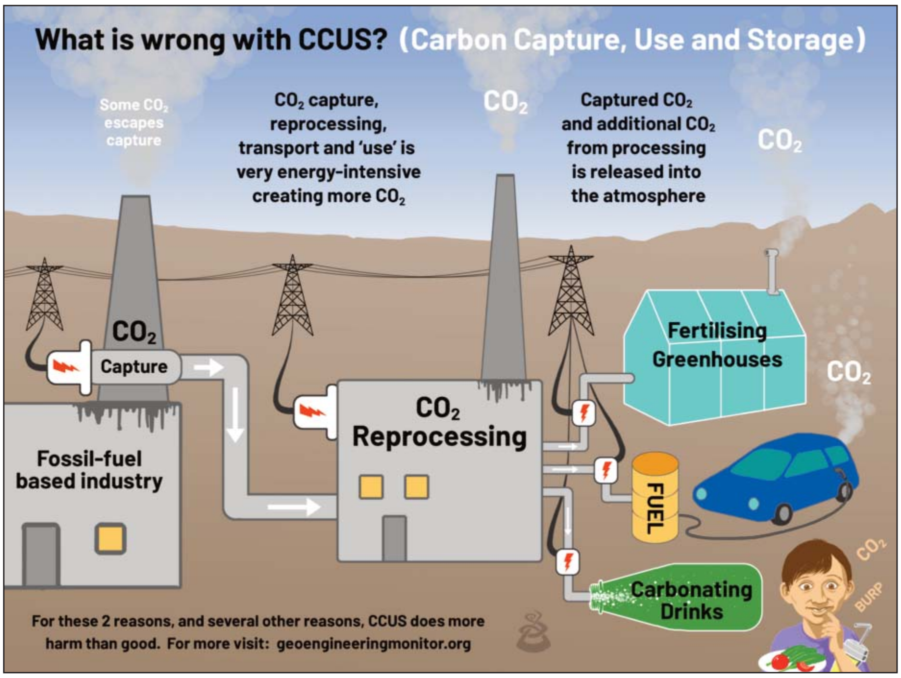
Carbon Capture Use and Storage (CCUS)

Description and purpose of the technology

Carbon Capture Use and Storage (CCUS) is a proposed carbon dioxide removal (CDR) technology that aims to capture CO_2 from industrial exhaust fumes or directly from the atmosphere. The captured CO_2 is used as a feedstock in manufacturing, so it becomes "stored" in manufactured goods – until it is again released into the atmosphere.



In theory, Carbon Capture Use and Storage aims to convert captured carbon into products like fuel, fertilizer and plastic.

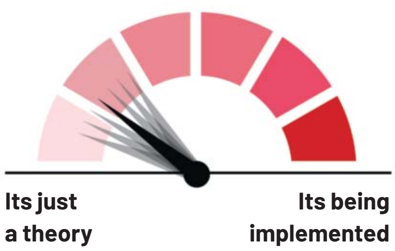
There are different CCUS pathways: Enhanced Oil Recovery (EOR), CO_2-based chemicals and fuels, microalgae-based fuels and products, CO_2-based plastics, CO_2 used in construction materials, and CO_2 used for agriculture, food and feed.[1] CCUS is understood as an attempt to make Carbon Capture and Storage (CCS) profitable. Most CCUS scenarios are still theoretical but some technologies are currently being commercialized.

The primary critique of CCUS – as with CCS and DAC- is that it extends the life of dirty energy in poor communities around the world, with acute environmental justice, health and economic impacts, while having little evidence it can address the climate crisis at the scale required.

Furthermore, the captured CO_2 emissions will be re-released into the atmosphere rendering the technology basically useless to stop climate change. Emissions are not permanently stored but are embedded in products or re-released through incineration or decomposition processes. Additionally, CCUS is based on CO_2 removal technologies, that are very energy-intensive, costly and technologically challenging.[2]

Point of Intervention:

Reality Check:



Production, transport and infrastructure require the production of additional emissions. The upshot: CCUS is likely to lead to more emissions rather than less – in particular if one takes into account that CCS is already prone to generating more emissions that it captures (see Technology Briefing on CCS).

