CEMCAP

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

Four technologies are studied oxyfuel combustion, retention of CO_2 from flue gas in a chilled ammonia solution, calcium looping where CO_2 from flue gas reacts with CaO particles to form $CaCO_3$, and membrane-assisted CO_2 liquefaction.

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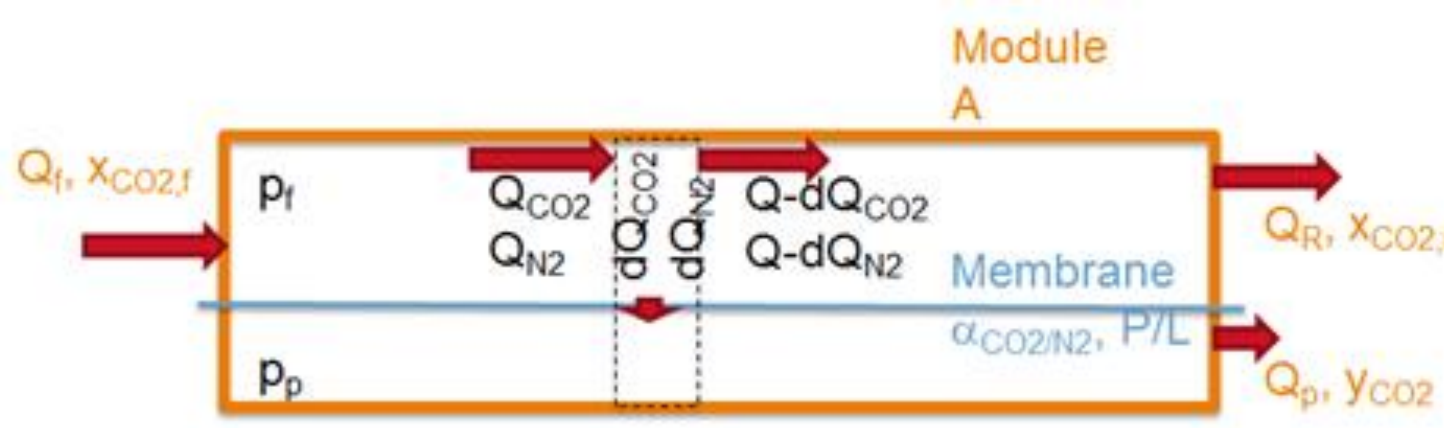
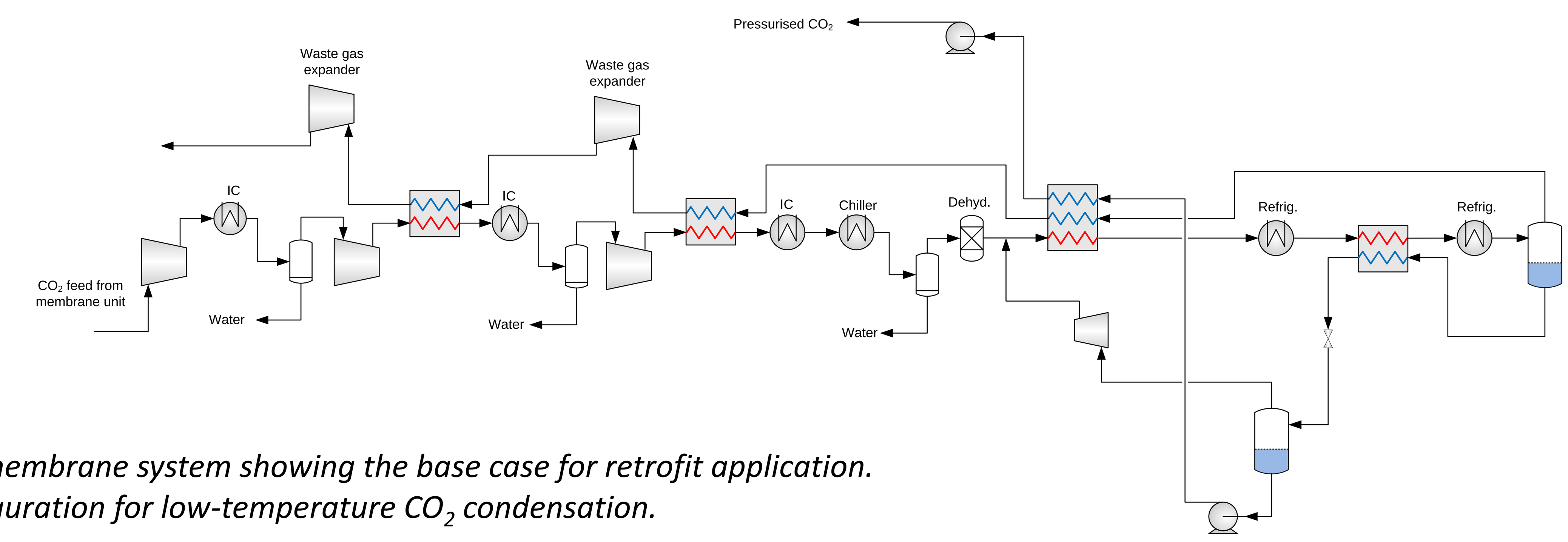
Membrane-assisted CO_2 liquefaction performance modeling of CO_2 capture from flue gas in cement production

