Les opportunités offertes par les politiques climatiques: du CO_2 comme matière première?

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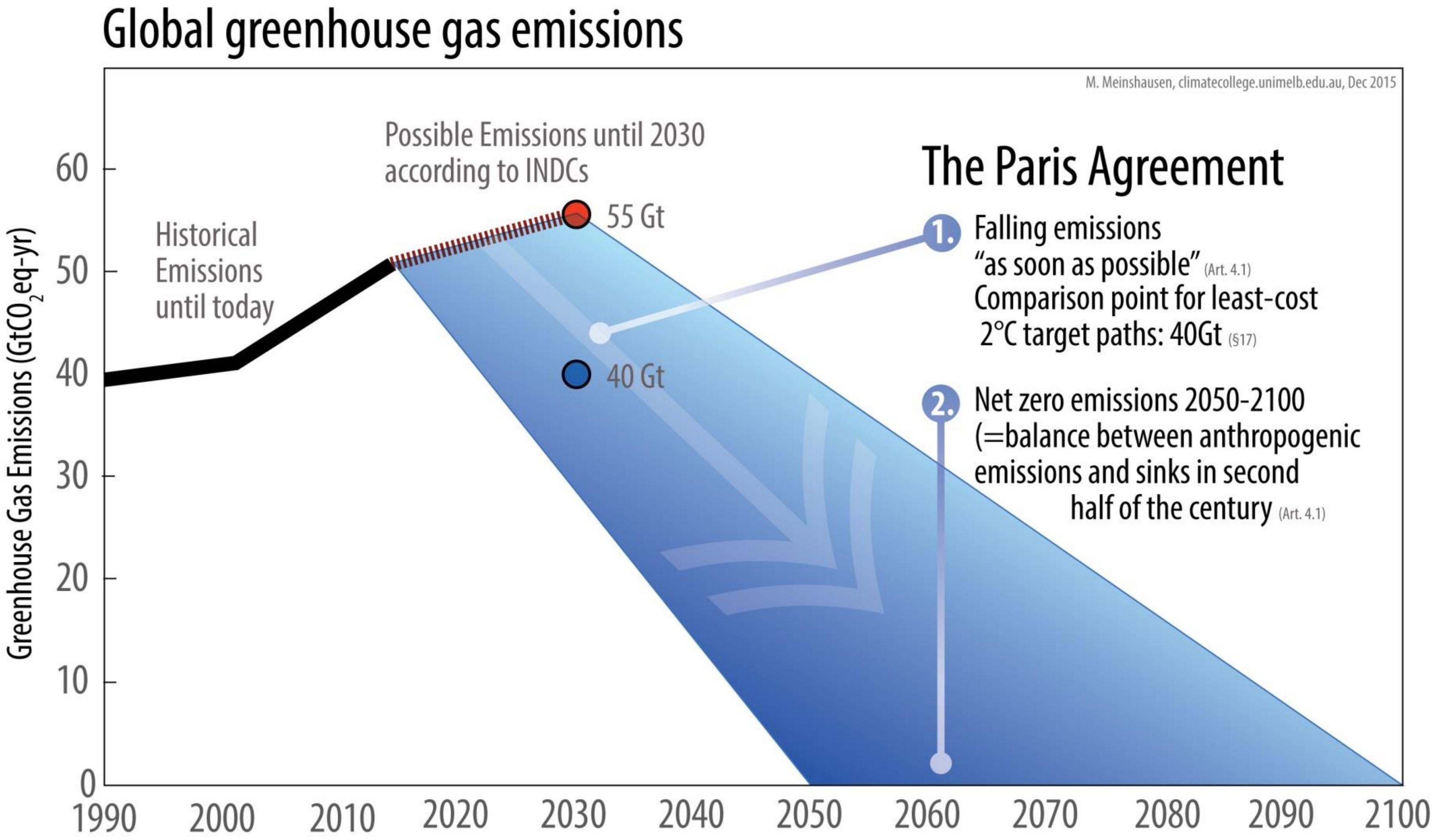
Content

- Context
- CO_2 capture
- CO_2 re-use
- FRITCO$_2$T Platform

The energy transition has already started…

But ther are still huge challenges to be addressed!

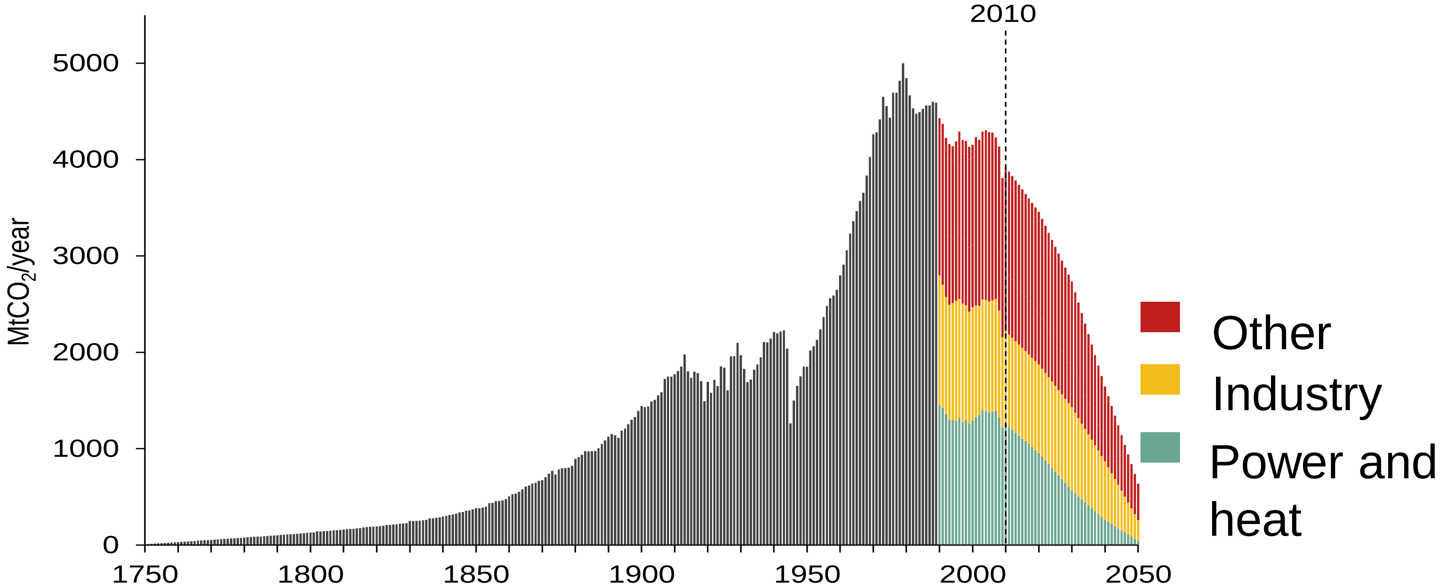
Worldwide goals and commitments…



European objectives

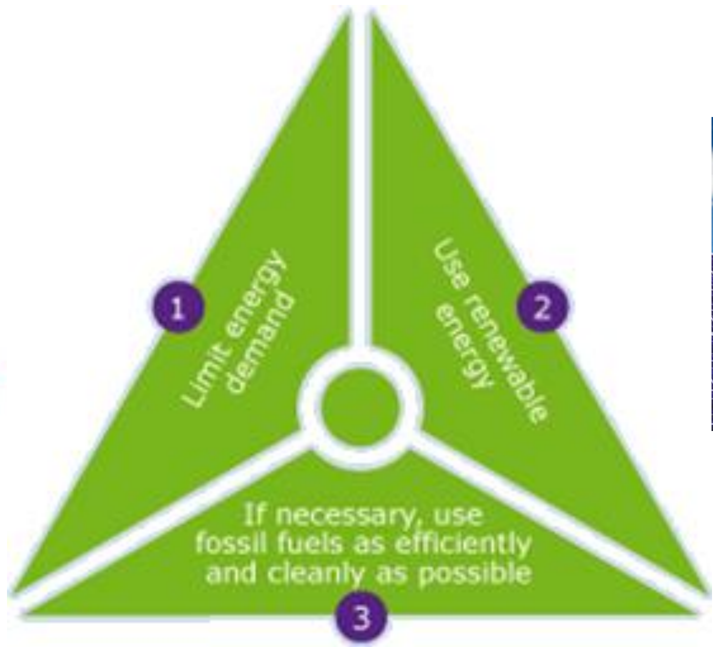
European targets: -80% CO_2

- - 93 to 99% CO_2 in power and heat
- - 83 to 87% CO_2 in the industry



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

Possible answers: Trias Energetica



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Lysen E., The Trias Energica, Eurosun Conference, Freiburg, 1996

