Carbon capture and sequestration: a solution that is struggling to materialise

Carbon capture and sequestration (CCS) prevents the release of greenhouse gases into the atmosphere by recovering carbon dioxide at the emitting facilities and then storing it or using it, possibly after transport. CCS could quickly reduce greenhouse gas emissions from power generation and industry without the need to reduce fossil fuel consumption. The technical feasibility of this solution has been demonstrated by pilot projects including Petra Nova which started in 2017. However, CCS struggles to get deployed: only 5 projects are underway in the world. We ask what the possible reasons for this reluctance may be.

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1 • CCS: MIRACLE OR MIRAGE

Carbon capture and sequestration is a set of techniques for recovering carbon dioxide from large emitting plants (thermal power plants, steel plants, etc.) and storing it sustainably to prevent its release into the atmosphere.

Unlike most mitigation techniques, **CCS could reduce emissions without the need to reduce fossil fuel consumption and thus without disrupting our consumption patterns or the structure of our economies. It also has the advantage of potentially allowing it to be implemented a posteriori in an existing industrial tool.**

• THE FUNCTIONING OF CCS • CCS comprises three main steps:

• Capture: separating carbon dioxide from other gaseous effluents at the chimney outlet or modifying industrial processes to release pure CO_2

• Sequestration: sustainably storing the recovered carbon dioxide to stop it reaching the atmosphere

• Transport: transporting carbon dioxide from the capture point to the storage point

Each of these steps can involve multiple technologies – sometimes with varying levels of maturity, costs, and environmental impacts.

The first step of CCS is capturing carbon dioxide at the output of thermal power plants or industrial facilities. The difficulty of this step comes from the fact that the effluents are not composed of pure carbon dioxide: similarly to ambient air, they contain approximately 2/3 nitrogen and various impurities. It is therefore necessary to separate carbon dioxide from other gases or to modify industrial processes to produce only CO_2.

There are three types of technologies for this:

• Post-combustion: carbon dioxide is separated from other gases and recovered directly from the exhaust fumes – allowing use on existing equipment without major modification

• Oxy-combustion: the installation is modified so that the combustion of fossil fuels is carried out in pure oxygen and thus produces only water vapor (easy to precipitate) and carbon dioxide

• Pre-combustion: this process consists in extracting carbon before combustion This can be done by producing carbon monoxide from the fuel (for example by steam reforming or incomplete oxidation) which reacts with water vapor to form carbon dioxide and dihydrogen (this is referred to as "shift-conversion"). Then, hydrogen is burned, producing only water vapor.

Atmospheric capture and CCS

Atmospheric capture consists in removing CO_2 not at the output of emitting facilities but directly from the atmosphere. This emerging sector is different from CCS because it does not only reduce emissions, it creates "negative emissions". It is experiencing a growing interest that has been stimulated in particular by the objective of net zero emissions stipulated by the Paris Agreement.

Atmospheric capture often relies on all or some of the technologies developed for CCS. For example, biomass + CCS (or "Bioenergy + CCS", BECCS) consists in using photosynthesis to remove CO_2 from the atmosphere and then burning the biomass produced and recovering and sequestering the CO_2: this technique therefore uses the whole chain of CCS. Direct air capture uses a technological process to extract CO_2 from ambient air where it is much less concentrated than in factory fumes (approximately 0.04% vs. 30%) before sequestering it: in this case, only the transport and the sequestration are common with CCS..

Source : center for carbon removal

TEXT BOX 1

The captured carbon dioxide then must be stored safely and sustainably to prevent it from entering the atmosphere. The solution most often considered is geological sequestration: CO_2 is injected into depleted oil or gas reservoirs into unusable coal seams or deep saline aquifers. **In practice, however, the captured CO_2** is rather used than stored – it is sold, which improves the profitability of the process but can also decrease its positive impact on the climate. **The valuation may consist of:**

- Injecting CO_2 into a hydrocarbon reservoir during operation: as the petrol or gas is being extracted, the pressure in the reservoir drops, and the injection of CO_2 (or other gases) can make it possible to increase it and increase production – this is referred to as enhanced oil recovery or EOR
- Using CO_2 as a raw material in chemical, industrial or agricultural processes, for example as a solvent, refrigerant or dissolved in sparkling beverages
- Using energy to convert CO_2 into liquid or gaseous fuel through photosynthesis (e.g. by producing microalgae used for biomass production) or by methanation.

It is not always possible to use the dioxide at the place of capture and it is rarely possible to store it there. An intermediate step therefore consists in transporting the gas. This transport can be done by gas pipelines, but also by truck, train or boat.

• CCS TODAY IN THE WORLD • Carbon transport and sequestration – usually by EOR – has been carried out on a small scale for several decades. These first experiments have almost all taken place within petrochemical processes already producing concentrated CO_2 without the necessity to modify the emitting installation. For example, this is the case of the purification of natural gas (Terrell Natural in the United States in operation since 1972, Sleipner in Norway since 1996, etc.) or the production of nitrogen fertilisers (Enid Fertilizer in the United States since 1982).

