Challenges of CO_2 capture as an application of fluid separation techniques

Grégoire LEONARD, Associate Professor
g.leonard@ulg.ac.be

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Outline

1. Context
2. CO_2 Capture configurations and technologies
3. Future trends and challenges
4. Conclusion

Context: let’s start ab initio…

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Mission statement of the EFCE

EFCE will help European society

- to meet its needs
- through highlighting the role of

Chemical Engineering

- in delivering sustainable processes and products

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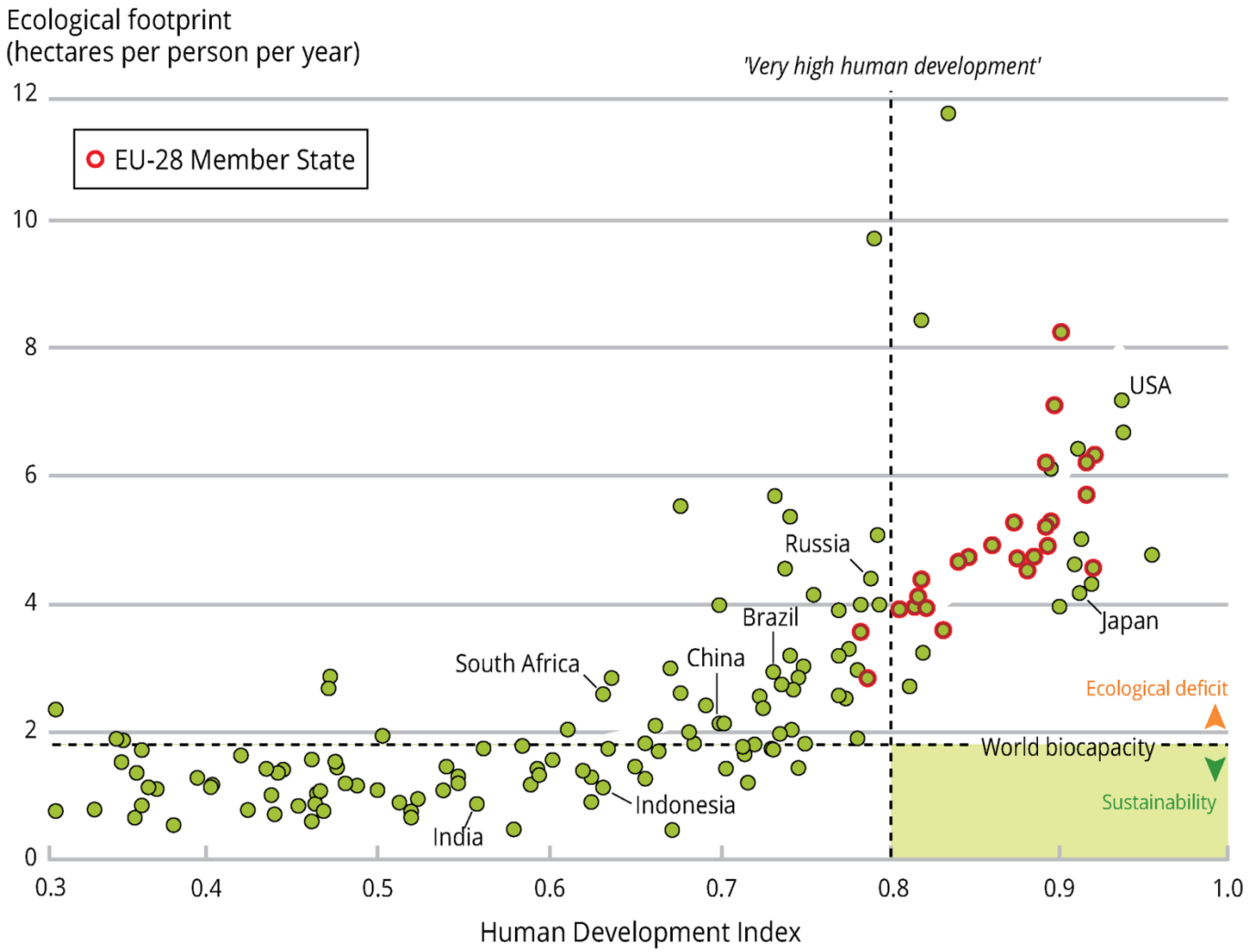
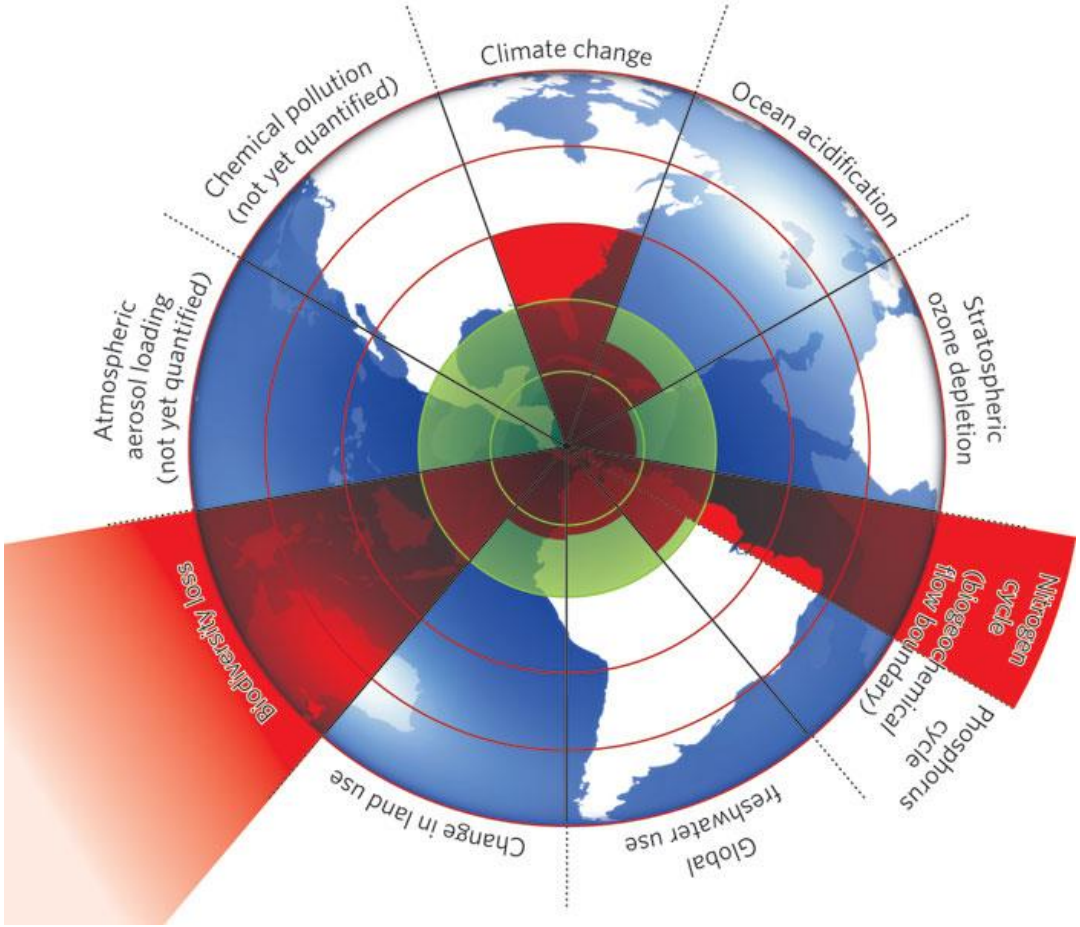
Europäische Föderation für Chemie-Ingenieur-Wesen
Fédération Européenne de Génie Chimique

What needs?



