Stripping the CO_2 capture process

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Research activities are focused on research related to:

- Environmental Engineering and Reactor Technology
- Catalysis
- Colloid and Polymer Chemistry
- Process Systems Engineering

Host for two Centres for Research-based Innovation (SFI):

- SUBPRO: Subsea production and processing
- iCSI: Industrial Catalysis Science and Innovation

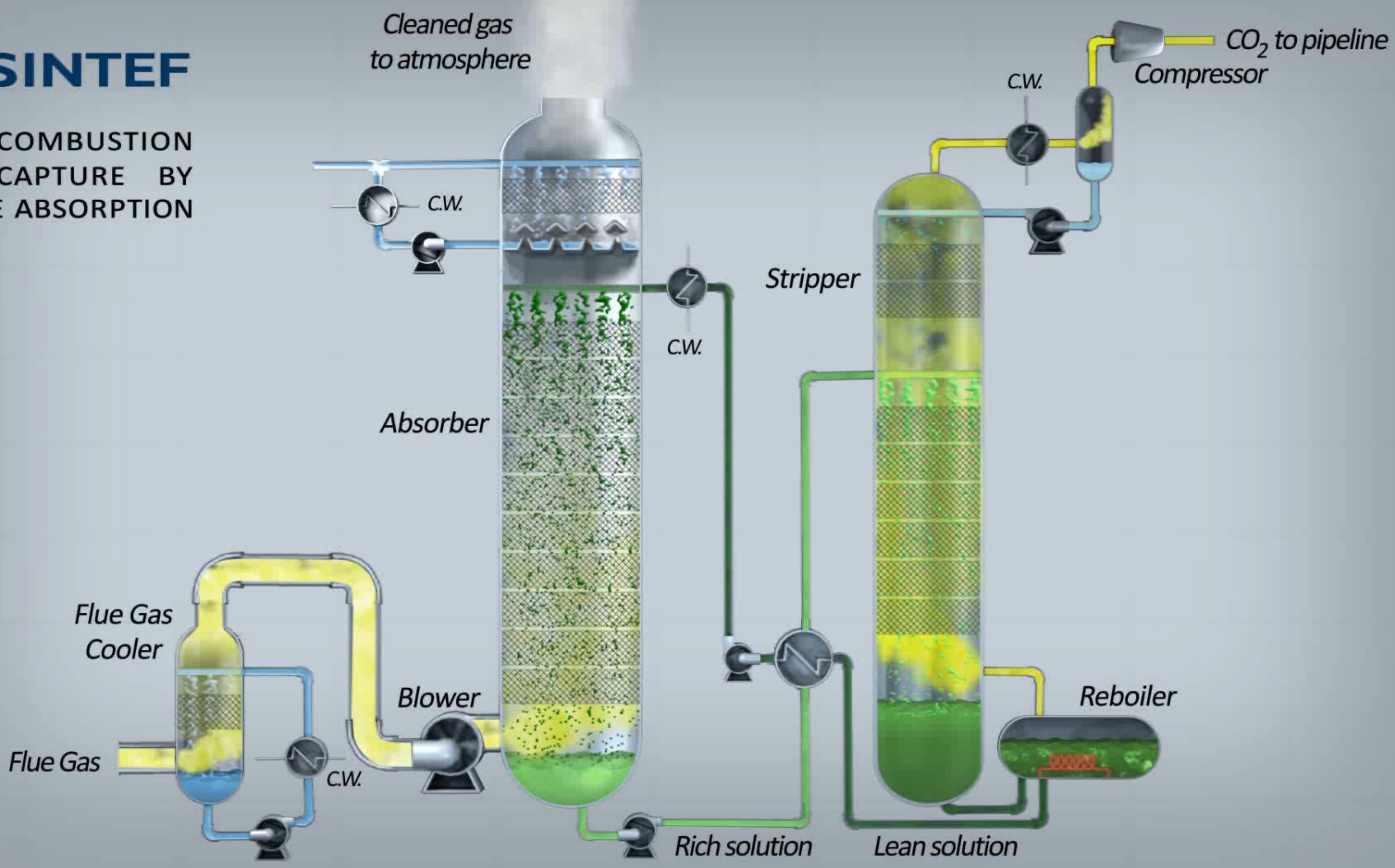
Participants in three Centres for Environment-friendly Energy Research (FME):

- NCCS, Bio4Fuels and HighEFF

STRIPPING THE CO_2 CAPTURE PROCESS

SINTEF

POST-COMBUSTION CO_2 CAPTURE BY AMINE ABSORPTION



Applications

P_{CO2} =20-100bar		P_{CO2} =0.03-0.5 bar		
Natural gas	Hydrogen	Coal flue gas	Gas turbines	Biogas upgrading