Actors involved

Most CCUS activities are based in Northern America, Europe, China, India and Japan. Many initiatives receive capital support by foundations, industry and public funding agencies. Industrial sponsors come primarily from energy-intensive industries, among them British Airways, Chevron, ExxonMobil, HuaNeng Group, Indo Guld Fertilizer Co., and Occidental. The US-DOE is the largest public investor.[3]

CCUS pathways

Enhanced Oil Recovery (EOR): While CCUS is sometimes referred to as an attempt to distance CCS from EOR, EOR is by far the single biggest user of captured CO_2 and most likely the most profitable market for it in the future. EOR is discussed in more detail in the CCS briefing. Briefly, EOR refers to injecting pressurized CO_2 to recover otherwise inaccessible oil or pumping CO_2 into aging oil reservoirs, extracting up to 50 percent more of the oil originally available in a well. Naturally-occurring CO_2 is used most commonly because it is cheap and widely available, but CO_2 from anthropogenic sources is becoming more common,[4] particularly from CCS installations in North America. For example, of 21 operational, commercial-scale facilities called CCS world-wide, 16 send their captured CO_2 for use in EOR, and both facilities listed as being under construction are for EOR too.[5] In this case, EOR is certainly Carbon Capture and Use, but it is not Storage: estimates indicate that about 30 percent of the EOR-CO_2 return back to the surface with the pumped oil, and any CO_2 that does stay underground enables even greater emissions from the extra oil that is extracted and then burned.[6]

CO_2-based chemicals and fuels

Another idea is to use captured CO_2 as a feedstock for chemicals and fuels. This can be achieved through carboxylation reactions where the CO_2 molecule is used to produce chemicals such as methane, methanol, syngas, urea and formic acid. CO_2 can also be used as a feedstock to produce fuels, e.g. in the Fischer-Tropsch process. However, CO_2 is, thermodynamically, a highly stable molecule, which is why reactions with CO_2 usually require considerable amounts of energy.

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Furthermore, chemicals and fuels are stored for less than six months before they are used and the CO_2 is released back into the atmosphere very quickly.[7] As with EOR, this is CCU, but not Storage.

Creating biofuels and further products from microalgae

This approach aims to use microalgae to fix captured CO_2 and use the harvested algae as a source material to produce biofuels, animal feed, nutraceutical or cosmetics. Most projects, the majority still in a fledgling state, plan to redirect CO_2-rich emissions from industrial facilities into algae ponds or photobioreactors.[8] It can be questioned, whether microalgae that have been in direct contact with polluted effluents can be successfully marketed for high-value products such as cosmetics. Some R&D approaches involve the use of genetically modified algae strains, e.g. to improve tolerance to high levels of CO_2 or introducing an ethylene-producing gene.[9] Containment of the organisms in production facilities would be next to impossible, and the consequences for human health and natural environments are unknown in case of an escape.[10] Roughly 40 percent of the approximately 50 known algae-based CCUS initiatives ceased activities over the last years. The majority of the remaining projects are in the development stages and aim to develop biofuels.[11]

Climate-saving technology?
CCUS is often more about Enhanced Oil Recovery (EOR) than reducing emissions
Photo: Richard Masoner / Cyclelicious via Flickr

CO_2-based plastics

The California-based Newlight Technologies and the UK-based Econic Technologies develop processes to convert captured CO_2 into plastic materials.[12] Besides having a questionable energy balance, this technology would only be an effective carbon capture approach if the plastics never degraded, or were never incinerated as waste.

CO_2 used in construction materials

In the construction sector, a small number of companies have developed and patented processes to turn captured CO_2 into calcium or magnesium carbonate to produce materials such as building blocks, roofing tiles or fill materials. During this mineral carbonation process, CO_2 reacts with a metal oxide such as magnesium or calcium to form carbonates. The process is similar to Enhanced Weathering (see Technology Briefing on Enhanced Weathering) where silicate and carbonate minerals rich in Calcium and Magnesium would react with atmospheric CO_2 to turn into stable carbonates. As with Enhanced Weathering, the energy penalty and costs including the mining, transportation and preparation of the minerals, are massive. These likely outweigh any benefits of the approach. The Finnish research project BECCU aims to develop insulation materials for the construction sector, using CO_2 and hydrogen as the feedstock.

Two Canadian companies seek to develop substitutes for cement: Terra CO_2Technologies Ltd. develops a process to convert CO_2 and mine waste into cementitious materials. Carbicrete received public and industrial funding to develop a concrete made from steel slag and CO_2. All approaches have the objective to lock CO_2 into construction materials as a way of "greening" the very significant emissions of the cement industry.

These processes, in theory, could be capable of storing a fraction of the emitted CO_2 for longer periods. However, all approaches are associated with considerable expenditure of energy, permanent CO_2 storage is not enabled and the potential to sequester CO_2 is rather limited.[13]

CO_2 used for agriculture, food and feed

This pathway uses CO_2 as a feedstock to produce food and feed, to distill and carbonate beverages, or for CO_2 fertilization in greenhouses. Among the products and R&D approaches are proteins for aquaculture feeds or meat substitutes, alcoholic beverages and beverage-grade CO_2. Under each of these approaches, the captured CO_2 re-enters the atmosphere within short periods of time, despite the high energy costs of capturing it in the first place.