European Environment Agency, SOER 2015

Ecological footprint

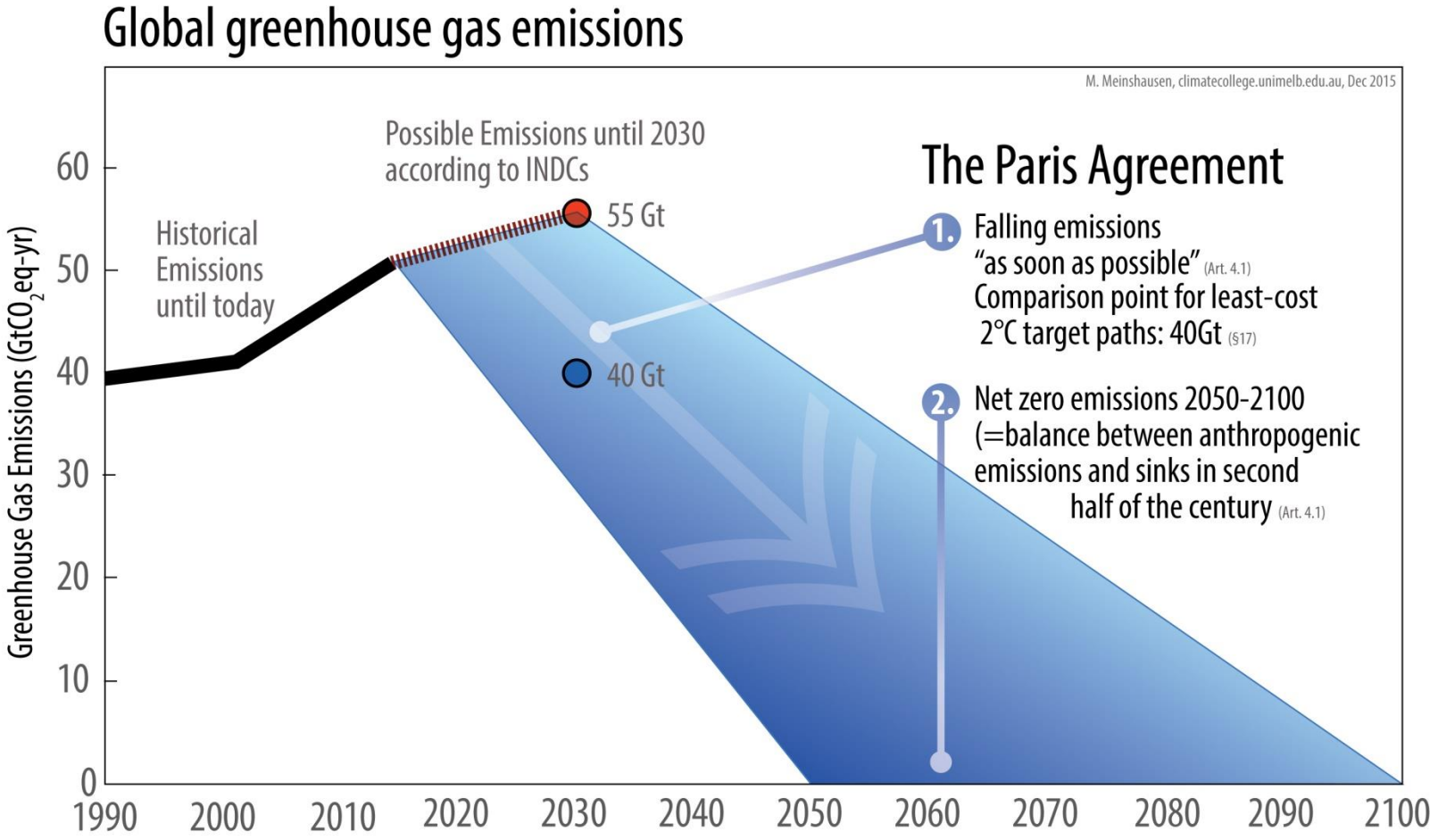


Rockström et al., 2009, Nature 461, 472-475

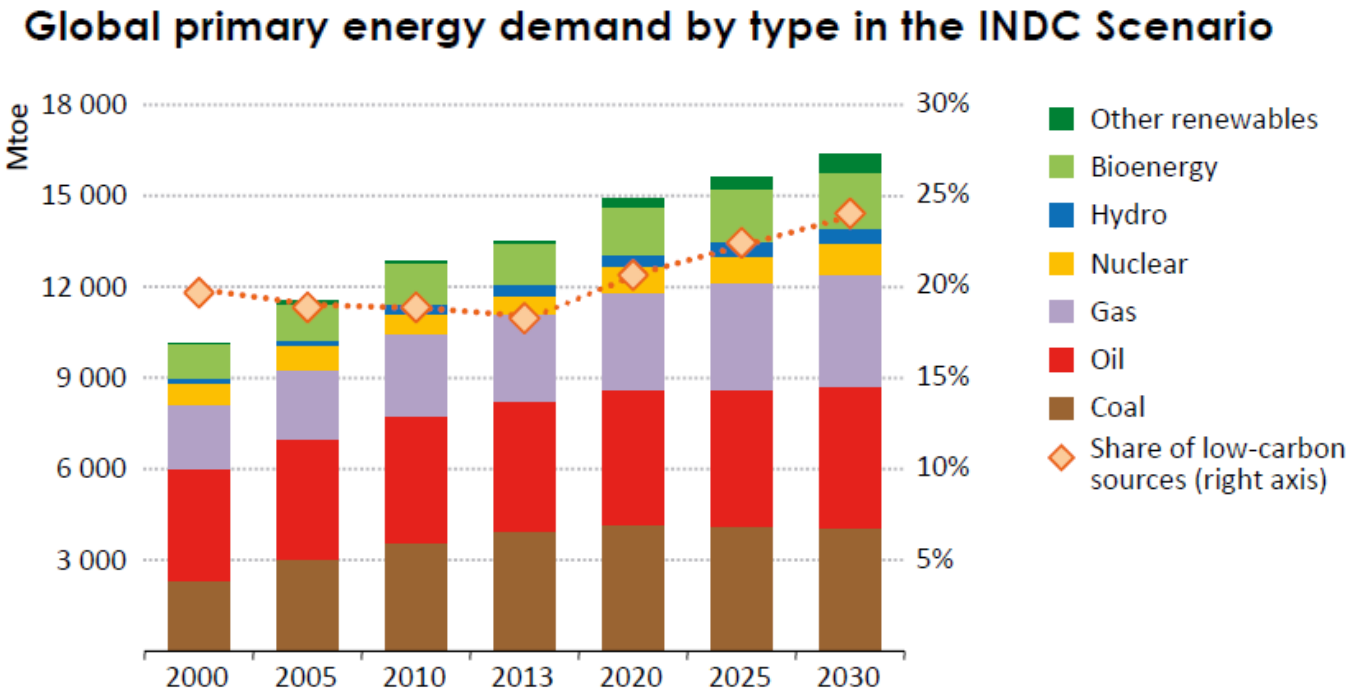
The energy transition has already started…

But it has to address 2 objectives in contradiction: Limit GHG emissions, and meet the increasing demand!

The COP […] notes that much greater emission reduction efforts will be required …



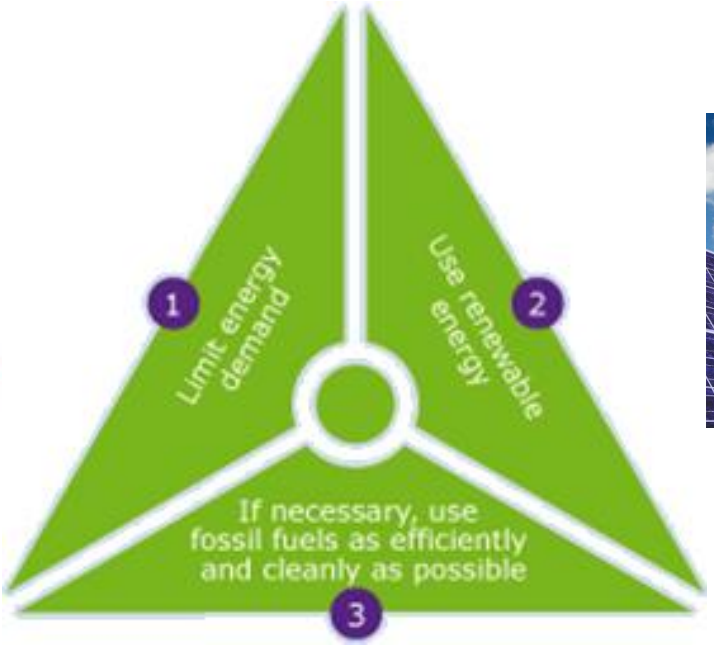
Meeting the increasing demand is already a challenge in itself!



Note: "Other renewables" includes wind, solar (photovoltaic and concentrating solar power), geothermal, and marine.

IEA 2015, WEO special report, Energy & Climate Change

Possible answers: Trias Energetica



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 technologies & configurations