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CO_2 capture is basically a matter of fluid separation

Purity of sources varies between 0.04% and almost 100%

2. CO_2 capture

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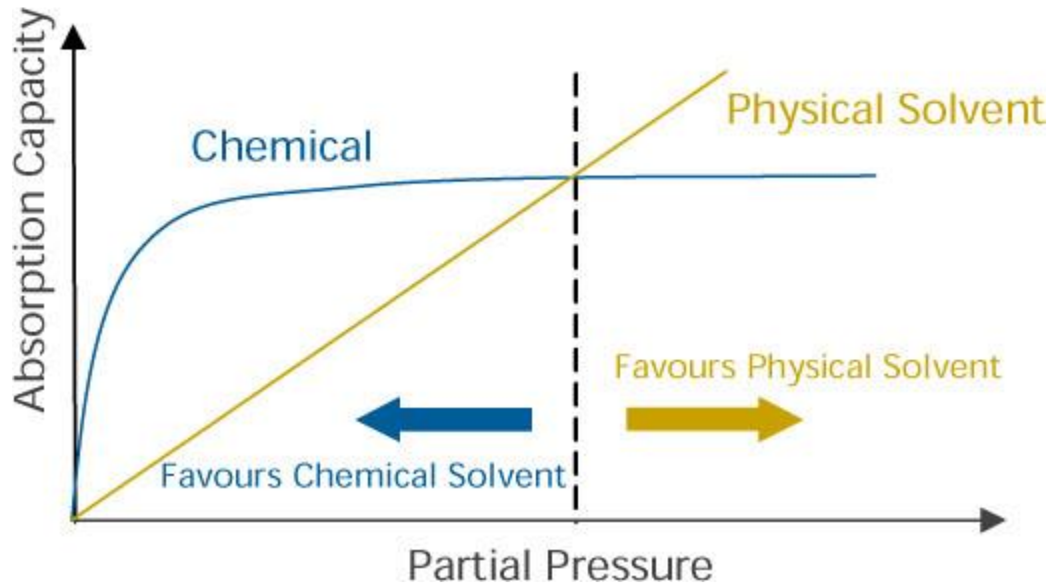
CO_2 separation technologies

- 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

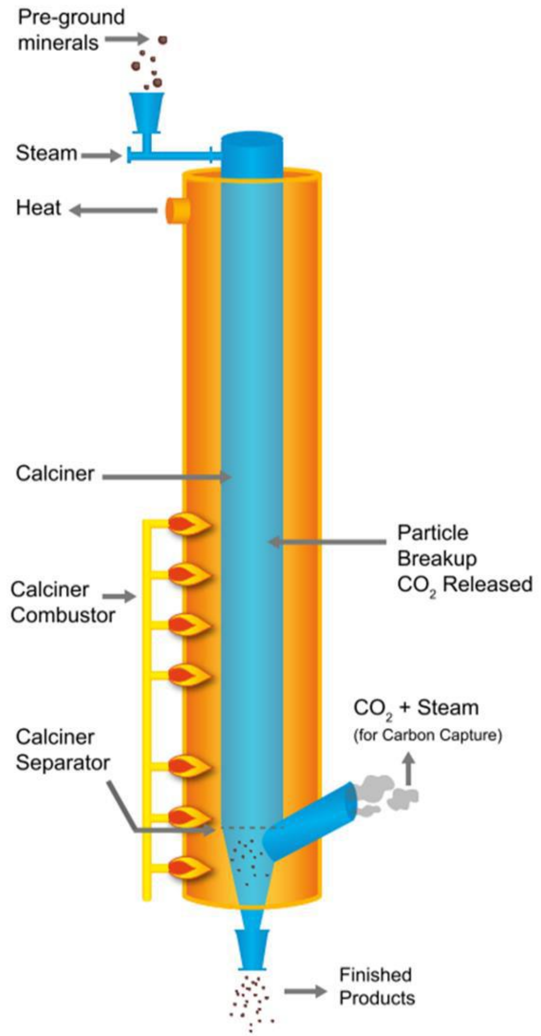
=> **Oxyfuel combustion**

Industrial processes

1. CO_2 not resulting from combustion

- Cement plants
  - $CaCO_3$ → $CaO + CO_2$
  - Potential gain: -60% CO_2
  - High temperature → 1000°C

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



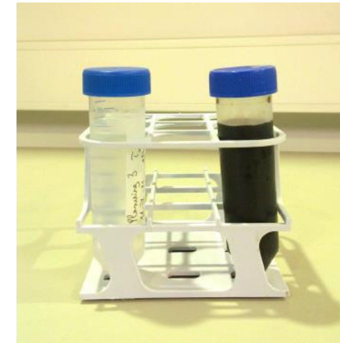
LEILAC public preFEED report, 2016

Post-combustion capture

2. **Capture CO_2 from combustion gases**

- Absorption – Regeneration with chemical solvents
- Boundary Dam (Ca), 2700 tCO_2/day from Coal PP
  - Flue gas: 180 Nm³/s ; Solvent: 550 L/s

Post-combustion capture

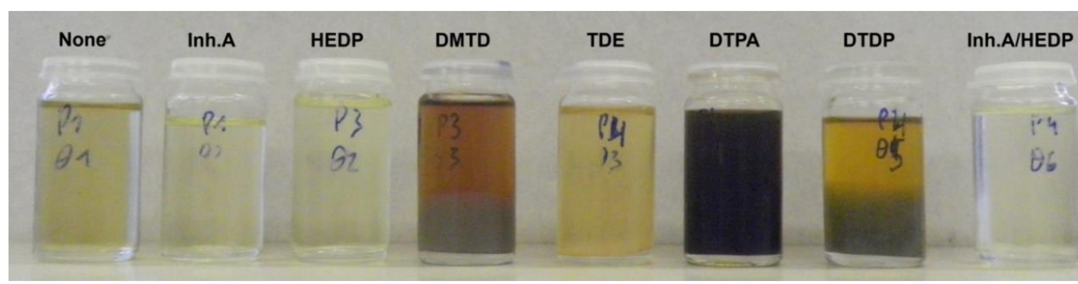


2. **Capture CO_2 from combustion gases**

- 2 main focus at ULiège: Solvent stability

- Operational issues
  - Viscosity change, decrease of solvent properties…
  - Corrosivity of amine systems
  - Emissions of VOC

