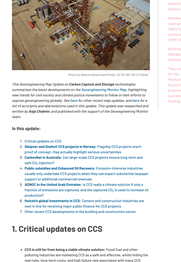

GEOENGINEERING
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OVER-PROMISING AND UNDER-DELIVERING FOR HALF A CENTURY: CCS IS STILL A RISKY AND UNPROVEN TECHNOLOGY

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*This Geoengineering Map Update on **Carbon Capture and Storage** technologies summarises the latest developments on the Geoengineering Monitor Map, highlighting new trends for civil society and climate justice movements to follow in their efforts to oppose geoengineering globally. See here for other recent map updates, and here for a list of acronyms and abbreviations used in this update. This update was researched and written by **Anja Chalmin**, and published with the support of the Geoengineering Monitor team.*

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1. Critical updates on CCS

- **CCS is still far from being a viable climate solution:** Fossil fuel and other polluting industries are marketing CCS as a safe and effective, whilst hiding the real risks, long-term costs, and high failure rate associated with many CCS projects.
- **Flagship projects show that CCS is risky**: CCS is often presented as proven technology by referencing flagship projects, but the unforeseen problems and challenges they have encountered are rarely mentioned.
- **Larger CCS projects may cause larger problems**: Extensive research into numerous small-scale CCS projects has shown that subsurface conditions are unpredictable. It is therefore doubtful that CO2 will remain effectively and safely contained whatever it is injected into in larger CCS projects with significantly higher CO_2 injection volumes.
- **Potential for GHG leaks remains a serious risk:** There is no evidence that CO_2 injected into geological formations will remain there in the long term, and many of the companies developing CCS projects and claiming that it is safe are also releasing large amounts of methane, a potent GHG, from abandoned oil and gas fields.
- **Lack of clear responsibility for high follow-up costs:** A common theme in many new CCS projects currently being planned is the lack of clarity over how CO_2

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injection sites will be monitored, and who will foot the costs in the event of leaks and other problems.

- **Huge number of projects in the pipeline do not prove the efficacy of the technology:** According to industry, the fact that there are hundreds of planned CCS projects shows that CCS is a functioning as a climate solution. However, the hundreds of CCS projects that have been cancelled or (prematurely) terminated are being ignored.
- ***"50-year track record of over-promising and under-delivering"***: Despite the fact that research into CO_2 capture and CCS has been around for 100 and 50 years respectively, and the billions of taxpayers' money that has been invested in CCS, companies claiming to be experts in the field still have little to show in terms of results. On top of this, emissions from fossil fuels reached a new record high in 2023, with CCS playing no visible role in mitigation efforts.
- **Inefficient, energy-hungry and costly**: Many of the large-scale CCS projects currently being planned will capture only a fraction of global CO_2 emissions, whilst ignoring the additional emissions created by energy-intensive CCS processes. It is also still much more expensive to remove carbon from the atmosphere than to avoid emitting it in the first place.
- **Only viable if taxpayer-funded or used to generate additional revenue:** CCS projects are often only implemented by emission-intensive industries if they receive substantial taxpayer support, earn carbon credits, or increase oil production through Enhanced Oli Recovery (EOR).
- **No contribution to the 1.5°C target:** Many of the CCS projects that have been announced to date are only due to begin operations from the 2030s and onwards, and most have not yet received final investment decisions. In addition to the unproven effectiveness of CCS, the timing and scale of these projects mean that they cannot contribute to the Paris Agreement's 1.5°C target in any meaningful way.

2. Sleipner and Snøhvit CCS projects in Norway: Flagship CCS projects aren't proof of concept, they actually highlight serious uncertainties

Norway's Sleipner and Snøhvit CCS projects are repeatedly cited as proof that CCS is technically proven and safe in the long term by oil and gas giants and lobbyists such as Gassnova, Equinor, Wintershall Dea, the Global CCS Institute (GCCSI), Norwegian Petroleum, the Zero Emissions Platform, and Carbon Capture & Storage Europe.

Sleipner and Snøhvit are two of the longest-running CCS projects, and are examples of the uncertainties associated with underground CO_2 injection. This is highlighted by the extensive research and monitoring that has taken place throughout the projects' lifetimes, which has included EU-funded research projects such as CO2ReMoVe, CO2STORE, ECO2, SACS1, and SACS2. They are also

The natural gas extracted from some of Sleipner's gas fields is not marketable due to its high CO_2 content, so the Sleipner CCS project separates CO_2 from it. The captured CO_2 is then injected into the offshore Utsira geological formation in the North Sea. Large-scale, unplanned and unexpected movements of injected CO_2 have been observed from deeper into upper parts of the formation. The injection of water, sand, and liquid waste into the Utsira formation has also resulted in unexpected cracks in the rock formation and oil spills. A gas leak at Equinor's Sleipner field in 2022 is another indication of the unpredictability of subsurface conditions, and shows that problems are still likely to occur in relatively small-scale CCS projects where the injection reservoir has been intensively researched and explored.