Carbon capture from facilities that do not produce pure carbon dioxide is a more recent occurrence. For example, there are many demonstrators in electricity generation but only two large-scale projects are currently in operation: Boundary Dam in Canada (commissioned in 2014) and Petra Nova in the United States (commissioned in 2017).

Boundary Dam

Boundary Dam is a coal power plant operated by Sask Power in the Canadian state of Saskatchewan. Its unit 3 has been equipped to capture the emitted carbon dioxide: up to 90% of the CO_2 produced during combustion, i.e. approximately 50,000 tonnes per month, which is captured by absorption using a chemical solvent. The CO_2 is sold and transported via a pipeline to the Weyburn oil field where it is pumped into wells to increase production. At the beginning of 2018, Boundary Dam 3 exceeded the threshold of 2 million tonnes of captured CO_2.

The project cost $1.35 billion Canadian dollars (€945 million). It is approximately 5 times more than a coal power station without CCS which would have cost €150 to 200 million at equivalent power. An overconsumption of energy of 25% is also added to these investments. In addition to its net capacity of 110 MW, the plant produces 29 MW which only serve to fuel the energy-intensive process of carbon capture. Despite these costs, the project demonstrated the technical feasibility of post-combustion CCS on an industrial scale.

Source : www.saskpower.com

TEXT BOX 2

Excluding small demonstrators and pilots, 17 carbon capture and storage projects are currently in operation around the world, preventing the release of just over 31 million tonnes of CO_2 annually. Five additional projects are under construction and another fifteen are in various stages of development (Global CCS Institute, 2018).

There have also been several costly failures in carbon capture such as the FutureGen projects or the Kemper County project in the United States and ZeroGen in Australia.

The technical feasibility of capturing and sequestering carbon has therefore been established, but projects likely to significantly reduce emissions are rare and difficult to materialise. We may ask how to explain these difficulties and what role do non-state actors play in the development or instead in the resistances to CCS.

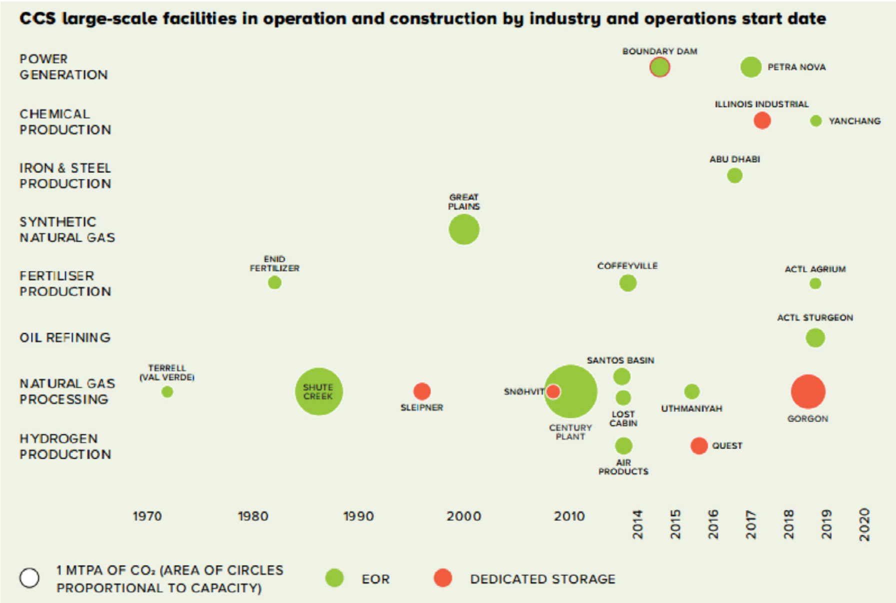

FIGURE 1. CCS PROJECTS ON AN INDUSTRIAL SCALE BY DATE OF COMMISSIONING, SECTOR AND THE QUANTITY SEQUESTERED (GLOBAL CCS INSTITUTE, 2018)

2 • COMPANIES: AN ENTHUSIASM WITHOUT A BUSINESS MODE

Carbon capture is attracting the interest of many economic players, especially those who depend on fossil fuels because its large-scale deployment would reduce emissions without jeopardising their activity. Coal industry, tankers, fossil electricity producers, heavy industries, etc. therefore support the development of this sector; however, like the Lacq pilot project (France) launched by Total, these experiments rarely lead to large-scale implementation.

One of the major causes of this reluctance is that carbon capture does not have economic rationality these days (Kapetaki, 2017).