Solvent selection

- Rate of reaction/mass transfer

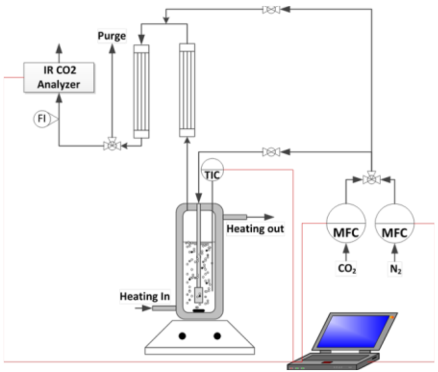
- Gas/liquid equilibria
- Heat of reaction
- Cyclic capacity

- Chemical stability
- Corrosion
- Solvent vapor pressure

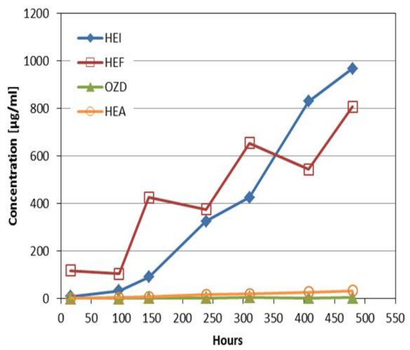
- Ecotoxicity and biodegradation
- Toxicity

- Cost and availability
- Foaming properties

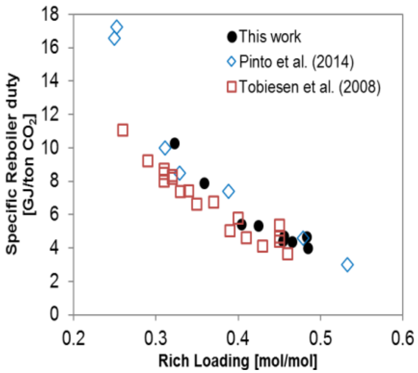
Solvents



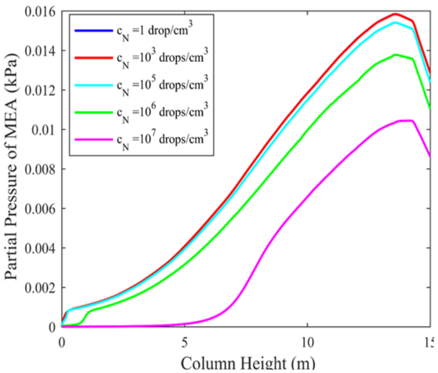
Solvent degradation



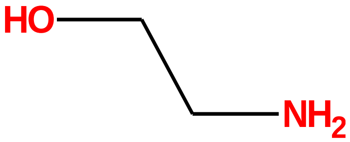
Energy consumption



Solvent emissions



30wt% MEA (ethonolamine) used as a referance case



- A lot of data available
- Used industrially
- Used as referanse/basecase in many papers

However, this can be considered to be old fashion.

