Carbon dioxide - the complex molecule, problem and solution in one

LUND UNIVERSITY AND THE FASTWATER CONSORTIUM

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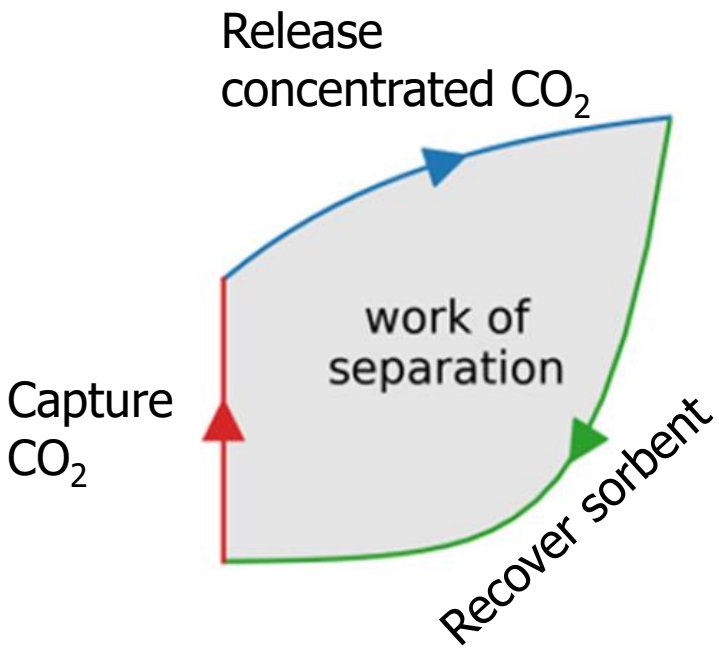
Christian Hulteberg

Introduction

- Drive to use carbon dioxide as a feedstock
  - Source of carbon atoms
  - Important for materials when transition to electricity-based society
  - Need for materials and chemicals will change but not disappear
  - No lack of carbon dioxide with global emissions 24 billion tpa…

Introduction

- Where is the CO_2 going to come from?
  - Point sources
    - Chemical plants
    - Combustion
  - Direct air capture (DAC)
- Costs energy to concentrate…
  - Point source 5-8 kJ/mol
  - DAC ≈22 kJ/mol



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Introduction

- Costs energy to concentrate…
  - Point source 5-8 kJ/mol
  - DAC ≈22 kJ/mol
- The energy input can be thermal
  - Overwhelmingly the most common approach
  - Medium temperatures common, but some use low
  - Can be combined with pressure swings
- Electricity is an exiting emerging field…

Carbon dioxide capture

Method of separation	DAC	Comments
Aqueous amine	N/A	• Industrial workhorse, • largest scale currently implemented, • stripper equilibrium and oxidative instability makes it less suitable for DAC
Solid amines	Yes	• No solvent, • lower regeneration energy input, • sensitive to water and impurities, • supported amines/imines on silicates, carbon, MOFs, zeolites, polymers, aluminates • Low technology maturity
Potassium carbonate	(Yes)	• Low throughput, • well established working mechanism, • good oxidative stability
Chilled ammonia	N/A	• Low temperature • Water condensation is a problem

Carbon dioxide capture

- Concentration costs
  - The higher the concentration…
    - The energy input requirement decreases per mol
    - The more mature the capture technology is
  - Lowest concentrations are for DAC (400 ppm)

Carbon dioxide capture

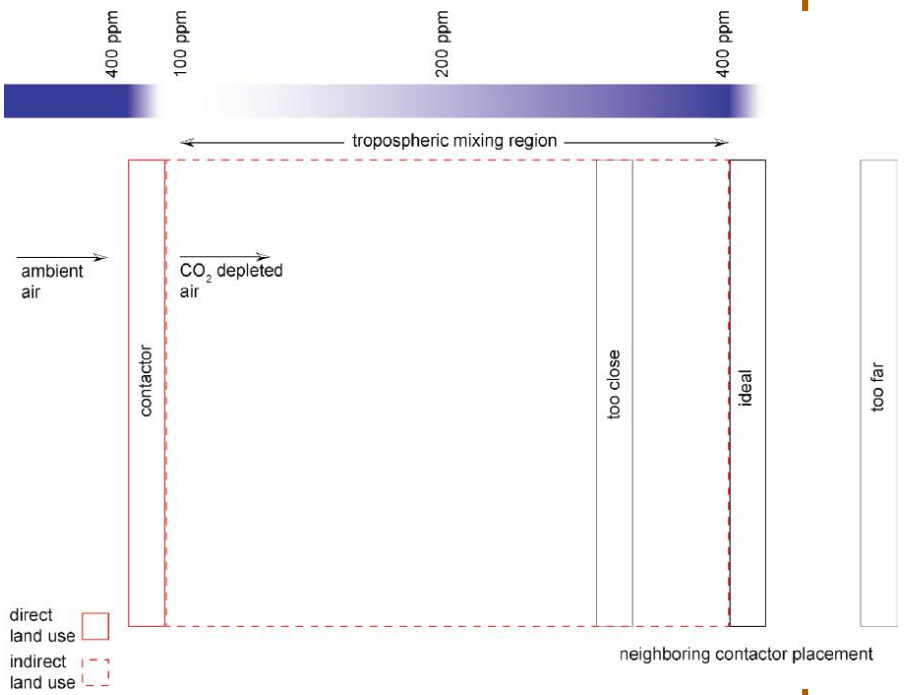
- DAC differs
  - Much more diffusion limited
  - Requires much higher volumes to be processed
  - Pressure drop large part of OPEX
  - Results in very large process units

Carbon dioxide capture

Carbon dioxide capture

Carbon dioxide capture

- For DAC the land and water use needs to be considered
  - Up to 4 moles of water may be needed per mole of CO_2
  - Still very efficient compared to forests