Membrane-assisted CO_2 liquefaction combines two different separation technologies, each of which can carry out a partial separation within its favorable regime of operation. The flue gas from a conventional cement kiln has a CO_2 concentration typically in the range of 14–35 % and is assumed to be pre-conditioned before entering the membrane system. With a CO_2 selective membrane system, the exhaust is depleted in CO_2, and the concentration in the permeate is increased to a level sufficient for recovery and purification by liquefaction. After liquefaction the captured CO_2 is in liquid phase at high purity, and can thus be pumped to dense-phase transport pressure.



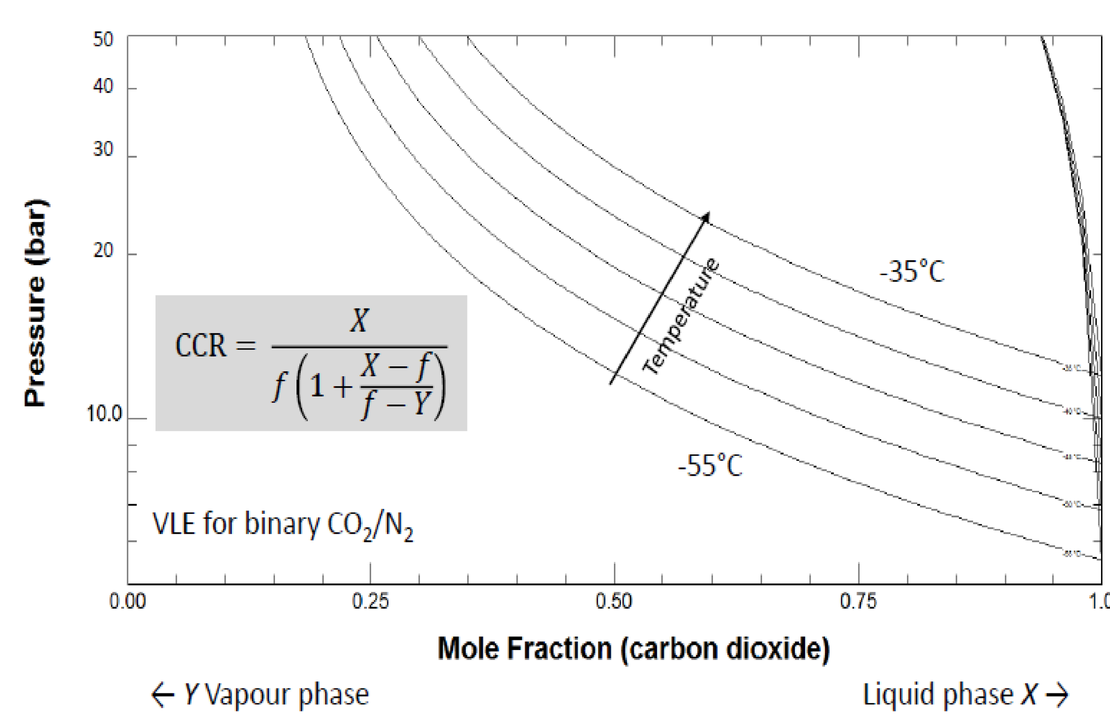
Up until recently the membrane separation and the liquefaction are modelled independently and calculations are performed iteratively as the feed flow and CO_2 concentration

