What are the limits of solvent-based CO_2 capture?

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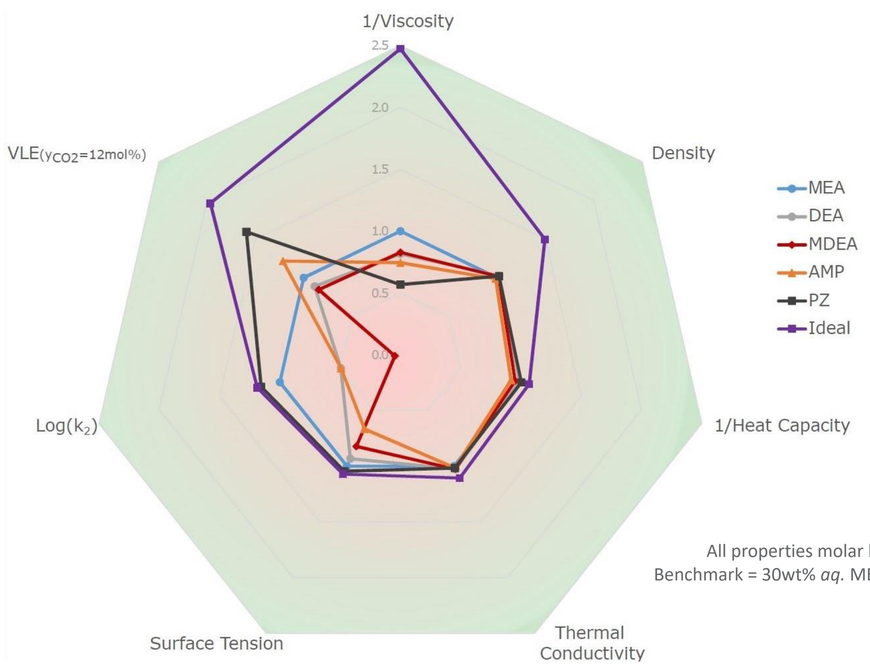
Overview of thermo-physical properties

Monoethanolamine (MEA), diethanolamine (DEA), N-methyldiethanolamine (MDEA), 2-amino-2-methyl-1-propanol (AMP), and piperazine (PZ) are representatives of the different amine classes that are used since the 1930 as aqueous capture solvents. The properties of 30wt% *aq.* amine relative to MEA are shown below:

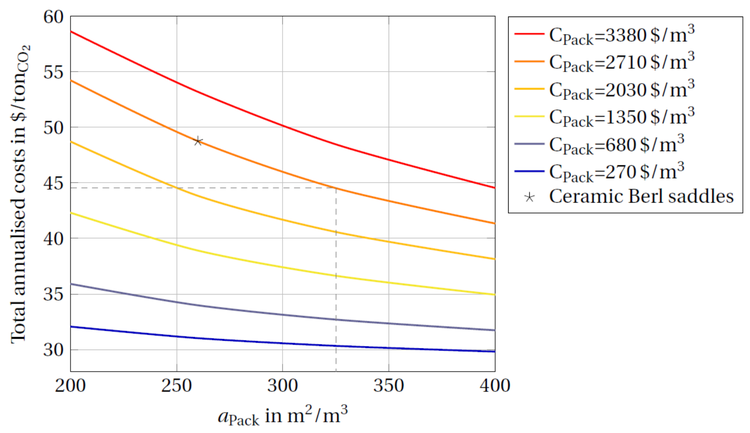


All properties molar based except density.
Benchmark = 30wt% *aq.* MEA at 40°C, unloaded.

➢ Do favourable properties outweigh unfavourable ones?

