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

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1. 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. [1, p. 1-2]

2. Carbon Capture Storage (CCS)

- carbon removal by different approaches (e.g. **direct air capture**) combined with (long-term) fixation of CO_2
- **BECCS:** [5, p. 1124ff]
  - based on biomass-combustion
  - temporary storage and further usage
- **CCS-EFR:** [5, p. 1115ff]
  - fossil-fuel recovery through injection of CO_2 in depleted oil or gas reservoirs
  - further usage
- **CCU:** [5, p. 1064]
  - conversion of captured CO_2 via chemical reactions
  - utilization: e.g. soft drinks
  - further usage
- **storage in geological formations:** [3, p. 80]
  - spent natural gas (NG) wells; only option that can be considered safe (after sealed correctly)
  - long-term storage
- **storage in water**: [3, p. 80]
  - (saline) aquifers or deep waters (<3000m)
  - as solid carbonhydrates or in containers
  - long-term storage

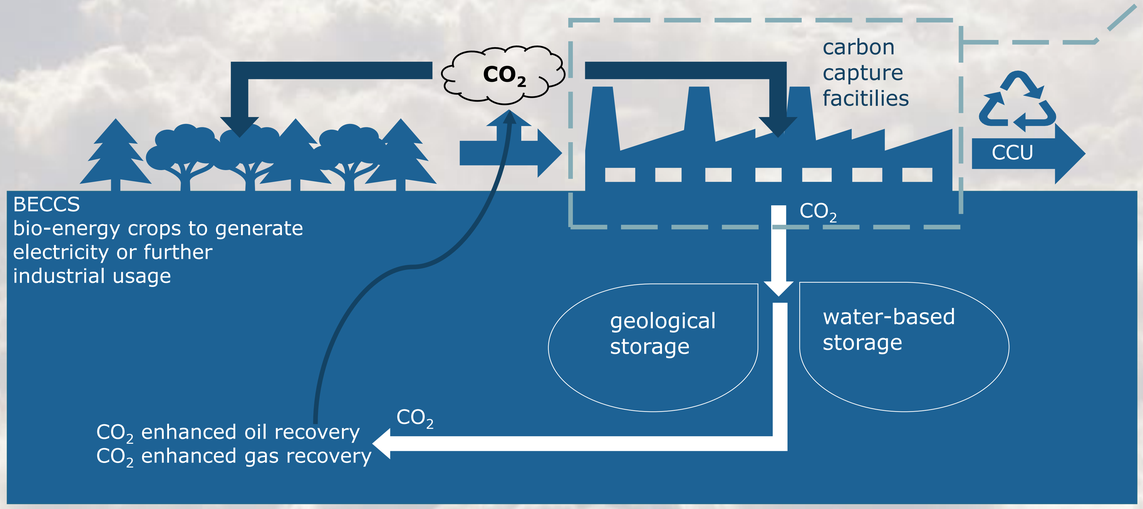

Figure 1: Circle of CO_2 in different carbon capture and storage (CCS) and utilization approaches. a) CCS via bioenergy with CCS (BECCS) or via carbon capture facilites combined with storage approaches. b) Carbon capture with the intention of further use through CO_2 enhanced fossil-fuel recovery (CCS-EFR) and carbon conversion and utilization (CCU). (source: own presentation)

3. Direct Air Capture (DAC)

Functionality

- large volume fans or pumps are supplied with ambient air [3, p. 79]
  - CO_2 gets removed by passing a CO_2-absorber, like NaOH or $Ca(OH)_2$
  - binding in sodium carbonates (soda) or calcium carbonates (chalk) [3, p. 88]
- after capture -> several other usage and storage possibilities

Advantages

- decentralized and ubiquitous approach [3, p. 79]
- low projected cost: 80-130$/t CO2 [3, p. 79]
- most cost-effective option when included in industrial plants or provided with energy from gas or water [2, p.1]

Disadvantages

- atmospheric CO_2-concentration is quite low **->** tight binding in strong chemicals is needed [3, p. 88]
- energy intensive: *Climeworks* needs 1100 kWh/t CO_2 [3, p. 98]
- actually cost intensive: 600$/t CO_2, won‘t commercialize [3, p. 90]
- applicability (example): one *Climeworks* collector captures 50t 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]

Can we really combat climate change through carbon removal approaches?

- carbon removal ≠ zero-emissions
- quite expensive
- key issues: [3, p. 81]
  - availability of sites
  - distance to the disposal site (transportation cost)
  - real economic costs and energetic costs
  - scarce knowledge of CO_2 persistence when disposed
  - trade-offs (e.g. food production) with different CCS approaches (mainly BECCS)
- possible negative feedback loops: [1, p. 9-10]
  - permafrost degradation
  - continuing sea-level rise
  - outgassing of CO_2 sinks
- other GHG, like CH_4, No_x have to be included in such approaches

Carbon removal **ain’t no silver bullet or game changer**.[1, p. 9f.] Due to the lack of knowledge it has various issues, that need to be fixed by **research**. It is an **“end-of-pipe”-technology** that doesn’t fight the cause of the climate crisis (high GHG emissions and neoliberalism). It should rather be considered as an **additional** approach to e.g. degrowth to achieve climate change mitigation.

- possible to lower GHG
- various studies confirm the possibility reverse temperature rise [e.g. 1, p. 1-2; 7, p. 54ff]
- possible integration of CCS into existing energy systems without large amendments [5, p. 1066]

Carbon removal has the **potential to mitigate climate change**. Actually it is **necessary** and it won‘t be possible to avoid dangerous climate change scenarios without carbon removal.[1, p. 1]

What potential has “direct air capture” and how feasible is it?

- cost-intensive [3, p. 90]
- CO_2-recovery at more concentrated sources (e.g. powerplants) is more convenient [3, p. 90]
- competition with other kinds of land-use [7, p. 55]
- depends on public acceptance [7, p. 55]
- feasability is quite low [3, p. 98]

DAC is a **promising approach** to combat climate change. Even companies like Microsoft invest in this **future-oriented technology**.[4]
But **more reseach** is needed to make the process **less expensive** and **more energy-effective**.

Figure 2: DAC facility by *Climeworks*, a swiss enterprise dedicated to carbon removal, in Hinwil, Switzerland [4]
© Climeworks; https://climeworks.com/co2-removal

References:

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