Demonstration of MEA based direct air capture and validation of process model for future integration with post combustion capture

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University of Sheffield

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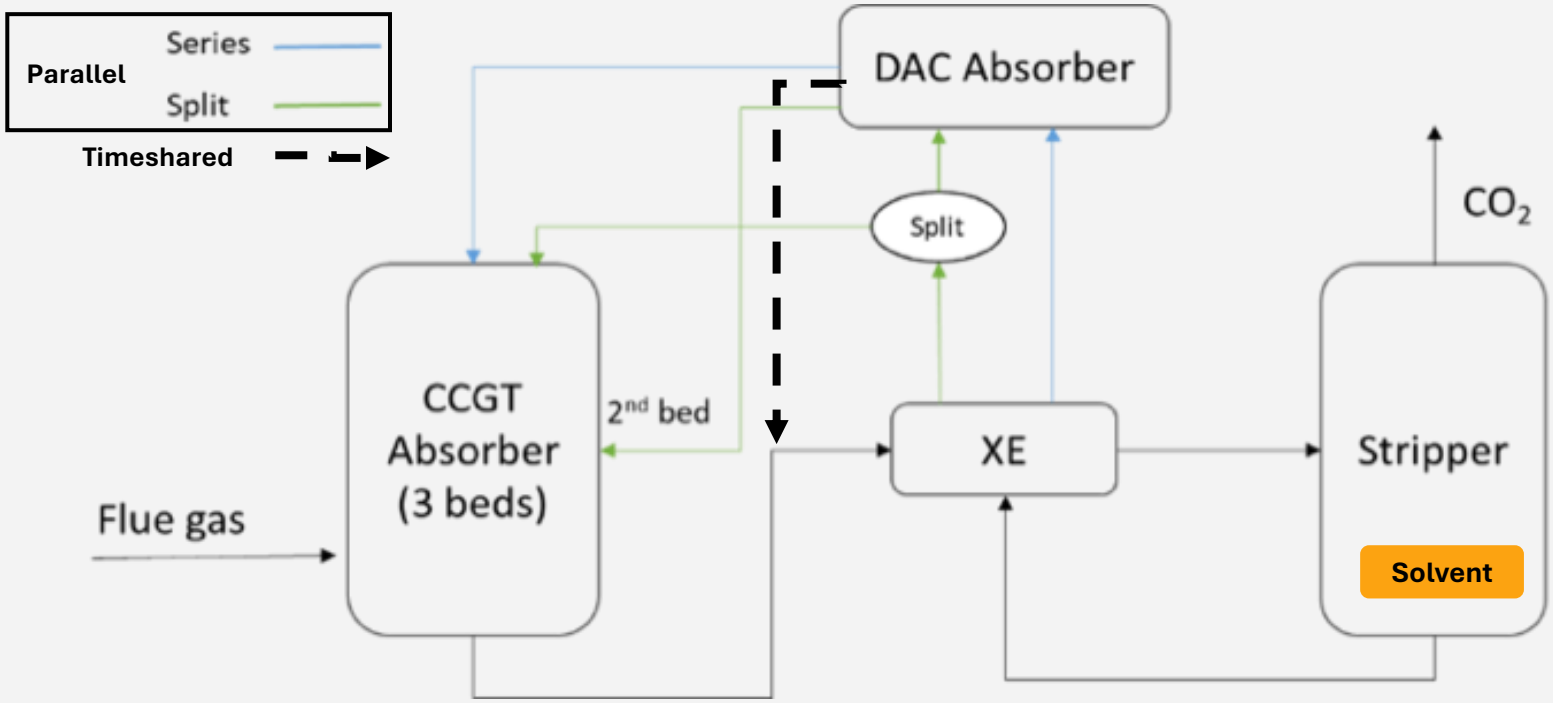
Context