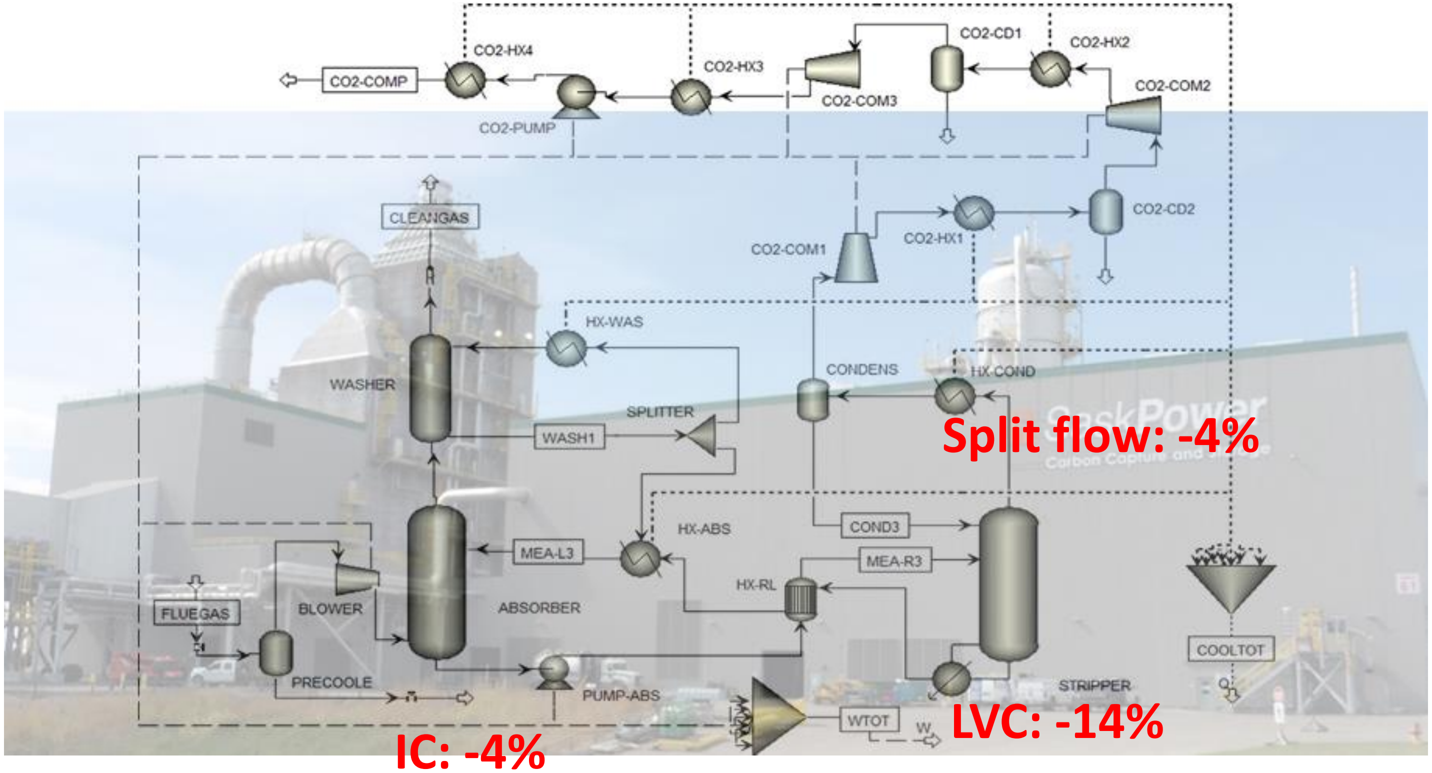
- Different types of degradation
  - Oxidative
  - Thermal
  - SO_X, NO_X …



Post-combustion capture

2. **Capture CO_2 from combustion gases**

- 2 main focus at ULiège: Process modeling, including solvent degradation



Trends and challenges

- Small scale CO_2 capture
- CO_2 capture from air

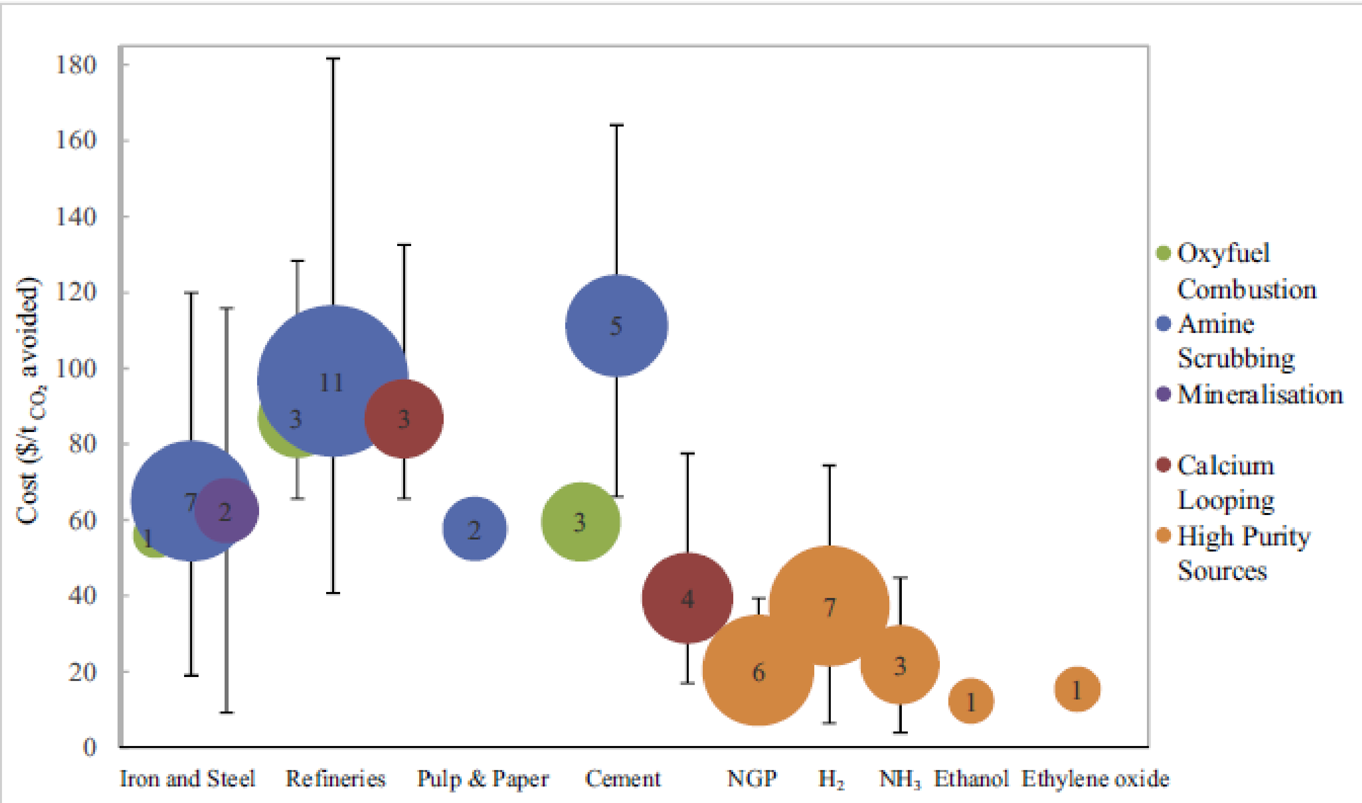
Exclusive: Carbon Engineering CEO discusses recent funding for DAC technology

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 CO_2 capture

- Merit curve for CO_2 capture
- NB: DAC ~100$/ton



Leeson et al, 2017, DOI: 10.1016/j.ijggc.2017.03.020

CO_2 market

- European Emissions Trading System (ETS)
- CO_2 price now reaches 25 €/t!

