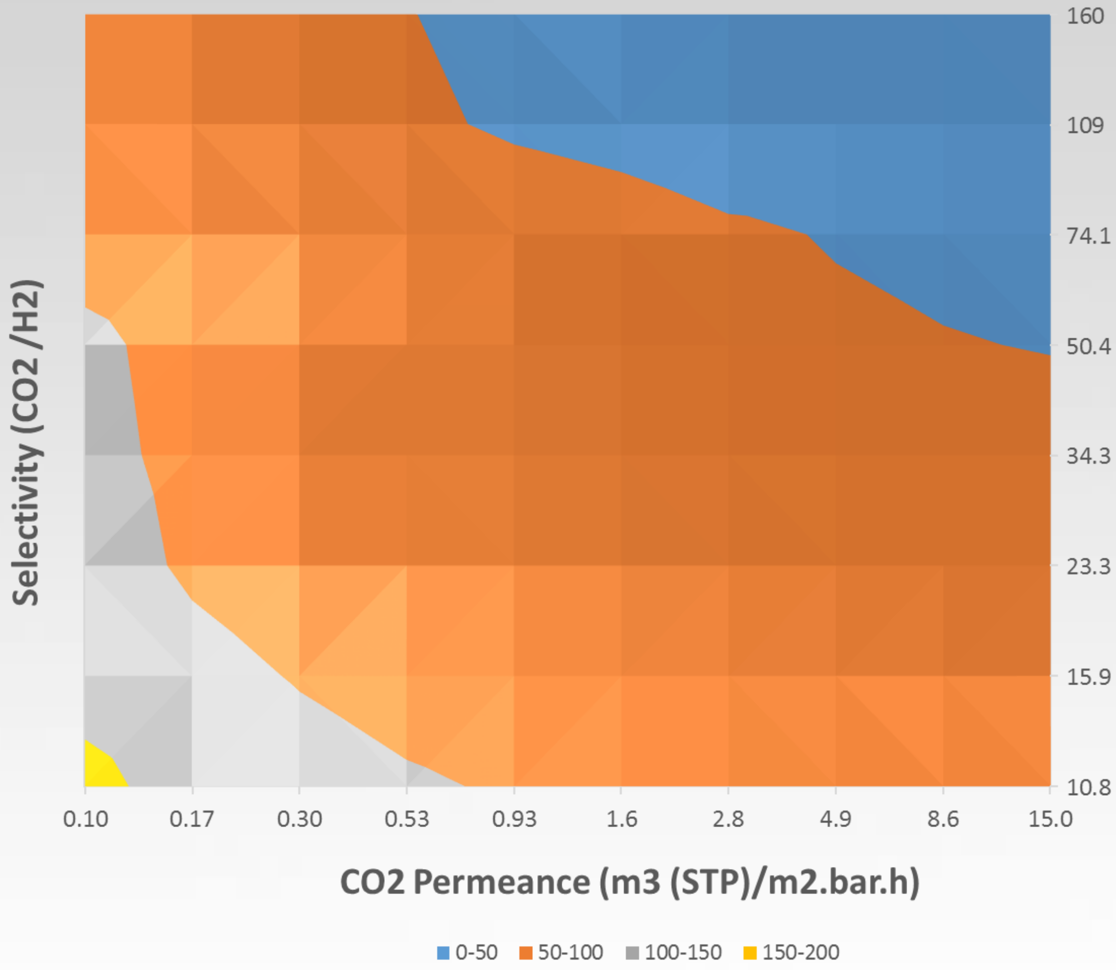
CO_2 membranes selected

Membrane	CO_2 permeance [$m^3_{(STP)}/m^2$ h bar]	Selectivity [CO_2/H_2]
Membrane 1	2.70	10
Membrane 2	0.81	21
Membrane 3	0.37	37