SOLVENTS

Solvent types

Liquid solvents

- Amines
- Carbonates
- Ionic liquids
- Amino acids…

Solvents forming two liquid phases

- Amine blends

Precipitating solvents

- Amino acids
- Carbonate systems
- Ammonia systems

Solvent development

amines

- Primary
- secondary
- Tertiary
- Polyamines

Carbonates

- Sodium carbonate
- Potassium carbonate
- Ammonium carbonate
- Promoted systems

Amino acids

- Amine + amino acid
- KOH/NaOH + amine acid

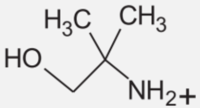
Ionic liquids

- Physical solvents
- Chemical solvents

Hybrid solvents

- Water lean solvents
- Combination of physical and chemical solvents

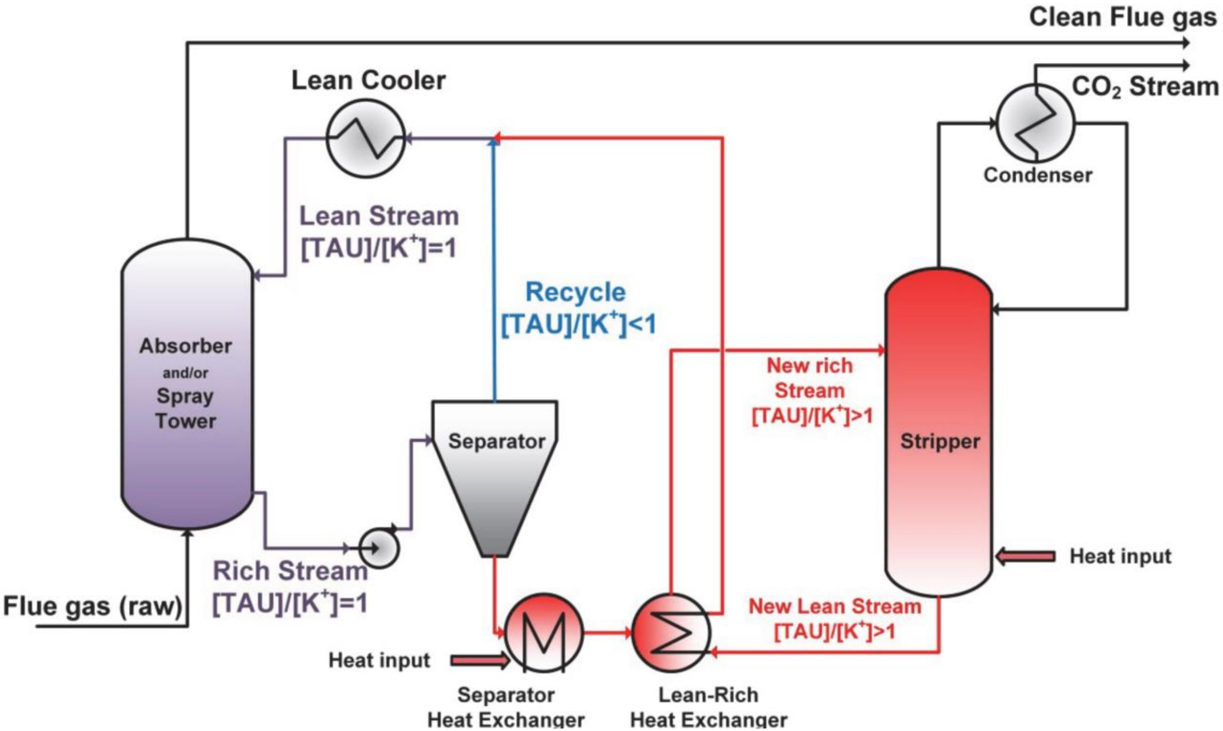
Heat of absorption >< kinetics

Class	Typical reaction	$-\Delta H_{abs}$ (kJ/mol)	Kinetics
Carbonate	$CO_3^{=} + CO_2 + H_2O \leftrightarrow 2HCO_3^-$	40	Very slow
Tertiary amine	$R_3N + CO_2 \leftrightarrow R_3NH^+ + HCO_3^-$	60	Slow
Hindered amine	 $+ CO_2 \leftrightarrow AMPH^+ + HCO_3^-$	60–70	Moderate
Secondary or primary amines	$2R_2NH + CO_2 \leftrightarrow R_2NHCOO^- + R_2NH_2^+$	70–80	Fast

→ Blends are often used

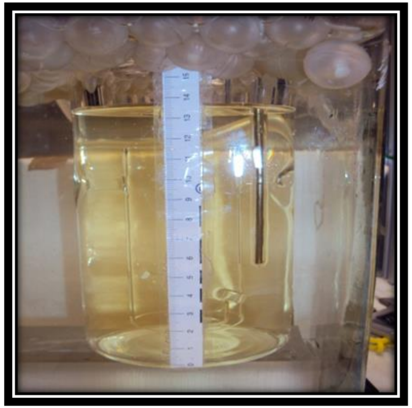
G.T. Rochelle: 3 - Conventional amine scrubbing for CO2 capture, Editor(s): Paul H.M. Feron, Absorption-Based Post-combustion Capture of Carbon Dioxide, Woodhead Publishing, 2016, Pages 35-67, ISBN 9780081005149

Solvents forming two phases

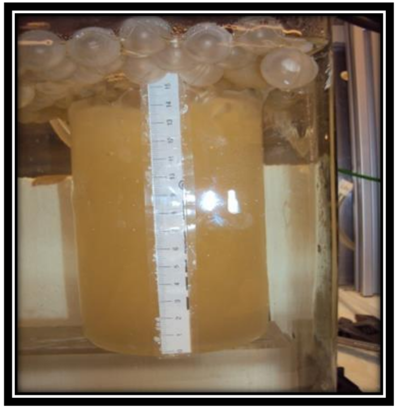


Eva Sanchez-Fernandez, Katarzyna Heffernan, Leen van der Ham, Marco J.G. Linders, Earl L.V. Goetheer, Thijs J.H. Vlugt, Precipitating Amino Acid Solvents for CO2 Capture. Opportunities to Reduce Costs in Post Combustion Capture., Energy Procedia, Volume 63, 2014, Pages 727-738,