https://markets.businessinsider.com/commodities/co2-emissionsrechte

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3. CO_2 re-use technologies

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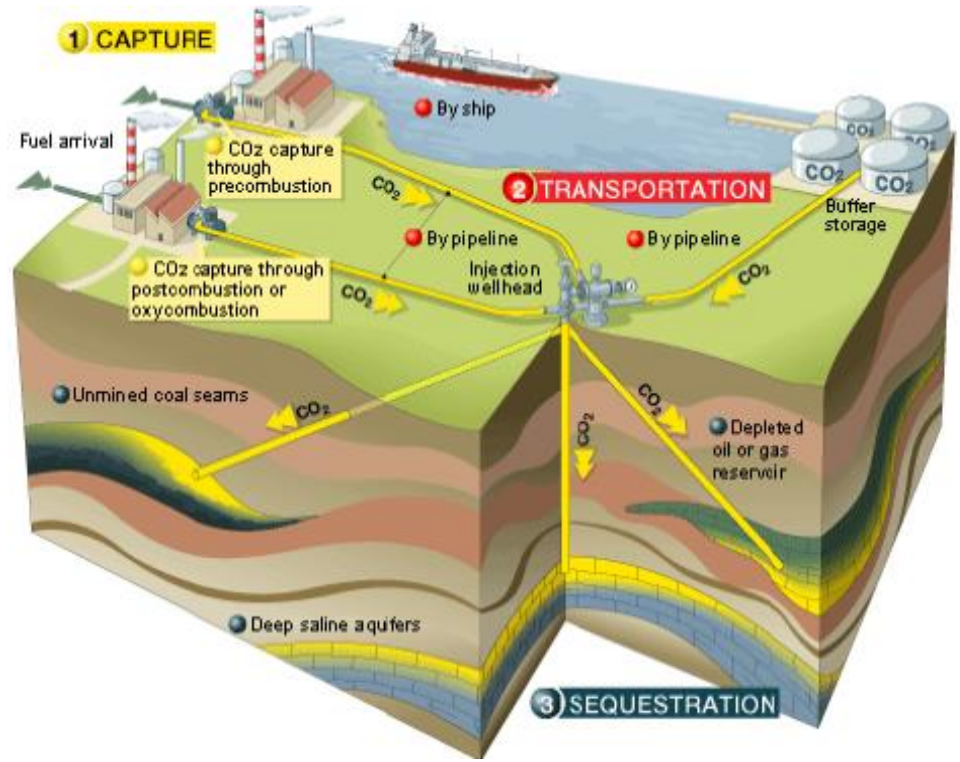
A full supply chain… but cost only!

- Capture – Transport – Storage…

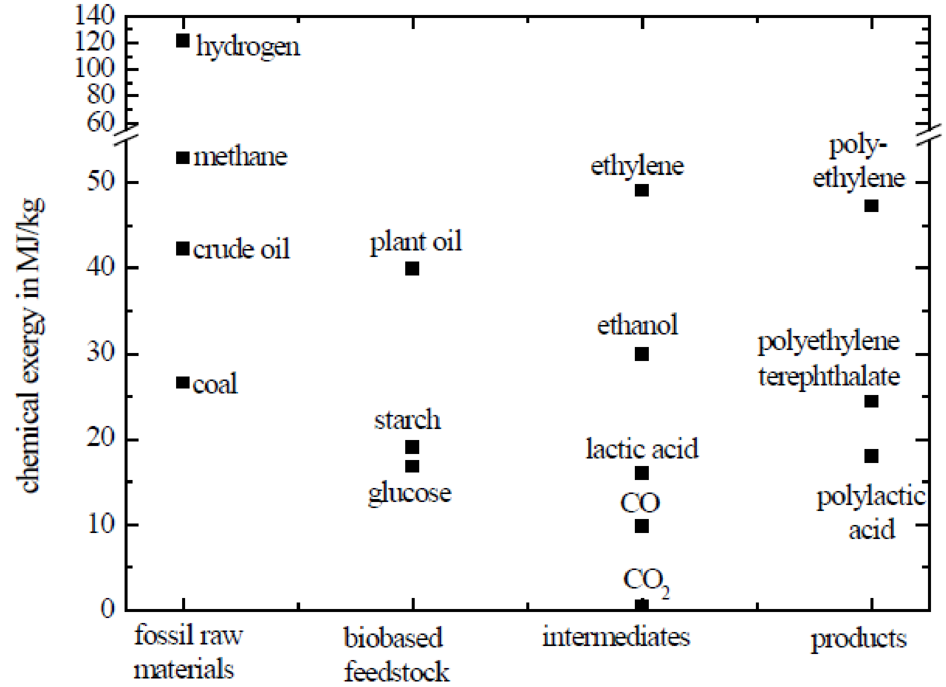


- … or re-use!
  - 2016: ~ 250 Mt CO_2 reused (15% CCS, 50% Urea, 35% others)
  - Large potential: ~ 4 Gtpa CO_2

Koytsumpa et al, 2018. https://doi.org/10.1016/j.supflu.2017.07.029

Main CO_2 re-use pathways

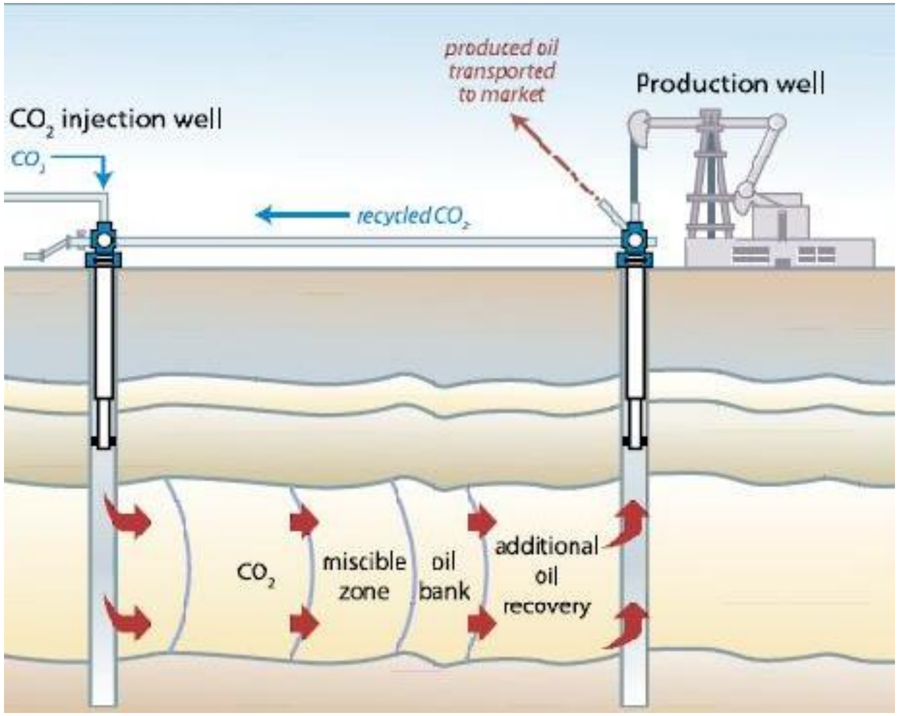
- Direct use, no transformation
- Biological transformation
- Chemical transformation
  - To lower energy state
  - To higher energy state

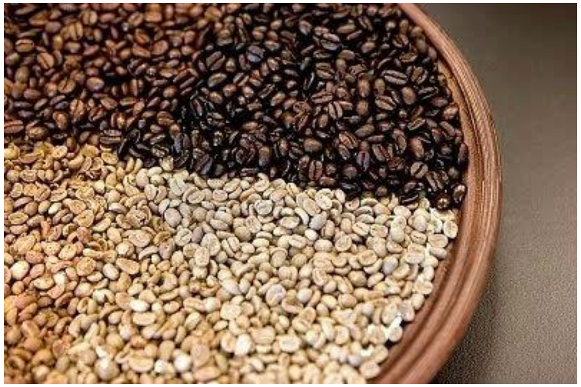


=> At large scale, need to make sure that energy comes from renewables!

