Experimental Screening of High-Performance Water Lean Solvents for Carbon Capture (DemoBECCS)

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DemoBECCS Overview

Funding: Danmarks Innovationsfond

Total budget: DKK 3.71 million

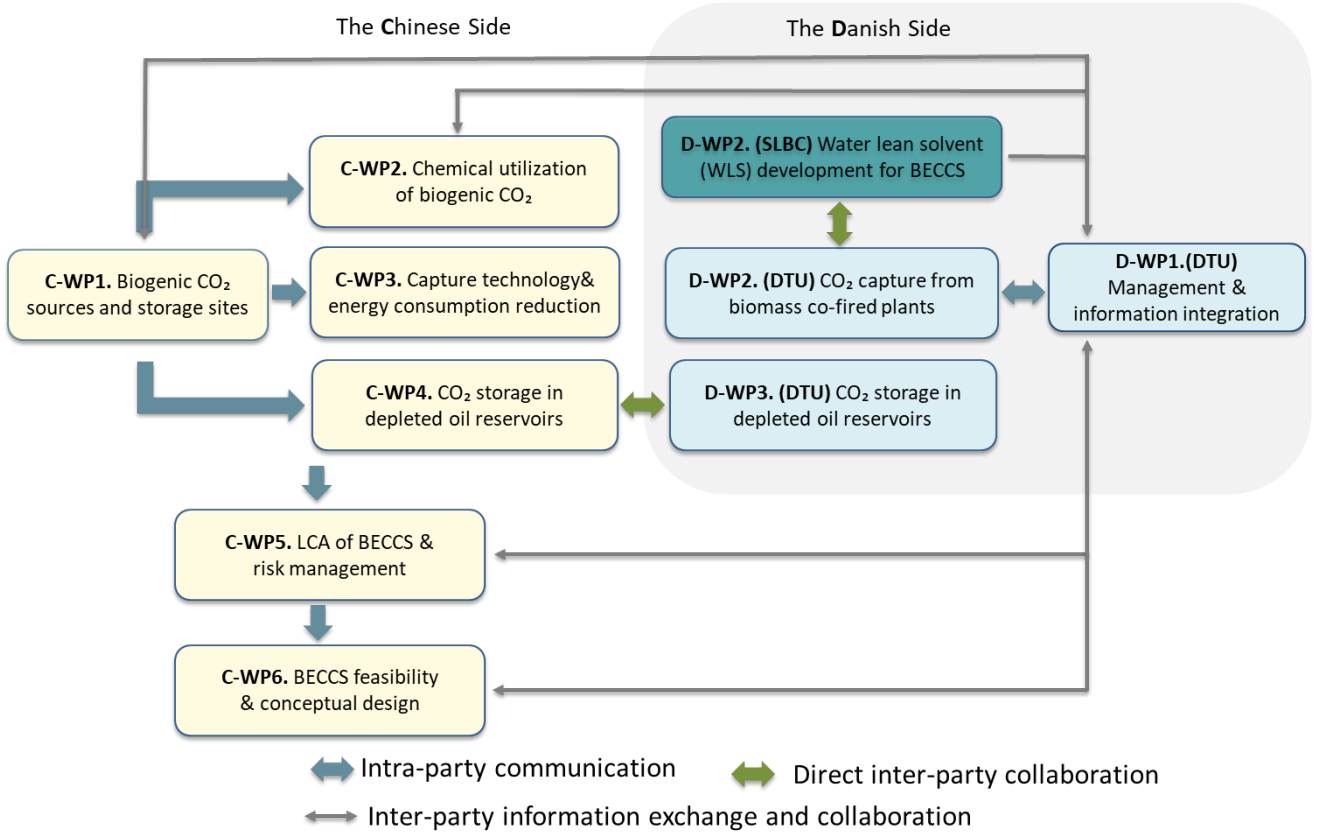
DTU budget: DKK 2.25 million (KT and Kemi)

SLBC budget: DKK1.46 million

D-WP1/3 lead: Prof. Wei Yan (DTU, Kemi)

D-WP2 lead: Prof. Philip Fosbøl (DTU, KT)

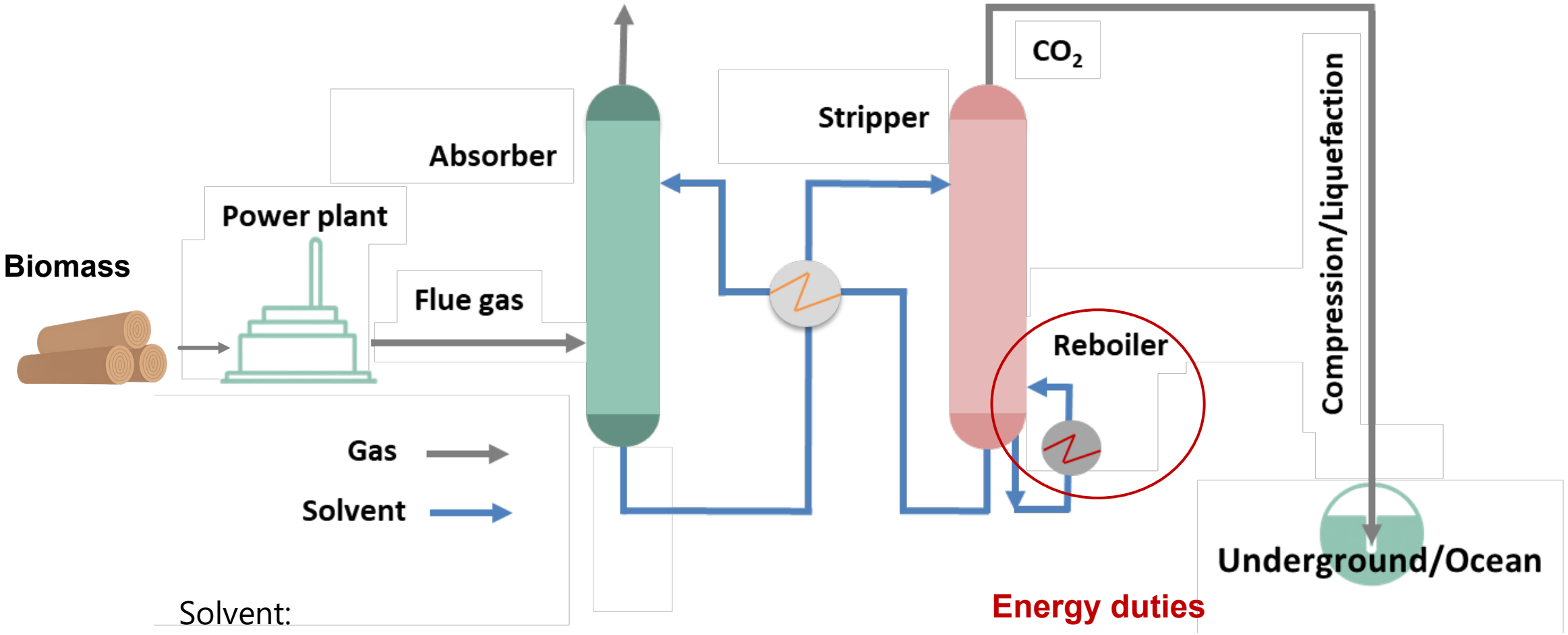
Dr. Jacob Knudsen (SLBC)



C-WP1–6:

- Institute of Rock and Soil Mechanics, Chinese Academy of Sciences
- Shanghai Advanced Research Institute, Chinese Academy of Sciences
- China University of Mining and Technology
- Chongqing University
- Tianjin University

BECCS application to Power Plant



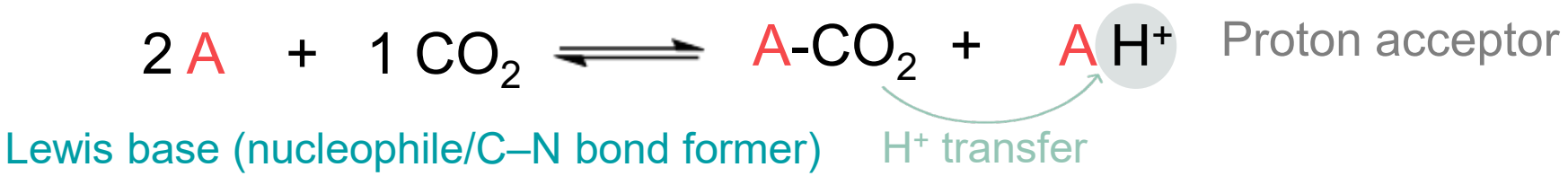
Solvent:

Amine (A):MEA, MDEA

Diluent (D):~~H_2O~~ MeOH, EG, NMP…

Screening methodology

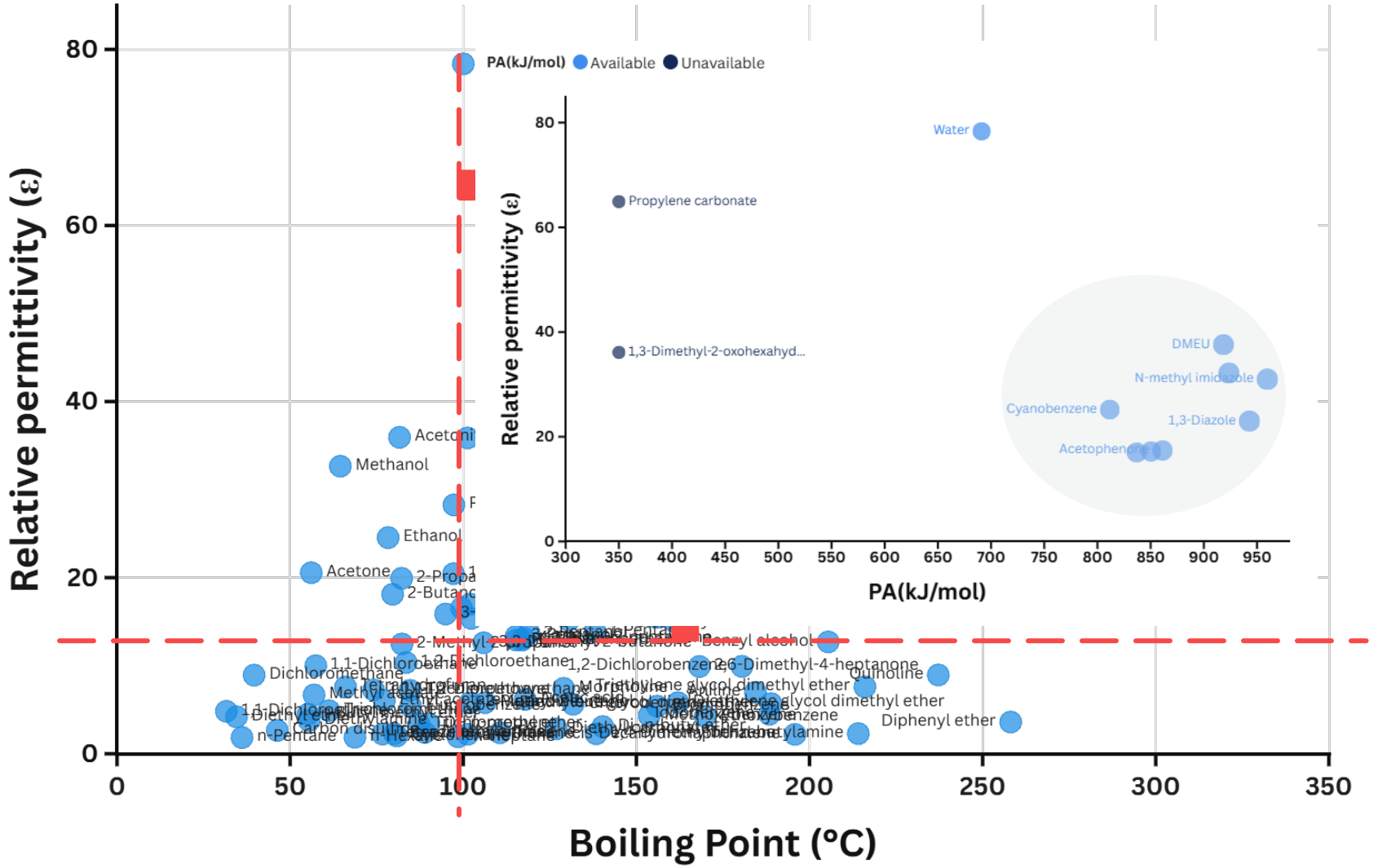
- `Carbamate formation: primary, secondary, polyamine



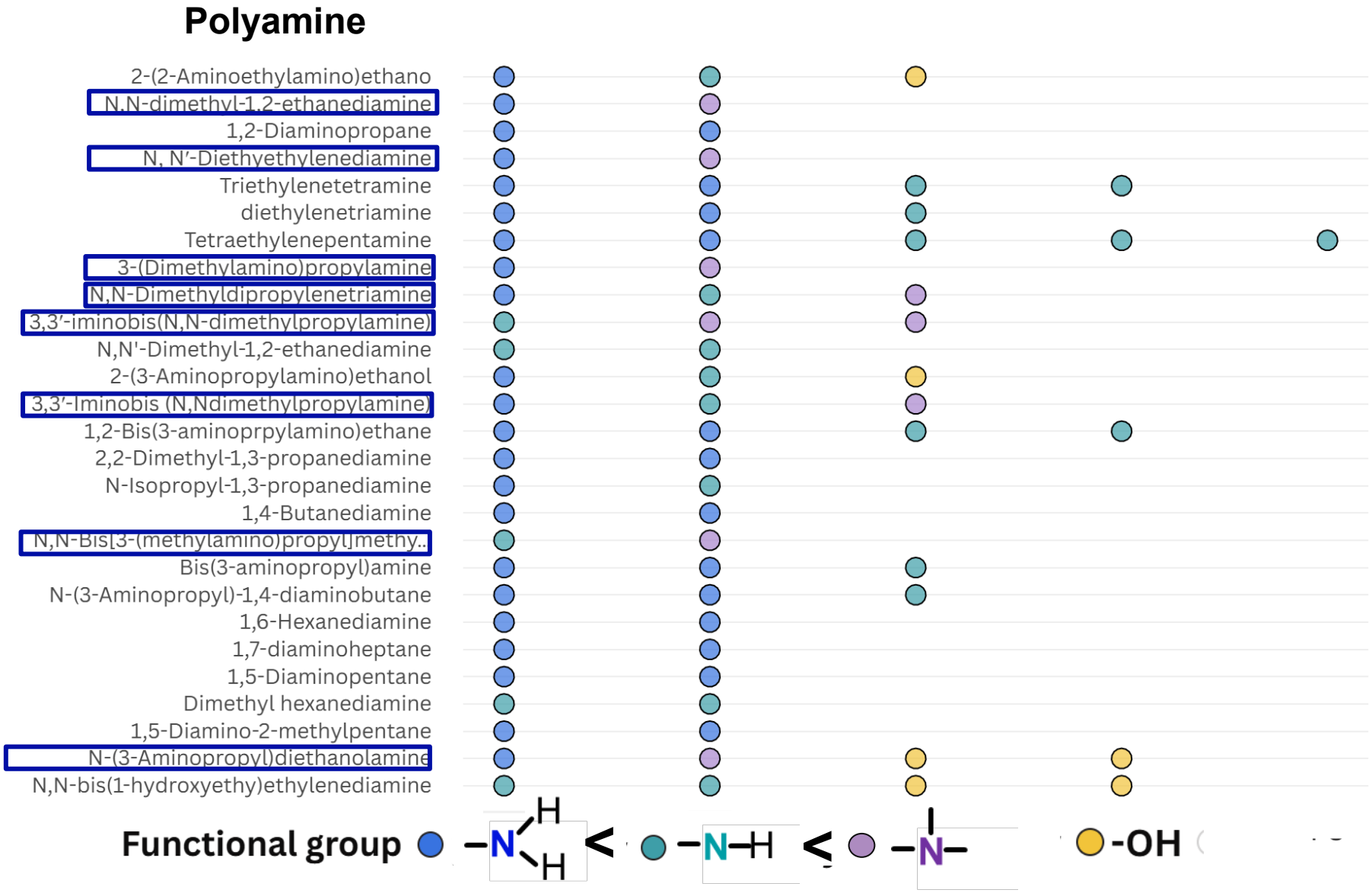
D is the proton acceptor:

A (polyamine) is the proton acceptor:

Diluent is the proton acceptor:



Amine (polyamine) is the proton acceptor:



Screening methodology

- `Alkyl carbonate formation: tertiary, hindered amine

$$D \rightleftharpoons D^- + H^+$$

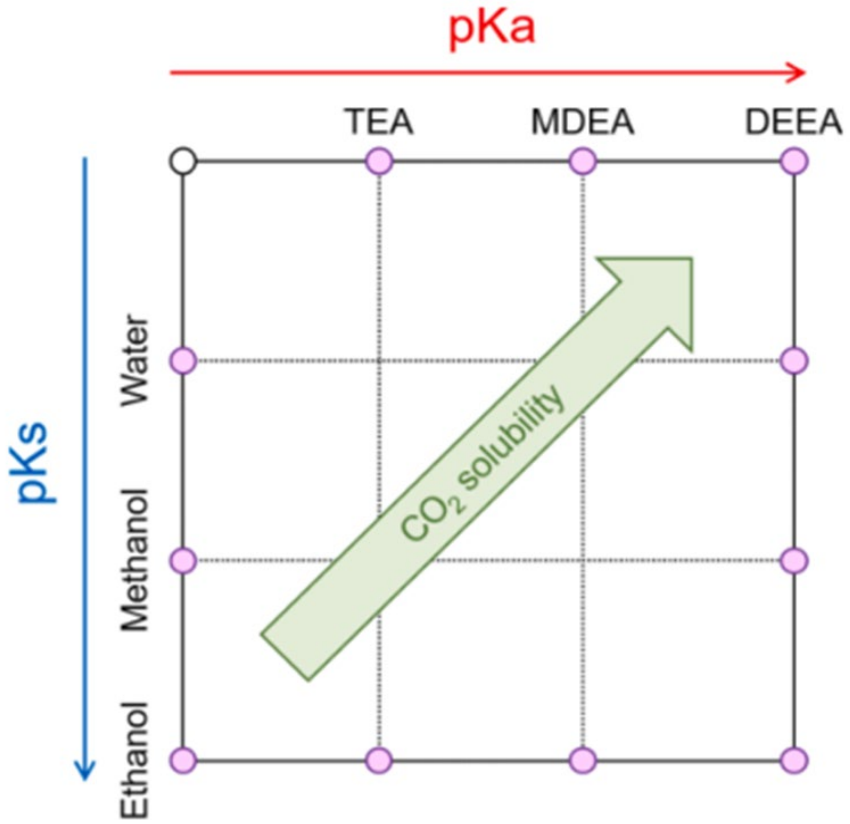
Non-nucleophilic diluent autoprotolysis (pKs)…