Due to unforeseen problems, Equinor's Snøhvit CCS project has had to drill CO_2 injection wells at three locations in the Snøhvit field instead of just one. Initially, the Tubåsen sandstone formation was chosen as the injection site, with a predicted lifetime of 18 years. CO_2 injection had to be stopped after less than two years because the pressure in the reservoir quickly rose to critical levels, much faster and higher than had been predicted. The second injection site was in the Stø formation, which turned out to have less CO_2 storage potential than expected and could only be used as an interim solution. As a result, Equinor had to find a third injection site, which was also in the Stø formation but closer to the Snøhvit gas production wells. Equinor invested US$ 225 million in drilling the third CO_2 injection well and two new production wells, but in 2023 cancelled plans to scale-up the Snøhvit CCS project.

3. CarbonNet in Australia: Can large-scale CCS projects ensure long-term and safe CO_2 injection?

The publicly-funded CarbonNet CCS project aims to develop a "commercial-scale" CCS network in the Gippsland region of Victoria, south-east Australia. The project plans to capture six million tonnes of CO_2 per year from a range of industries, and the captured CO_2 will be transported to AGL's Loy Yang A coal-fired power station. From there it will be piped offshore to the Gippsland Basin in the Bass Strait for injection into the Pelican and Kookaburra formations. In 2022 AGL announced it would close the Loy Yang A plant in 2035, a decade earlier than originally planned. The final investment decision for the CCS project was due in 2023, but has now been delayed to 2024.

CarbonNet is just one example of many projects that aim to capture larger volumes of CO_2 for injection into underground formations, but where there is a lack of clarity over the extent to which and how the injection sites will be monitored, and who will pay for remedial action in the event of leakages and other problems that could occur. Furthermore, unpredictable subsurface conditions observed in extensively-monitored small-scale CCS projects make it doubtful that safe and effective storage can be ensured in much larger CCS projects, such as CarbonNet's. The project is also one of several examples that presents CCS as a working technology simply by listing other ongoing and planned CCS projects, whilst projects that have developed problems or been cancelled or prematurely terminated are ignored.

4. Public subsidies and EOR:

Emission-intensive industries usually only undertake CCS projects when they can expect substantial taxpayer support or additional commercial revenues

The Porthos CCS project aims to capture CO_2 in the Rotterdam port area in the Netherlands, compress it and then pipe it for injection into the depleted North Sea P18 gas field. In 2021, Porthos signed CO_2 transport and storage contracts with Air Liquide, Air Products, ExxonMobil, and Shell. The four companies are expected to capture a total of 2.5 million tonnes of CO_2 annually from their industrial sites in the port area, representing 10 % of the Port of Rotterdam's industrial emissions. In 2020, the port emitted 22.4 million tonnes of CO_2, equivalent to almost 16 % of the Netherlands' total emissions.

Although the Porthos project will only capture a small fraction of the port's total emissions, Dutch taxpayers will be footing over € 2 billion for the project, and the EU has also invested more than € 100 million in it. On top of this, two similar CCS projects at the Port of Rotterdam have already failed: The Rotterdam CCS Demonstration Project (ROAD) was cancelled in 2017 despite having received more than € 200 million in public funding, and the Rotterdam Climate Initiative was cancelled in 2018.

The Petra Nova CCS project is located at NRG Energy Inc.'s W.A. Parish gas and coal-fired power plant near Houston, Texas, which is one of the five most polluting power plants in North America. The project aims to capture CO_2 from the 240MW coal-fired Unit 8, and pipe it to the West Ranch oilfield where it is used for EOR. It was suspended in 2020, after three and a half years of operation, due to low oil prices and technical problems that it encountered. According to press reports, the CCS unit was unable to operate for a third of the time that the project was running for, and only captured 7 % of the plant's total emissions.

In 2022, NRG sold its stake in the Petra Nova CCS project to JX Nippon for US$ 3.6 million – a tiny fraction of the project's estimated US$ 1 billion cost. JX Nippon restarted the CCS project in September 2023 in order to take advantage of the fact that, since the project had been halted, the US's Section 45Q Carbon Capture Tax Credit, which subsidises CCS projects, had risen from US$ 12 to US$ 60 per tonne of CO_2 captured, and the price of oil had almost doubled in the same time. The Institute for Energy Economics and Financial Analysis (IEEFA) analysed Petra Nova's performance and documented issues around transparency and finances, and demanded that the company should "*Stop taking U.S. taxpayers for a ride on a CCS money guzzler* [...] *the U.S. government must sharply scrutinize all claims made by applicants for federal dollars to promote CCS technology*".

