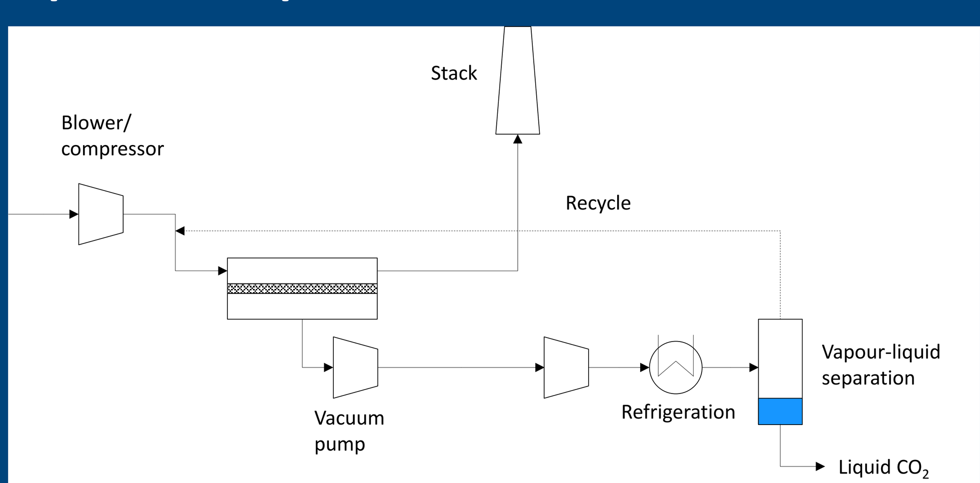
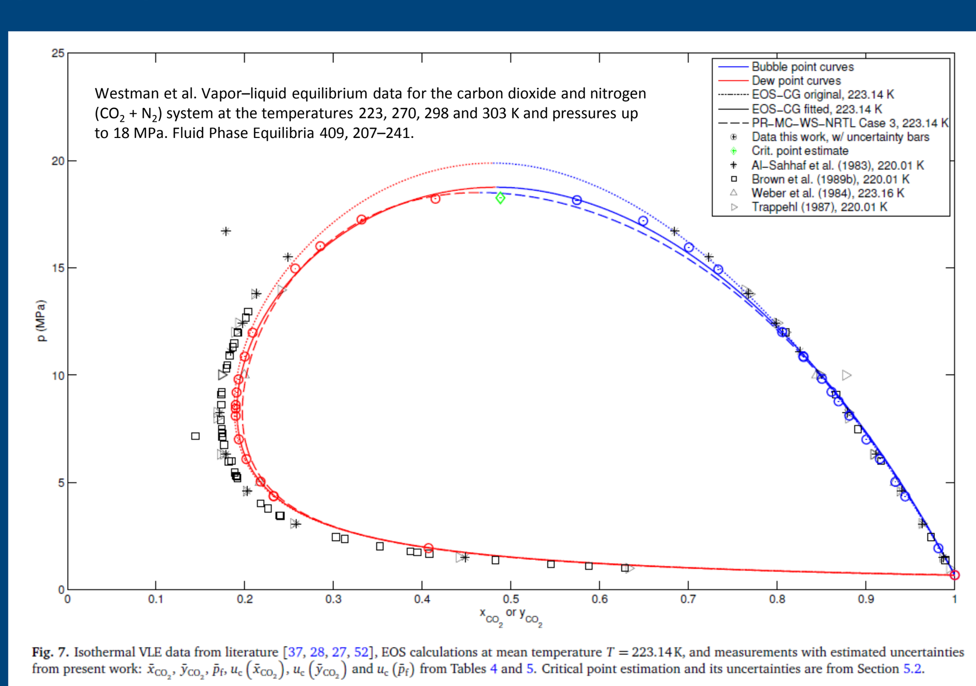
WP11 Membrane-assisted CO_2 liquefaction

CEMCAP is a Horizon 2020 project with the objective to prepare the grounds for cost- and resource-effective CCS in European cement industry.

Principal layout of membrane-assisted CO_2 liquefaction process



CO_2 purity at vapour-liquid equilibrium (-50°C)



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Motivation for combining membrane and CO_2 liquefaction

- Prospect for lower investment cost for CO_2 capture
- No need for chemical solvents and steam generation and consumption, only grid power
- The indicated optimal CO_2 capture rate for two-stage membrane processes is limited
  - Approximately 40–60 % indicated
- The CO_2 concentration after the first membrane stage can be configured to be typically 60–70 vol%
  - These conditions are close to typical oxyfuel flue gas conditions (see illustration below), and can thus be otained without retrofitting a plant to oxy-combustion operation
  - CO_2 liquefaction is regarded as mandatory in oxy-fuel applications, membranes are not considered as preferred oxy-fuel separation technology
- CO_2 liquefaction expected to be a better 2nd-stage option

The membrane CO_2 separation process

Partial pressure difference between feed and permeate is the principal driving force of permeation of the difference gas components.