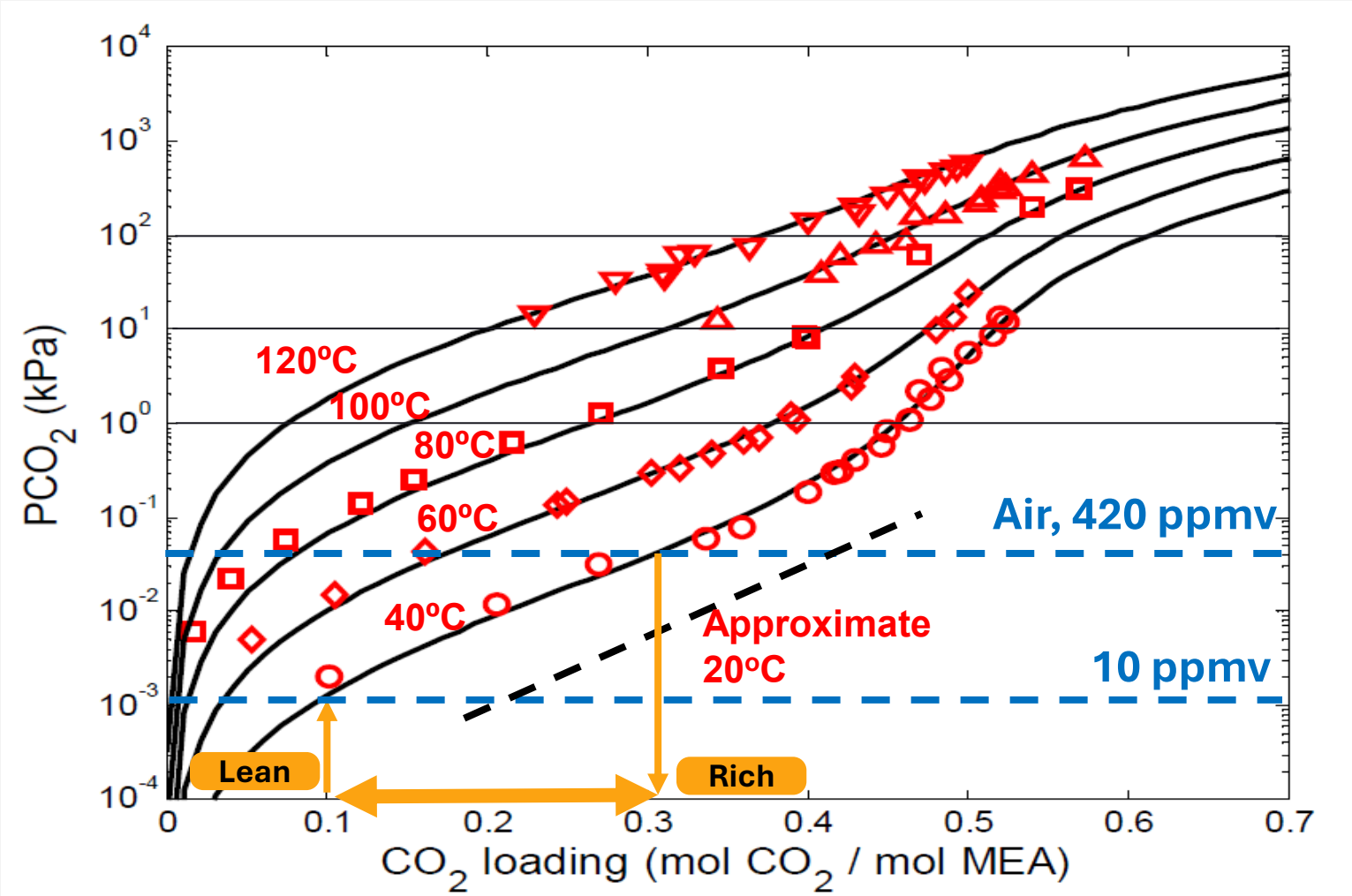
- Using the same amine for DAC as is used for PCC is desirable for parallel Co-DACCS
- Regeneration of DAC CO_2 can then have a similar energy consumption to CO_2 captured from flue gasses (Michailos et al, 2022)
- A once-through DAC absorber has improved driving force for mass transfer, but needs much lower L/G ratio [kg/kg] for air than for flue gas
- This study uses monoethanolamine (MEA)
  - Reclaimability of MEA – See Marcin Pokora, Thursday, 7C
  - Doesn't form nitrosamines directly – See Jon Gibbins, Thursday, 7B

CoDAC – Proposed by Michailos et al, 2022



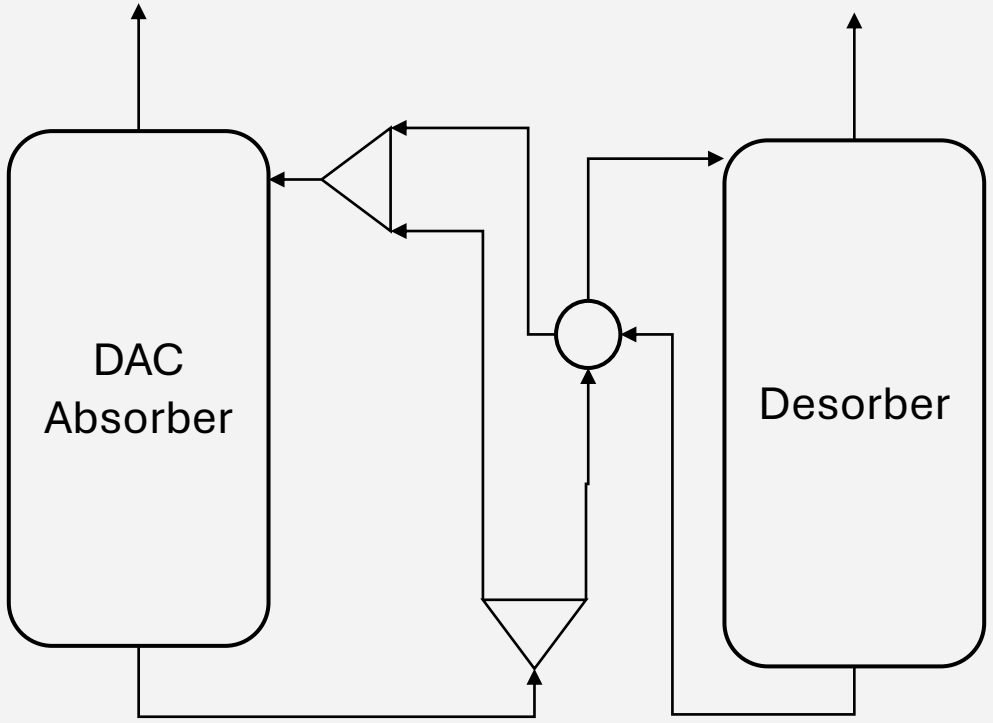
Michailos et al., 2022, A performance modelling study of integrating a MEA direct air capture unit with a CCGT absorber,
16th International Conference on Greenhouse Gas Control Technologies, GHGT-16.