Another recently-announced CCS project linked to EOR is set to take place at Indian Oil Corporation Ltd's Koyali refinery in the state of Gujarat, in India. The project aims to capture CO_2 at the refinery and transport it around 110 km to Oil and Natural Gas Corp. Ltd's (ONGC) Gandhar oil field, where it will be used to boost oil production from ageing wells. ONGC also signed an MoU with Norway's Equinor in 2023 to jointly explore further CC(U)S opportunities in India.

5. ADNOC in the United Arab Emirates:

Is CCS really a climate solution if only a fraction of emissions are captured, and the captured CO_2 is used to increase oil production?

ADNOC is one of the world's largest oil and gas producers, and is wholly owned by the Emirate of Abu Dhabi. The company says it emits seven kilograms of CO_2 equivalent per barrel of oil, but it only takes responsibility for emissions relating to the extraction of fossil fuels (Scope 1 & 2 emissions). It does not include the amount of CO_2 emitted when the fossil fuels it extracts are burned or processed by the end user (Scope 3 emissions) in its own inventory, which Global Witness analysis estimates to have reached up to 487 million tonnes in 2023. Sector-wide, the oil and gas industry's Scope 3 emissions account for approximately 85 % of the total GHG emissions they are responsible for.

In 2022, ADNOC produced approximately 960 million barrels of oil and 60 billion cubic metres of gas, and the company plans significant increases in its production. Recent estimates show that ADNOC will produce more than 1.3 billion barrels of oil and nearly 90 billion cubic metres of gas by 2030, resulting in an increase in annual CO_2 emissions of more than 40.5 %, to 684 million tonnes.

ADNOC's website touts CCS as an effective climate change mitigation measure, but fails to mention that its only CCS project to date is designed to increase oil production. ADNOC has been implementing the Al Reyadah CCS project at Emirates Steel Industries' iron and steel plant in Mussafah, UAE, since 2009 and, according to the company, 0.8 million tonnes of CO_2 have been captured annually since 2016. The captured CO_2 is compressed and piped to ADNOC's mature onshore Rumaitha and Bab oil fields, where it is used to extract hard-to-reach oil reserves, thereby increasing production volumes. The project therefore results in significant new emissions due to the fact that CO_2 capture is very energy-intensive and, when the it is used for EOR, a large proportion of the captured CO_2 escapes into the atmosphere.

ADNOC is planning further CCS projects, including the Fujairah and Ruwais pilots. Both were expected to be operational in 2023, but there is no indication that this is now the case. The Fujairah pilot, in partnership with Omani company 44.01, aims to test the mineralisation of CO_2 in geological formations in the UAE. The Ruwais CCS pilot is expected to capture 4,000 tonnes of CO_2 per year at the Fertiglobe fertiliser plant in the Al Ruwais Industrial Complex, UAE. ADNOC was previously involved in another geoengineering project at the same site, a CCUS scheme which aimed to produce additional fertiliser using captured CO_2, but the project was cancelled for unknown reasons.

ADNOC also plans to implement three more CCS projects in the UAE by the second half of this decade. One project aims to produce "blue ammonium", combining the production of ammonium from natural gas with CCS. The CCS projects at the Habshan and Hail & Ghasha sites are each expected to capture 1.5 million tonnes of CO_2 per year from natural gas or oil production. The Hail & Ghasha site alone is expected to produce around 40 million cubic metres of natural gas per year, equivalent to about 24 million tonnes of CO_2. This means that the CCS project will only capture around 6 % of the site's total CO_2 emissions, not including the additional emissions resulting from the energy-intensive CCS process and the likelihood that the captured CO_2 will be used for EOR.

6. Holcim's global investments in CCS:

Cement and construction industries are next in line for receiving major public finance for CCS projects

The Holcim Group is the world's largest producer of cement and building materials and is headquartered in Zug, Switzerland. According to the University of Massachusetts Amherst's 2022 Greenhouse Polluters Index, Holcim ranks 47th out of the US's top 100 emitters. According to its 2022 Sustainability Report, Holcim's operations globally emitted around 78 million tonnes of CO_2 (Scope 1 emissions) into the atmosphere.