Frenzel et al, 2014. Doi:10.3390/polym6020327

Direct industrial use





Biological transformation

- Photosynthesis
  - Greenhouses
  - Microalgae

  - Drawbacks:
    - Area for cultivation (+- 120 t CO_2/ha)
    - Energy for post-processing

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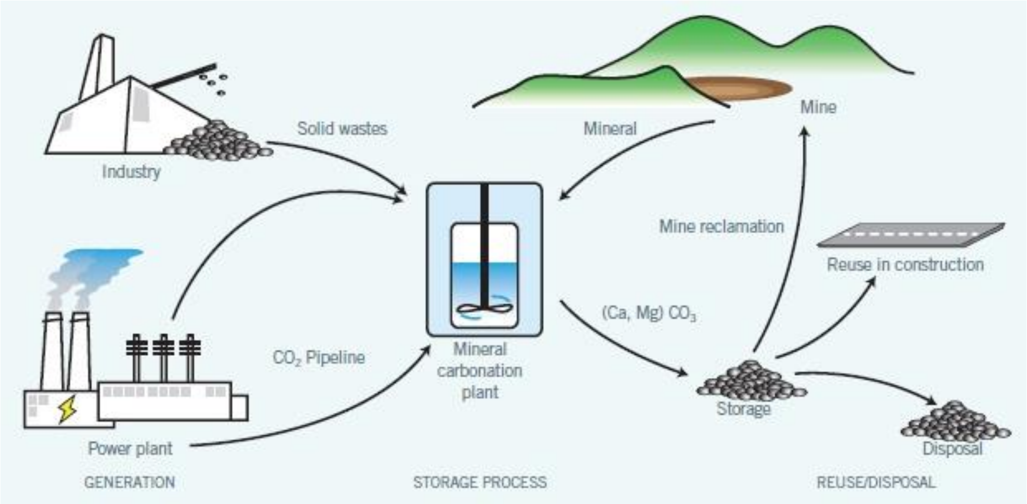
Chemical transformation to lower energy

- Mineralization - Carbonatation
  - $CaO + CO_2 \rightarrow CaCO_3$
  - $MgO + CO_2 \rightarrow MgCO_3$
  - $Mg_2SiO_4 + 2\ CO_2 \rightarrow 2\ MgCO_3 + SiO_2$



Carbstone, ORBIX, 2019

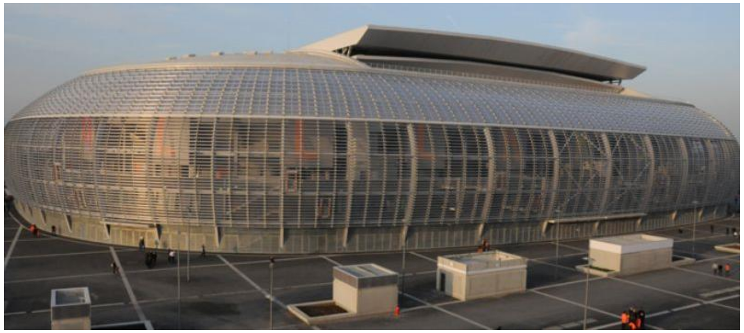
Hemcrete, 2015

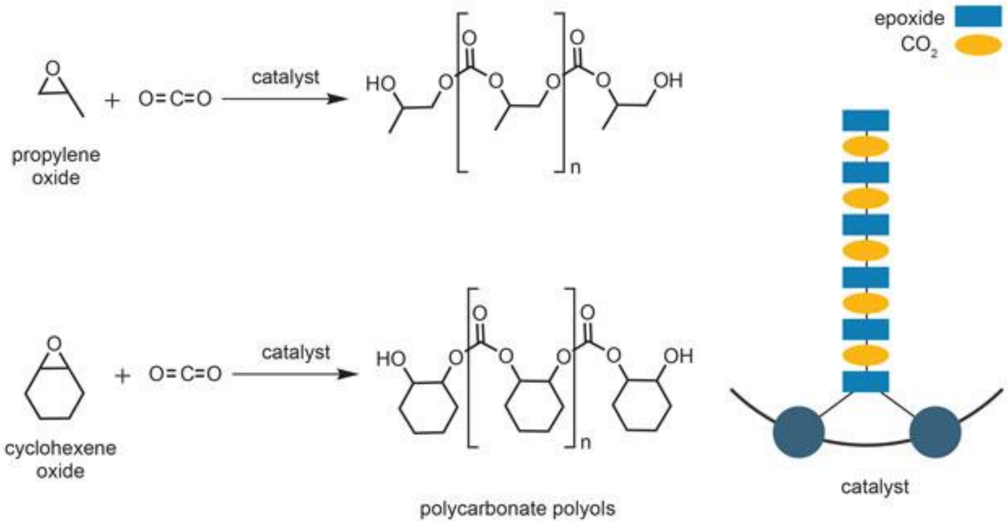
- Spontaneous but slow reaction

CO_2 to chemicals: C source for petrochemistry

- Urea
  - $2\ NH_3 + CO_2 \rightarrow (NH_2)_2CO + H_2O$
  - Already large use (~ 120 $MtCO_2$/an)

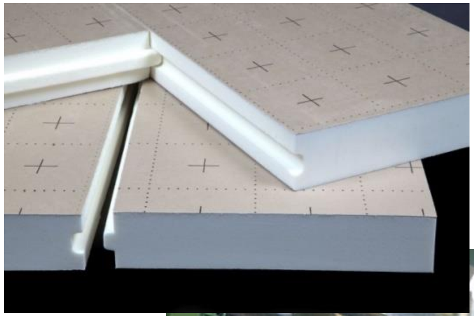
- Polycarbonates
  - CO_2 + epoxides
  - Up to 40% CO_2 in the plastic!