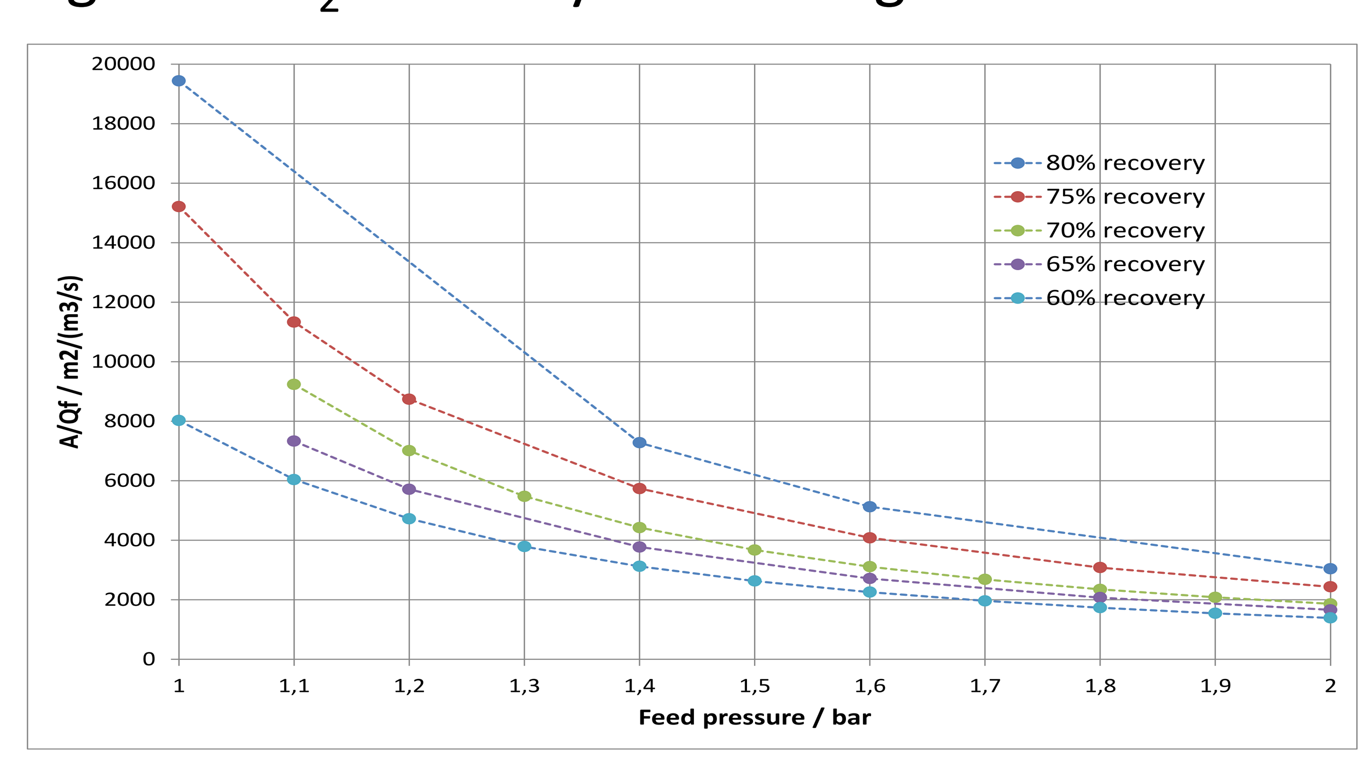


Top: Schematic of membrane system showing the base case for retrofit application.
Bottom: Base configuration for low-temperature CO_2 condensation.

Preliminary modeling results

Calculations are made with a permeate pressure of 0.2 bar, CO_2 permeance of $7.5 \cdot 10^{-9}$ $m^3(STP)/(m^2 s Pa)$. Membrane area, CO_2/N_2 separation factor of the membrane, and liquefaction pressure have been varied for targeted CO_2 recovery in the range of 60–90 %.





Left: CO_2/N_2 vapour-liquid equilibrium.
Right: Membrane area per unit feed flow versus feed pressure at indicated CO_2 recovery. Permeate pressure is 0.2 bar, liquefaction pressure 33.5 bar, membrane separation factor is 40, and CO_2 concentration in the feed flow is 20 %.

Conclusions

- The required membrane area is a strong function of CO_2 concentration in the cement kiln flue gas, desired CO_2 recovery, pressure ratio across the membrane, membrane separation factor and CO_2 permeance.
- Substantial recovery of CO_2 can be realized with a CO_2 concentration of $\gtrsim$ 20 % and a recycle of the purged waste stream from the liquefaction to the membrane unit.
- Any lowering of permeate pressure below 0.2 bar is highly beneficial.

Ongoing work is focused on:

1. Integrated modelling of membrane-assisted CO_2 liquefaction in the same process simulation interface
2. Experimental membrane characterisation
3. Experimental study of liquefaction and gas/liquid separation

Modelling will yield data for economic evaluation. Experimental work at realistic conditions is needed e.g. to study co-permeation of water, actual CO_2/N_2 separation by liquefaction, and required flue gas preconditioning.