$$A + H^+ \rightleftharpoons AH^+$$

Catalysed by the amine (pKa)…

$$D^- + CO_2 \rightleftharpoons DCO_2^-$$

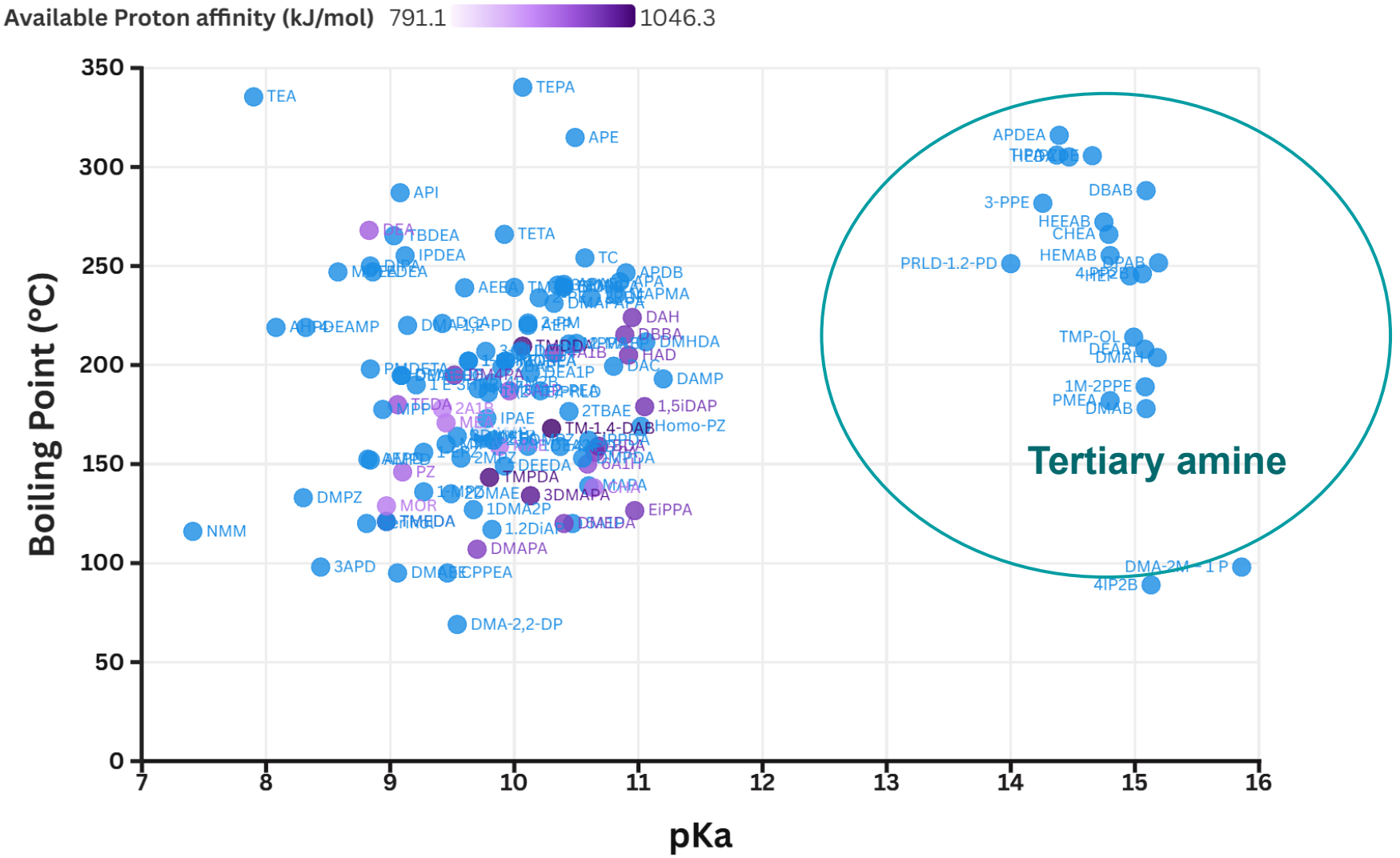
Forming an alkylcarbonate



Wanderley et al., Int. J. Greenh. Gas Control, 2021, 109, 103398.

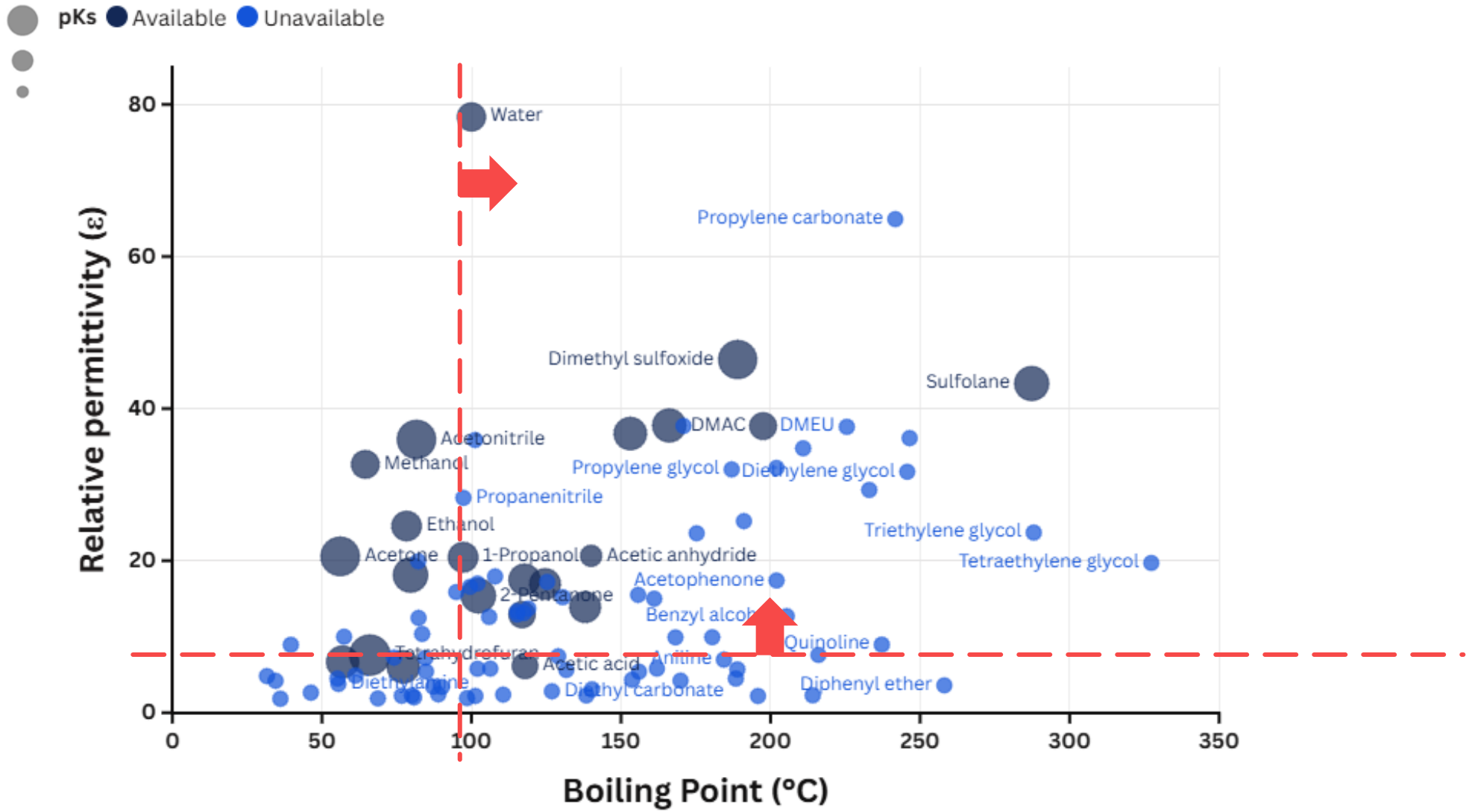
Alkylcarbonate formation:

Choose of amines..high pKa

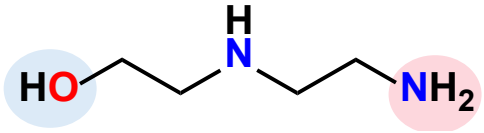


Alkylcarbonate formation:

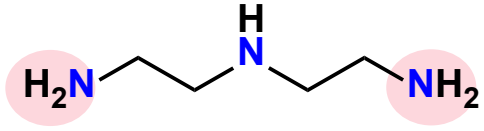
Choose of diluents..low pKs



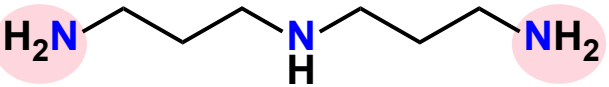
Amine and Diluent candidates



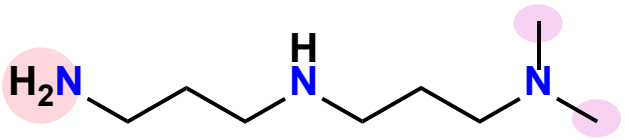
AEEA



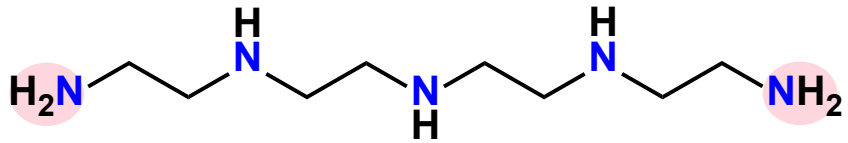
DETA



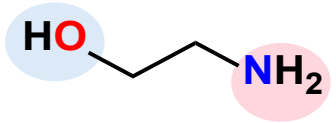
APA



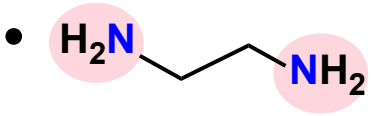
DMAPAPA



TEPA



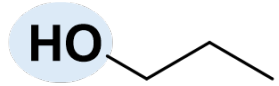
MEA



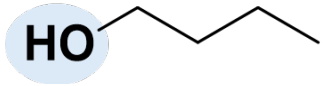
EDA

- AMINE 1 (Cyclic amine)
- AMINE 2 (High pKa)
- AMINE 3 (Primary amine)
- AMINE 4 (Guanidine)
- AMINE 5 (Polyamine)
- AMINE 6 (Polyamine)

