Accelerating industrial electrification

Strategies for integrating CO$_2$ capture and conversion

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"BRIDGING SCIENCE WITH TECHNOLOGY"

**KNOWLEDGE TRANSFER**
Knowledge exploitation by spin-offs, licences, in partnership with other companies

**DEVELOP FUNDAMENTAL KNOWLEDGE**
Together with universities

**KNOWLEDGE APPLICATION**
Contract research for and with clients

**KNOWLEDGE DEVELOPMENT**
In public-private partnership with partners from the triple helix

CLIENTS & PARTNERS
WE DO THIS BY TAKING A MULTIDISCIPLINARY APPROACH
CAPTURE EFFICIENCIES THEORY & PRACTICE

*Highest energy cost is desorption of CO$_2$ at high T

Direct air capture: 19–21 kJ/mol CO$_2$
- 50% capture; 80% purity
- 75% capture; 80% purity
- 90% capture; 80% purity
- 50% capture; 95% purity
- 75% capture; 95% purity
- 90% capture; 95% purity

Natural gas combustion: 6–9 kJ/mol CO$_2$
Coal combustion: 5–7 kJ/mol CO$_2$
Coal gasification: 1–4 kJ/mol CO$_2$

~ factor 20 higher*


Home
CCS PROVEN TECHNOLOGY ... PUBLIC PERCEPTION

FOR THE LAST TIME, CCS! YOU'RE NOT A SWAN! YOU'RE JUST UGLY!

by: Andy Read & Mark Kombrink
Grand challenge: Our Man On The Moon

Renewable production of fuels and (platform) chemicals from CO₂, water and nitrogen based on photochemistry, electrochemistry, biotechnology

* Modified from NWO solar fuel
CONVERSION TECHNOLOGIES

1. Catalytic Hydrogenation

2. Direct Electrochemical

3. Polymerization

4. Biochemical

5. Mineralization
RENEWABLES WILL CREATE OPPORTUNITIES

0.9 GW (2016) → 4.5 GW (2023) → 250? GW (2050)

On-shore sub-station converts power back to AC for grid transmission

Offshore wind turbines generate Medium Voltage AC power

HVDC station converts High Voltage AC to DC for transmission

Hydrogen plant (electrolyser) converts DC direct, or indirect via E-grid, power into H₂

Catalytic conversion into alternative fuels. H₂, CO₂, and N₂ as feedstocks.
INDIRECT VERSUS DIRECT CONVERSION

H₂O → H₂ + CO₂

CO₂ + H₂O → products

High TRL

Low TRL
INTEGRATION CAPTURE WITH CONVERSION

*Ammonia is just an example*
DESCRIPTION OF THE SYSTEM

Flue Gas → Absorber
- Recovery for ammonia losses
  - Gas out
  - Ammonia Solvent

Rich out
- NH₄⁺ HCO₃⁻

Hydrogenation
- 20 bar, 80°C

Hydrogenation
- 20 bar, 100°C

Stripper
- 150°C

HCOOH → HCHO + H₂O

CO₂ + NH₃ + H₂O → NH₄HCO₃

NH₄HCO₃ + H₂ → NH₄COOH(aq)

NH₄⁺ HCOO⁻ → NH₄⁺ HCOOH

HCHO + H₂O → CO₂ + NH₃ + H₂O

O₂ + H₂ → H₂O

NH₃ + H₂O → NH₄HCO₃

HCOOH + H₂ → HCHO + H₂O
• Comparison with formaldehyde market prices for a purity of 37%

• Interesting CO₂ utilization route from an economic and sustainable perspective

Comparison of formaldehyde (37%) produced by integrated capture and utilization:

- H₂ = 1.5 €/kg
- H₂ = 3.5 €/kg
MERIT IN ELECTROLYSIS

- Current density
- System design
- Internal resistance
- Selectivity
- Stability
PROCESS AND SYSTEM INTEGRATION

CO₂ source

CO₂ capture

transport

Electrochemical reactor

SEPARATION & PURIFICATION

flue gas

CO₂

UP-STREAM

REACTION

DOWN-STREAM
INTEGRATION OF CO$_2$ CAPTURE & CONVERSION

Flue gas → Absorber → CO$_2$ rich solvent → Electrochemical Reactor → Formic acid Syngas → Lean solvent → Depleted flue gas
CO₂ REDUCTION FROM CAPTURE SOLVENTS

Concept defined

Selectivity towards formic acid

Aqueous capture solvent A

Aqueous capture solvent B

Low aqueous capture solvent B

Organic capture solvent B
WHAT IF WE MAKE CO

Techno-economic Comparison for CO Production

- CO2 Capture
- Electricity
- Heating Duty Electrolyser
- CAPEX Electrolyser
- Market Price

TOTAL PRODUCTION COSTS [€/KG CO2-1]

- Base Case
- High Pressure
- GDE
- Integrated
- Market Price
SUMMARY: THE FUTURE IS CIRCULAR
Let’s energize innovation together!

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