Solvents forming two liquid phases



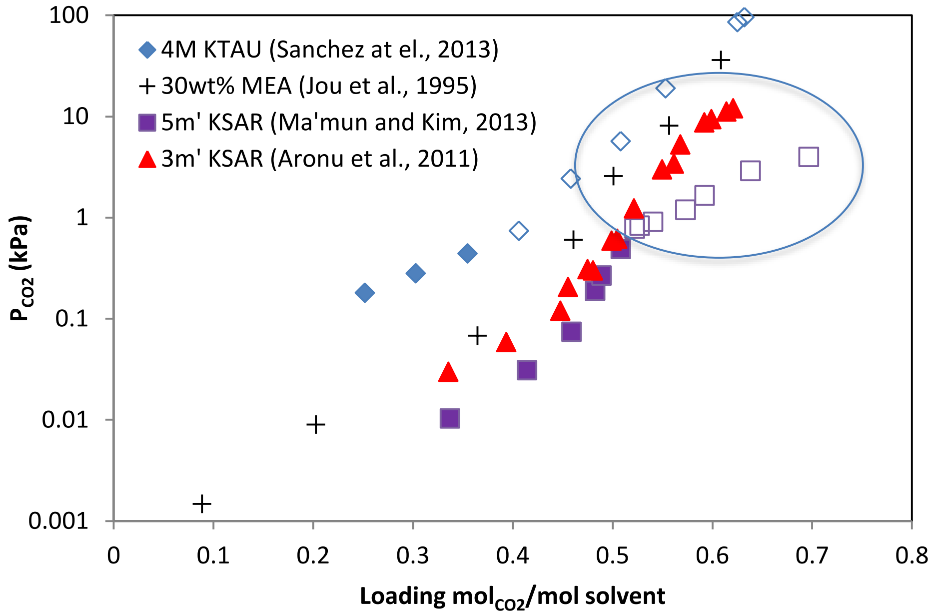
Before experiment

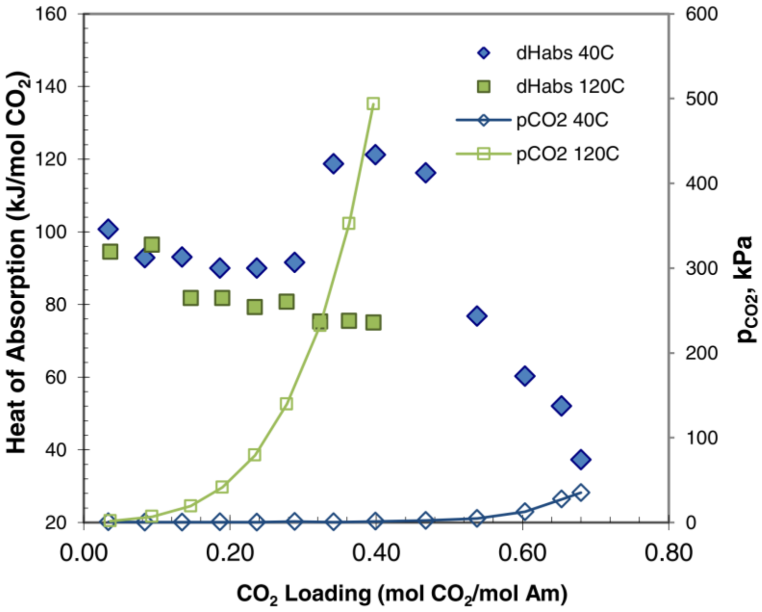


During Experiment

After separation

Precipitating solvents



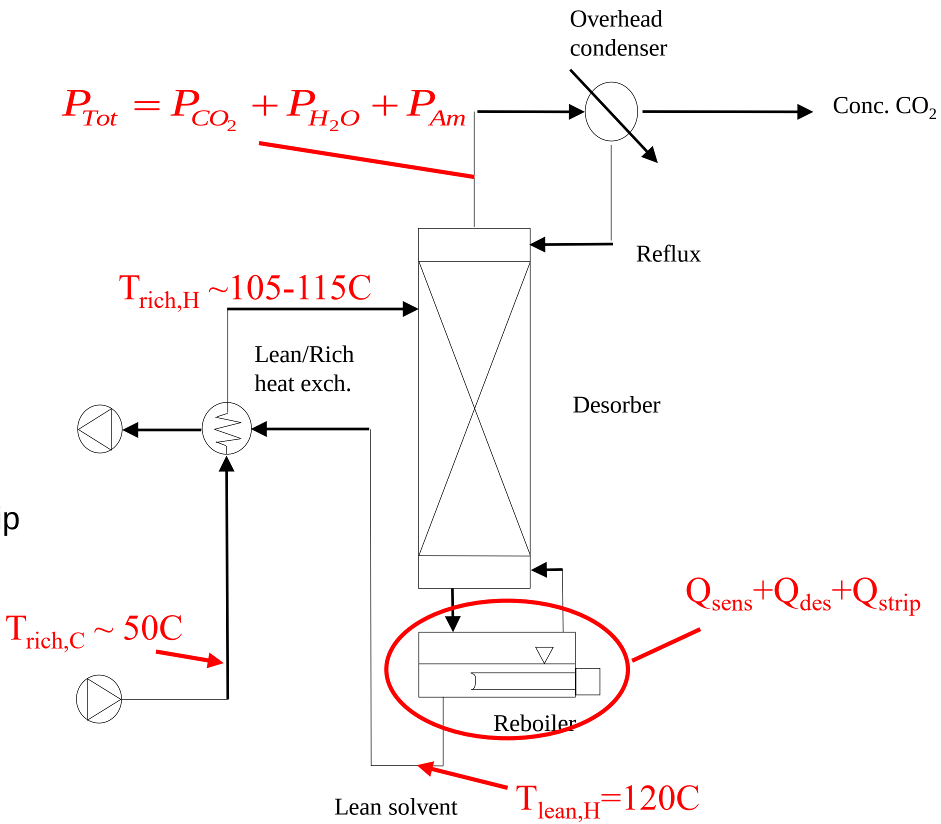


Aronu, U., Kim, I., Haugen, G. Evaluation of energetic benefit for solid-liquid phase change CO2 absorbents , Energy Procedia 63 (2014) 532 – 541