The Geoengineering Map features around 20 projects involving Holcim, including five that are ongoing, 13 planned, one completed, and one cancelled. On its website, Holcim commits to reducing its emissions and describes CC(U)S as a key technology for achieving this. Holcim also describes itself as being "*at the forefront of Europe's decarbonization*" and as having "*CCUS projects around the world*", but to date has only conducted small-scale CO_2 capture trials at three sites. Further still, one of the major findings of Holcim's completed R&D Project, AC^{2}Ocem, was that CO_2 capture at cement plants increases overall operational costs by around 30 %, mainly due to higher energy consumption. This casts serious doubts over the commercial viability of CCS in the sector.

Holcim has committed to investing € 2.15 billion in CC(U)S projects worldwide by 2030, but no final investment decisions have yet been made for its planned CC(U)S projects, and how the projects will be financed has not yet been disclosed. For example, Holcim estimates that its planned projects at the Lägerdorf cement plant in Germany and the Kujawy cement plant in Poland will cost € 6 billion and € 4.7 billion respectively. It is therefore very likely that, with a total budget of € 2.15 billion, Holcim will be looking for large amounts of public finance in order to implement future projects.

The Holcim Group is a representative example of a company investing in CCS: It claims that the technology works at scale, even though the few operational projects it is involved in do not capture significant amounts of CO_2. Most of its projects are in the planning stage, and project financing is unclear and in many cases dependent on large public subsidies. In addition, many new CCS projects are being touted as large-scale, even though they plan to inject little more (and sometimes less) CO_2 than Norway's 27-year-old Sleipner CCS project.

Holcim's five ongoing projects include:

- Three small-scale CO_2 capture tests at Holcim cement plants in Beckum, Höver, and Richmond that have received millions in public funding from the Canadian Federal Government, various Canadian research programmes, the Government of British Columbia, the German Federal Ministry of Economics and Climate Protection, and the German Federal Ministry of Economics and Technology.
- Two collaborations that aim to generate income through carbon credits (Neustark AG and Solidia Technologies).

Holcim's 13 planned projects include:

- Six CC(U)S projects at Holcim cement plants (Koromacno, Kujawy, Lägerdorf, Le Teil, Milaki, and Obourg) that have been selected for support by the EU Innovation Fund, including three projects in Croatia, Germany, and Poland that will receive a total of € 575 million, and which plan to capture 0.4 to 1.2 million tonnes of CO_2 per year. Details of the projects in Belgium, Greece and France are yet to be fully released.
- Further CC(U)S projects are planned at the following Holcim cement plants: Carboneras, Exshaw, Genevieve, Mannersdorf, Portland, and an undisclosed Canadian Lafarge plant. The projects are expected to capture between 0.01 to 2.75 million tonnes of CO_2 per year and will receive millions in public funding.
- The All4Zero CCUS hub in Spain was announced in September 2023 by Holcim, Spanish airline Iberia, and oil producer Repsol. Information on the financing and timescale of the project has not yet been disclosed.

Completed project: EU-funded AC^{2}Ocem R&D project on CO_2 capture technology

Cancelled project: Algae project in Sri Lanka.

7. Other recent CCS developments in the building and construction sector

Belgium – Holcim's Obourg cement plant: Holcim has sought financial support from the EU to ensure the CCS project's viability.

Croatia / Mediterranean – Holcim Koromacno CCS project: The project involves transporting captured CO_2 by ship for injection into an offshore formation in the Mediterranean Sea. This is the first known example of a CO_2 injection site in the Mediterranean, but the exact location has not yet been revealed.

Germany – Holcim Höver cement plant: UK-based Cool Planet Technologies Ltd. was established with the aim of commercialising a membrane-based CO_2 capture technology, and Holcim started testing Cool Planet's CO_2 capture technology at its Höver cement plant in 2023.

Poland – Holcim's Kujawy cement plant: The project is expected to capture 1.2 million tonnes of CO_2 per year from a cement production plant, and is described as *“the first CO_2 capture project of this size in the world”.* For comparison: The 27-year-old Sleipner CCS project in Norway captures on average 0.8 million tonnes per year.

USA – Holcim's Genevieve cement plant: In October 2023, Holcim announced plans to increase production capacity to more than 5.1 million tonnes of cement per year at the site by the end of 2025. A CCS project has been announced as part of the planned expansion and is expected to capture 2.75 million tonnes of CO_2 per year, but it will not start until 2028/2029. The high energy consumption associated with CO_2 capture is cited as a major drawback in a recent study conducted at the site.

Abbreviations and acronyms

ADNOC	Abu Dhabi National Oil Company
CCS	carbon capture & storage
CCUS	carbon capture use & storage
CO_2	carbon dioxide
EOR	enhanced oil recovery
EU	European Union
GHG	greenhouse gas emissions
H_2	hydrogen
IEEFA	Institute for Energy Economics and Financial Analysis
R&D	research and development
UAE	United Arab Emirates

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