Impact of packing development

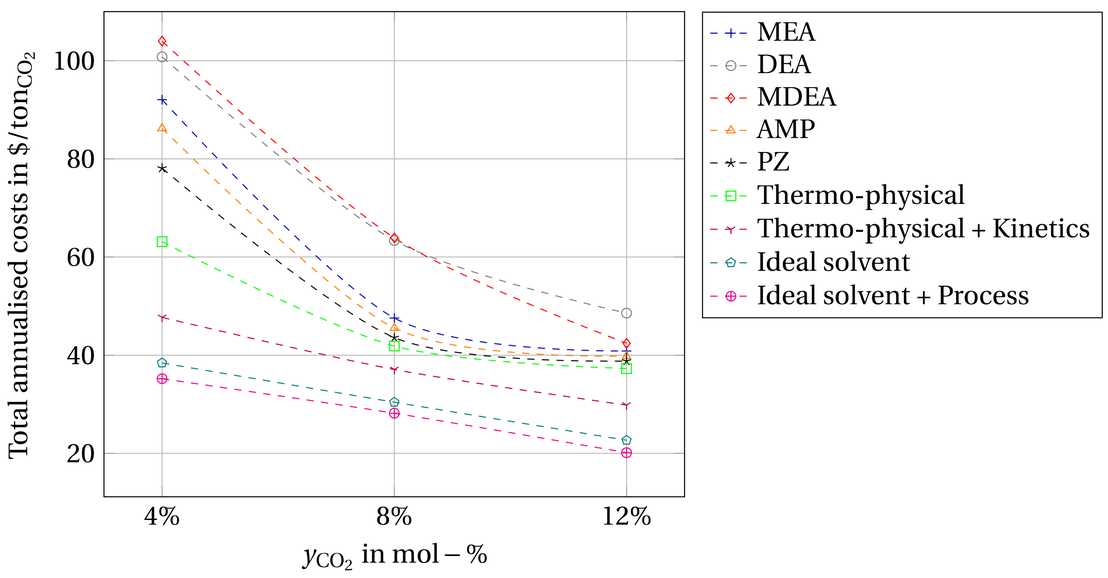
The columns' specific packing area a_{Pack} impacts heat and mass transfer and is an important performance parameter. R&D, *e.g.,* 3D-printed packing, aims to increase the area at ideally lower cost.



➢ Increasing a_{Pack} by 25% at same cost reduces the capture cost by 9%

Limit of solvent-based CO_2 capture

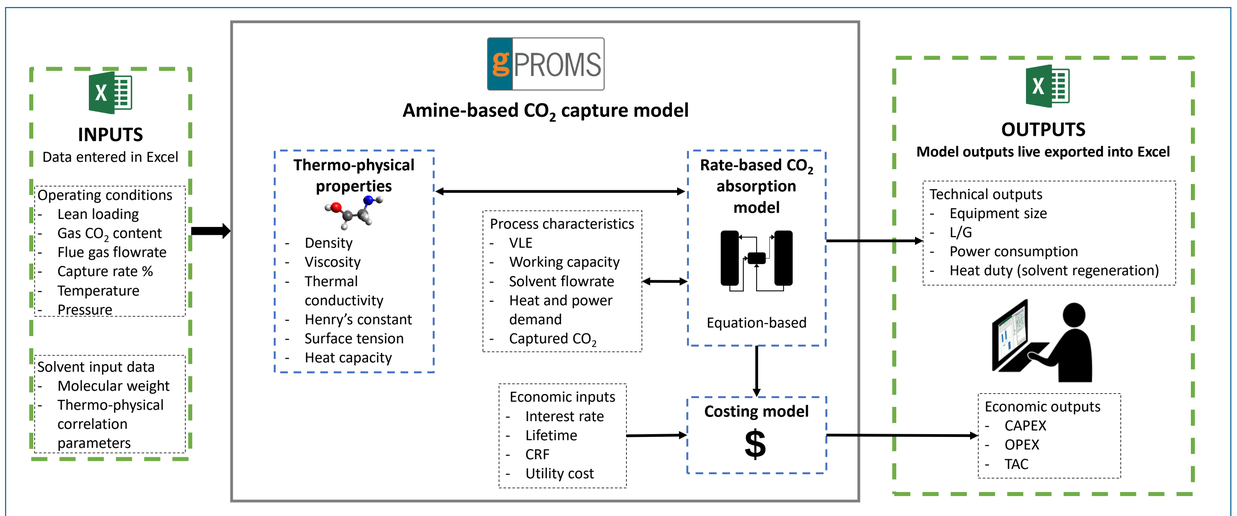
The capture cost of amines representing the five classes (primary, secondary, tertiary, sterically hindered, hetero-cyclic) utilised at their optimal operating conditions [2] are shown below. The trends over CO_2 concentration are mainly driven by the VLE. Imposing the ideal properties and process R&D (see right box) quantifies a realistic limit ranging between 35$/ton$_{CO2}$ for y_{CO2}=4% (gas power) down to 20$/ton$_{CO2}$ for y_{CO2}=12% (coal power).