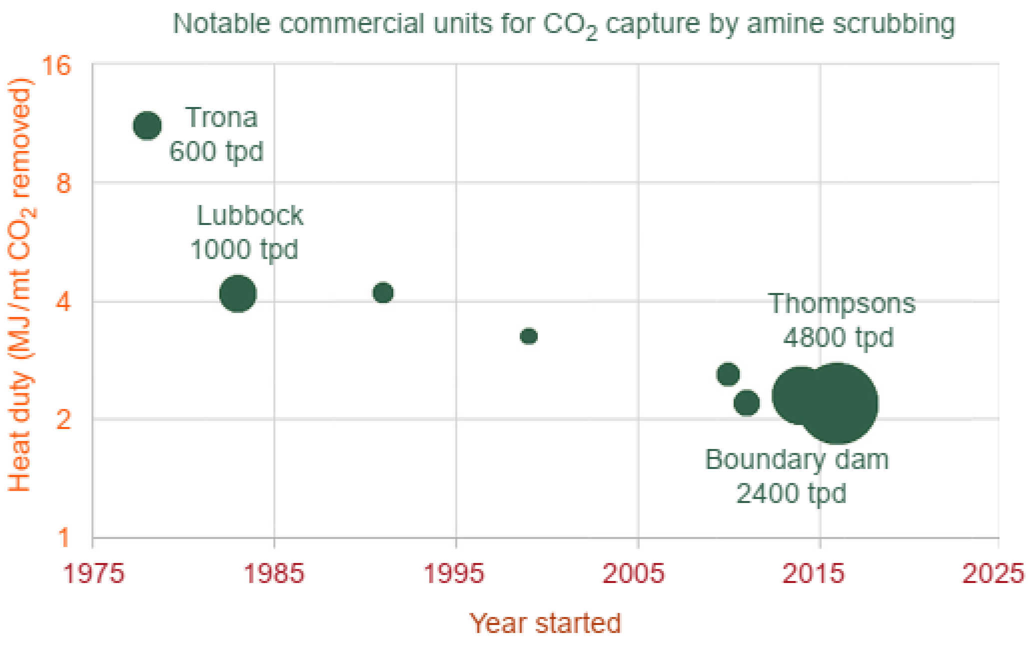
ENERGY CONSUMPTION

Energy consumption

Total heat required = Q_{sens} + Q_{des} + Q_{strip}



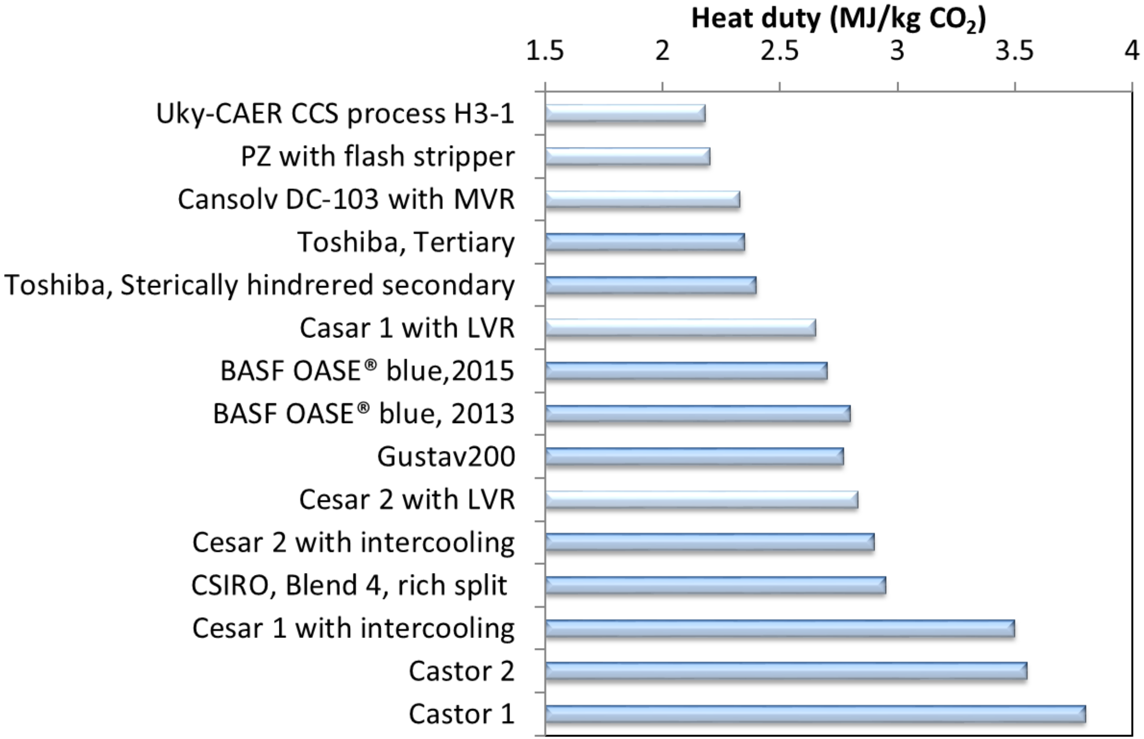
Energy consumption of commercial units