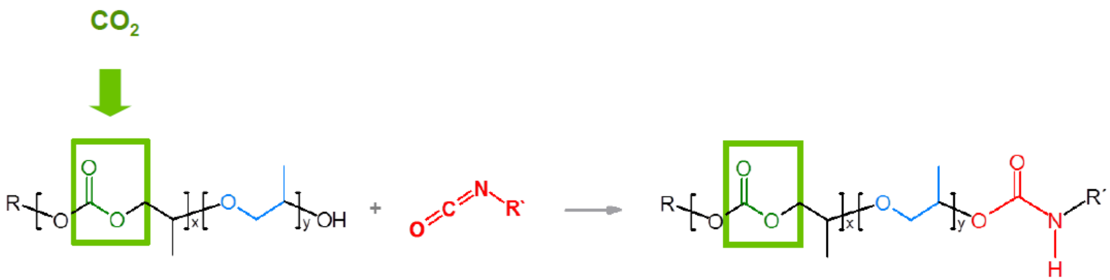


breakingenergy.com, 2014

CO_2 to chemicals



- Polyurethanes
  - 18 Mtpa market
  - 20% CO_2 in the final plastic

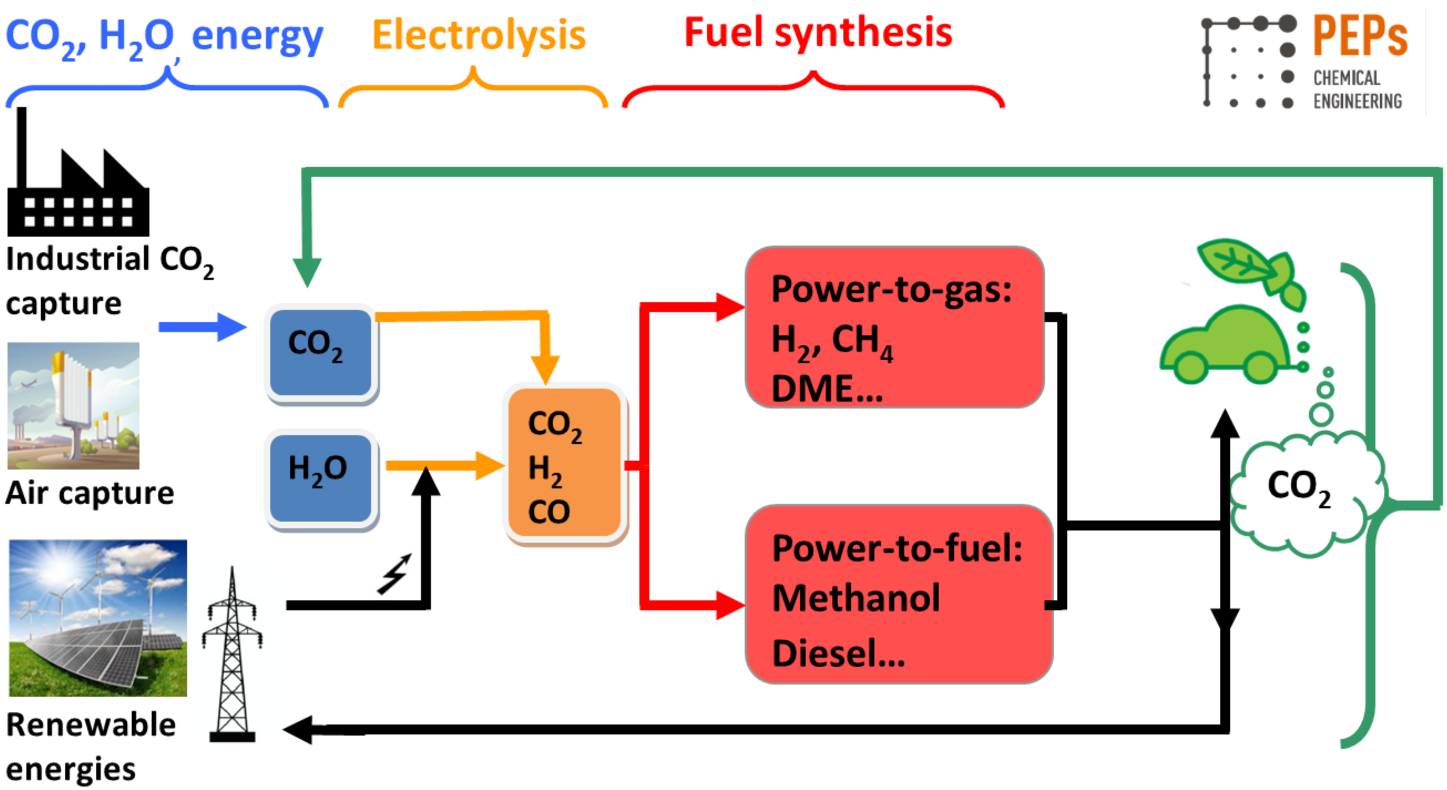


  - Covestro: 5000 t/a pilot reactor
  - Next step: remove isocyanates => NIPU
    - Grignard B. et al., Green Chem., 2016, 18, 2206

CO2-production-line at Bayer Material Sciences' site in Dormagen, Germany. ChemEurope.com, June 2015

CO_2 to fuels

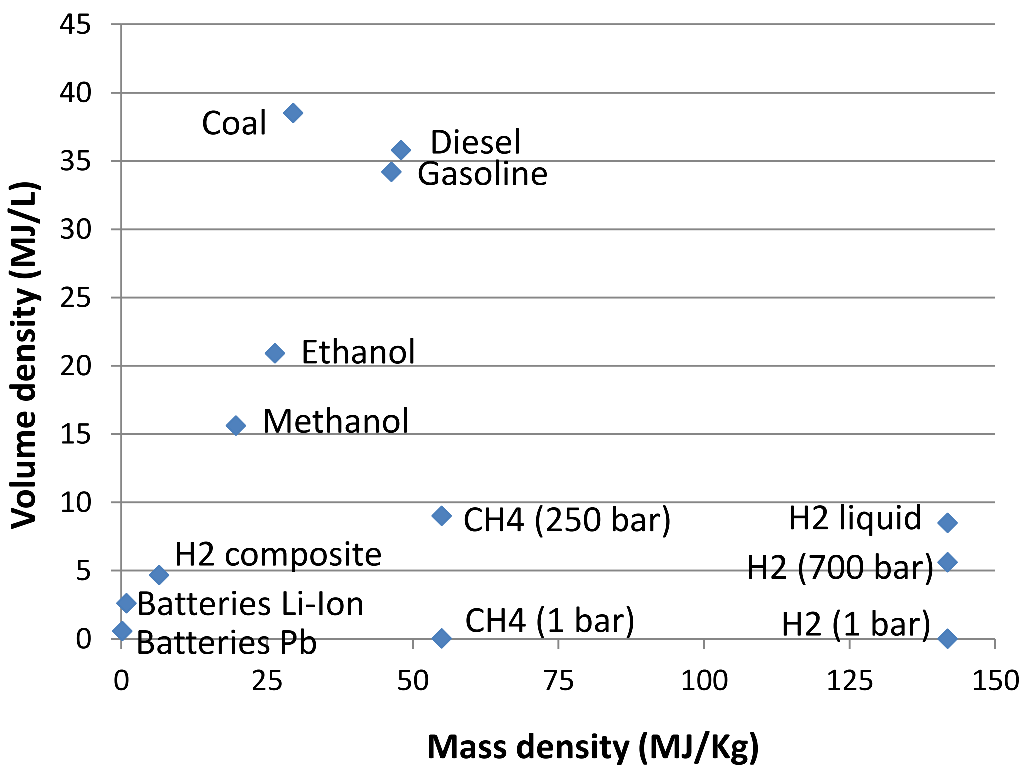
- CO_2 as energy carrier for renewable energies
- Power-to-liquid, power-to-gas



=> Sustainability is possible with carbonated fuels!

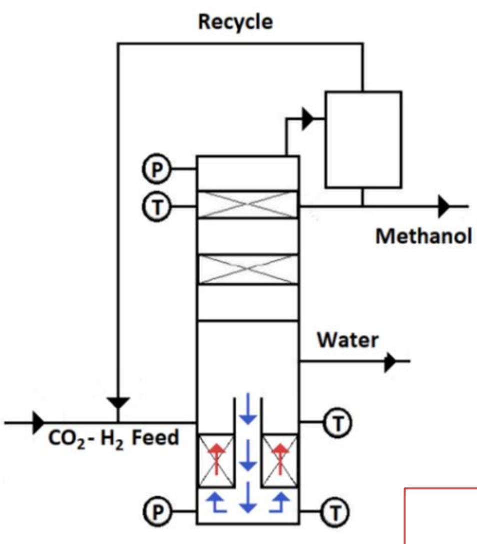
CO_2 to fuels

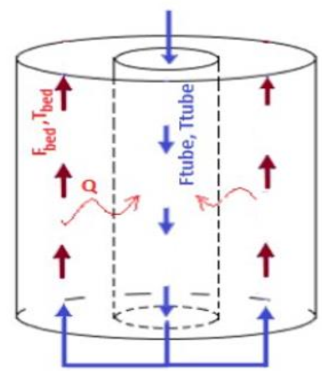
- Decisive advantage: a fantastic energy density!
  - Methanol (CRI), DME, Fischer-Tropsch (Sunfire)…
  - Interseasonal energy storage is possible!