The membrane's ability to favour CO_2 over the other gas components promotes CO_2 permeation and therefore an increased CO_2 concentration of the permeate side.

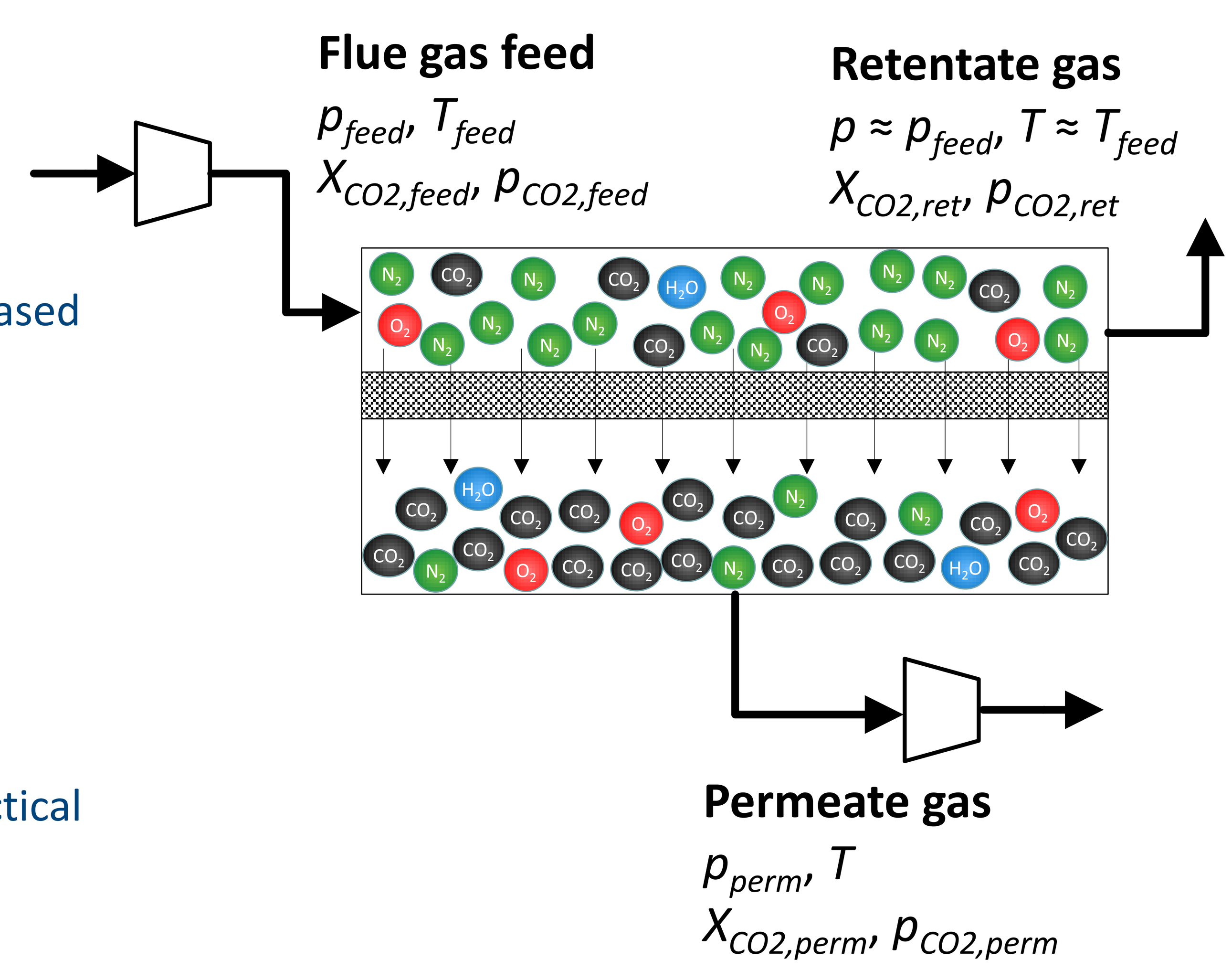
Max theoretical enrichment of CO_2 through membrane:

$$\frac{X_{CO_2,perm}}{X_{CO_2,feed}} \leq \frac{p_{feed}}{p_{perm}}$$

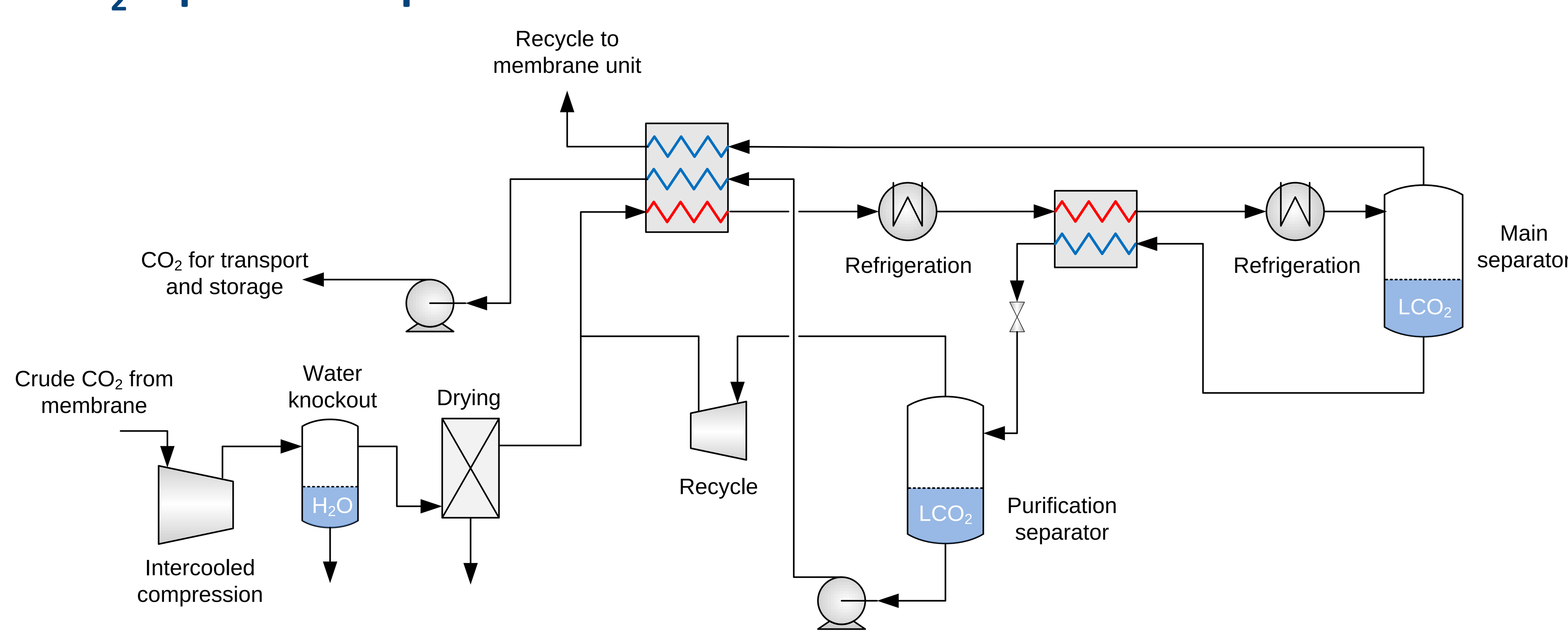
Example: CO_2 enrichment from 15 vol% to 75 vol%:

$$\frac{p_{feed}}{p_{perm}} \geq 5$$

The actual p_{feed}/p_{perm} pressure ratio must be higher due to practical considerations.

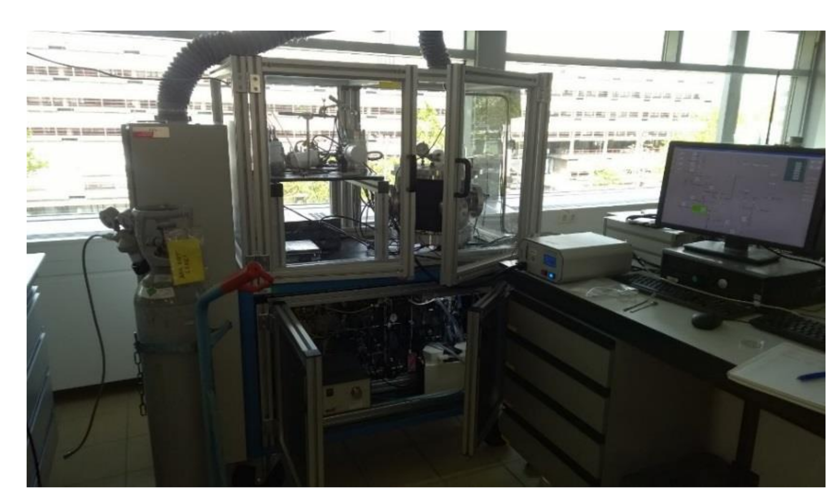


The CO_2 liquefaction process



WP11 research

- Process modelling and simulation of the capture process
  - Membrane unit
  - CO_2 liquefaction unit
  - Overall hybrid process configurations
- Testing of permeability and selectivity of membrane materials in bench-scale test unit (TNO)
- Testing of CO_2 liquefaction process in a 10 ton-per-day laboratory pilot rig (under commissioning at SINTEF/NTNU thermal laboratories)



Preliminary conclusions and further tasks

- Commerical membrane material tested thus far has selectivity suitable for bulk separation of CO_2 from flue gas
- Optimal CO_2 capture rate for membrane-assisted CO_2 liquefaction can be increased relative to a 2-stage membrane process
- Competitive energy results
- Very high CO_2 purity can be expected, as will be verified in laboratory experiments
- Experimental and simulation work will be used to derive a layout for a scaled up pilot process for the hybrid concept