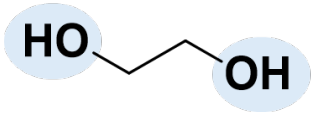
- Primary Alkanols



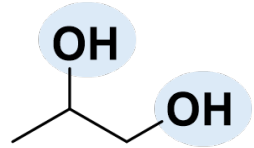
1-PrOH



1-BuOH

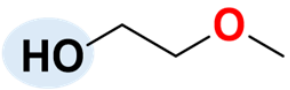


EG



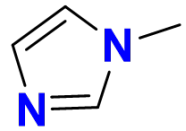
PG

- Hydroxy ether



EGME

- Heterocycle compound

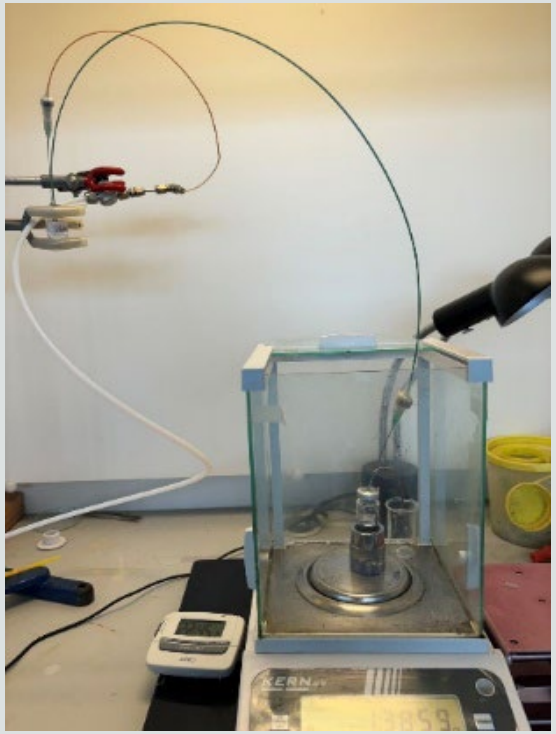


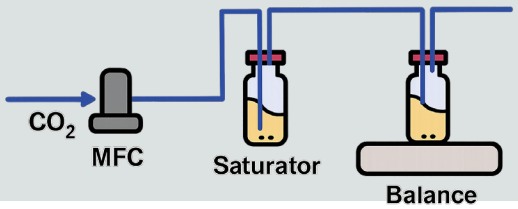
1-MIm

Methodology

	Property	Expected start up time	Approx. time for analysis	Available at DTU?
Simple properties	Phase changes	2 w	1h	Yes
	Density	2 w	1-2 h	Yes
	Viscosity	2 w	1-2 h	Yes
	Surface Tension	4 w	3-6 h	Yes
	T boiling	2 w	1-2 h	Yes
	SLE	2 w	1-2 h	Yes
	pKa	1 w	4 h	Yes
	Dielectric permittivity	NA	NA	No
Advanced properties	VLE	16 w	1-2 d	Yes
	Heat capacity	16 w	2-3 d	Yes
	Heat of Abs.	16 w	3 h	Yes
	Mass transfer rate	3 w	1-2 h	Yes
	T Degradation	24 w	2-15 d	Yes
	O Degradation	24 w	2-15 d	Yes
	Corrosion	16 w	1 d	Yes
	Impact of impurities	30 w	NA, depends on property	Yes
	Speciation	36 w	1-2 w	Yes
	Mini pilot	12 w	1-2 d	Yes
	Heat transfer coef.	NA	NA	No
	Speed of Sound/joule Thomson	12 w	1d	Yes
	Heat of Vap.	NA	NA	No (equipment could be developed)

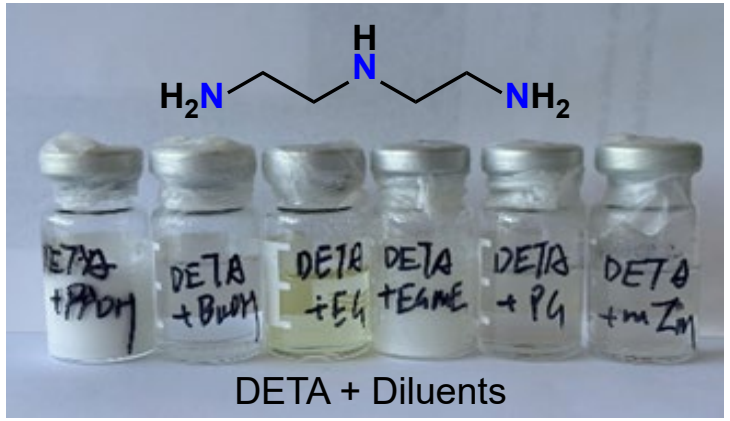
Miscibility and phase changes





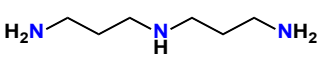
CO_2 Saturation

Precipitation

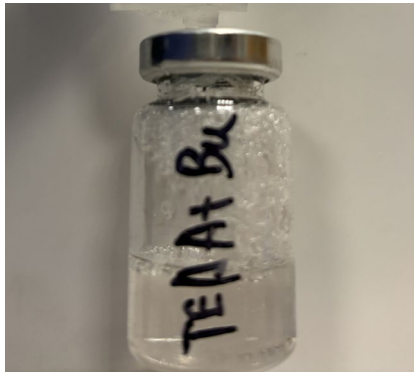


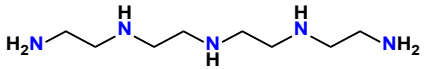
DETA + Diluents

Foaming tendency



APA+EGME





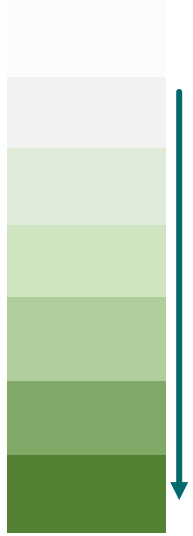
TEPA+1-BuOH

High viscosity

EDA+1-BuOH

CO_2 solubility

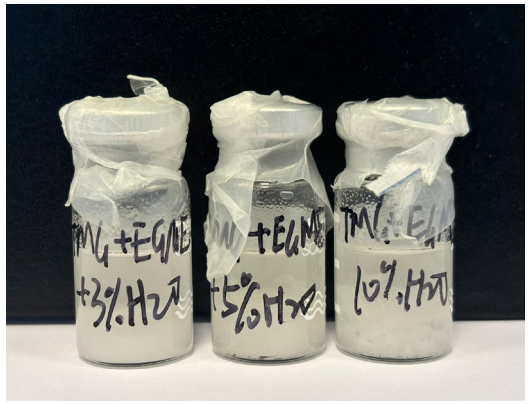
	EG	1-PrOH	1-BuOH	EGME	1-MIm	PG
APA	V	P	P	F	P	V
TEPA	V	F	F	F	F	
A-1 (Cyclic)		P		P	P	
A-2			V			
AEEA	V	P	P	V	F	
A-3				V		V
DMAPAPA	V	V	V	V	V	
IBDMPA	V					
A-4			P			
MEA			P			
EDA	V	V		P		P
13DAP	P	P	P	P	P	P
A-5						
DETA	V	P	P	P	P	V