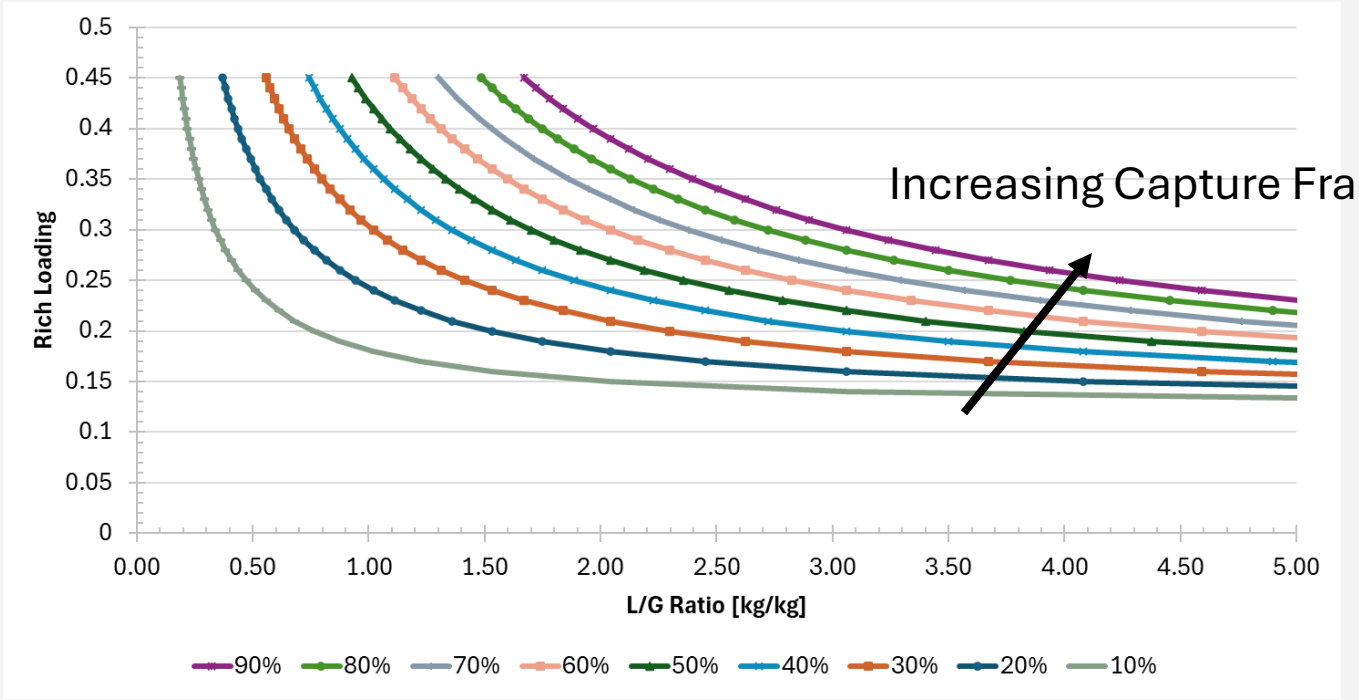
Vapour-Liquid Equilibrium for 30% w/w MEA



Ugochukwu E. Aronu, Shahla Ghondal, Erik T. Hessen, Tore Haug-Warberg, Ardi Hartono, Karl A. Hoff, Hallvard F. Svendsen, Equilibrium in the H_2O-MEA-CO_2 system: new data and modelling, Proc. 1st Post Combustion Capture Conference, Abu Dhabi,17th -19th May 2011.