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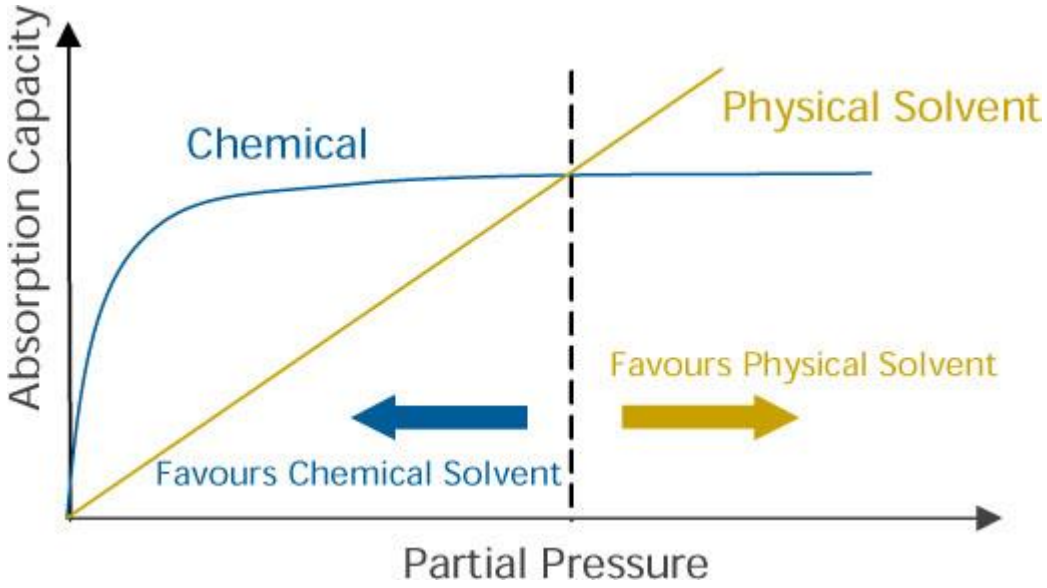
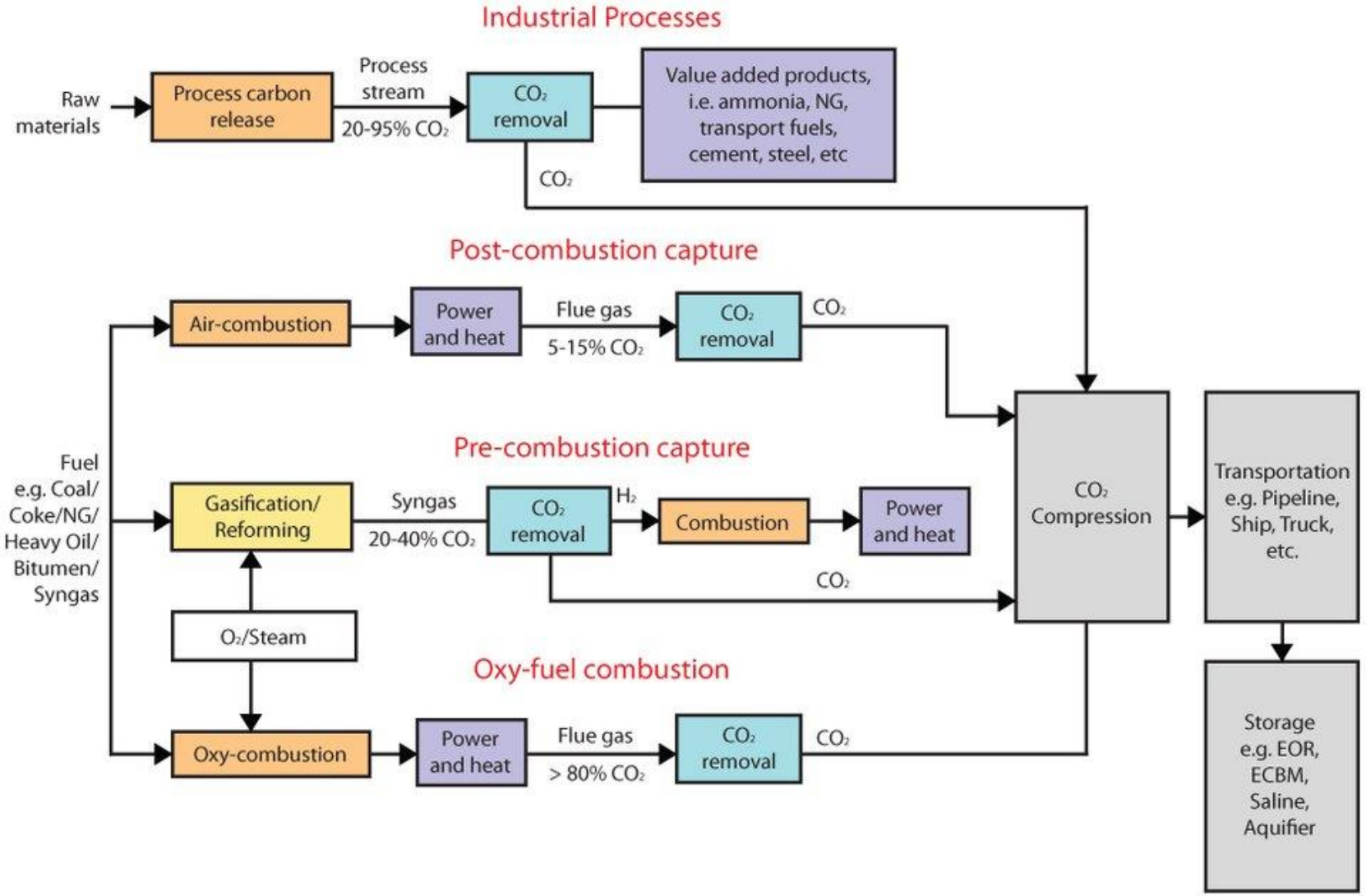
CO_2 separation technologies

- Avoid fluid mixtures
- Absorption
  - Physical
  - Chemical
- Adsorption
- Membranes
- Cryogenic separation
- Others…

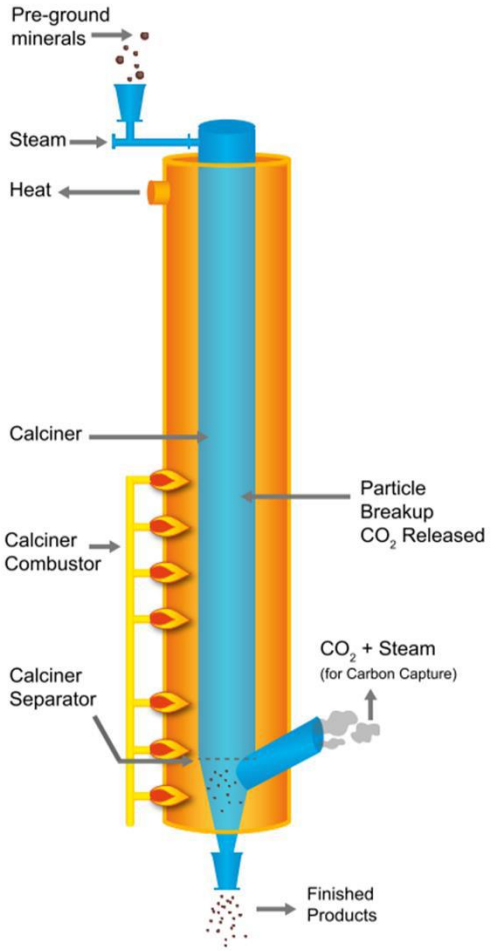


CO_2 capture configurations



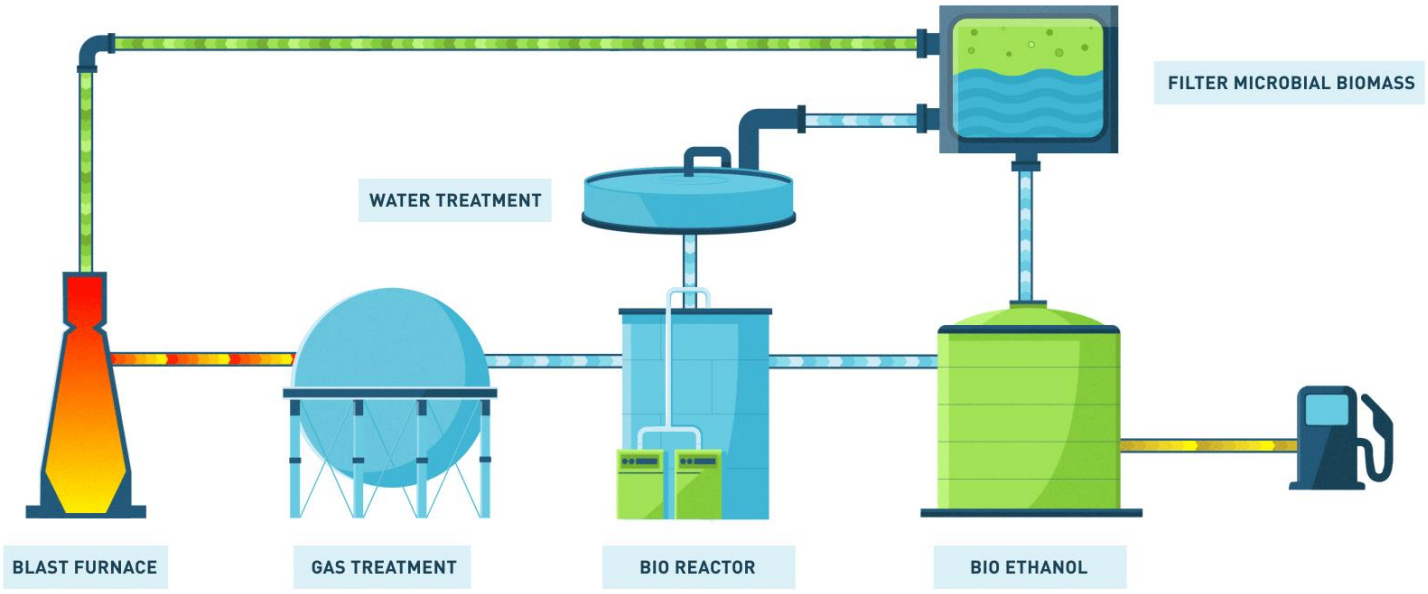
Industrial processes

1. **CO_2 not resulting from combustion**
   - Cement plants
     - Leilac: 21 M€, -60% CO_2