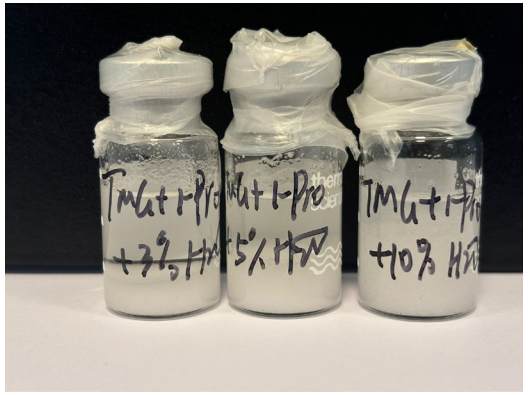
Phase changes

V	High viscosity
F	Foaming
P	Precipitation

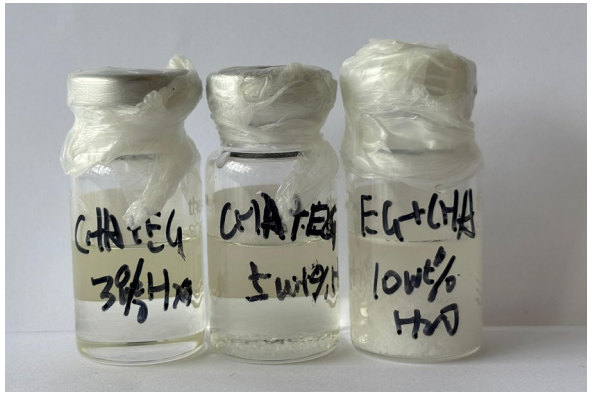
Water compatibility



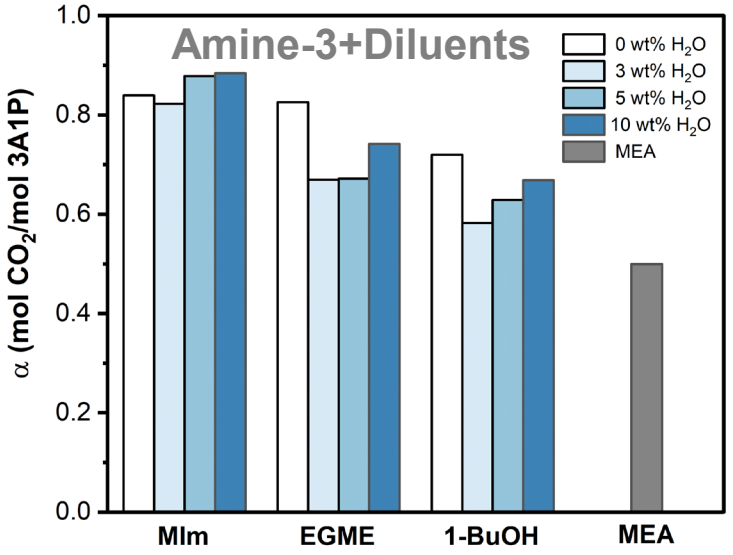
TMG+EGME+H_2O

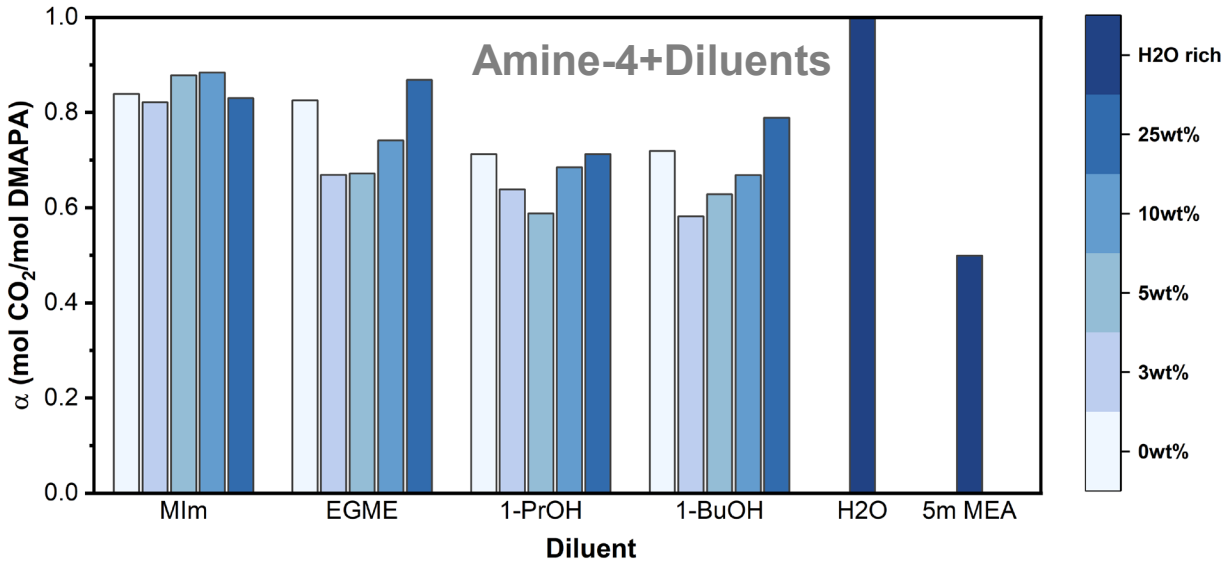