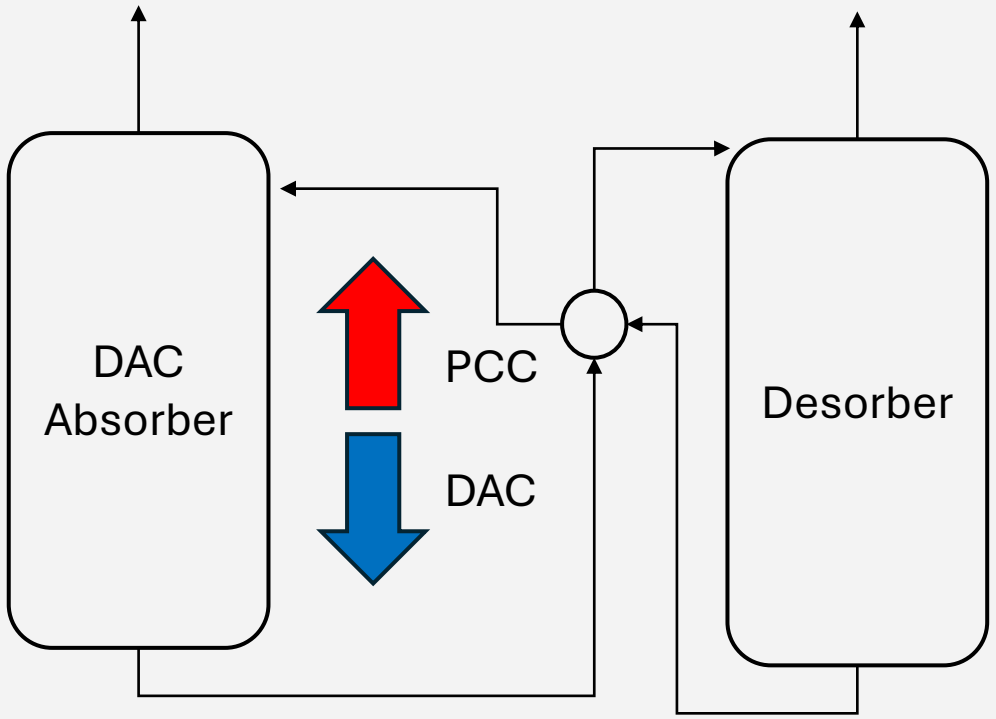
L/G For PCC

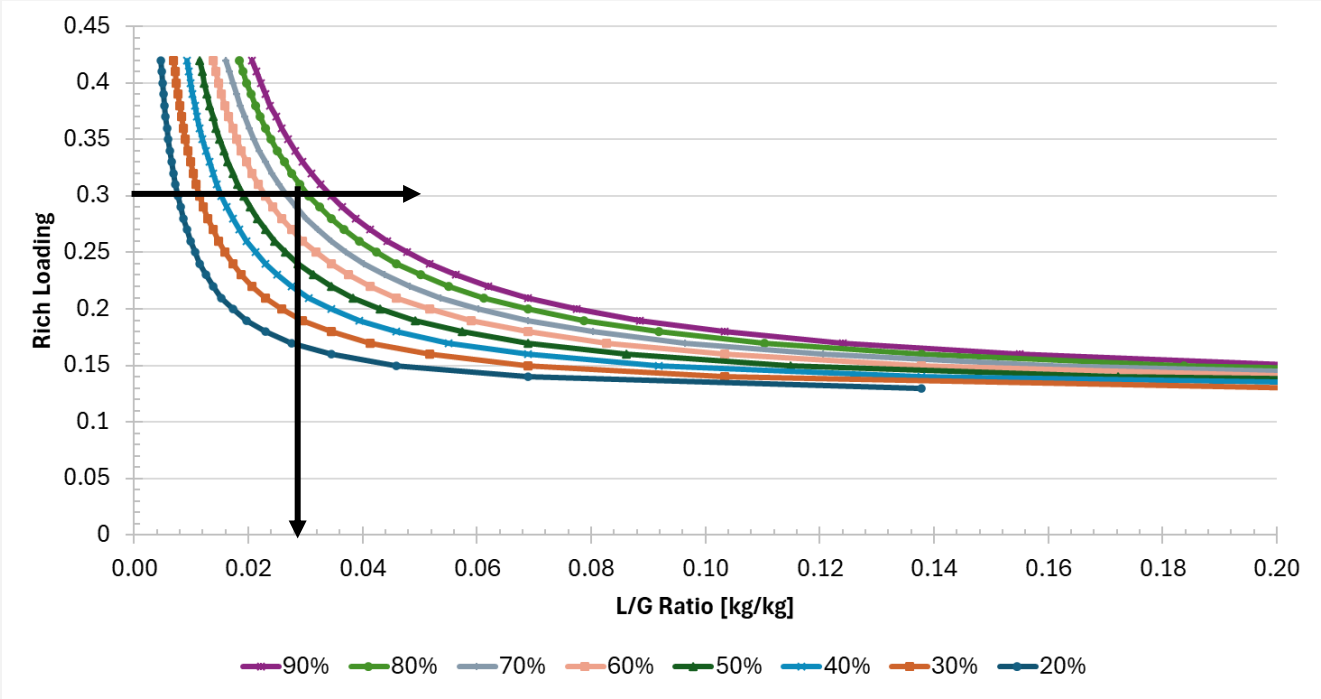




PCC: L/G = 2.54

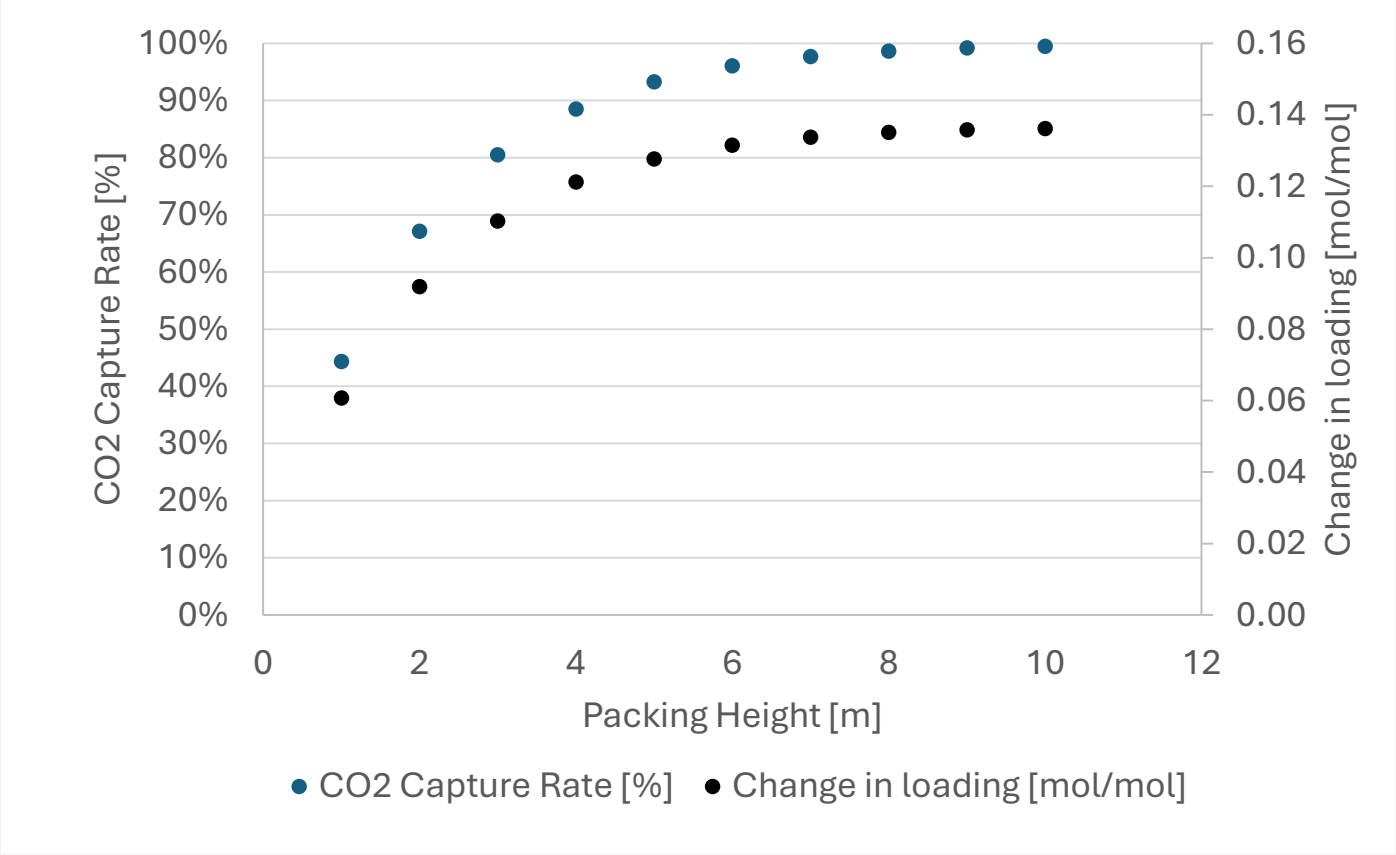
L/G For DAC





DAC: L/G ~ 0.03

Standalone DAC modelling results



Variable	Value	Unit
Liquid/gas ratio	0.025	[kg/kg]
Lean Loading	0.1	[molCO_2/molMEA]
Superficial gas velocity	2.43	[m/s]

Modelling Methodology

- Aspen Plus rate-based absorber
  - Song mass transfer correlations
  - Tsai liquid holdup
- ELECNRTL framework
  - rigorous chemistry
  - parameters regressed v. VLE
- CO_2 kinetic reactions
- Validated v. flue gas capture pilot plant data
  - 3.6-13%mol CO_2
- Cownden et al. (Session 1C, this conference)