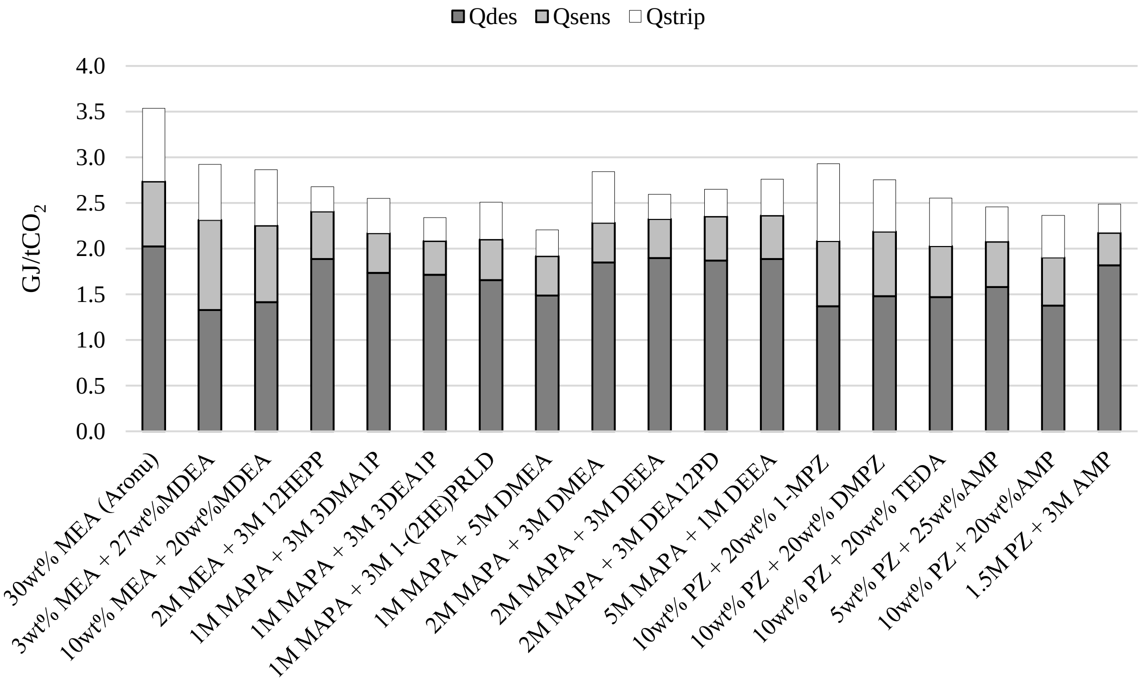
tpd= ton/day

Rochelle, G.T., 2014. From Lubbock, TX to Thompsons, TX: a technical review of the progress in amine scrubbing. In: Plenary Presentation at GHGT-12, Austin, Texas, October 10, 2014