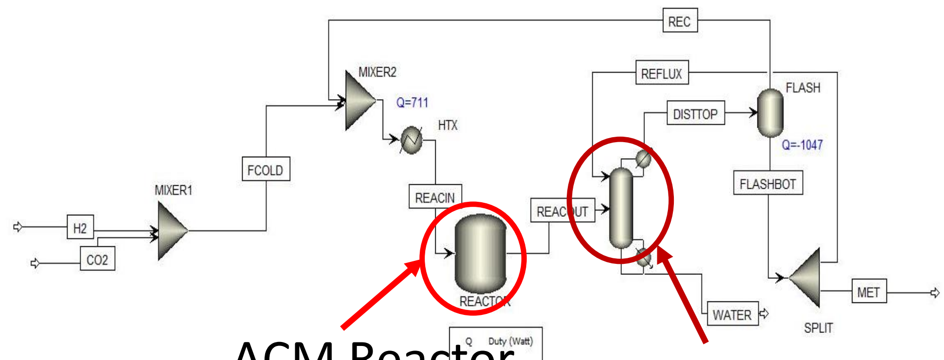


Research ULiège at process scale

- Novel methanol reactor design
  - Intensification of synthesis reactor for CO_2 reduction to methanol







$$r_{MeOH} = \frac{k'_{5a}K'_2K_3K_4K_{H2}p_{CO2}p_{H2}[1-1/K^*(\frac{p_{H2O}p_{CH3OH}}{p^3_{H2}p_{CO2}})]}{(1+K_{H2O}/K_8K_9K_{H2})(\frac{p_{H2O}}{p_{H2}}+\sqrt{K_{H2}p_{H2}}+K_{H2O}p_{H2O})^3}$$

$$r_{RWGS} = \frac{k'_1p_{CO2}[1-K^*_3(\frac{p_{H2O}p_{CO}}{p^3_{H2}p_{CO2}})]}{(1+K_{H2O}/K_8K_9K_{H2})(\frac{p_{H2O}}{p_{H2}}+\sqrt{K_{H2}p_{H2}}+K_{H2O}p_{H2O})^3}$$

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Vanden Bussche and Froment , 1996. Journal of catalysis, 161, pp. 1-10.
Bos and Brilman, 2014. DOI: 10.1016/j.cej.2014.10.059

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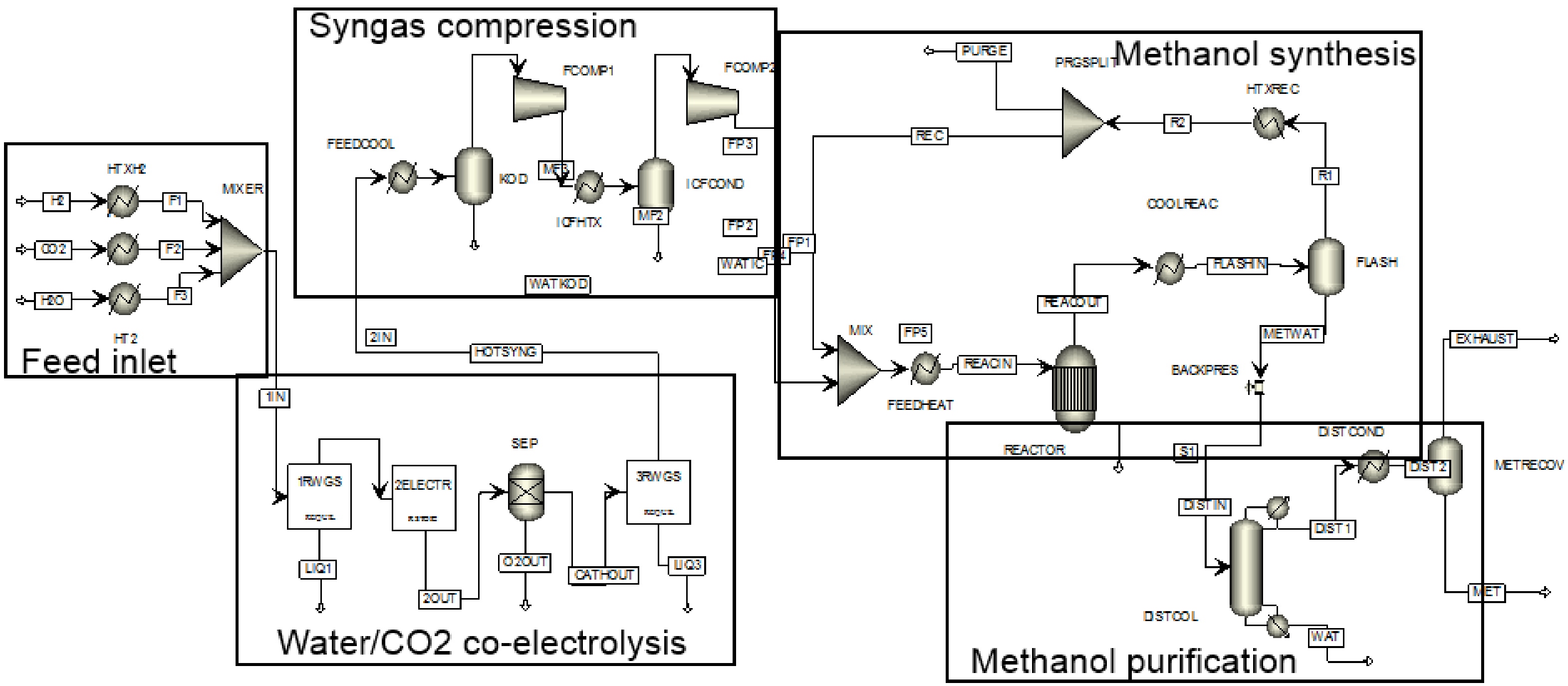
Research ULiège at process scale

- Process integration
  - Models for electrolysis, CO_2 capure 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

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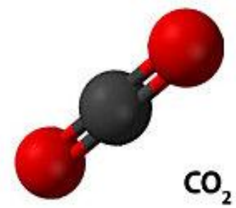
The FRITCO_2T Platform

Chemical Transformation

Synthetic Fuels

Monomers & Polymers

Mineralization



Sourcing

Capture & Purification

Physical Use

Pharmaceutics & Cosmetology

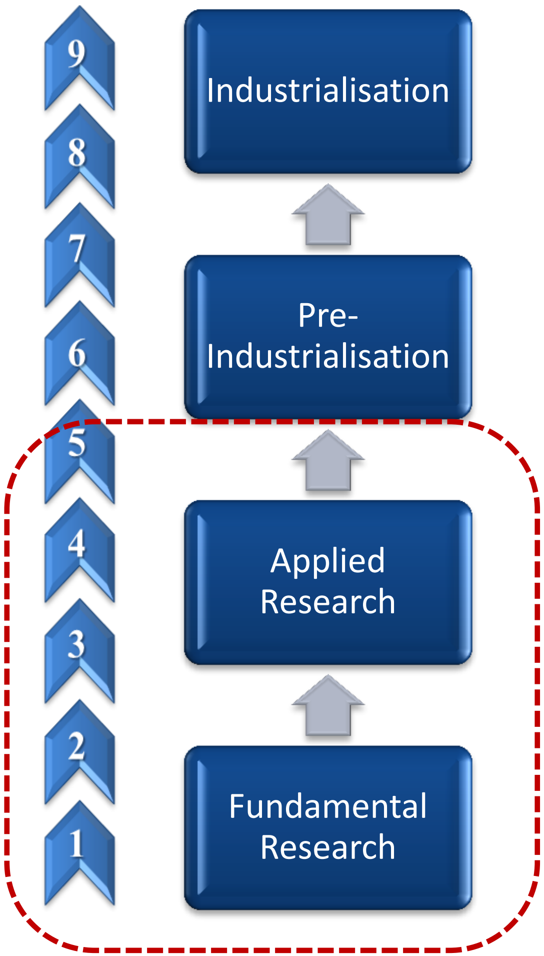
Direct CO_2 use (solvent, foaming…)

Transversal WP

Process sustainability (LCA and economics)

Missions of the platform

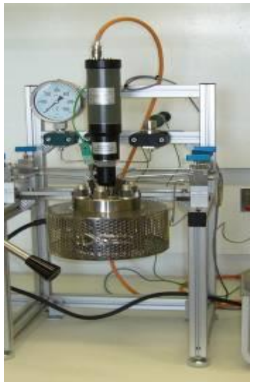
- Market needs, fundamentals pushes
  - Give rationals and scientific background to new ideas
  - Accelerate climbing of the TRL scale
- Lead large-scale research projects
  - From Regional to European projects
- Support technological developments
  - Support for operational issues
  - Holistic view: Circular economy and life cycle thinking