In the case of CO_2 fertilization in greenhouses, a pathway used and promoted by several Direct Air Capture companies, a complete absorption of CO_2 by the greenhouse crops is not achievable. The described pathways are further examples of CCU (but not storage!): as soon as the food or feed is digested or composted, a significant amount of the carbon will be re-released.[14]

Reality check

All of the technologies described above are being commercialized to varying extents and levels of success. However, the large majority of them are still in the development stage. Hundreds of millions of USD have been invested by industry as well as by public sources.

With the exception of EOR, which is a well-established process (but not a carbon storage technique) companies involved tend to be start-ups aiming to profit from the hype around so called "negative emissions", in an attempt to increase the value of captured CO_2.[15]

Further reading

ETC Group and Heinrich Böll Foundation, **"Geoengineering Map",** https://map.geoengineeringmonitor.org/

Geoengineering Monitor (2020) ***An introduction to CCUS proposals and their viability,*** http://www.geoengineeringmonitor.org/2020/07/can-captured-carbon-be-put-to-use/

Endnotes

1 ETC Group and Heinrich Böll Foundation (2020) Geoengineering Map, https://map.geoengineeringmonitor.org/

2 Ibid; Heinrich Böll Foundation and ETC Group (2020) Geoengineering – Technology Briefing: Direct Air Capture (DAC), October 2020, http://www.geoengineeringmonitor.org/2020/10/direct-air-capture-2/

3 ETC Group and Heinrich Böll Foundation (2020) Geoengineering Map, https://map.geoengineeringmonitor.org/

4 Cuéllar-Franca and Azapagic (2015) Carbon capture, storage and utilisation technologies: A critical analysis and comparison of their life cycle environmental impacts, Journal of CO2 Utilization, Vol. 9: 82 - 102, https://doi.org/10.1016/j.jcou.2014.12.001; Heinrich Böll Foundation and ETC Group (2020) Geoengineering – Technology Briefing: Carbon Capture and Storage (CCS)

5 Global CCS Institute (2019) Global Status Of CCS 2019, https://www.globalccsinstitute.com/wp-content/uploads/2019/12/GCC_GLOBAL_STATUS_REPORT_2019.pdf; Global CCS Institute (2020) Global CCS Institute welcomes the 20th and 21st large-scale CCS facilities into operation, published: June 3, 2020, https://www.globalccsinstitute.com/news-media/press-room/media-releases/global-ccs-institute-welcomes-the-20th-and-21st-large-scale-ccs-facilities-into-operation/

6 Cuéllar-Franca and Azapagic (2015); Heinrich Böll Foundation and ETC Group (2020) Geoengineering – Technology Briefing: Carbon Capture and Storage (CCS)

7 For more information see: https://en.wikipedia.org/wiki/Fischer%E2%80%93Tropsch_process; ETC Group and Heinrich Böll Foundation (2020) Geoengineering Map, https://map.geoengineeringmonitor.org/

8 ETC Group and Heinrich Böll Foundation (2020) Geoengineering Map, https://map.geoengineeringmonitor.org/

9 Heikkinen (2015) Genetically Modified Algae Could Replace Oil for Plastics, in: Scientific American, published: August 17, 2015, https://www.scientificamerican.com/article/genetically-modified-algae-could-replace-oil-for-plastic/; Wei, et al. (2019) Knockdown of carbonate anhydrase elevates Nannochloropsis productivity at high CO2 level, in: Metabolic Engineering, Vol. 54: 96 - 108, https://doi.org/10.1016/j.ymben.2019.03.004

10 Biofuelwatch (2017) Microalgae Biofuels Myths and Risks, published: September 2017, https://www.biofuelwatch.org.uk/wp-content/uploads/Microalgae-Biofuels-Myths-and-Risks-FINAL.pdf

11 ETC Group and Heinrich Böll Foundation (2020) Geoengineering Map, https://map.geoengineeringmonitor.org/

12 ETC Group and Heinrich Böll Foundation (2020) Geoengineering Map: Econic Technologies Ltd, https://map.geoengineeringmonitor.org/Carbon-Cioxide-Removal/econic-technologies-ltd/; ETC Group and Heinrich Böll Foundation (2020) Geoengineering Map: Newlight Technologies, https://map.geoengineeringmonitor.org/Carbon-Cioxide-Removal/newlight-technologies/

13 Cuéllar-Franca and Azapagic (2015); ETC Group and Heinrich Böll Foundation (2020) Geoengineering Map

14 ETC Group and Heinrich Böll Foundation (2020) Geoengineering Map, https://map.geoengineeringmonitor.org/

15 ETC Group and Heinrich Böll Foundation (2020) Geoengineering Map, https://map.geoengineeringmonitor.org/