  - "Improving on the CCSI model for MEA-based CO2 capture"

Equilibria Reactions

$$2H_2O \rightleftarrows H_3O^+ + OH^-$$

$$CO_2 + 2H_2O \rightleftarrows H_3O^+ + HCO_3^-$$

$$HCO_3^- + H_2O \rightleftarrows H_3O^+ + CO_3^{2-}$$

$$MEAH^+ + H_2O \rightleftarrows H_3O^+ + MEA$$

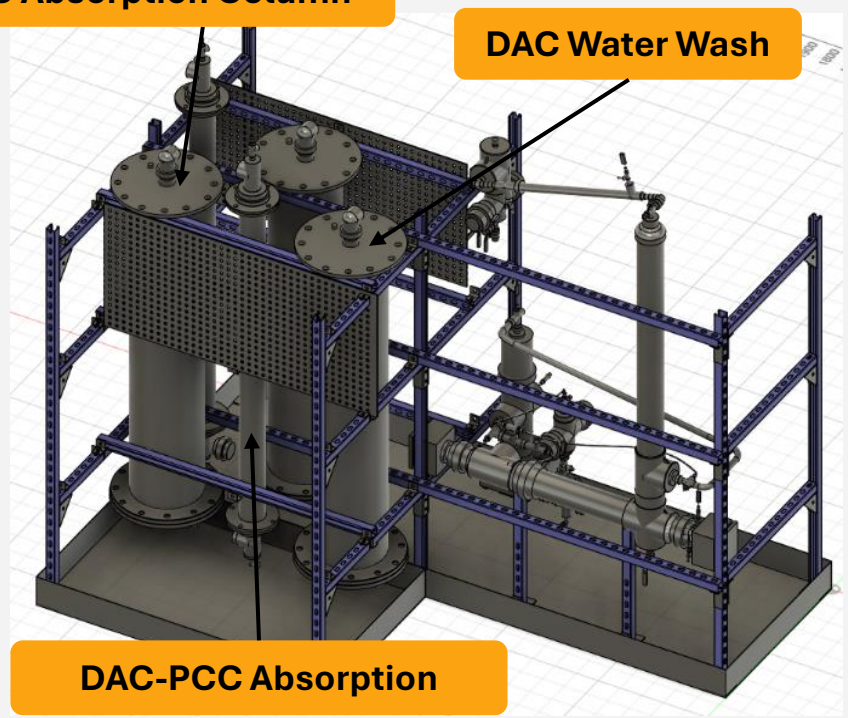
$$MEACOO^- + H_2O \rightleftarrows HCO_3^- + MEA$$

Kinetic Reactions

$$MEA + CO_2 + H_2O \rightleftharpoons MEACOO^- + H_3O^+$$

$$CO_2 + OH^- \rightleftharpoons HCO_3^-$$

University of Sheffield Equipment



Design Features	
Absorber Packing Type	BX
Absorber Packing Height	1 m
Absorber Diameter	300 mm
Solvent Flowrate (minimum)	0.05 $m^3/m^2/h$
Air Superficial Velocity (Max)	3 m/s