Energy consumption - pilots



Estimated reboiler duties based on Vapor-liquid equilibrium



Bernhardsen, Ida Mortensen; Knuutila, Hanna K. Evaluation of Solvent Blends for Post Combustion CO2 Capture. 14th International Conference on Greenhouse Gas Control Technologies; 2018-10-21 - 2018-10-26

Towards lower energy consumption

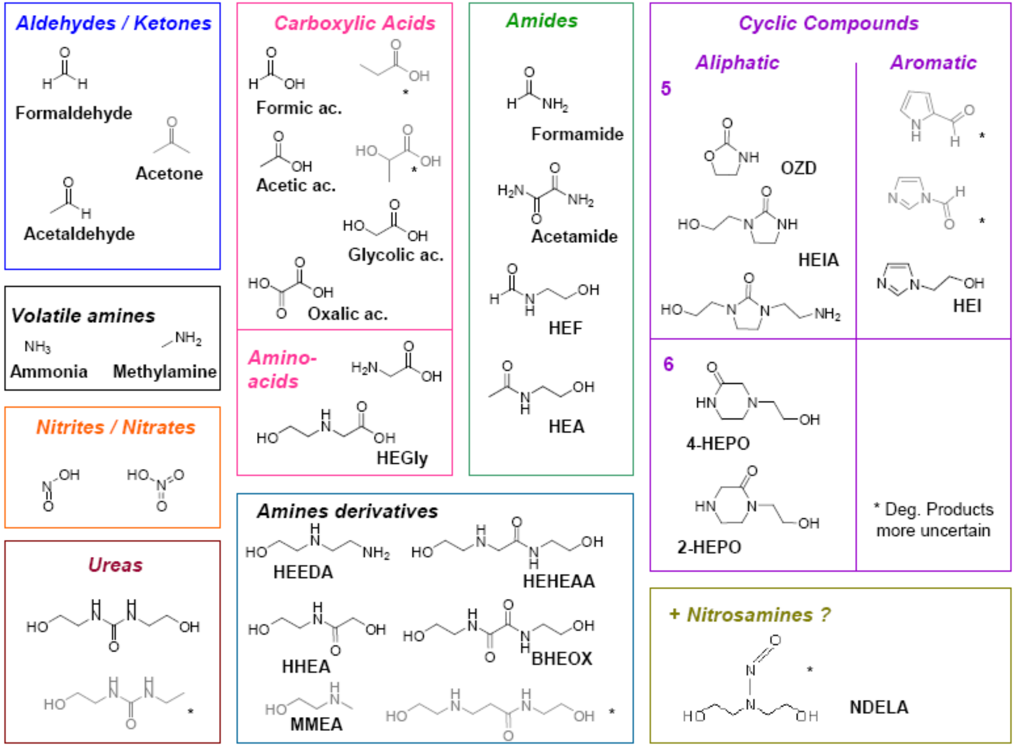
High rich loading	• Close to equilibrium in absorber • Fast absorbent, high heat of absorption
Low heat of reaction	• Low absorption rate
High equilibrium sensitivity	• High heat of absorption
Plant design	• Intercooler, Vapor recompression, Split flow • High pressure stripping

SOLVENT DEGRADATION

Amine degradation: An overview

O_2	CO_2	Temp.
NO_x	SO_x	Particles
	Iron	

MEA degradation compounds



Analysis methods for MEA degradation products

Ion chromatography

- Anionic species: acetate, formate, oxalate, nitrate, nitrite, sulfate, propionate (glycolate not yet)

Liquid chromatography

- Nearly all degradation products
- No library of unknown degradation products
- Methods for each compound must be developed

Gas chromatography

- Not as sensitive as liquid chromatography, but unknown products can be matched with libraries

Solvent emissions

Products	
Volatile • Amine • Ammonia, • aldehydes etc.	• Low temperature in the water wash section • Use of staged water wash • Use acid wash
Non-volatile(Typically heat stable salts, organic acids, etc.)	Reclaimer waste
Mist	• High absorber top temperature • Dry bed • Brownian diffusion filter

