The Second Steps: Carbon Capture & Sequestration

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1. Introduction

The second steps are directly capturing the primary greenhouse gas (GHG) from either the exhaust of some process that emits it, or:

- Directly from the atmosphere, or
- The oceans & other large bodies of water

And sequestering it. The best sequestration method is injecting the gas in deep geological strata.

Carbon Capture & Sequestration (CCS) is a process with a long history. Unfortunately, that history is in the petroleum industry, and thus I'm going to change my style for this paper. The main source for this is the same as for my first "First Steps…" paper (summarized and linked below),[1] albeit the next chapter in that book. This story has a strong protagonist, and I will seek to paint him in a positive light, because he effectively promotes CCS. We will badly need this technology, although it will be tough for my readers to trust a technology developed by the petroleum industry. Thus, I'm presenting a more personal viewpoint in hopes of buying a bit of sympathy.

The First Steps: Low-Carbon Cement: *Important first steps in mitigating the current and future effects of climate change are moving to net-zero greenhouse gas (GHG) emissions. But assuming we don't wish to wait around for a millennium or two for Mother Nature to clear all of the human-caused GHG from our atmosphere, they are not enough. We also need to actively remove GHG from our biosphere.*

This post is about one of the "Important first steps…" Making cement causes as much as 8% of global GHG emissions, and there aren't yet any economical technologies capable of significantly reducing the product's carbon footprint. Cement plants can last for fifty years or more, lowering the turnover rate for new technologies to enter the market. Cement is also a cheap and bulky product, which means plants have to be widely distributed geographically…

The cement industry also enjoys laxer regulations on emissions compared with, say, power plants. Fortunately, Breakthrough Energy Ventures (BEV), a multi-billion-dollar fund has invested in over 100 climate startups, including companies that produce low-carbon cement, and thus low carbon concrete.

[*https://energycentral.com/c/ec/first-steps-low-carbon-cement*](https://energycentral.com/c/ec/first-steps-low-carbon-cement)

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[1] Akshat Rathi, Climate Capitalism, Section 7, The Wrangler, Greystone Books, Copyright, 2024

2. CCS

Climate change is a problem of what is up in the air, but Dr. Julio Friedmann's focus is oriented in the opposite direction: under the ground. For that's where the story began, as fossil fuels were dug up and burned. And, he argues with conviction, that's where the story should end, as carbon dioxide is buried back down.[2]

Friedmann is a geologist, a storyteller of the subsurface. Bore down through the Earth's crust, and he can walk you through the history of our planet over hundreds of millions of years. In fact, sometimes there is no need to drill. Just as ultrasound can be used to peer inside a soon-to-be mother's belly, revealing the tiny toes of her growing baby, so geologists can send soundwaves into the ground. Different layers of rock then reflect the sound back differently, revealing what they are made of and the secrets they may hold.

And in the same way an ultrasound can change a parent's life forever, a readout changed Friedmann's life. In 2001, during a routine meeting at the University of Maryland, he saw ultrasound images of a piece of crust off the coast of Norway. State-owned oil company Statoil (now Equinor) was capturing carbon dioxide from its oil and gas extraction, compressing it into a liquid, and then pumping it down deep underground. Often oil and gas fields also contain carbon dioxide, and the company had figured out a way to reinject the greenhouse gas underground, even as fossil fuels were extracted.

'I looked at the picture and - boom - I got the whole thing,' he says. Injected carbon dioxide in a rock changes the way the sound is reflected and shows up, 'like a Christmas tree', on the seismic reflection readout. 'Once the CO_2 *was injected underground;' he says, 'it's just going to stay there for 50 million years' - just as oil remained trapped at those depths, until humans poked a sophisticated straw in and slurped it up.*

By the time Friedmann grasped the potential of this technology to reduce global-warming gases, the oil industry had already commercialized it for decades albeit for a completely different reason. The first use of carbon capture and storage (CCS), as the technology is called, was not to reduce the amount of greenhouse gases dumped in the atmosphere. Rather, it was to increase the production of oil from aging fields.

The fact that CCS was invented by the very industry whose incentives have been aligned with promoting the use of climate-polluting products, rather than cutting emissions, has plagued the technology's development for climate good. That's despite the fact that the technology can, in theory, be applied to cutting emissions of existing facilities, such as power plants and oil refineries, without hindering how they operate, and the fact that it is likely to be an economically viable option to decarbonizing heavy industry, such as cement and steel, which together make up more than 10% of global emissions.

As we have delayed lowering emissions so CCS has become more important in the effort to avert the worst impacts of global warming. In fact, the delay has been so great that most futures modelled by the IPCC to meet the goals set out under the Paris climate agreement require the use of 'negative emissions'. That involves the use of CCS technology to capture carbon dioxide that humans have already emitted directly from the air and then bury it underground.