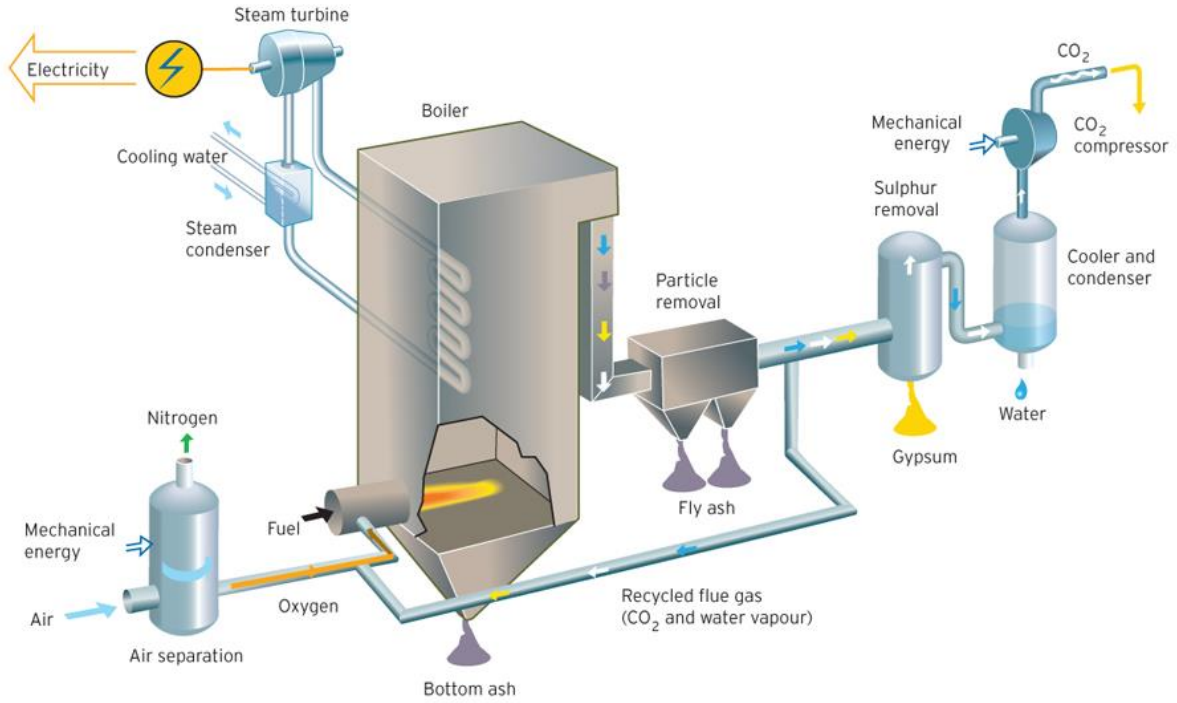
Industrial processes

1. **CO_2 not resulting from combustion**
   - Steel mills
     - Steelanol: 87 M€, -70% CO_2



Oxyfuel combustion

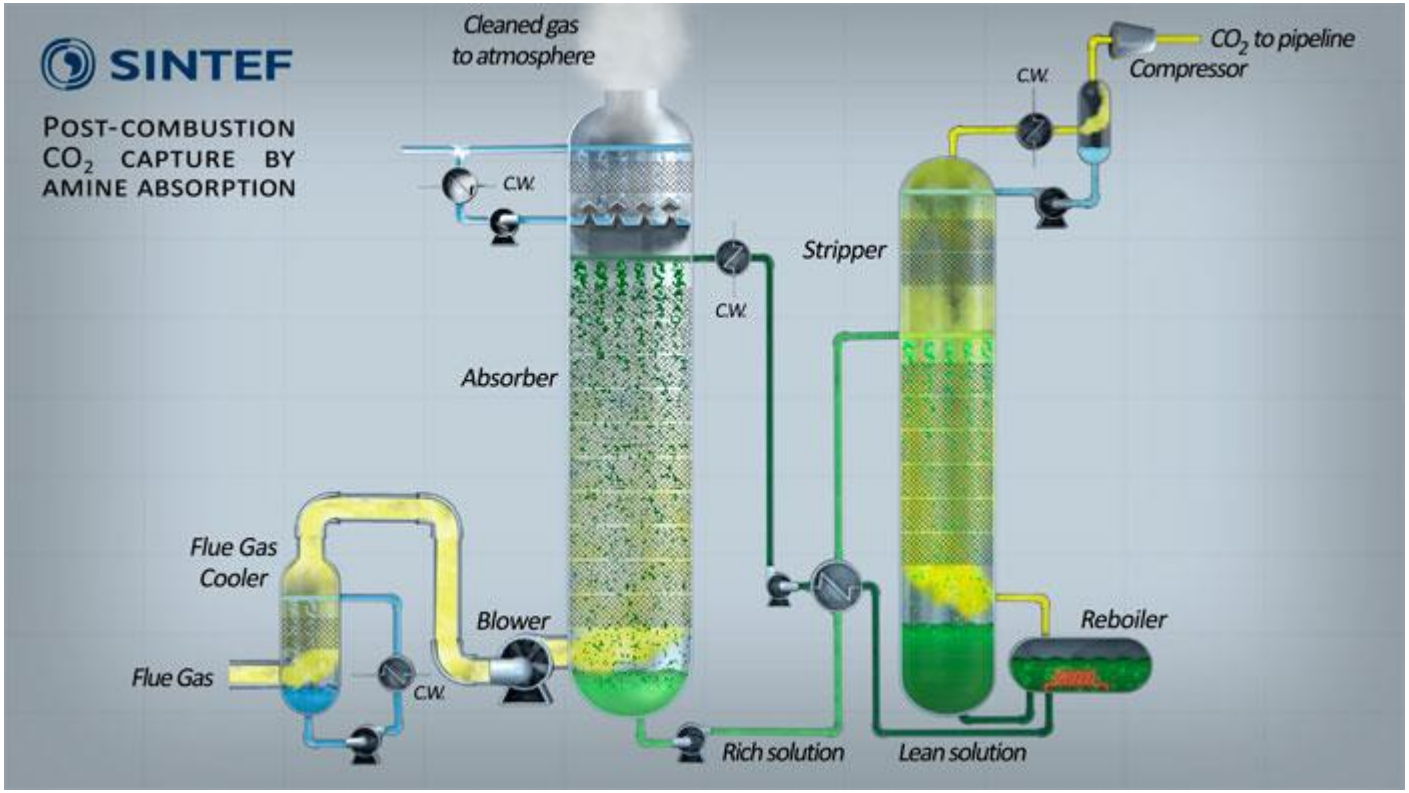
2. **Burn the fuel with pure oxygen**
   - Air separation needed
   - Waiting for large-scale projects