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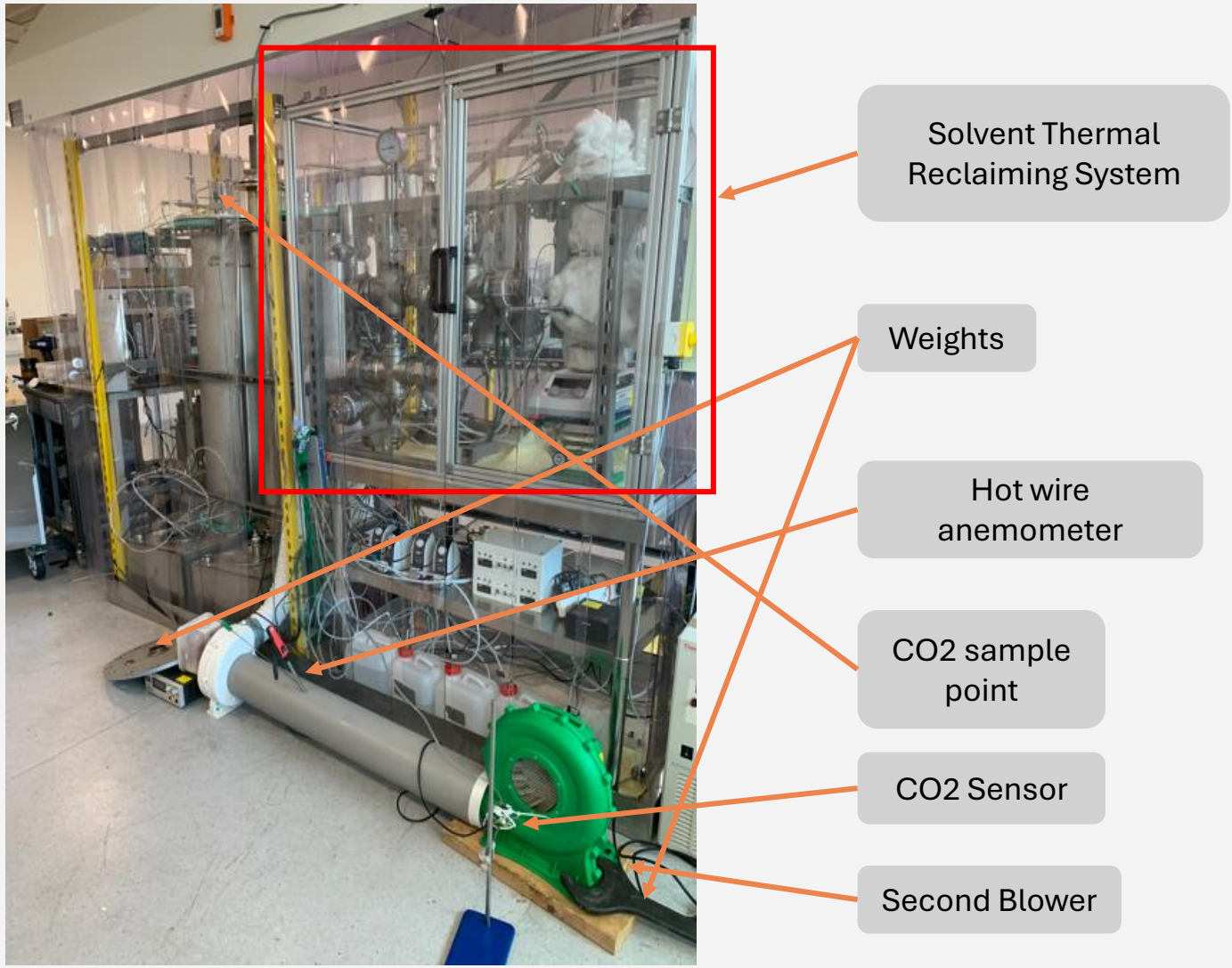
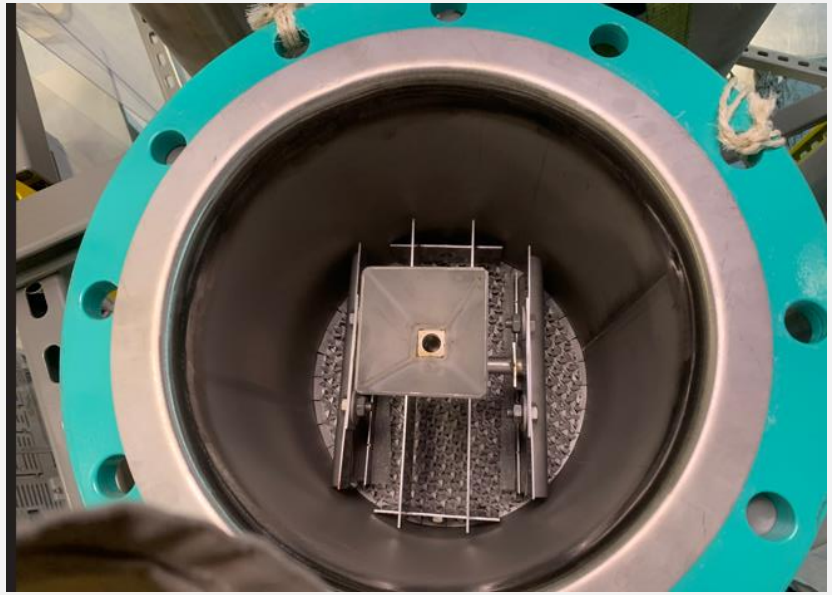


