Les opportunités offertes par les politiques climatiques: du CO$_2$ comme matière première?

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Content

- Context
- CO$_2$ capture
- CO$_2$ re-use
- FRITCO$_2$T Platform
The energy transition has already started…

But there are still huge challenges to be addressed!
Worldwide goals and commitments...

Global greenhouse gas emissions

The Paris Agreement

1. Falling emissions “as soon as possible” (Art. 4.1)
   Comparison point for least-cost 2°C target paths: 40Gt (917)

2. Net zero emissions 2050-2100 (=balance between anthropogenic emissions and sinks in second half of the century) (Art. 4.1)
European objectives

European targets: -80% CO\textsubscript{2}

- 93 to 99% CO\textsubscript{2} in power and heat
- 83 to 87% CO\textsubscript{2} in the industry

Data sources: [Boden et al., 2010; EC-JRC/PBL, 2009; European Commission 2011; EEA, 2015]
Possible answers: Trias Energetica

Limit energy demand

Use renewable energy

If necessary, use fossil fuels as efficiently and cleanly as possible

Lysen E., The Trias Energica, Eurosun Conference, Freiburg, 1996
CO$_2$ capture is basically a matter of fluid separation

Purity of sources varies between 0.04% and almost 100%
2. CO$_2$ capture
CO₂ separation technologies

- Avoid fluid mixtures

- Absorption
  - Physical
  - Chemical

- Adsorption

- Membranes

- Cryogenic separation

- Others…
CO$_2$ capture configurations

1. Industrial processes (cement, steel…)
   => CO$_2$ resulting from process

2. Capture CO$_2$ from combustion gas
   => Post-Combustion capture

3. Remove C from fuel
   => Pre-combustion capture

4. Burn fuel with pure oxygen
   => Oxyfuel combustion
1. CO₂ not resulting from combustion

- Cement plants
  - \( \text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2 \)
  - Potential gain: -60% CO₂
  - High temperature \( \rightarrow 1000°C \)

- Pilot plant close to Liège
- End of construction: 2019
- Investment: 21 M€
Post-combustion capture

2. Capture CO₂ from combustion gases
   - Absorption – Regeneration with chemical solvents
   - Boundary Dam (Ca), 2700 tCO₂/day from Coal PP
     - Flue gas: 180 Nm³/s ; Solvent: 550 L/s
Post-combustion capture

2. Capture CO$_2$ from combustion gases
   - 2 main focus at ULiège: Solvent stability
   - Operational issues
     - Viscosity change, decrease of solvent properties…
     - Corrosivity of amine systems
     - Emissions of VOC
   - Different types of degradation
     - Oxidative
     - Thermal
     - SO$_X$, NO$_X$ …
Post-combustion capture

2. Capture CO$_2$ from combustion gases
   - 2 main focus at ULiège: Process modeling, including solvent degradation

Split flow: -4%
IC: -4%
LVC: -14%
Trends and challenges

- Small scale CO₂ capture
- CO₂ capture from air

Exclusive: Carbon Engineering CEO discusses recent funding for DAC technology

By Molly Burgess | 24 April 2019

Last month, Carbon Engineering, a Canadian clean energy company announced the completion of an equity financing round of $68m, marking the largest private investment made into a Direct Air Capture (DAC) company to date.
Cost of CO₂ capture

- Merit curve for CO₂ capture
- NB: DAC ~100$/ton

Leeson et al, 2017, DOI: 10.1016/j.ijggc.2017.03.020
CO\textsubscript{2} market

- European Emissions Trading System (ETS)
- CO\textsubscript{2} price now reaches 25 €/t!

https://markets.businessinsider.com/commodities/co2-emissionsrechte
3. CO$_2$ re-use technologies
A full supply chain… but cost only!