[2] Dr. Julio Friedmann, https://www.carbon-direct.com/team/dr-julio-friedmann

'We live in a world that is fast and dynamic,' Friedmann says. 'But geological systems are not.' That perhaps can be said of CCS, too. After years of efforts from environmental groups that want to scale the technology, there are now some two-dozen plants capturing and pumping 40 million tons of carbon dioxide into the bowels of the planet. That's a relative pittance, accounting for merely 0.1% of all annual global emissions. The world will need to build infrastructure capable of capturing and storing 100 times as much CO_2 within the next few decades to keep global warming to below 2 °C.

Friedmann, who now works as chief scientist at the consultancy Carbon Direct, understands better than most both the urgency of scaling the technology and the multiple forces holding it back. In a thirty-year career he has worked for the oil giant ExxonMobil, as a researcher at a university and then in a secretive national lab, as a high-level bureaucrat in the US government with a big annual budget, at think tanks shaping policy and in a start-up scaling climate solutions. In all but one of those jobs he's been focused on, as he puts it, 'putting as many tons of carbon back into the ground' as he can. That's why he calls himself a 'carbon wrangler'.

Friedmann has worked all his life in the US, which remains a leader in deploying CCS, even as it has lost the lead in other crucial climate technologies, such as batteries and solar. Crucially, CCS's slow development exposes what's wrong with capitalism as it exists and what needs to be done to reform some aspects of it. If CCS is as necessary as the scientists tell us it is, then Friedmann's experience over the last two decades points to the kinds of lessons that will need to be implemented globally and fast.

Carbon capture was first developed in the 1930s in order to remove a contaminant in natural gas. Many gas fields also contain carbon dioxide (and hydrogen sulphide) - the mixture is called 'sour gas' because CO_2 is slightly acidic in nature and thus sour to taste, like citric acid in lemon juice. Those gases need to be separated before pure natural gas can be sold for commercial use.

One way to neutralize an acid, as students learn in chemistry lessons, is to use a base; the resulting solution will be a salt. To separate out acidic carbon dioxide from any mixture of gases, scientists use a base or alkali called amine (which is essentially ammonia - one nitrogen atom attached to three hydrogen atoms - but with one or more of its hydrogen atoms replaced by something else). As the gas mixture passes through the amine solution, carbon dioxide molecules get caught, like iron filings on the surface of a magnet, forming a salt. Out of one end comes a CO_2-free stream of natural gas ready for use in homes for heating or industrial use; out the other is carbon dioxide, released by heating the amine salt in a separate chamber. The CO_2-free amine is then ready to capture more carbon dioxide from additional gaseous mixture run through the system.

In the early days the expelled carbon dioxide was simply dumped into the atmosphere. Then, in the 1970s oil companies found a use for the greenhouse gas. As oil fields age so their yields decline. That forces engineers to get creative. One method to enhance the recovery of oil is to pump steam underground, increasing the pressure and pushing out more oil. But because oil and water don't mix, steam's ability to draw more oil simply based on increased pressure hits a limit after a while. That's when someone had the bright idea to use carbon dioxide.

In its liquid state, carbon dioxide acts in the same way soap does on food-stained clothes, it dissolves oily matter. It does an even better job than pressurized steam at pushing out oil trapped in tiny pores of sedimentary rock. For every ton of carbon dioxide pumped into these fields, about three-fourths of it comes back up with newly extracted oil. The rest takes the place of the oil it just pushed out, getting trapped in the same pores where oil had been sitting tight for millions of years. That inadvertent benefit is what scientists want to exploit on a much larger scale. Dotted through the earth's crust are many geological formations that can hold CO_2 in much the same way fields trap oil and gas. In fact, there's enough space to put in trillions of tons of carbon dioxide, or much more than humans have put into the atmosphere burning fossil fuels in the last 200 years.

Oil company Equinor, which is majority owned by the Norwegian government, pumps carbon dioxide into underground brine fields found offshore. As liquid carbon dioxide fills up the pores, it pushes out harmless salt water. In Iceland, public utility Reykjavik Energy captures carbon dioxide from a geothermal power plant and then buries it into basaltic rock. At a depth of about 2,300 feet, the greenhouse gas reacts to form minerals - turning CO_2 into rock in less than two years.

But neither CCS's fifty-year history nor its climate potential are widely known or understood, even among many top decisionmakers. 'There are plenty of people on the left and the right, who will tell you that this technology is not ready for prime time,' says Friedmann. 'That's just hogwash.'

Some sceptics fear the unintended consequences of leaks, such as unmonitored escapes of large amounts of greenhouse gas. Others compare CCS to fracking for natural gas, which involves injecting liquids at shallow depths and has a bad reputation among environmentalists for causing contamination of water and small earthquakes. CCS typically involves storing carbon dioxide deep underground, which eliminates fracking-type risks. Still others, who fall for the 'not in my backyard' rhetoric, simply oppose any activity in their immediate surroundings, regardless of its safety or utility. But years of scientific studies suggest these worries are unfounded.

