About „game changers“ and „silver bullets“
Negative emissions from carbon capture, storage and utilization

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Introduction

Anthropogenic climate change must be seen as the greatest challenge of humanity. Since the industrial revolution, atmospheric carbon dioxide (CO_2) levels have risen sharply, due to the burning of fossil fuels. Because of its reflective properties, CO_2, among other gases, acts as a greenhouse gas (GHG) in the atmosphere and is now heating earth by 1.5°C. Because of mankind's disregard, the resulting climate change is on its way to end in devastating and irreversible consequences. To prevent this dangerous scenario, there is no other option than the steady reduction of the ongoing CO_2 emissions, along lowering the atmospheric CO_2 levels. This technique is described as „carbon removal“ and is seen as "silver bullet" or "game changer" in terms of combating climate change. What exactly lies behind this „end-of-pipe“-technology and how much potential it actually has will be presented in the following. [1, p. 1-2]

Atmospheric carbon removal can happen through various capture methods. One they all have in common is available space and storage. A really promising land-based approach are BECCS (brief for bio-energy with carbon capture and storage) followed by afforestation, optimized land use management and biomass combustion to produce electricity or fuel, paired with sequestering of CO2 in geological formations. Another ocean-based method is referred to the ocean-fertilization with iron. But it's rather criticized due to its possible environmental side effects. More chemical approaches mean the mineralization of CO_2 to form carbonates. A further type is the direct carbon dioxide capture from ambient air by different solvents. [2, p. 2; 7, p. 46]

Direct Air Capture (DAC)

Advantages

- decentralized and ubiquitous approach [3, p. 79]
- projected cost: 80-130$/t CO2 [3, p. 79]
- most cost-effective option when using existing energy sources (gas, water) [2, p.1]

Demo plants

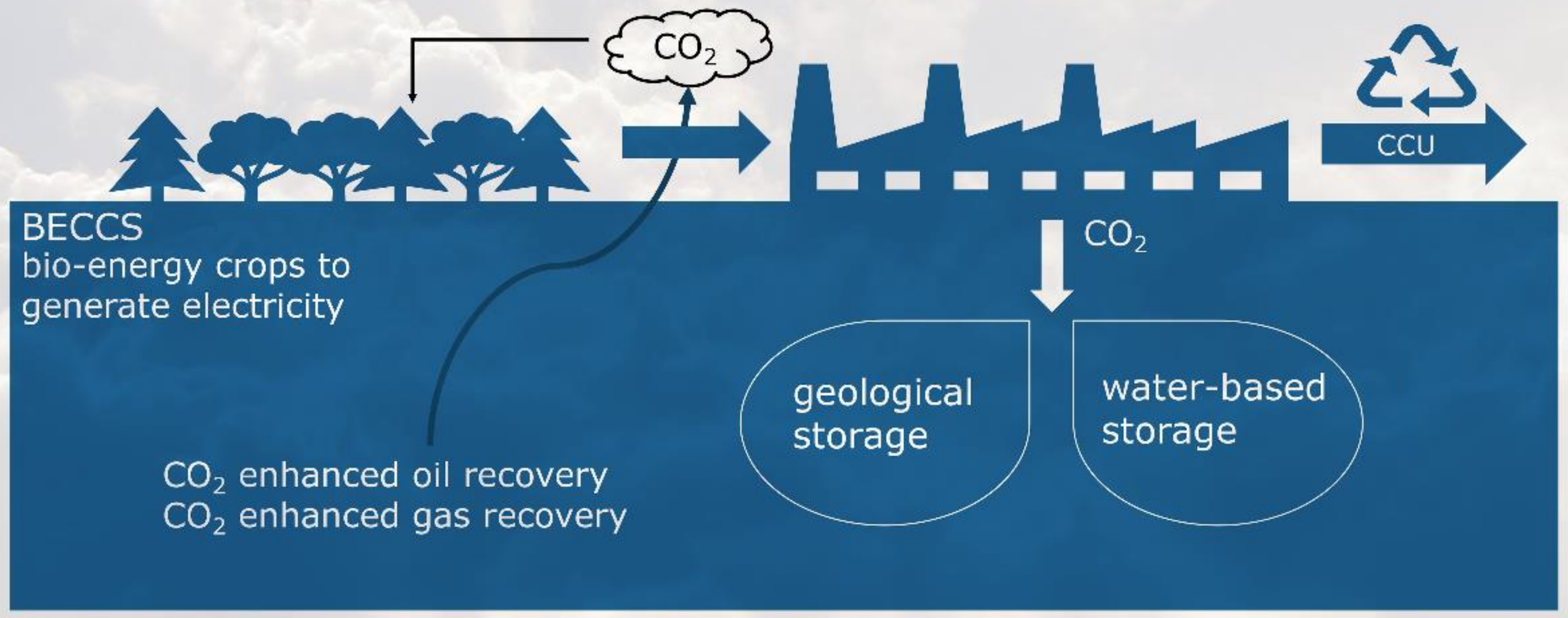
- *Climeworks*, swiss enterprise dedicated to carbon removal [4]
- first commerzialized plant in Hinwil, Switzerland[4]
  - captured carbon supplies neighboring greenhouse
- biggest climate-positive capture plant „Orca“ in Hellisheiði geothermal park, Iceland [4]
  - CarbFix technology: captured carbon is stored permanetaly underground in basaltic rock