Column Internals

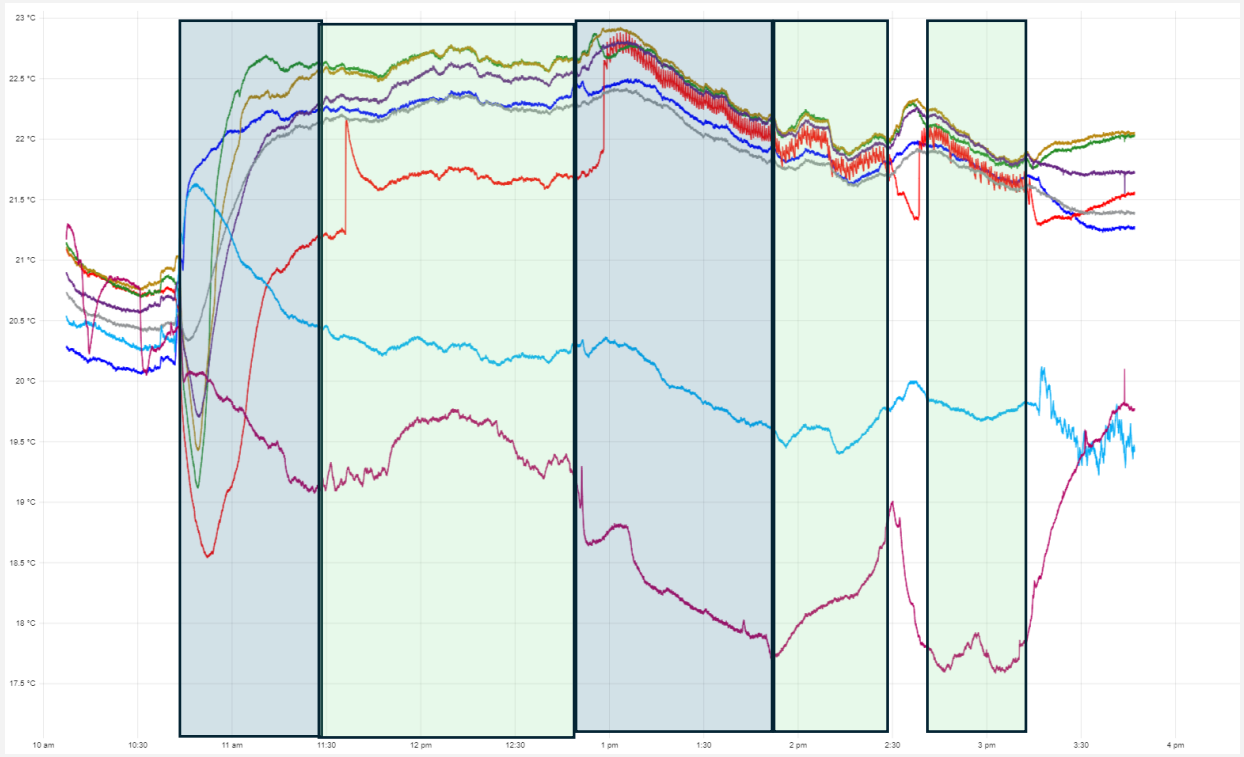
BX Structured Packing



Line liquid Distributor on the packing

Test matrix and collected data

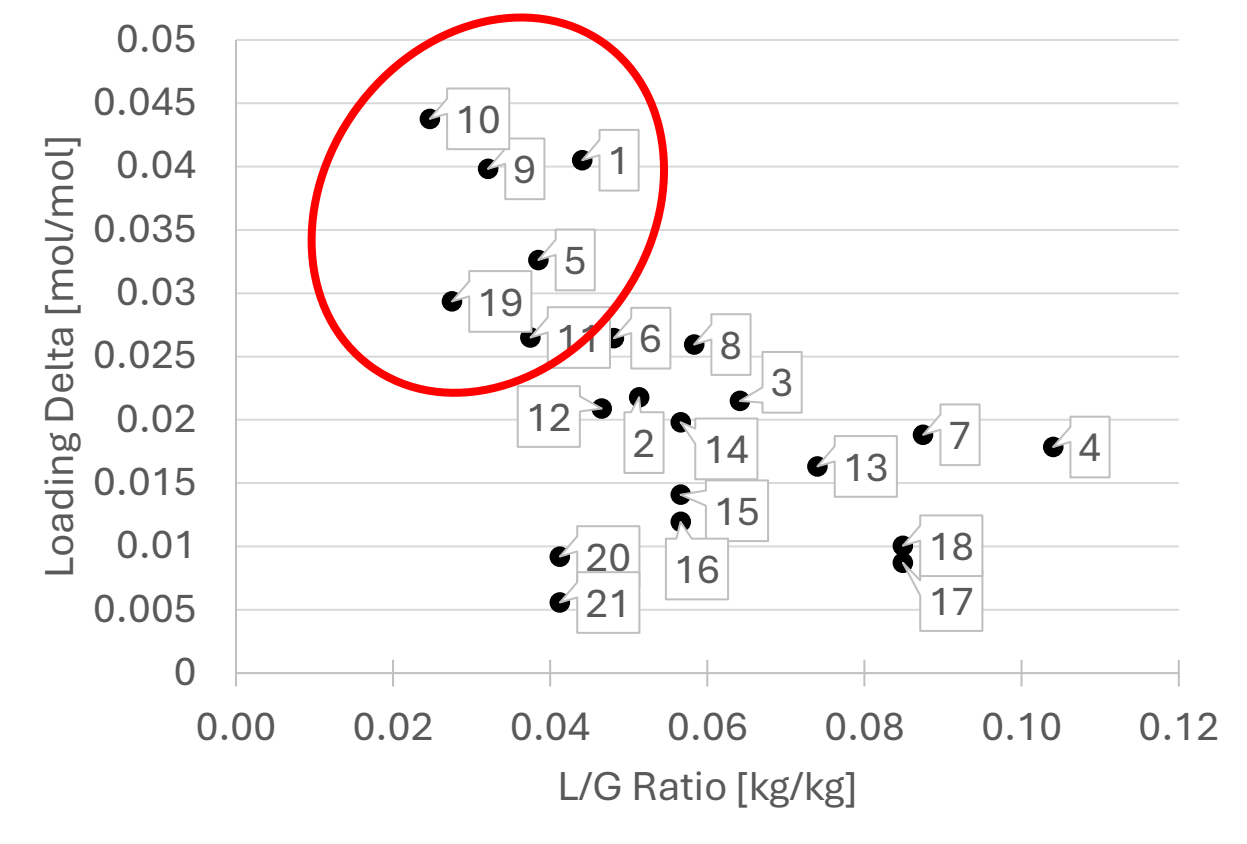
Absorber Temperature Profile

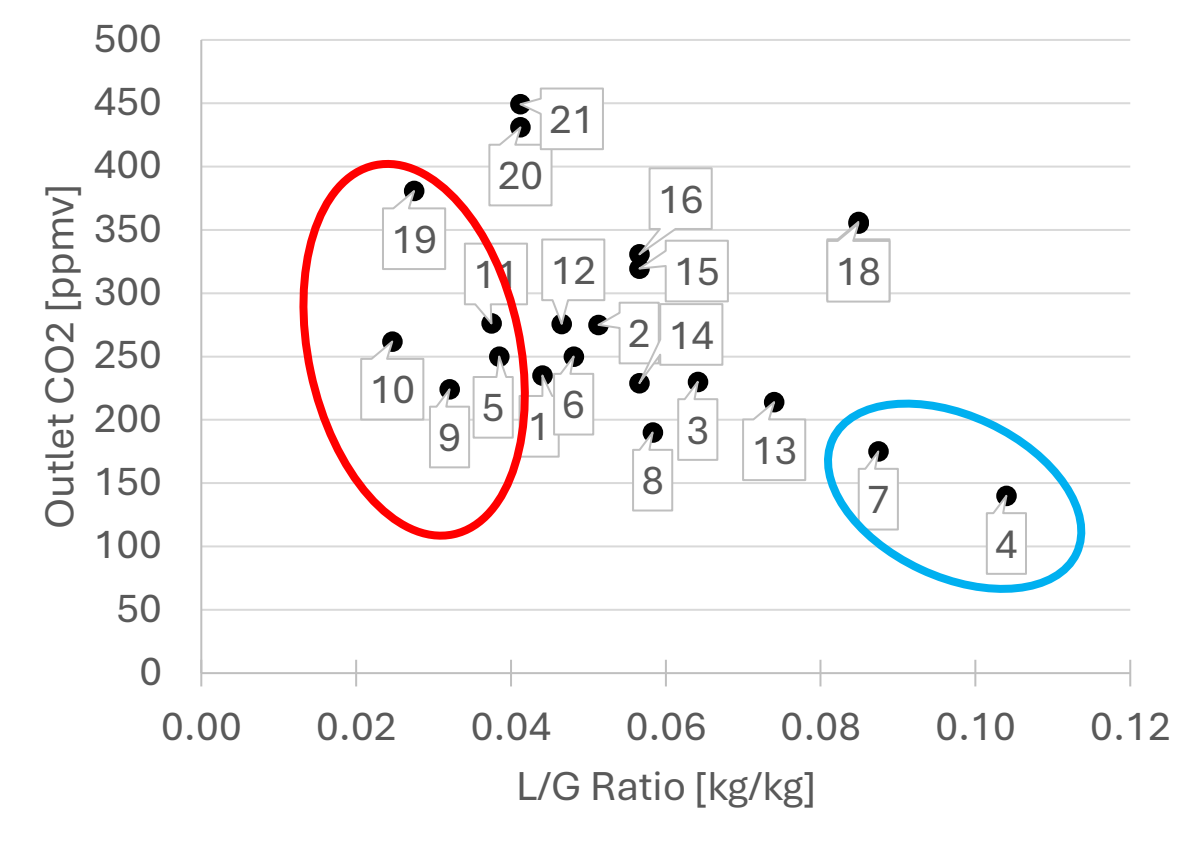


23.1%→25.3% → 28.5%→ 30.2% →31.9% →33.4%

CO2 Outlet ppmv

Effects of L/G ratio





Preliminary Results

Run	Minutes	L/G	Estimated lean loading [mol/mol]	Liquid Flowrate [ml/min]	Superficial Gas Velocity [m/s]	Inlet CO2 [ppmv]	Outlet CO2 [ppmv]	Concentration MEA [wt%]	Loading delta [mol/mol]	Loading delta with 100 ppmv exit CO2
1	18	0.044	~ 0	300	1.42	480	235	26%	0.041	0.063
4	30	0.104	0.06	400	0.80	500	140	37%	0.018	0.020
8	30	0.058	0.15	200	0.71	515	190	41%	0.026	0.033
9	78	0.032	0.17	200	1.29	505	224	42%	0.040	0.057
10	66	0.025	0.07	200	1.68	505	262	43%	0.044	0.073
18	20	0.085	0.23	300	0.73	512	355	35%	0.010	0.026

Results are indicative only – results should not be used and will be updated

Conclusions and Future Work

- Demonstrated very low L/G ratio for once-through amine capture
- Experimentation ongoing
- Validation of DAC model with lab data
- Preliminary results suggest acceptable loading delta with once-through design for parallel (low energy) Co-DAC
- Amine carryover and water losses
- Degradation in the system

Acknowledgements

Co-DAC – Combined Direct Air Capture and PCC Amine Capture for Reduced Energy and Capital Cost Requirements
https://ukccsrc.ac.uk/research/flexible-funding/flexible-funding-2022/dr-stavros-michailos/

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