Post-combustion capture

3. **Capture CO_2 from combustion gases**

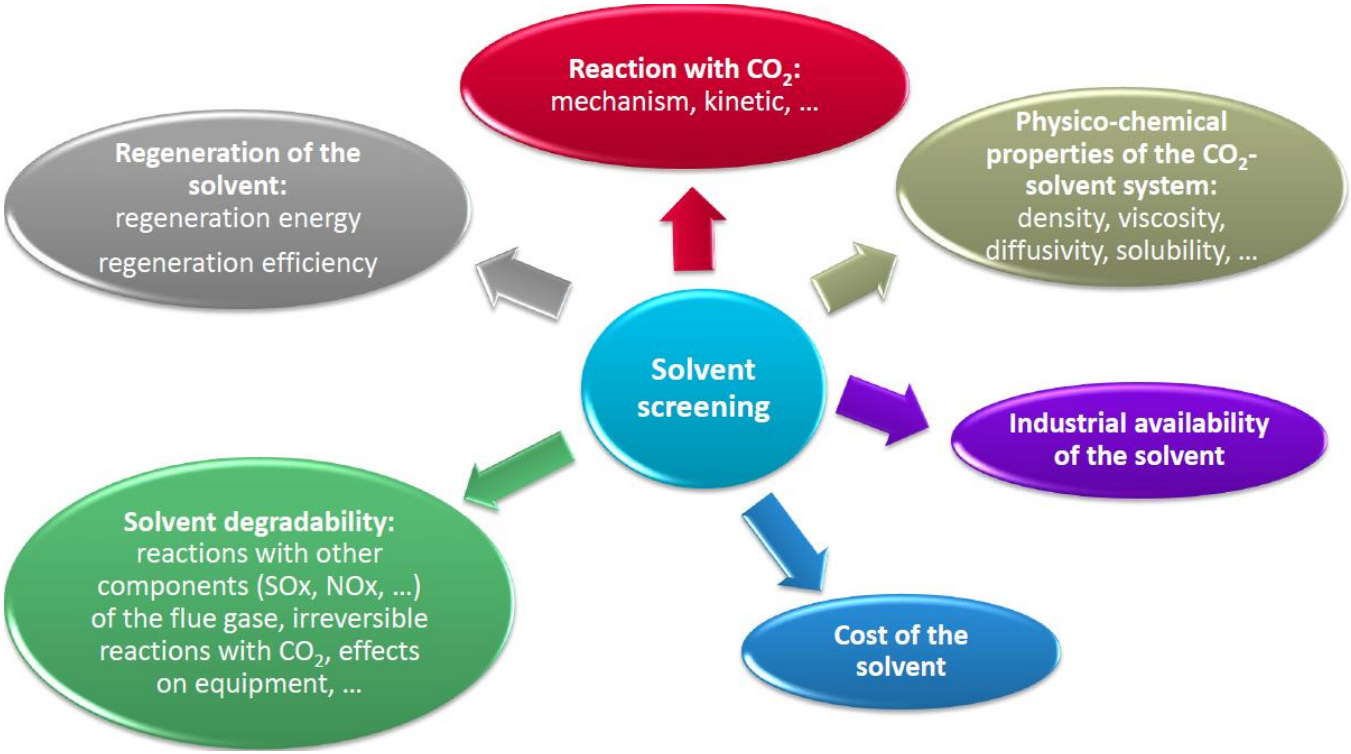
- Usually chemical solvents



Post-combustion capture

3. **Capture CO_2 from combustion gases**

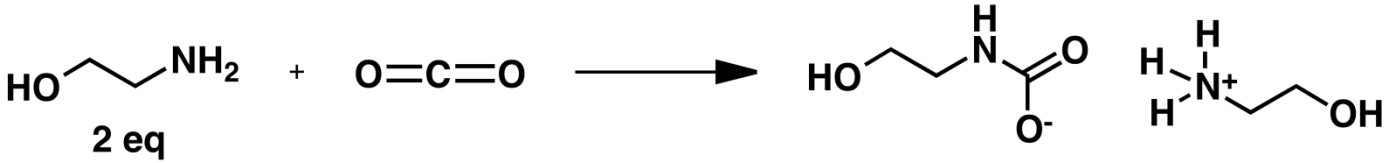
- Characteristics of a chemical solvent

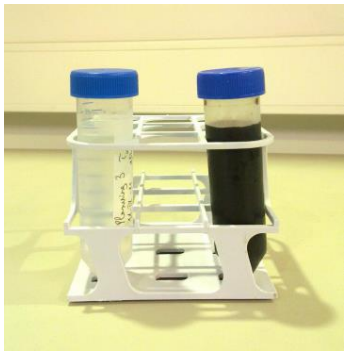


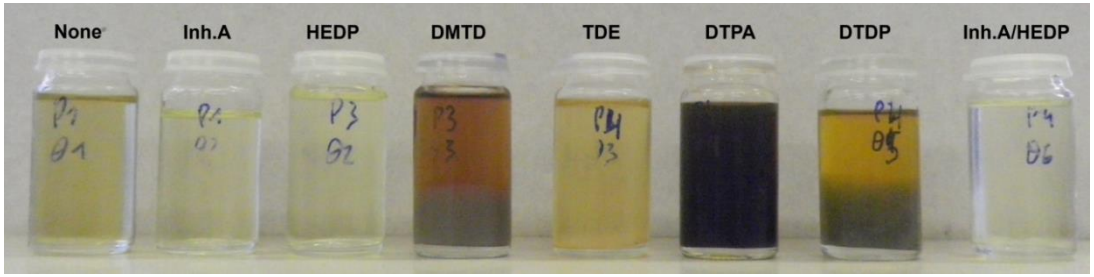
Post-combustion capture

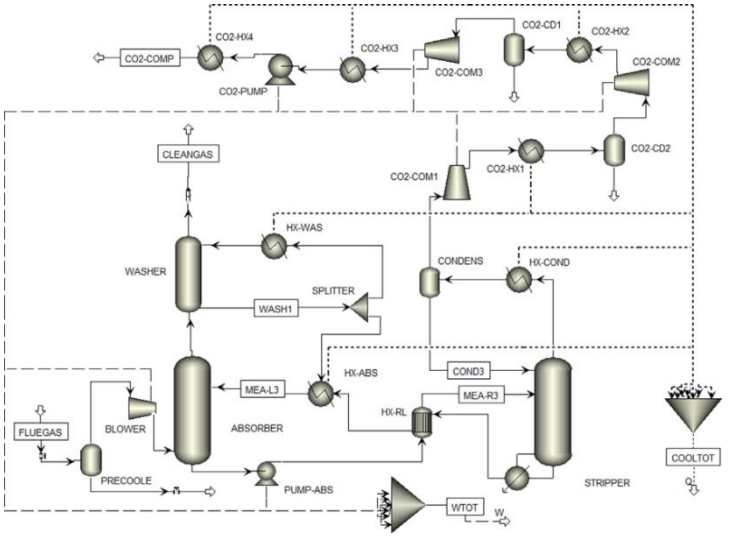
3. **Capture CO_2 from combustion gases**

- Amines (1, 2, 3ary) in water







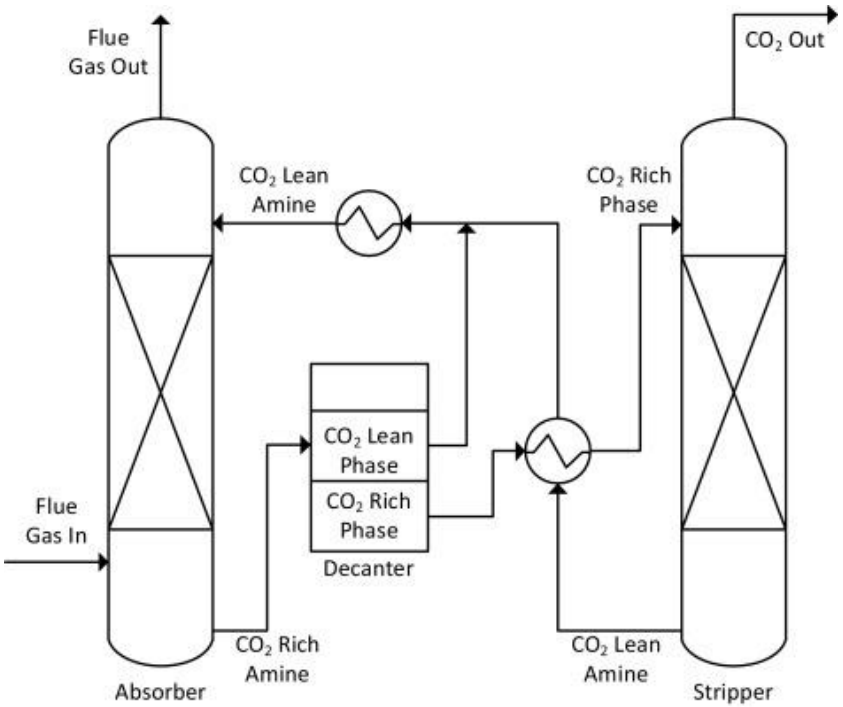


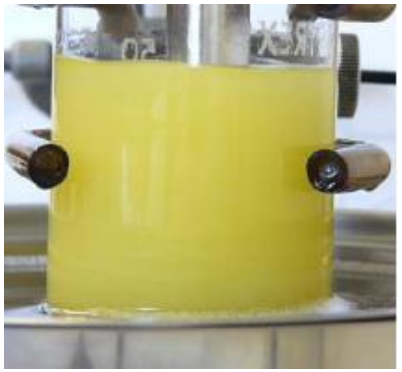
Léonard et al., 2014&2015. DOI:10.1021/ie5036572, DOI: 10.1016/j.compchemeng.2015.05.003

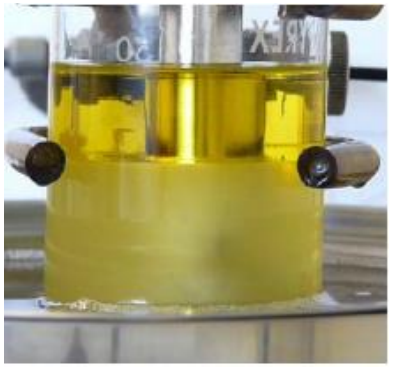
Post-combustion capture

3. **Capture CO_2 from combustion gases**

- Alternatives to amines
  - Chilled Ammonia, amino-acids, ionic liquids…
  - Demixing solvents => LLV and thermo models







Heldebrant et al., 2009; Raynal et al., IFP, 2011

Post-combustion capture

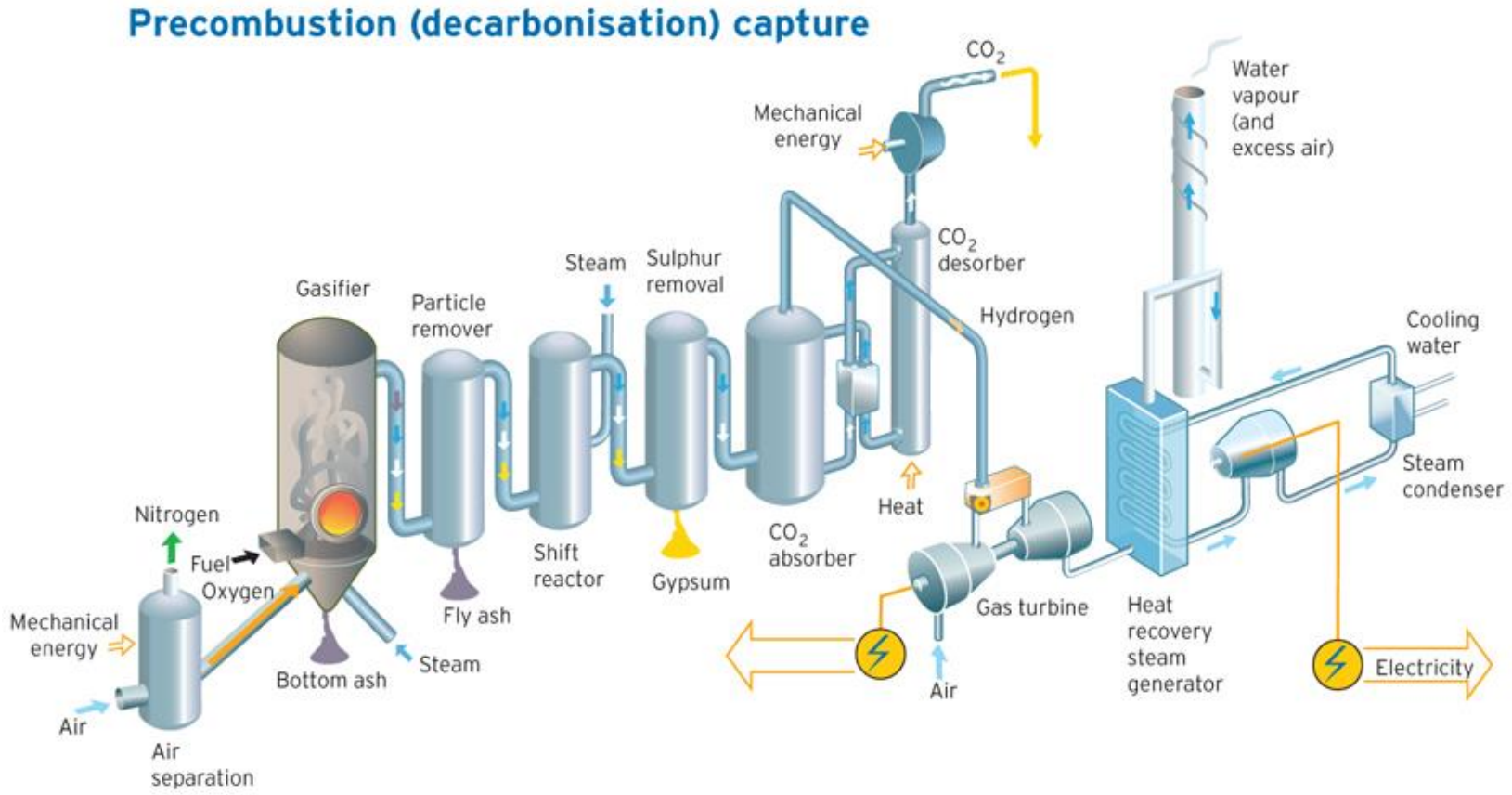
3. **Capture CO_2 from combustion gases**