Functionality

- how it works:
  - large volume fans or pumps are supplied with air [3, p. 79]
  - CO_2 gets removed from the air by passing a CO_2-absorber, like NaOH or $Ca(OH)_2$
    - binding in calcium carbonates (chalk) or sodium carbonates (soda) [3, p. 88]
- after the carbon capture -> several other usages like storage or further utilization…

Issues

- atmospheric CO_2-concentration is quite low
  -> tight binding in strong chemicals necessary [3, p. 88]
- energy intensive: *Climeworks* needs 1100 kWh/t CO_2 [3, p. 98]
- actually cost intensive: 600$/t CO_2; with such a high price it won't commercialize [3, p. 90]
- applicability (example): one *Climeworks* collector captures 50 t CO_2/y
  - if one would capture 5% of the total CO_2 emissions per year (1855Mt/y)
    -> 371 million collectors necessary [3, p. 98]
- **limitations:**
  - land requirements and availability, storage capacity, size of utility markets for captured CO_2, public acceptance [7, p. 55]



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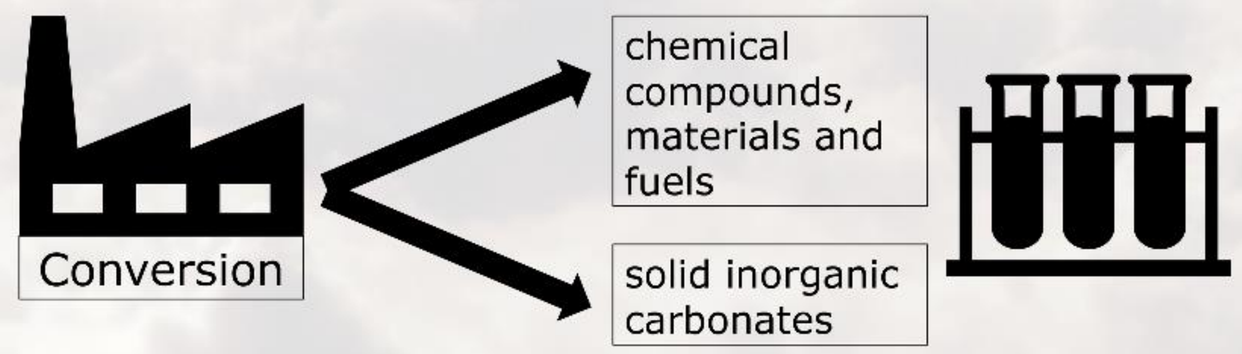
https://climeworks.com/co2-removal



Carbon Capture Storage (CCS)

- **storing in geological formations** such as spent natural gas (NG) wells
  - only option that can be considered safe (after sealed correctly) because they already held carbon (C) [3, p. 80]
- **storage it in water**: [3, p. 80]
  - deep waters (<3000m) as a solid carbonhydrates in containers
  - (saline) aquifers
  - environmental effects: [3, p. 81]
    - warm water streams may convert solid carbonates -> leakage of CO_2
    - leakage in ocean: CO_2 lowers pH of the aquifers -> changing physiology of fishes
  - **key issues:** [3, p. 81]
  - availability of sites, distance to the disposal site (transportation cost), real economic costs, real energetic costs, plus scarce knowledge of the persistence of CO_2 in the disposal sites
- **role of CCS in climate change mitigation:**
  - possible integration into existing energy systems without large amendments [5, p. 1066]
  - decarbonisation of emission-intensive industries like cement, iron, steel [5, p. 1074-1076]
  - possible combination with low-C or C-neutral bioenergy (BECCS) [5, p. 1066]

Conclusion

- both CCS and CCU aim for mitigation of climate change -> complementary not competitive approaches [5, p. 1120]
- CCS addresses the end-of-life problem, CCU addresses a beginning-of-pipe problem [5, p. 1121]
- **DAC:**
  - cost-intensive [3, p. 90]
  - CO_2 recovery at more concentrated sources (like powerplants) is more convenient [3, p. 90]
  - competition in different kinds of land-use [7, p. 55]
- possible to mitigate rising temperature with carbon removal [7, p. 45]
  BUT: unpredictable negative feedback loops (permafrost, sea-level rise, outgassing of CO_2 sinks (ocean, terrestrial biosphere)) [1, p. 9-10]
- **carbon removal ain't no silver bullet or game changer but it's a necessary support to mitigate climate change**

Carbon Conversion and Utilization (CCU)

- conversion of captured CO_2 via chemical reactions
  - **further usage:** carbonated drinks, urea or methanol production, technological fluid like solvents, fuels, solid inorganic carbonates, … [5, p. 1064]
- **carbon negative production:** [3, p.74]
  - energy intensive and often requires additional hydrogen
  - provided energy cannot has to emit lesser amounts of CO_2 than converted
- **role of CCU in climate change mitigation:** [5, p. 1120]
  - carbon-negativity only possible if C is from DAC or biomass
  - carbon-reduction still possible if the result replaces an existing product with less GHG

References:

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