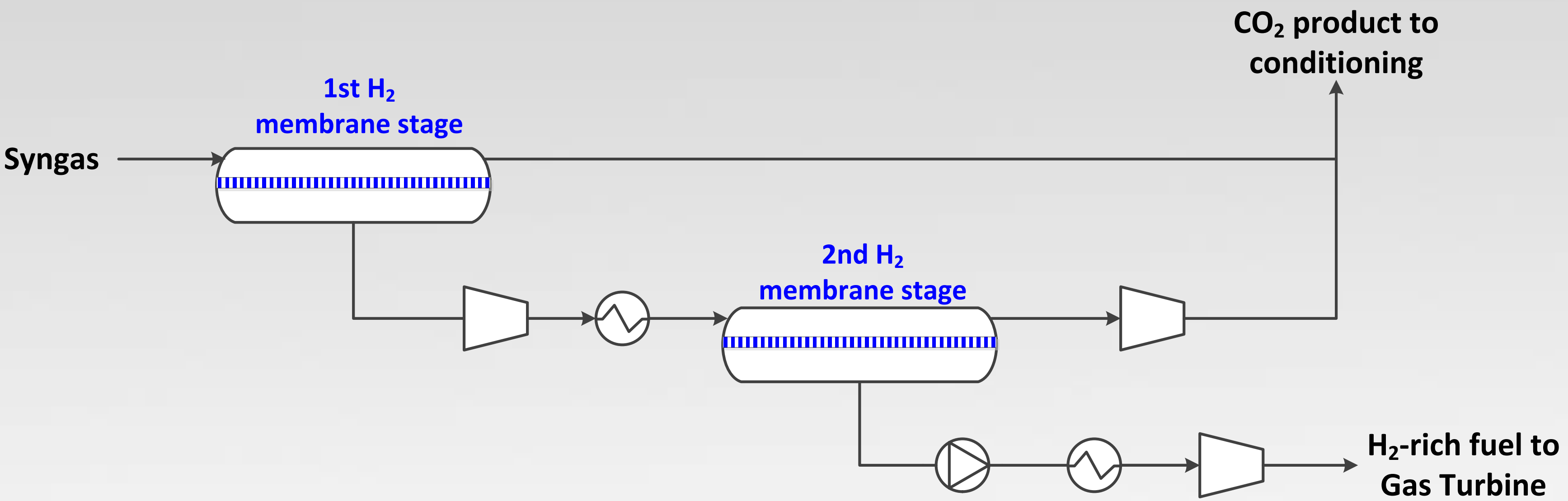
CO_2 membranes – Performance

Performance Parameter	Memrabane 1	Membrane 2	Membrane 3
Total membrane area [10^3 m^2]	22.1	47.2	84.6
Power losses [MW]	42.8	20.1	17.8
Net power [MW]	177.2	199.4	205.7
CO_2 emission [ton/MWh]	0.150	0.133	0.129
Electricity cost [€/MWh]	119.0	103.0	102.7
CO_2 avoided cost [€/ton]	91.4	63.7	62.9

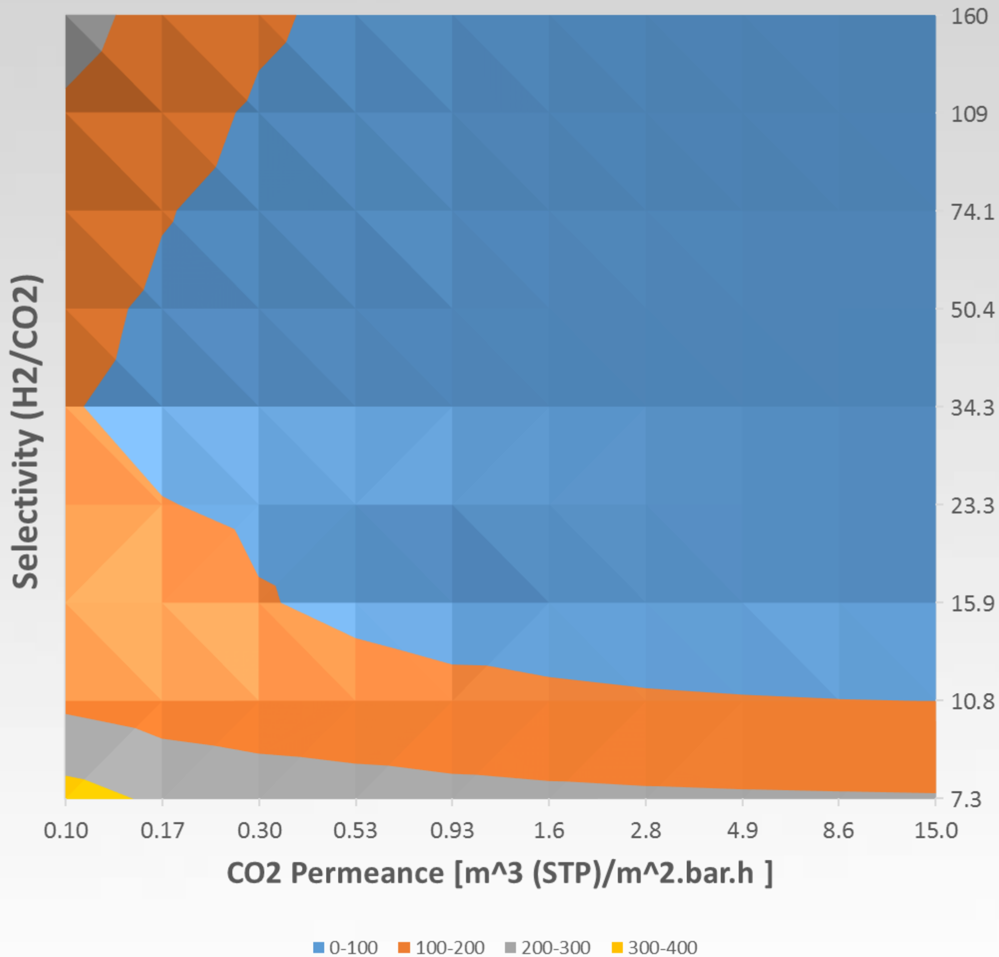
Membrane property map
CO_2 membrane



H_2 membrane


CO₂ product to conditioning
1st H₂ membrane stage
Syngas
2nd H₂ membrane stage
H₂-rich fuel to Gas Turbine

Membrane property map
H_2 membrane



Summary

- The Attainable Region approach for systematic membrane process design has been extended to pre-combustion capture processes
- Process configurations for typical membranes presented in literature have been designed
- The methodology developed at SINTEF Energy Research allows to identify the membrane properties required for CO_2 capture from a specific application

- The results identify:
  - When advanced configurations will be required
  - The trade-off between membrane properties

- Results can:
  - Guide the development of membrane materials for cost-effective CO_2 capture
  - Help the industry to select membranes that can compete with solvent-based capture systems.