➢ Amines show similar cost with a wider spread at dilute concentration

➢ Pushing the solvent to a realistic limit leads to cost <40$/ton$_{CO2}$

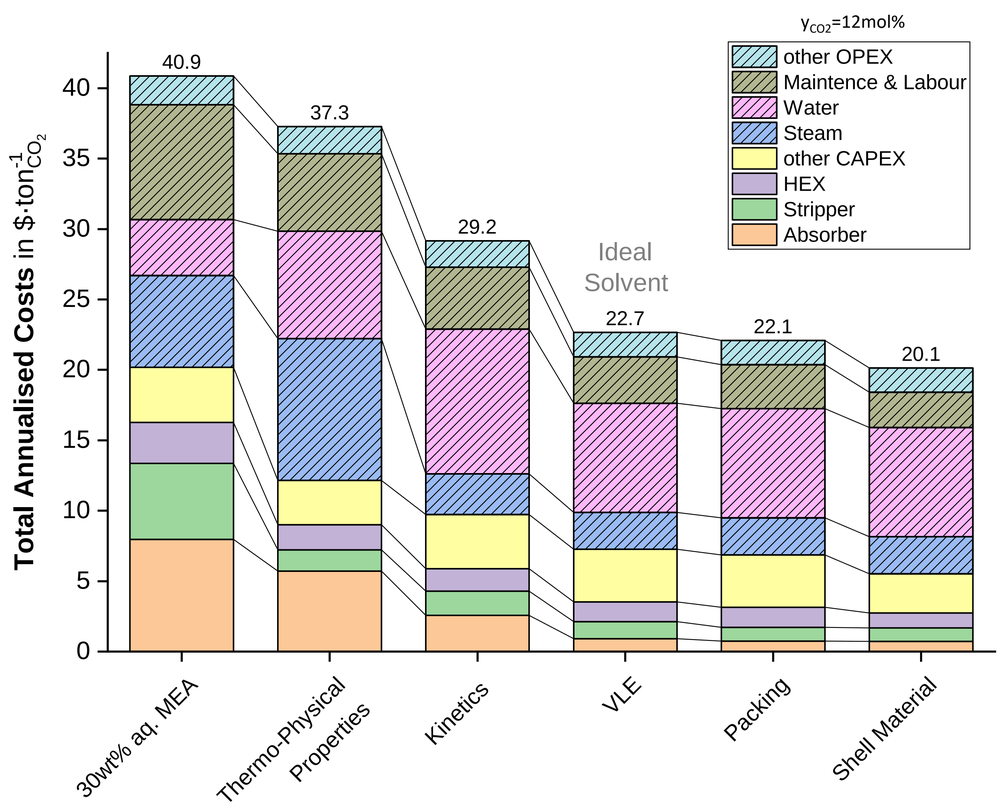
Modelling framework



Schematic flow of information and calculation of key characteristics from input (Excel), equation based process model (gPROMS) [1] and output (Excel). The framework has been designed to provide the user with a live feedback as the model is running.

Ideal CO_2 capture solvent

Limiting thermo-physical properties (see left box) are derived from pure reference liquids *e.g.,* viscosity of pure water, or reaction rate constant of KOH+CO_2. Imposing these limiting properties on 30wt% *aq.* MEA leads to an ideal solvent shown below. Assuming futher R&D in packing and shell material leads to a realistic limit which includes all thermodynamic inefficiencies.



➢ Ideal properties mainly reduce CAPEX

➢ Unlikely to find all ideal properties in one molecule

➢ Projected limit at nearly half the cost of 30wt% *aq.* MEA

Conclusions

1. The amines show similar cost despite their different properties because of the high water content of the solvents.
2. The limit of capture is realistic, but it is unlikely to find all ideal properties in one molecule.
3. The ideal solvent reduces mainly the CAPEX compared to MEA.
4. A different process (non typical absorber-stripper configuration) is needed to further reduce the OPEX.
5. Solvent development alone is not a silver bullet to reach long term cost targets such as $20/ton$_{CO2}$ at y_{CO2}=12%.

References and acknowledgements

[1] Mota-Martinez MT *et al.,* Sustainable Energy Fuels, 2017,1, 2078-2090
[2] P. Brandl *et al.* 14th Int. Conf. Greenh. Gas Control Technol. GHGT-14 (Melbourne, Oct. 2018)

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