- Boundary Dam, Saskatchewan
  - Coal power plant 160 MWe
  - 2700 tCO_2/day captured (~90% capture rate)

    => Flue gas: 180 Nm^3/s ; Solvent: 550 L/s
  - Petra Nova, Texas: 4400 tCO_2/day

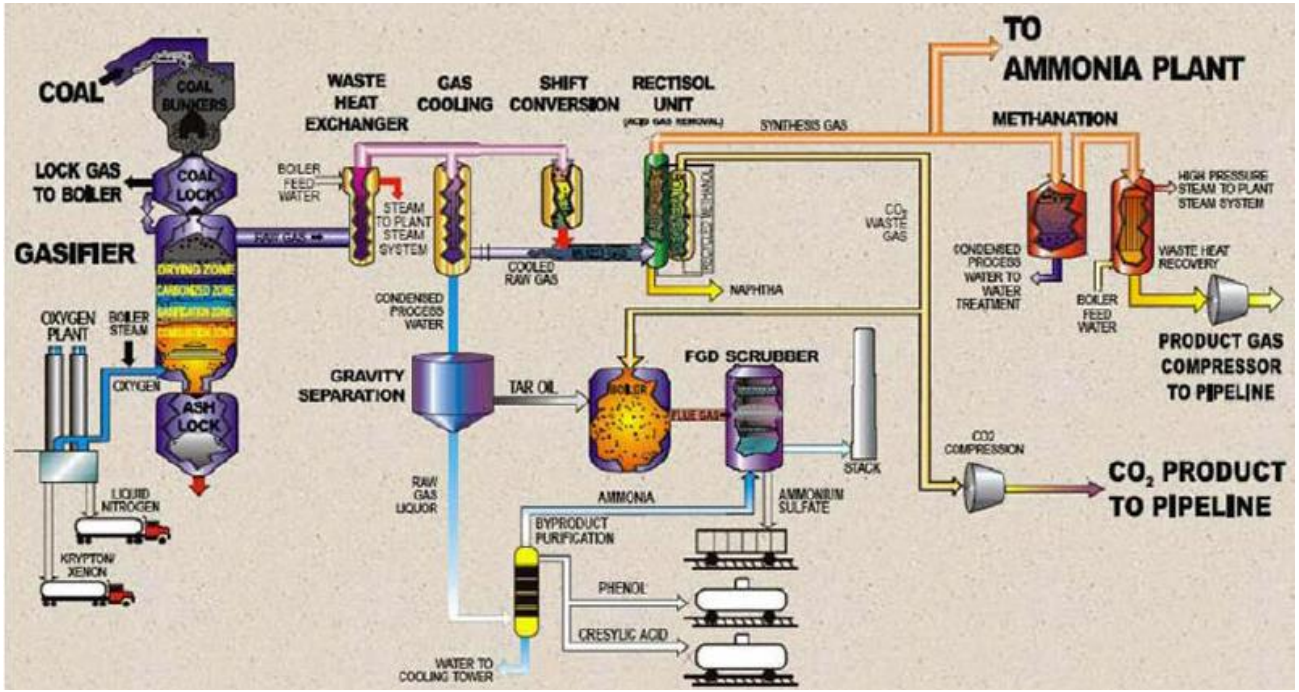
Pre-combustion capture

4. **Remove C from the solid fuel by gasification**



Pre-combustion capture

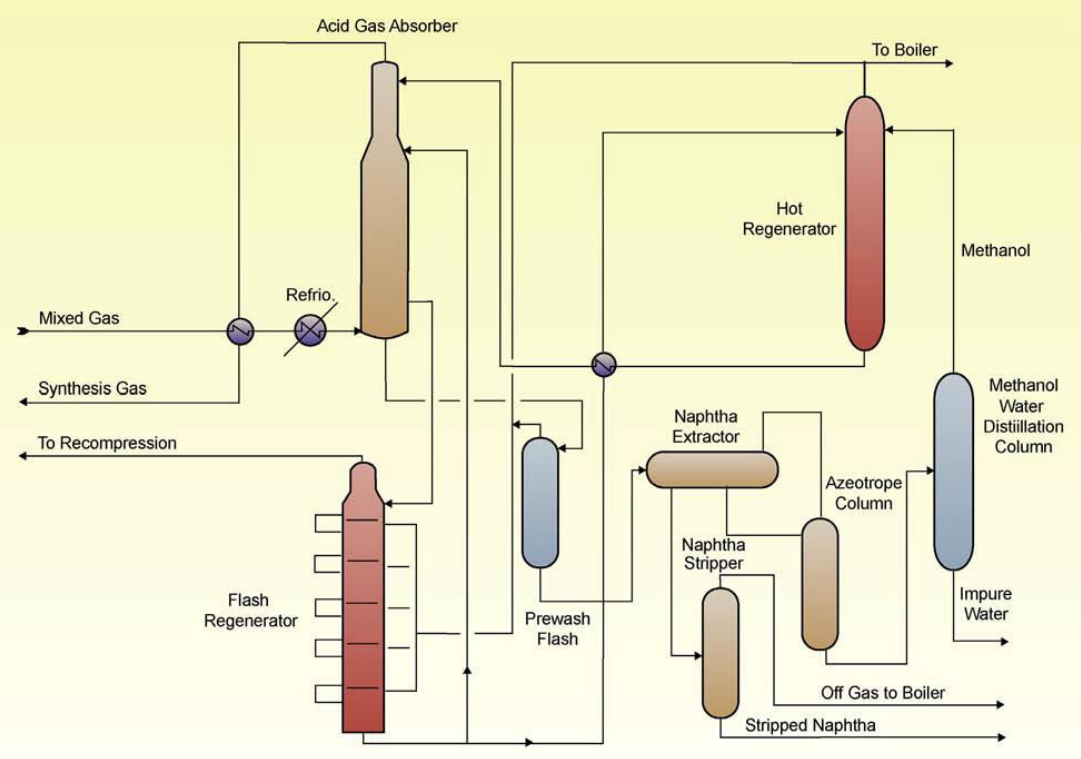
4. **Remove C from the solid fuel by gasification**
   - Great Plains Synfuel Plant, North Dakota (US)
   - 8 200 tCO_2/day captured (~50% capture rate)



http://www.netl.doe.gov/research/coal/energy-systems/gasification/gasifipedia/great-plains

Pre-combustion capture

4. **Remove C from the solid fuel by gasification**
   - GPSP Rectisol process: physical absorption in cold methanol
   - Largest utility consumption and largest plant bottleneck