Weeks before countries were set to meet in Paris in 2015 to settle on the now famous climate agreement, a group of forty CCS experts from around the world wrote an open letter to the United Nations. It said: 'As geoscientists and engineers representing decades of scientific research worldwide, we would like to reassure the United Nations... that the geological storage of carbon dioxide… is safe, secure and effective, and we have considerable evidence to show this,' And they went on to present a long list of peer-reviewed studies as evidence. But those facts have not swayed the opinion of enough people – yet.

3. How London Got Its Sewers

I thought I was done with this section. I had used several excerpts from reference 1 and put together a complete story. However, as I was reading near the end of the section referenced, I found a related interesting and amusing story regarding the title of this section, and how it relates to CCS. This is presented below.

Peter Kelemen, a professor of Earth sciences at Columbia University, made the best case for CCS I've ever heard. In about 1820, Kelemen said, London became the world's largest and arguably most important city. It wasn't just the capital of Great Britain; it was the seat from which the empire's rulers controlled nearly half the world's population. But London, in some ways, was still a backwater - it lacked a central sewerage system. 'If you were poor, you threw your waste down in the street,' Kelemen told an audience at the Columbia Global Energy Summit in 2017. 'If you were wealthy, you had a pipe that took it to a cesspool.'

British physician John Snow, now regarded as the father of epidemiology, undertook research in the mid-1800s that eventually showed links between these cesspools and at least three cholera outbreaks, which killed more than 30,000 people in London in the first half of the nineteenth century. To add to the woes, most of the human waste eventually found its way into the River Thames. 'I can certify that the offensive smells, even in that short whiff, have been of a most head-and-stomach-distending nature,' Charles Dickens wrote in a letter to a friend in 1857.

'Then in 1858, there was a summer when it didn't rain,' Kelemen continued. The Thames dried up, and the stench got stronger. It was called the Great Stink. Queen Victoria and the royal court left London; Members of Parliament debated moving to Oxford. Fortunately for those of us who have lived on this Earth since, instead of leaving, they passed legislation to do something. 'They dug up all the largest streets in the world's largest city, and installed central sewers over the next ten years,' Kelemen said. 'It cost about 2% of GDP, and even today it costs about 1% of GDP to maintain the sewers. No one questioned whether that was worth it.'

'Until people have the idea that (throwing CO_2 in the air) is like throwing poop in the street, we're not going to spend what it costs,' he said. In other words, at 2% of global GDP, we can make the CO_2 problem go away. An International Monetary Fund study suggests that GDP in 2100 could be 7% higher if not for climate change. That means the damage climate change can cause far outweighs the cost of preventing it.

Thought about in that way, climate capitalism is about aligning the world with what is considered economic common sense. As much as cutting emissions is going to be hard, it's certainly economically feasible. Government policy plays a huge role in nudging capital to the right places, but it's worth remembering that new policies are experiments that can go wrong. What's most important is to learn from those failures.

I first came to know Friedmann[3] in 2017, a year after he had left the DOE. He was glad of the opportunity to do the work of pushing forward new CCS projects, but: wasn't satisfied. With every year, global emissions were rising. 'We are not close to hitting our climate targets,' he blurted. 'We are making progress on renewables, but we are not making progress on CCS.'

We've kept in touch through the years, and, though the world is still nowhere close to building as many CCS plants as are needed to meet climate goals, Friedmann is happy to see there's been some progress. Surprisingly, under Trump, the US government passed a tax credit to support the deployment of CCS, which has bipartisan support in Congress.

[3] Dr. Julio Friedmann, See Section 2.

Across the Atlantic, both the UK and Norway in 2020 announced impressive funding for the creation of new CCS projects that will be built within a decade. Under the European Union's Green Deal, the price of carbon in the bloc's emissions trading scheme is set to rise, which will help support a business model conducive to the success of CCS projects.

Also in 2020, almost all the major European oil companies set goals to reach net-zero emissions by 2050. That goal will require these companies to not just cut oil and gas production but also invest in cleaner technologies - not just renewables but also CCS. Friedmann's conviction remains that carbon management, including carbon capture, is a crucial solution to the climate problem. That's why, after the stint at Columbia, he joined the start-up Carbon Direct, which works on carbon management solutions.

A CCS plant being built in Norway is an exemplary model of the kind of innovation that can come about if governments and oil companies work together. The Northern Lights project will capture emissions from a cement factory near the capital, Oslo, then compress and load carbon dioxide on to a ship to take it up north, where it will be piped offshore and injected underground. Crucially, because the gas can be transported on ships run by oil companies like Shell, Total and Equinor, there is an opportunity for other countries to pay Norway to carry away their carbon waste and store it in the Norwegian shelf- much like some countries pay others to get rid of their household waste.

'If you care about climate change, you've got to care about climate math,' says Friedmann. And there is just no way to make the math work without CCS, not least because humanity has the task of cutting emissions for decades. In fact, keeping our climate goals will mean we need to draw down some of the carbon dioxide dumped in our atmosphere.