- Capture – Transport – Storage…

- … or re-use!
  - 2016: ~ 250 Mt CO₂ reused (15% CCS, 50% Urea, 35% others)
  - Large potential: ~ 4 Gtpa CO₂

Main CO$_2$ re-use pathways

- Direct use, no transformation
- Biological transformation
- Chemical transformation
  - To lower energy state
  - To higher energy state

=>$\text{At large scale, need to make sure that energy comes from renewables!}$

Direct industrial use
Biological transformation

- Photosynthesis
  - Greenhouses
  - Microalgae

- Drawbacks:
  - Area for cultivation (+- 120 t CO$_2$/ha)
  - Energy for post-processing
Chemical transformation to lower energy

- Mineralization - Carbonatation
  - CaO + CO$_2$ → CaCO$_3$
  - MgO + CO$_2$ → MgCO$_3$
  - Mg$_2$SiO$_4$ + 2 CO$_2$ → 2 MgCO$_3$ + SiO$_2$

- Spontaneous but slow reaction
CO₂ to chemicals: C source for petrochemistry

- **Urea**
  - 2 NH₃ + CO₂ → (NH₂)₂CO + H₂O
  - Already large use (~ 120 MtCO₂/an)

- **Polycarbonates**
  - CO₂ + epoxides
  - Up to 40% CO₂ in the plastic!
CO₂ to chemicals

- Polyurethanes
  - 18 Mtpa market
  - 20% CO₂ in the final plastic
  - CO₂ → chemicals

- Covestro: 5000 t/a pilot reactor

- Next step: remove isocyanates => NIPU
  - Grignard B. et al., Green Chem., 2016, 18, 2206

Image: CO₂-production-line at Bayer Material Sciences’ site in Dormagen, Germany. ChemEurope.com, June 2015
CO₂ to fuels

- CO₂ as energy carrier for renewable energies
- Power-to-liquid, power-to-gas

=> Sustainability is possible with carbonated fuels!
CO₂ to fuels

- Decisive advantage: a fantastic energy density!
  - Methanol (CRI), DME, Fischer-Tropsch (Sunfire)…
  - Interseasonal energy storage is possible!

![Graph showing energy density comparison]
Research ULiège at process scale

- Novel methanol reactor design
  - Intensification of synthesis reactor for CO₂ reduction to methanol

Bos and Brilman, 2014. DOI: 10.1016/jcej.2014.10.059
Research ULiège at process scale

- Process integration
  - Models for electrolysis, CO$_2$ capture and fuel synthesis
  - Heat integration to increase efficiency from 40 to 53%!

Léonard et al., 2016. Computer aided chemical engineering 38, 1797. DOI: 10.1016/B978-0-444-63428-3.50304-0
4. The FRITCO$_2$T Platform at ULiege

www.chemeng.uliege.be/FRITCO2T
The FRITCO\textsubscript{2}T Platform

**Chemical Transformation**
- Synthetic Fuels
- Monomers & Polymers
- Mineralization

**Physical Use**
- Pharmaceutics & Cosmetology
- Direct CO\textsubscript{2} use (solvent, foaming...)

**Transversal WP**
- Sourcing
- Capture & Purification
- Process sustainability (LCA and economics)

**PEPs CHEMICAL ENGINEERING**

LI\`GE universit\`e
Missions of the platform

- Market needs, fundamentals pushes
  - Give rationals and scientific background to new ideas
  - Accelerate climbing of the TRL scale

- Lead large-scale research projects
  - From Regional to European projects

- Support technological developments
  - Support for operational issues
  - Holistic view: Circular economy and life cycle thinking
Success stories

- About 20-25 Researchers
- More than 45 research projects in the last 20 years, 10 on-going
- About 12 M€ funding achieved, > 3 M€ unique equipment

From lab to pilot scale

High performance analytical tools

CO₂-assisted processes
Conclusion: to store or to use?

- **CCS**: mature technology, but cost only!
- **CCU**: may help to create viable business

World CO₂ emissions abatement in the 450 Scenario (Bridge Scenario 2015-2040), IEA 2015, WEO special report, Energy & Climate Change
Conclusion

- Synergies to be developed

**Bio-based Industry**
- Biomass (produced and residual)
- Pretreatment
  - Sugars, fibers, lignin...
- Transformation (biological, chemical)

**CO₂-based Industry**
- Power & Industry (Point sources)
  - Low & high concentration of CO₂
- Capture & Purification
- Direct use
  - CO₂ Sustainable Process
- Transformation

**Low-Carbon Circular Economy**
- Bio-based co-reactant
- CO₂-based co-reactant
Thank you for your attention!

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