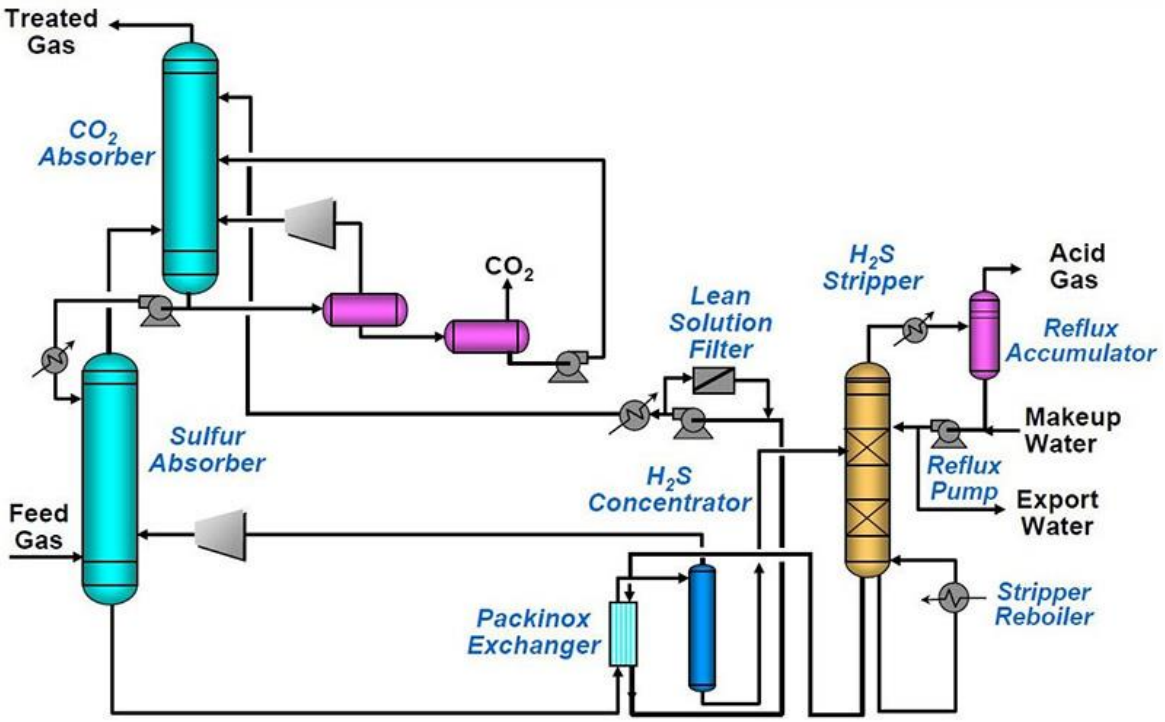
Practical experience gained at GSPS, US DOE report, 2006

Pre-combustion capture

4. **Remove C from the solid fuel by gasification**
   - Kemper County (Mississippi): IGCC, 582 MWe
   - 9500 tCO_2/day captured (~65% capture rate)
   - Cost estimation: from 2.9 to 6.6 bn$ (still increasing)

Pre-combustion capture

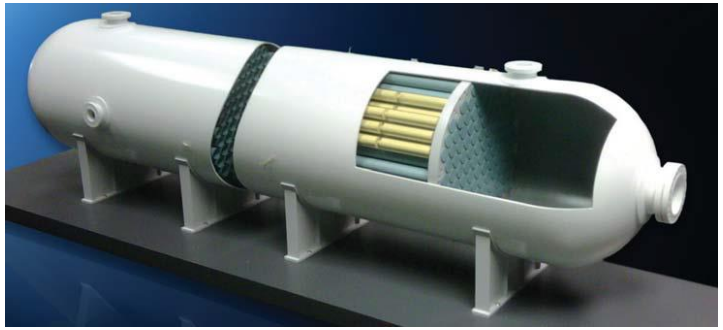
4. **Remove C from the solid fuel by gasification**
   - Kemper County: CO_2 separation using the Selexol process
   - Physical absorption in dimethylethers of polyethylene glycol

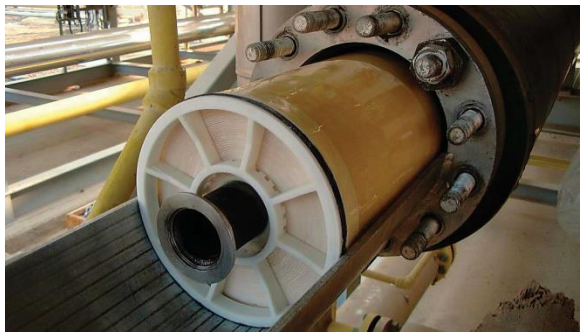


UOP Selexol™ Technology for Acid Gas Removal, UOP LLC, 2009

Pre-combustion capture

4. **Remove C from the fuel => Natural gas sweetening**
   - Usually physical and/or chemical solvents
   - Also membranes for off-shore platformssd
     - Pre-treatment: TSAdsorption for Hg, H_2O and heavy HC





UOP Separex™ Membrane Systems, UOP LLC, 2011

3. Future trends and challenges

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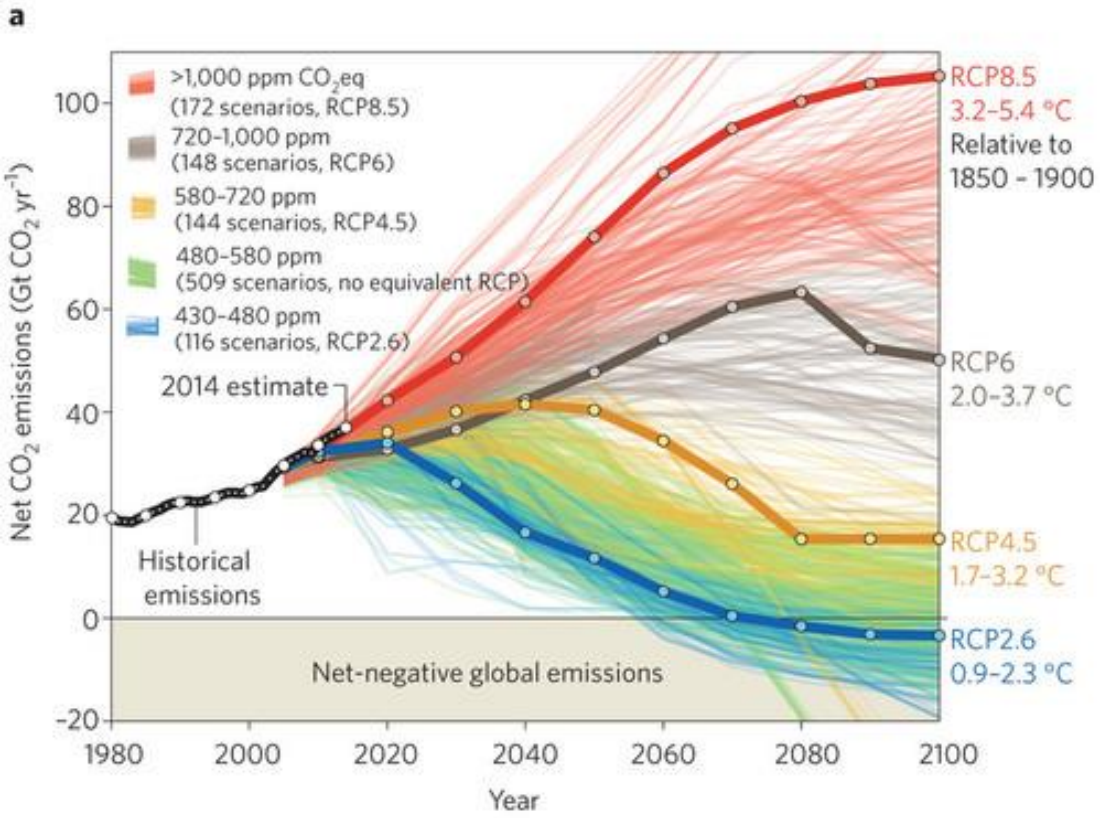
Negative CO_2 emissions

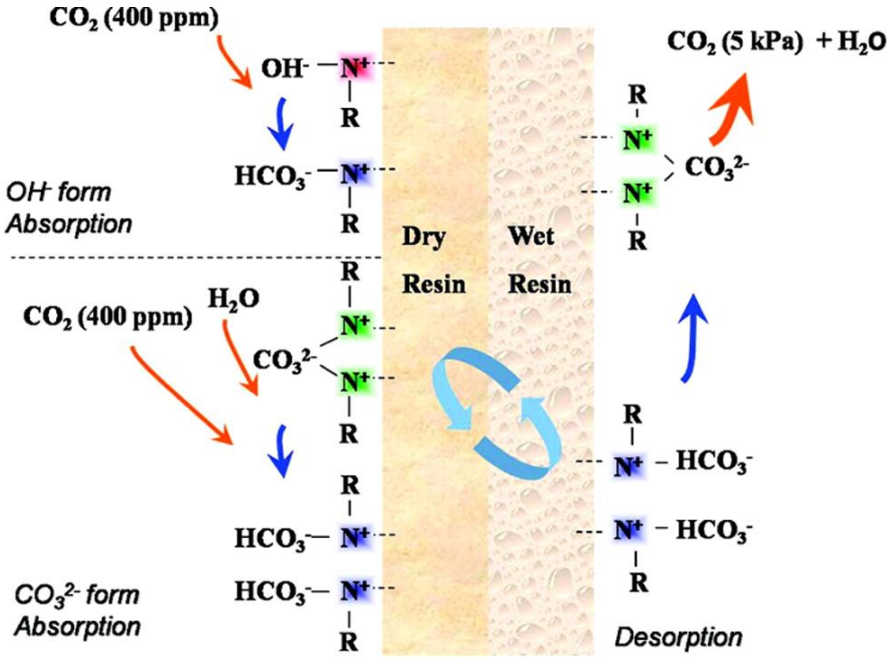


- Biomass-enhanced CCS
- Direct air capture

Fuss et al, Nature, 2014, doi:10.1038/nclimate2392

Direct air capture

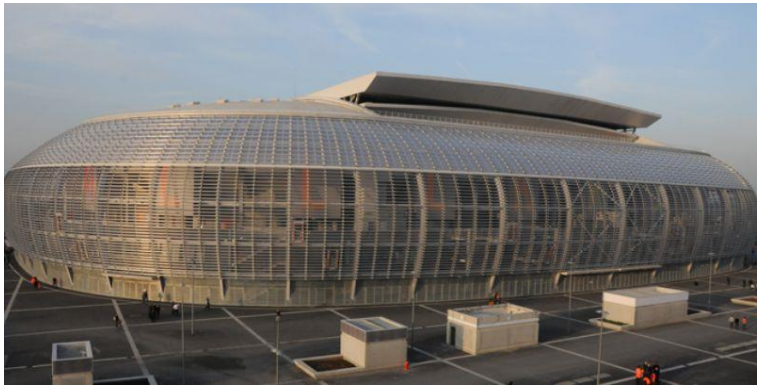
- ~ 400 ppm in the air
  - Adsorption
  - Temperature-swing, or humidity-swing