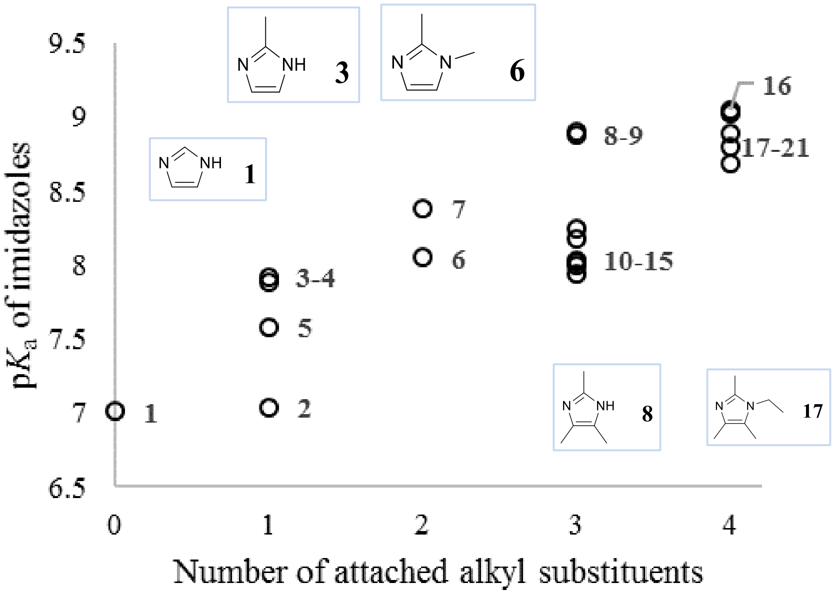
Solvent degradation and emissions - summary

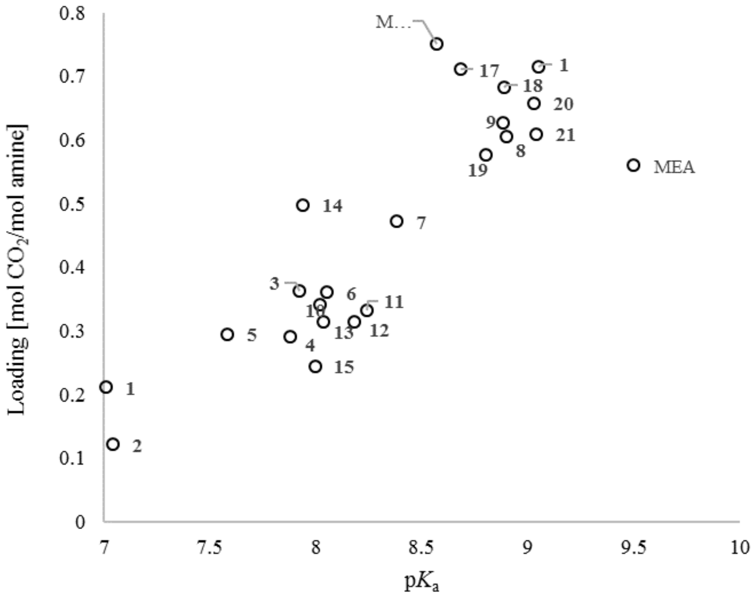
- Emissions of absorbent(amines) can be brought down to less than 0.02-0.03 ppm
  - If no aerosols are present
- Volatile degradation products can be handeled by acid wash
- Methods for reducing degradation and corrosion rates are continuously being developed
  - Degradation inhibitors / corrosion inhibitors

FUTURE TRENDS

Task specific solvents

Polyalkylatedimidazoles





Evjen, S., Fiksdahl, A., Pinto, D.D.D., **Knuutila, H.K.,** 2018. New polyalkylated imidazoles tailored for carbon dioxide capture. International Journal of Greenhouse Gas Control 76, 167-174.

Solvent degradation and emissions

- Important for emissions and solvent management

- Countermeasures
  - Inhibitors
  - Filters to prevent earosol emissions
  - O_2 removal from solvent

- Degradation prediction
  - Modelling
    - Black box
    - Reaction based

Process improvement

- High pressure stripping
  - Addition of volatile solvent
  - High temperature stripping

Reduces the CO_2 compression energy

- New contactors
  - 3D-printing, plactic materials
  - Membrane contactors
  - Compact contactors
  - Catalytic desorption

Less corrosion and degradation

Smaller contactors

No mist formation

Summary

Several solvents and processes available

Challenges – still

- Energy requirement
- Degradation, oxidation, contaminents
- Corrosion
- Emissions to air (aerosols/mist)

- Methods to fast characterize degradation needed

THANK YOU!