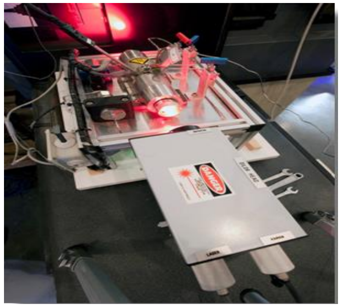
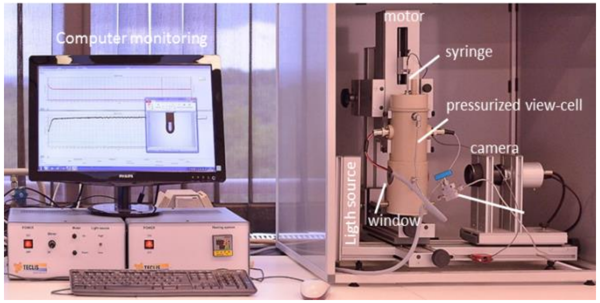
Success stories

- **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

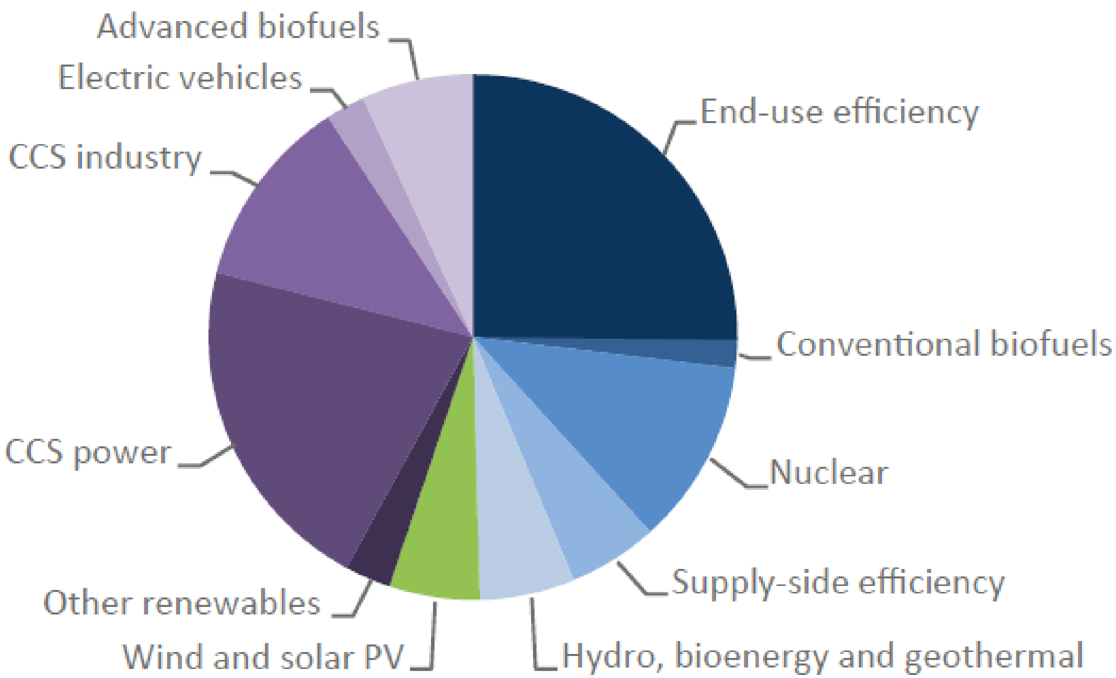




High performance analytical tools

CO_2-assisted processes


Conclusion: to store or to use?

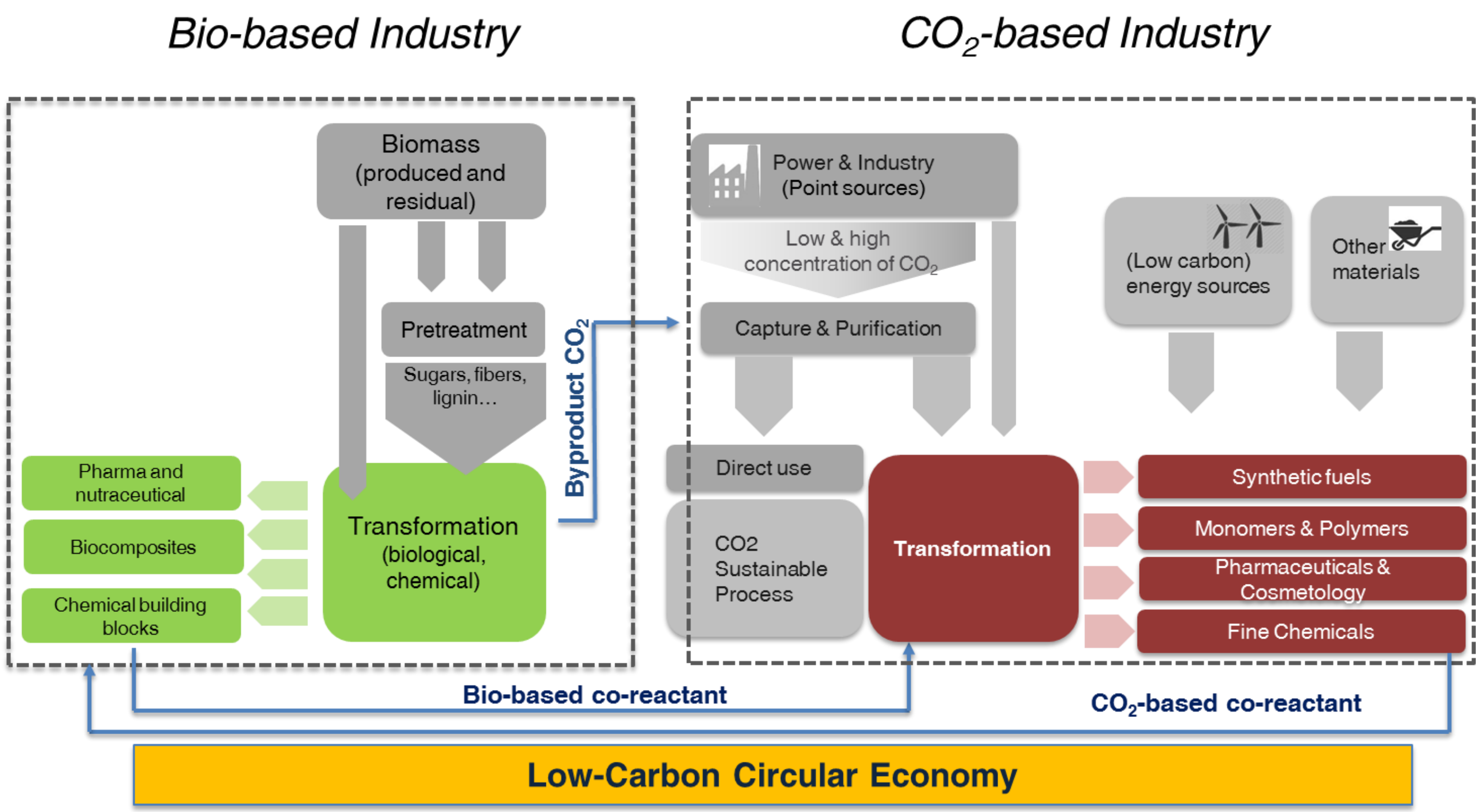


World CO_2 emissions abatement in the 450 Scenario (Bridge Scenario 2015-2040), IEA **2015**, WEO special report, Energy & Climate Change

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

Conclusion

- Synergies to be developed



Thank you for your attention!

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