Current uses

- Carbon dioxide is normally derived from
  - Fossil fuels from energy production
  - Fossil fuels from other sources, e.g. in the chemical industry
  - Fermentation processes
- Very little DAC is done at this time…

Current uses

- Carbon dioxide can be used either
  - Through physical utilization
    - Molecule is used as is
    - May include change in aggregation state
  - Through chemical conversion
    - Molecule is cracked
    - Converted into some other product
- In both cases the use can be as a booster or direct

Current uses

- Through direct physical utilization
  - Dry ice
  - Carbonation
  - Refrigerant
  - Welding medium
  - Solvent

Current uses

- Through boosting physical utilization
  - Enhanced oil recovery
  - Enhanced natural gas recovery
  - Power production via supercritical cycle

Current uses

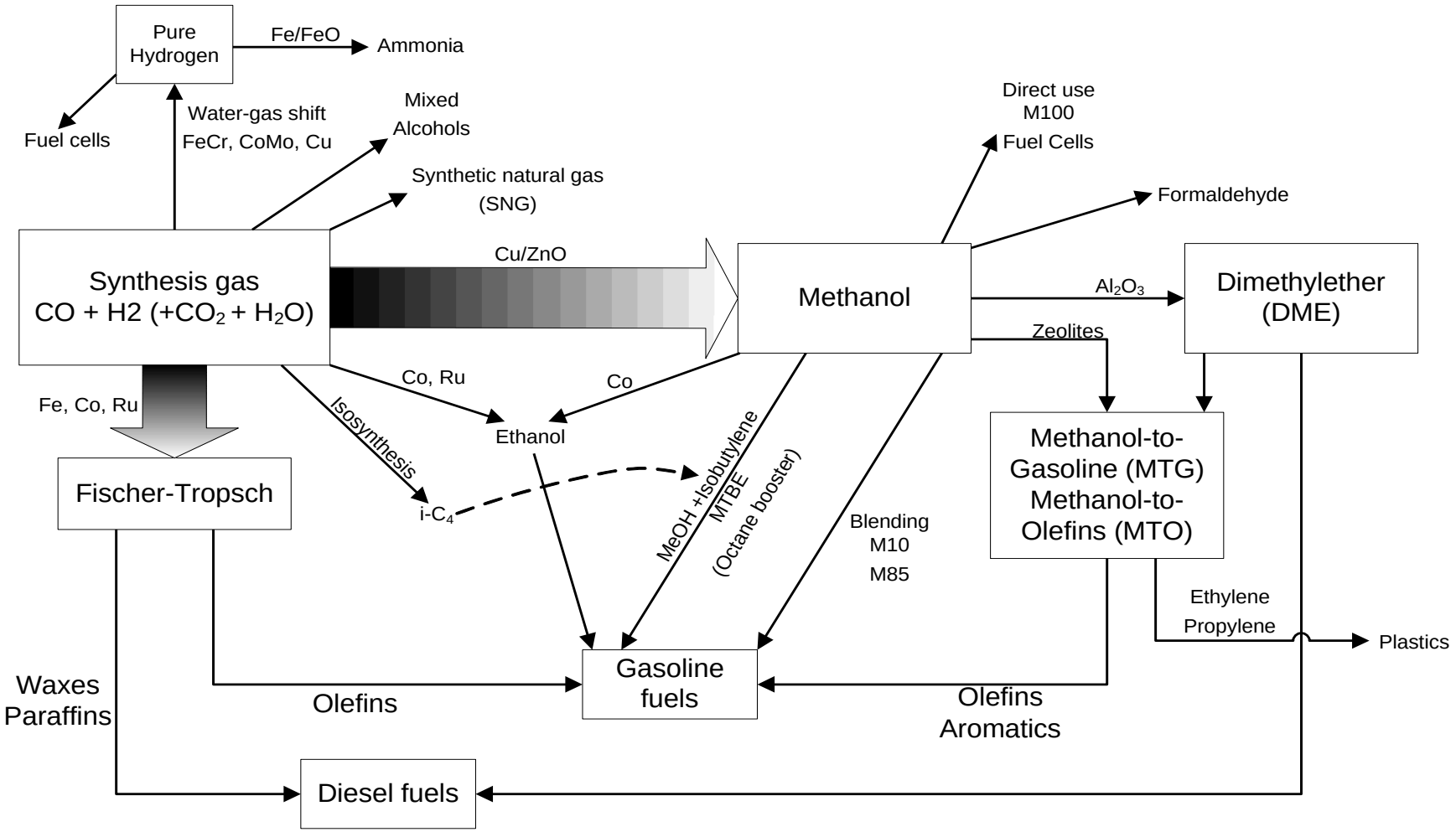
- Through direct chemical utilization
  - Calcium carbonate
  - Cetylsalicylic acid
  - Urea
  - Salicylic acid
  - Polypropene carbonate
  - Formic acid

Current uses

- Through indirect/boosting chemical utilization
  - Polyurethane
  - Dimethyl carbonate
  - Dimethyl ether
  - Methanol
  - Algae fuel

New applications

- Electrification of the chemical industry is a game changer…
- Opening up for direct electrochemical conversion of carbon dioxide into, e.g. formic acid, formaldehyde etc.
- Also indirect using electricity to produce hydrogen and to synthesize, e.g. methane, methanol, diesel etc. using carbon dioxide as a carbon source



Generation of synthesis gas for fuels and chemical products
P. Tunå, reproduced with permission

Conclusions

- Concentration is everything…
- … and it costs energy
- Current use is surprisingly large
- Any future use for making fuels and chemicals requires energy input
- DAC has potential but is still far from realization in large scale

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