TMG+1-PrOH+H_2O



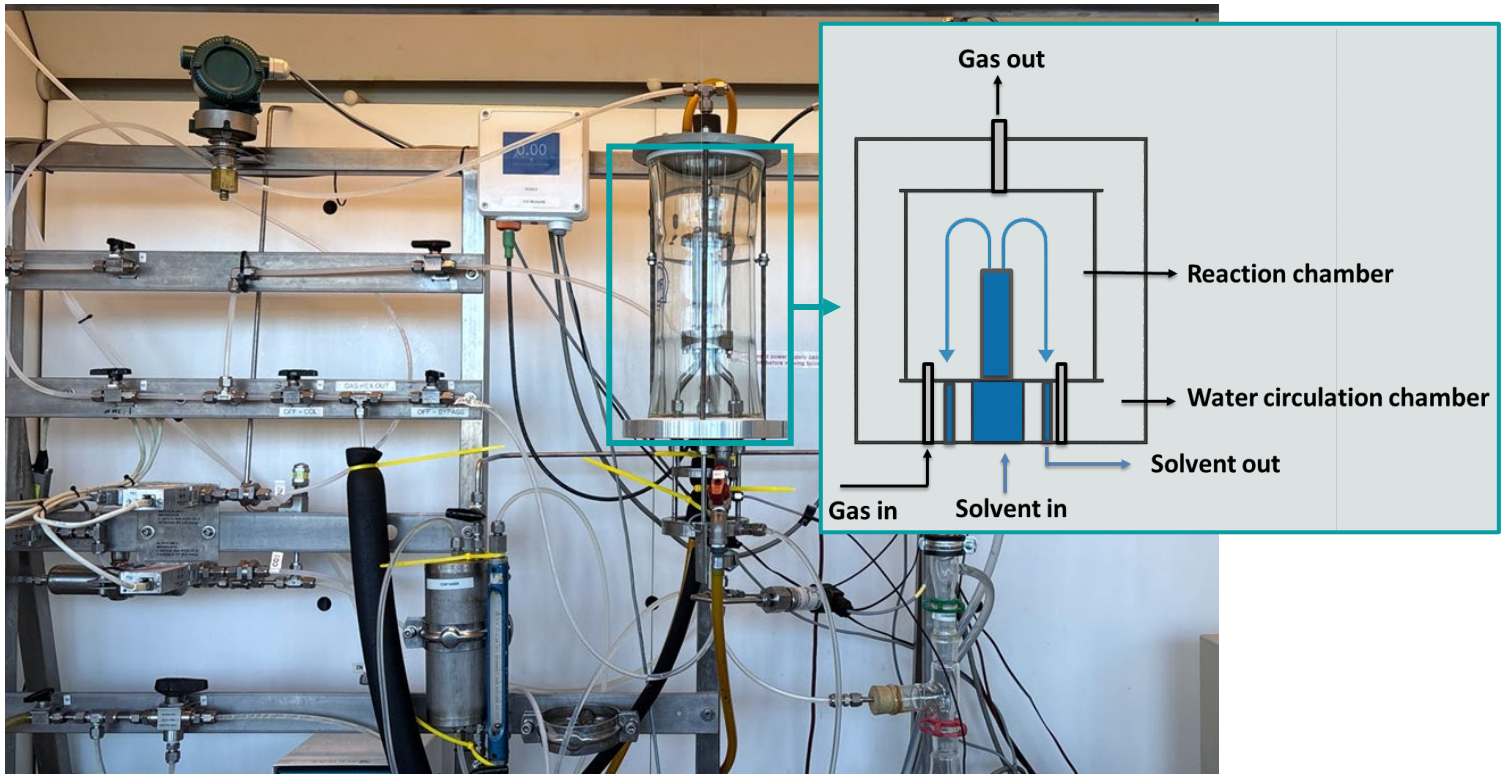
CHA+EG+H_2O

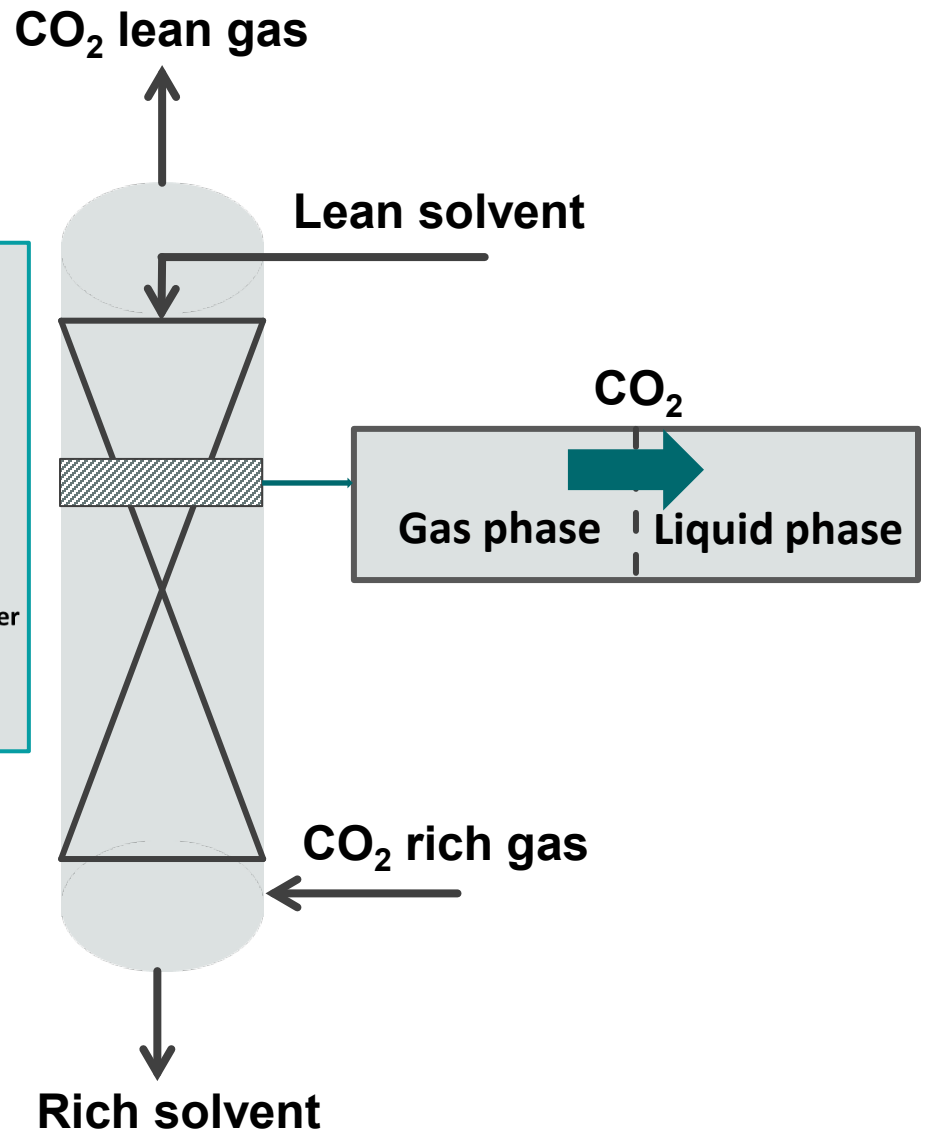




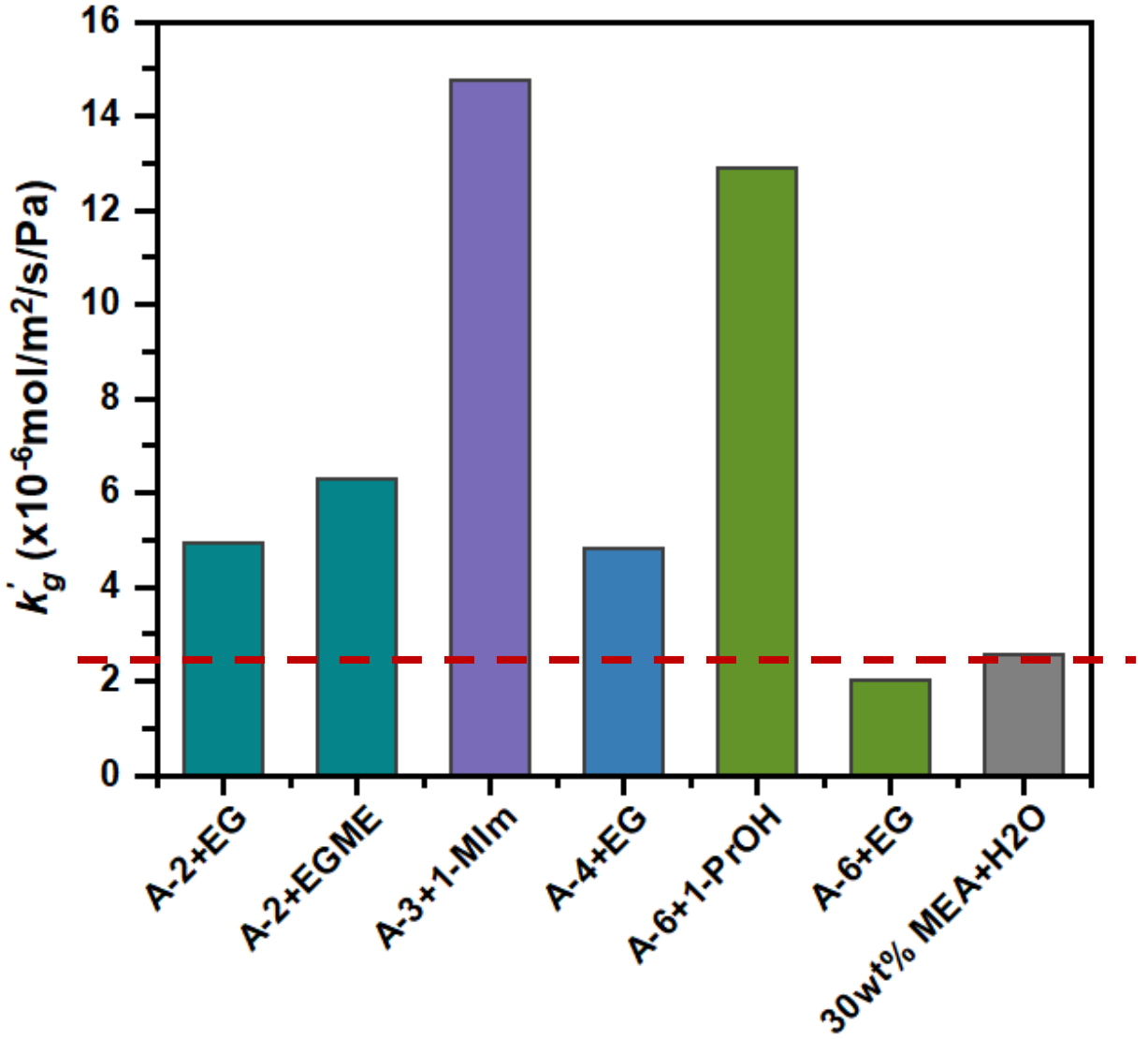
Advanced property: mass transfer rate

Wetted Wall Column (WWC)