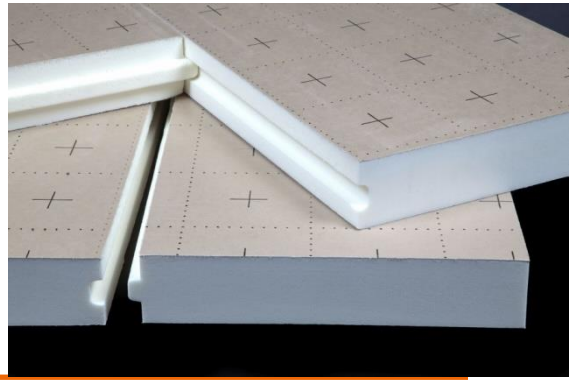


Wang et al, 2011

CO_2 re-use

- CCS has become CCUS

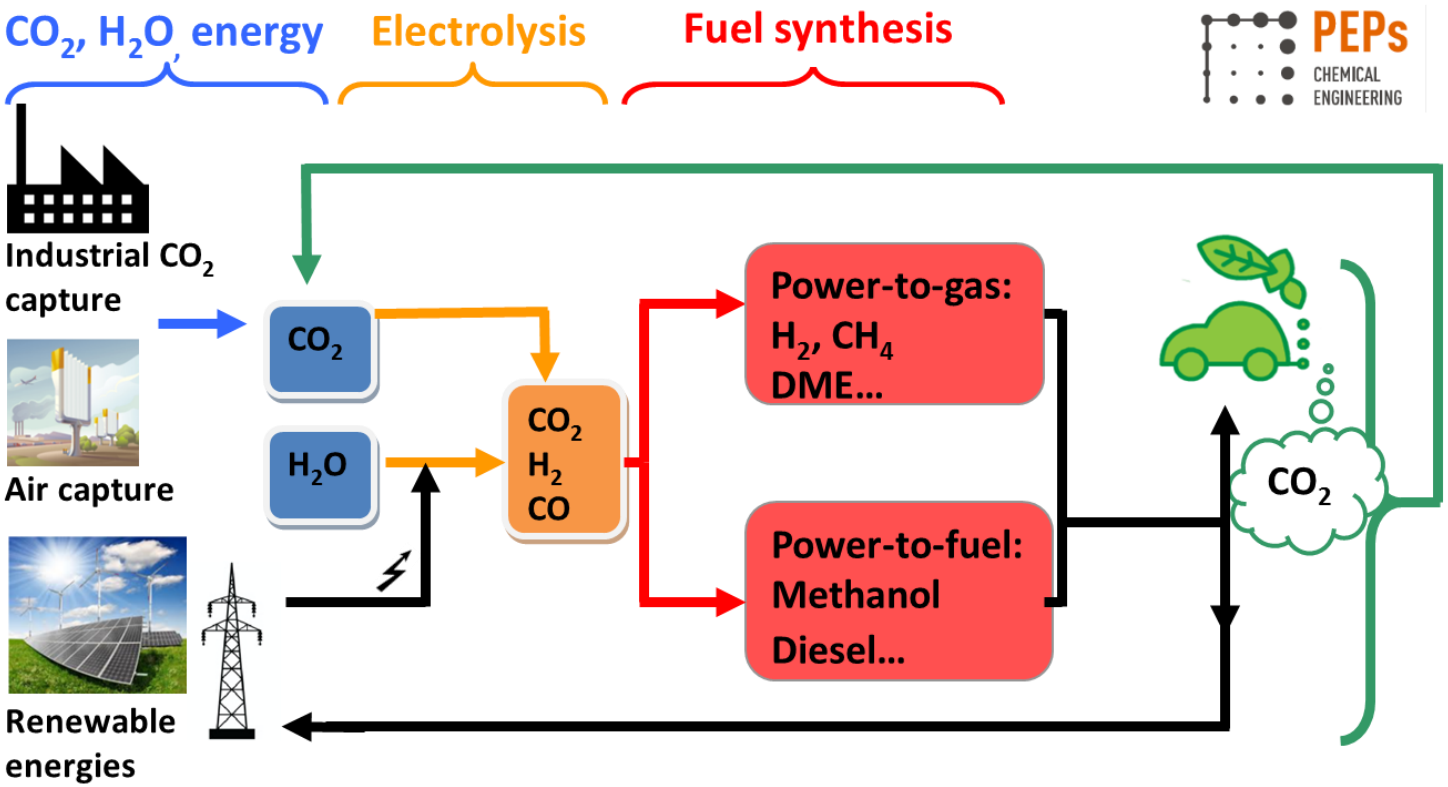




Hemcrete, 2015

CO_2 re-use

- CCS has become CCUS



5. Conclusions

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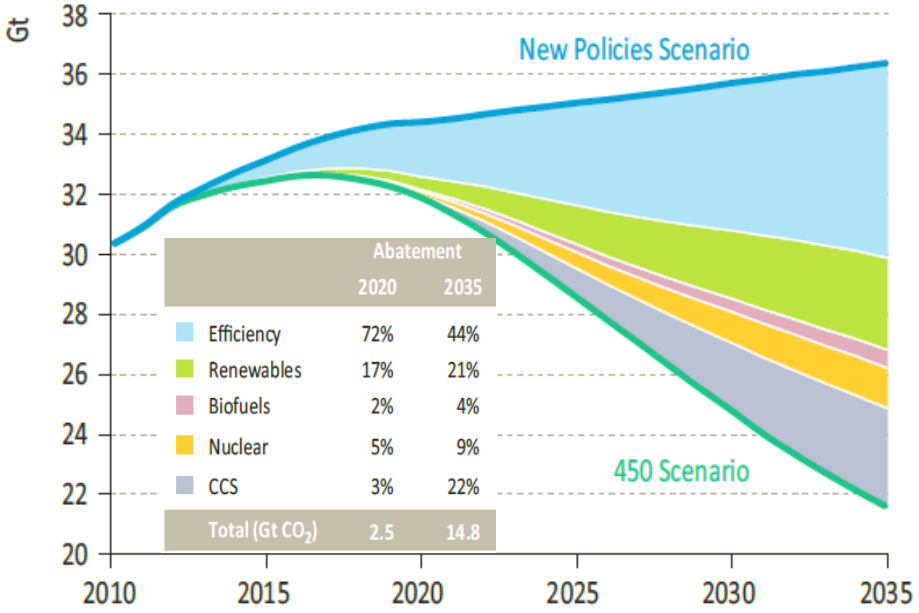
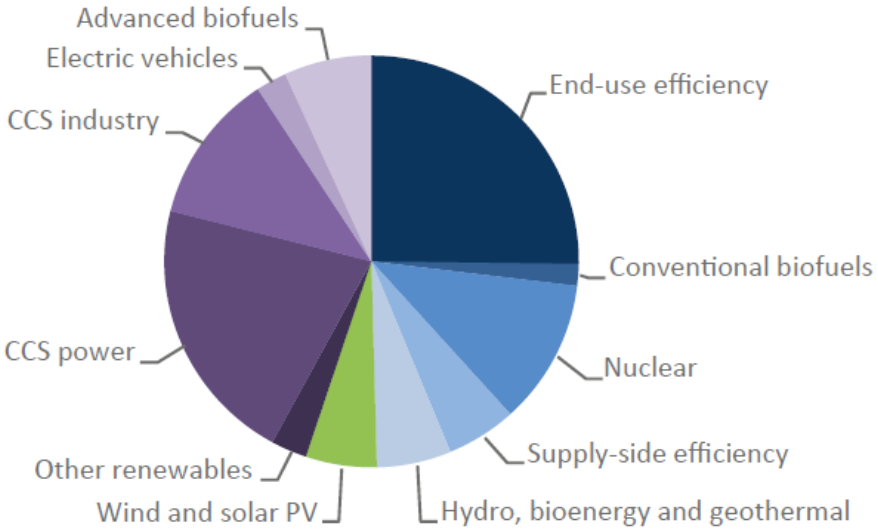
Perspectives

- World-scale challenge
- Large variety of technologies and of TRL



World CO_2 emissions abatement in the 450 Scenario (New Policies Scenario), IEA **2011**, WEO2011.



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

EFCE to create the EFCE energy section

- Support the key contributions of chemical engineering in the energy sector and the key aspects of energy for the chemical industry.
  - Sub-section 2: Energy conversion, renewable energy and CO_2 mitigationon CO_2
  - Sub-section 7: CO_2 capture & reuse

http://efce.info/Energy.html

Thank you for your attention!

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