Advanced property: mass transfer rate

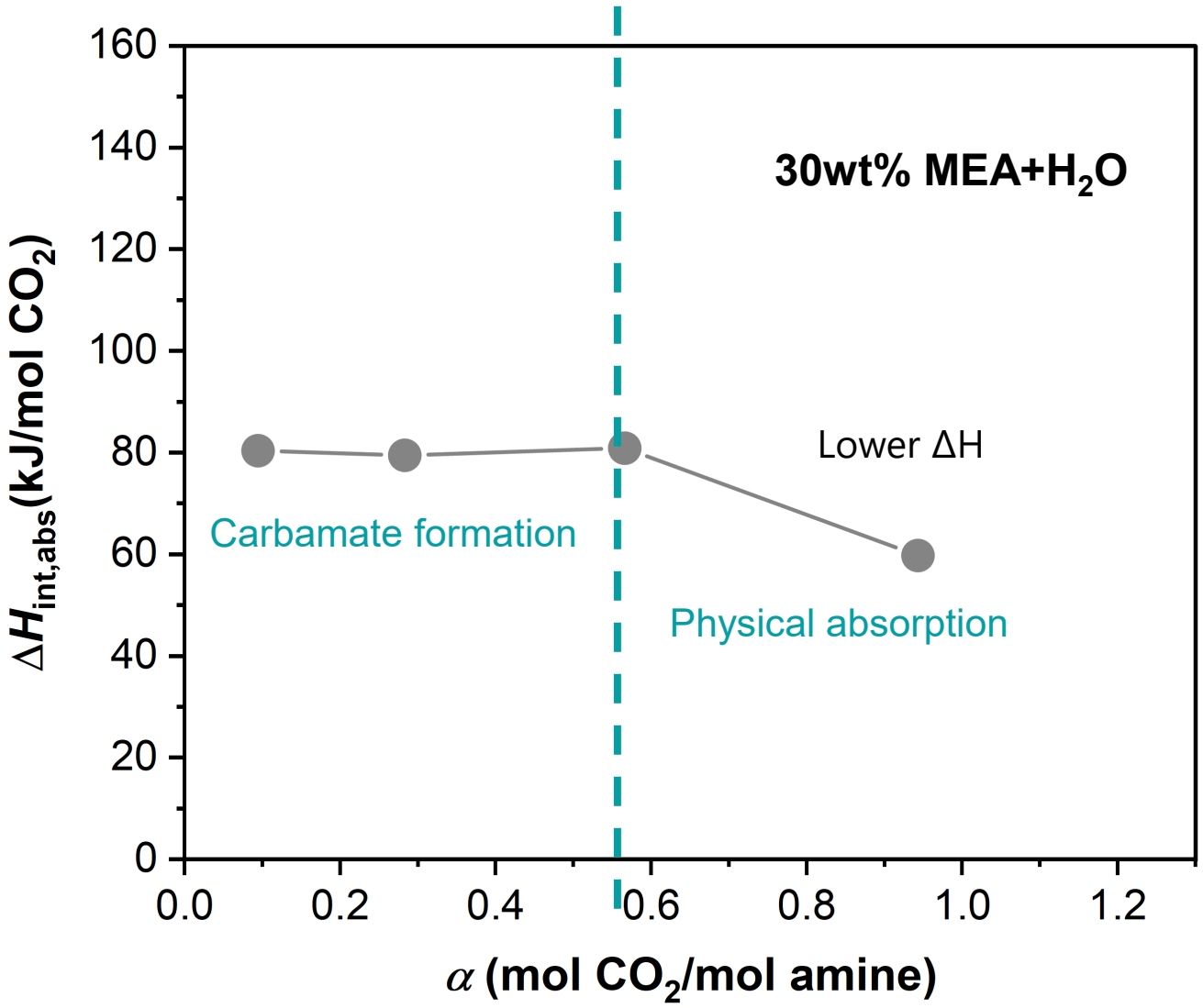


Advanced property: Heat of absorption

Setaram Calorimeter

Determine heat of absorption

Adjustable CO_2 content and flow rates



Advanced property: Heat of absorption

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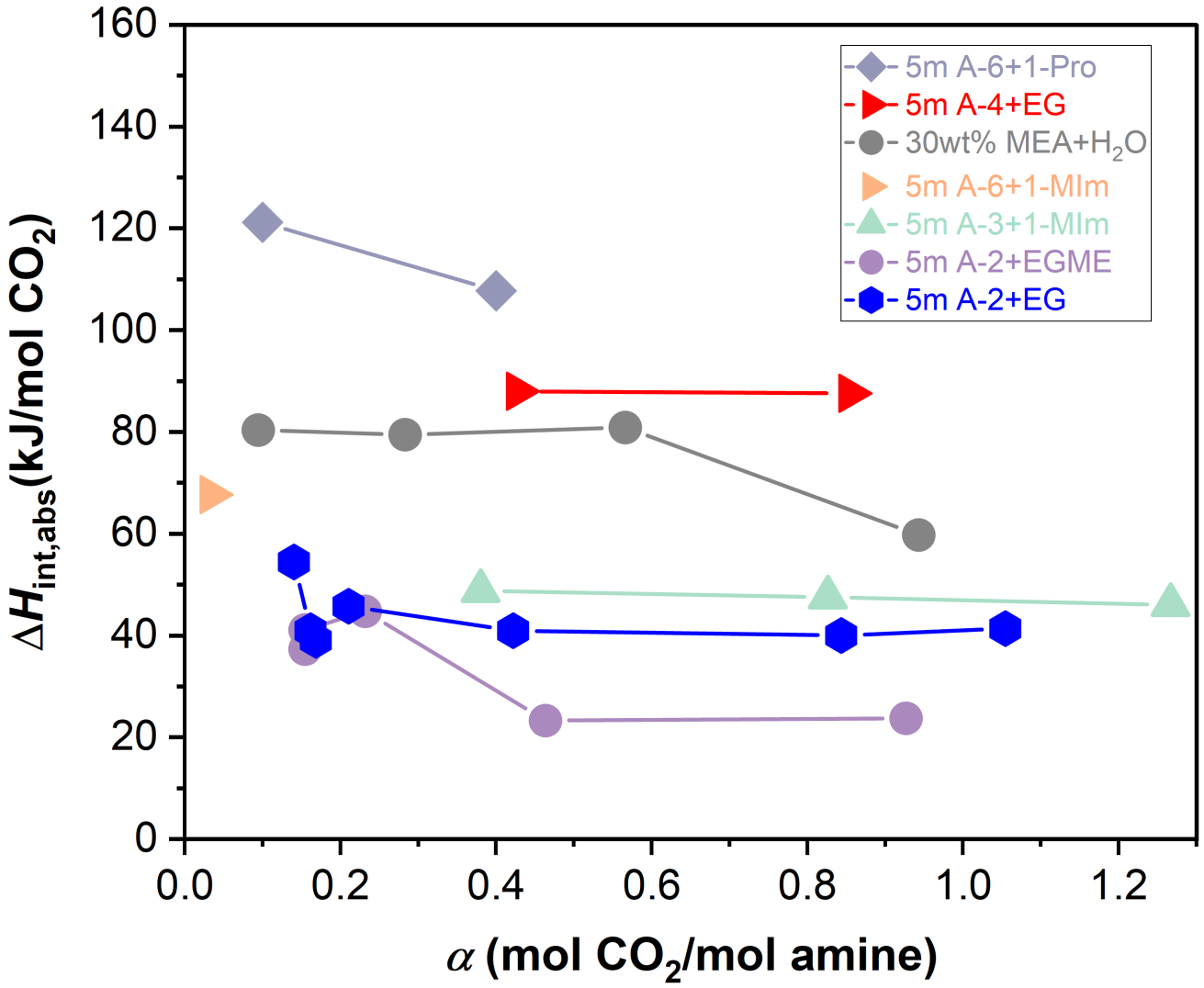
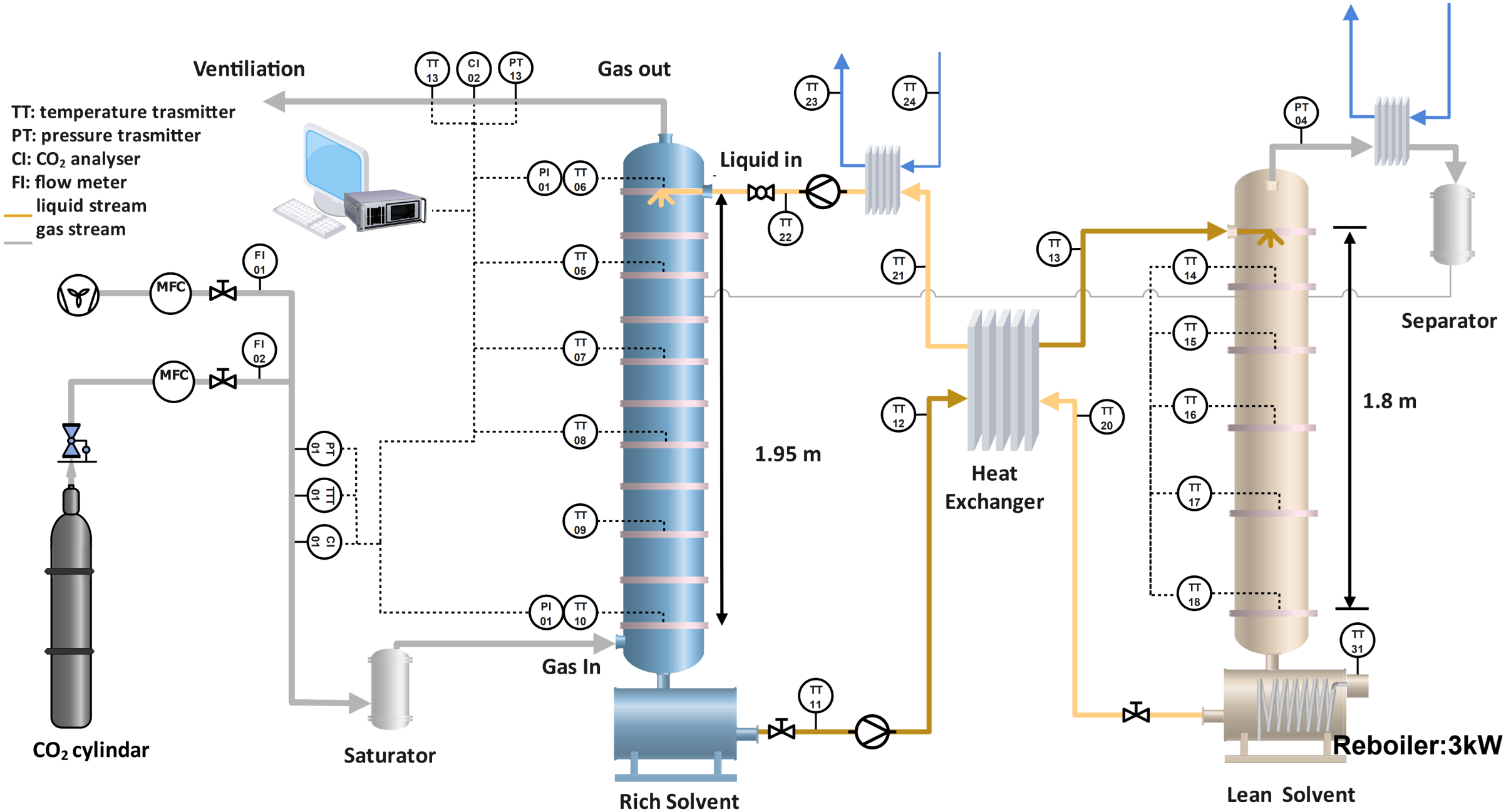


Thermal Minipilot

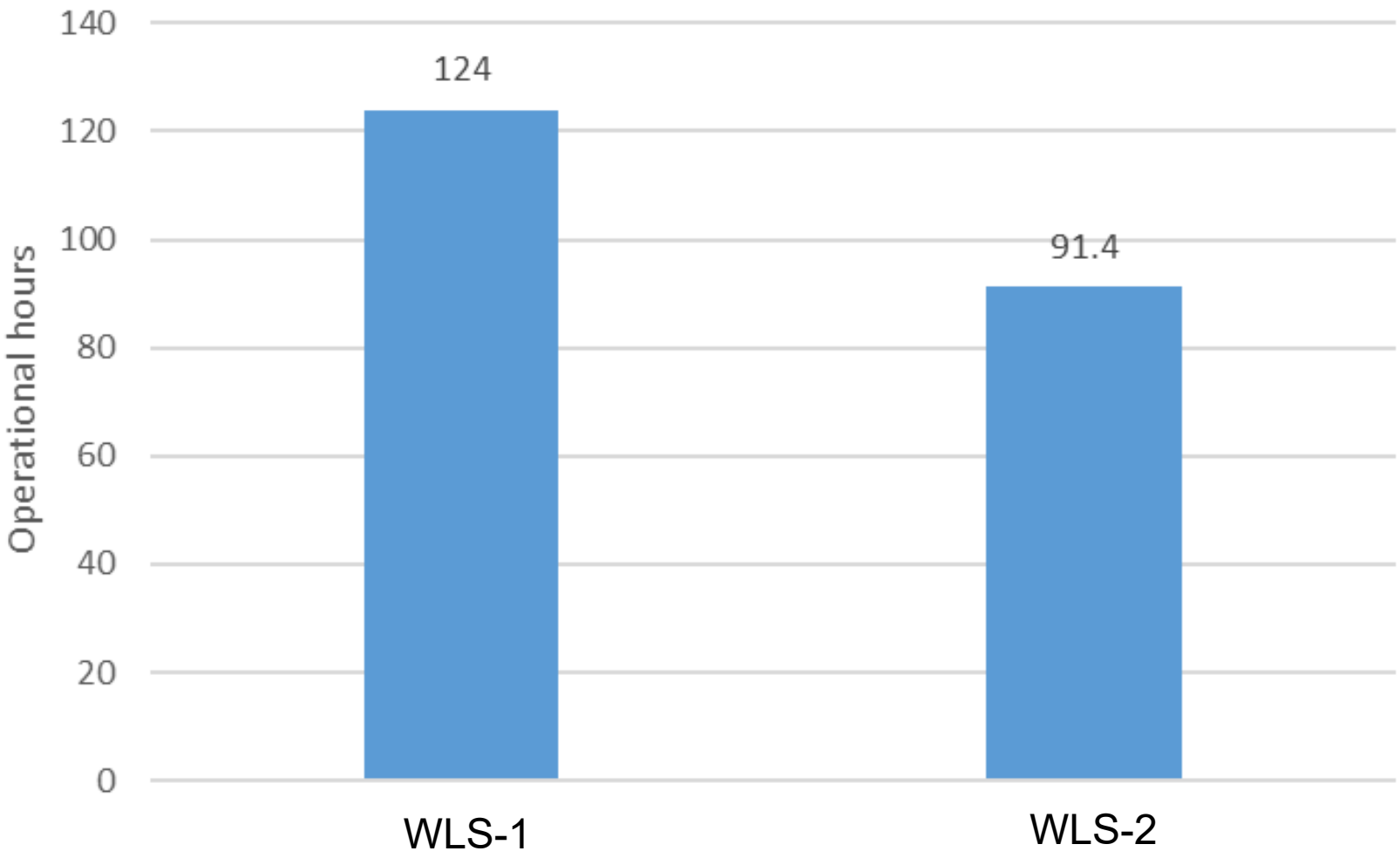


Thermal Minipilot

Parking materials: 4mm Dixon rings

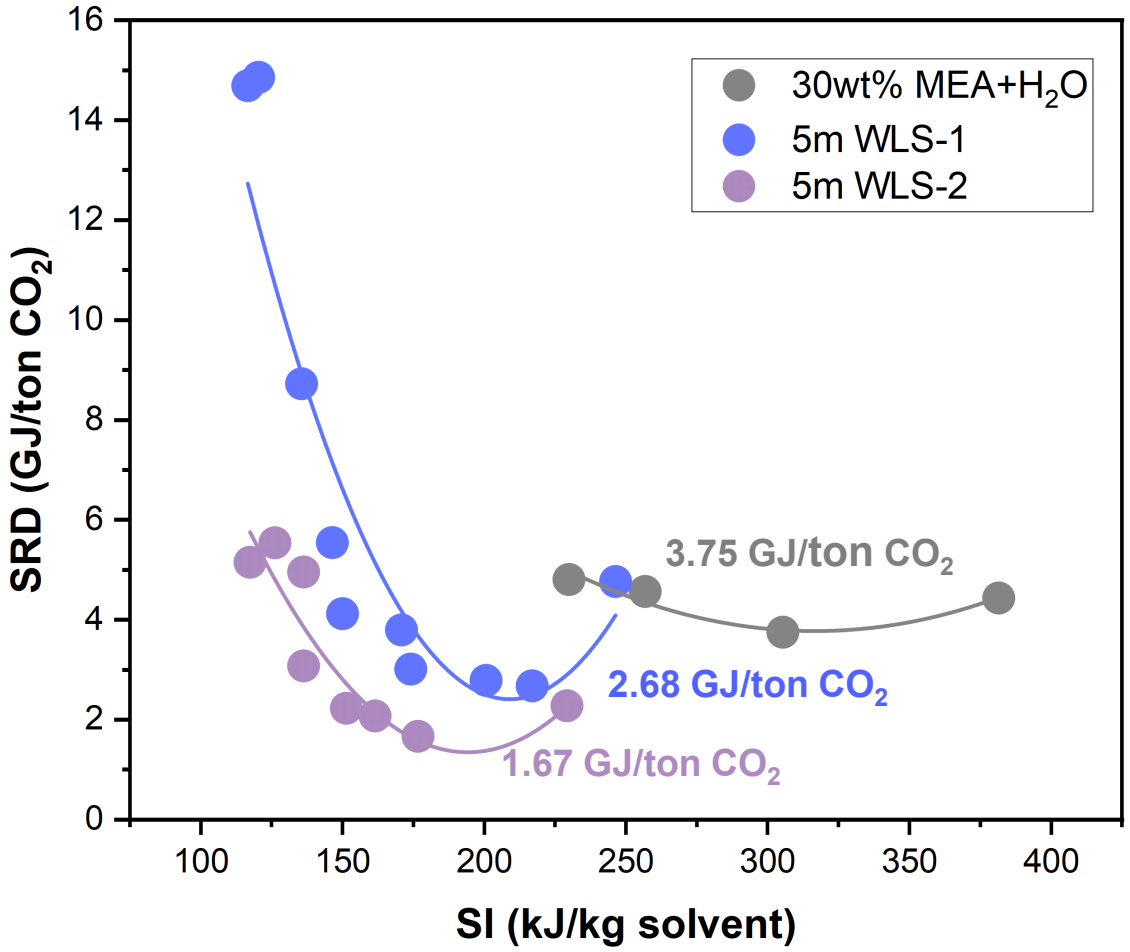
- **Gas flow :** 0.94 Nm^3/h
- **Residence time:** 15 s
- **CO_2 inlet concentration:** 14 mol%
- **Solvent flow:** 2.96–5.78 kg/h
- **L/G:** 2.3–4.5

Total operation hours



Solvent samples through campaigns

Minipilot results



Solvent	Lean loading (mol C/mol A)	Rich loading (mol C/mol A)
30wt% MEA+H_2O	0.17	0.48
5m WLS-1	0.54	0.89
5m WLS-2	0.35	0.64

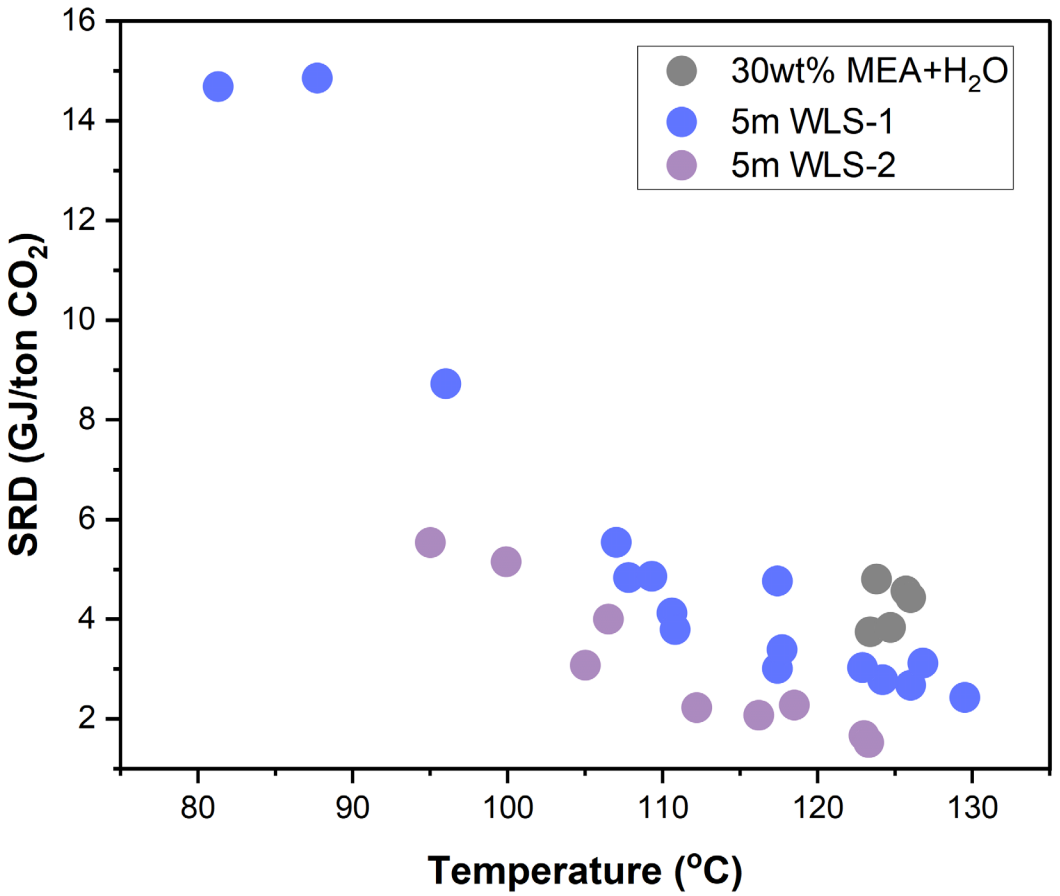
Stripping intensity (SI, kJ/kg solvent):

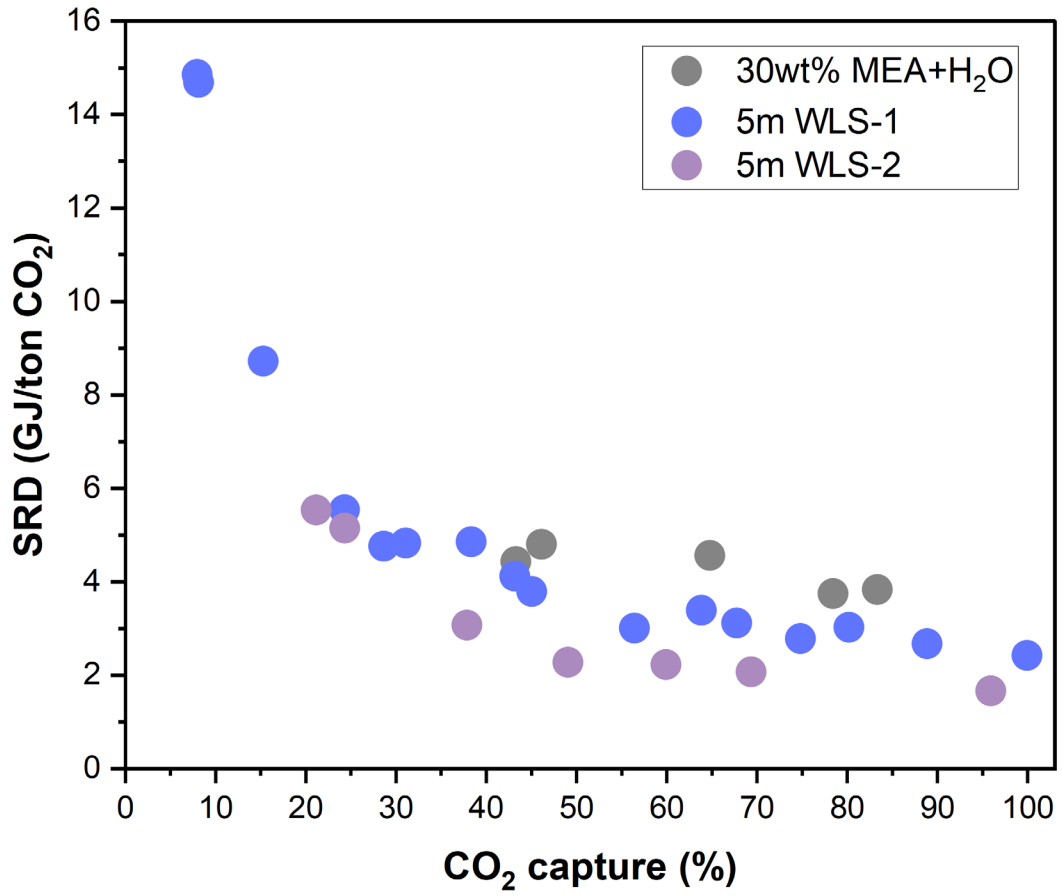
$$\mathrm{SI} = \frac{\dot{Q}_{boiler} - E_{loss}}{\dot{m}_{rich}}$$

Specific reboiler duty (SRD, GJ/ton CO_2):

$$\mathrm{SRD} = \frac{\dot{Q}_{boiler} - E_{loss}}{\dot{m}_{CO2,captured}}$$

Minipilot results





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