• INSUFFICIENT CARBON PRICE TO MOVE BEYOND PILOT PROJECTS •

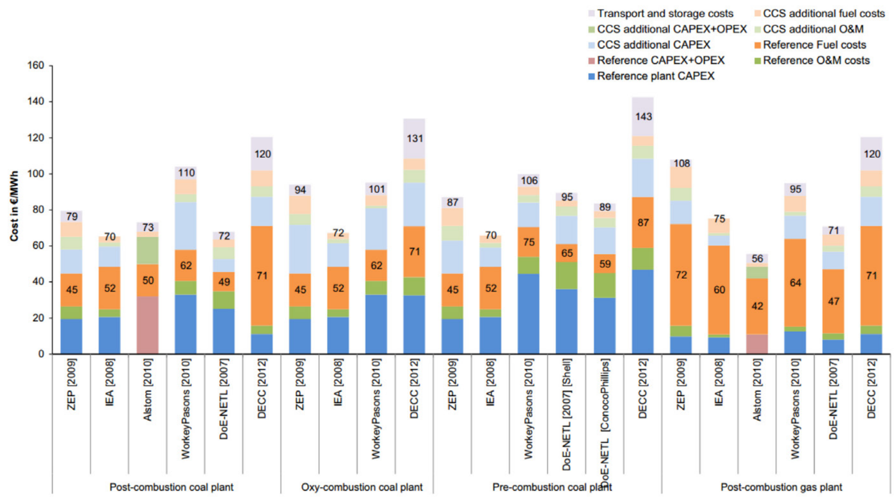

FIGURE 2. ADDITIONAL COST (LCOE) OF CARBON CAPTURE AND SEQUESTRATION PER MEGAWATT HOUR PRODUCED BY VARIOUS STUDIES

(Renner, 2014)

These projects are expensive and significantly decrease the performance of the facilities on which they are conducted. According to the considered studies and technologies, carbon capture and sequestration in a thermal power plant would increase the cost of electricity from €56 to €143 per megawatt. In Europe the price of electricity is around €40/MWh – it would therefore mean at least a doubling of the wholesale price.

Under these conditions, it would necessitate a price of carbon of €115 per tonne in Europe for thermal power plants with CCS to become the most profitable option. For comparison, the price of European carbon credits has been fluctuating between €4 and €20 per tonne of CO_2 since the creation of the European carbon market. In China, the tipping point is lower: a carbon price of €45 per tonne would be enough to make CCS profitable in the electricity sector. This threshold could be reached by 2030 (Renner, 2014), but the Chinese carbon market pilots currently place the price per tonne of CO_2 between €0.13 and €15.5.

Where it exists, **the price of carbon is therefore too low and often too volatile to justify the development of carbon capture and sequestration.** Companies have no incentive to go beyond pilot projects.

The new US carbon capture tax credit

In the United States, the 2018 budget has created a strong incentive for carbon sequestration: geological sequestration of one tonne of CO_2 gives the right to a tax credit of $50. The other uses of CO_2 are accompanied by a tax credit of $35 per tonne. This system applies both to CO_2 captured from energy or industrial installations and CO_2 removed directly from the atmosphere. It may not be sufficient to allow carbon capture and sequestration to become profitable, but this system should help many projects come closer to it.
This tax credit is also original by the variety of support that it gets, bringing together both climato-septic and environmental activists, Republicans and Democrats, coal producers, unions and NGOs.

Source : MIT Technology review

TEXT BOX 3

• THE REGULATORY WAY • In the absence of economic rationality, regulators may be tempted to impose carbon capture and sequestration on companies. The first example of this strategy can be found in Australia in the case of the Gorgon and Wheatstone gas projects: the Western Australian Government authorised the construction of these facilities by Chevron provided that 80% of the CO_2 removed from the gas is captured and sequestered.

This initiative replaces the carbon price: the Western Australia compulsory compensation scheme was abolished in 2011 when Australia created a carbon tax, but this tax was in turn abolished in 2014 by Tony Abbott's government. Chevron no longer has any financial incentive to reduce its emissions.

As part of the deal, Chevron invested $2.5 billion (out of a total investment of $88 billion) to capture 4 million tonnes of CO_2 per year. The sequestration will take place in a reservoir located 50 km from the coast and 2 km below the surface in the Isle of Barrow nature reserve.

However, the regulatory approach shows some limitations: the Gorgon site has been operating since March 2016, but carbon capture and sequestration is still not operational and it will ultimately only address 40% of emissions. This delay was not foreseen by the agreement whose application is therefore included. Two investigations were initiated by the local environmental protection agency.

The European Union has taken a more flexible approach: the 2009 CCS Directive does not require carbon capture and sequestration, but a feasibility study is required for new thermal power plants above 300 MW. When transposing this directive, some member states including France and Great

Britain decided to allow only CCS-ready projects, meaning projects fulfilling the conditions (space, access, etc.) allowing them to be retrofitted for carbon capture.

3 • A DIVIDED CIVIL SOCIETY

Another obstacle for carbon capture and sequestration projects is its image in civil society: this sector is little known and often leads to a rejection response.

• NGOS AND THE ACADEMIC WORLD• Some researchers see carbon capture as a "Faustian pact" (Spreng, 2007) that can lead to a technological impasse and hinder the development of low-carbon technologies such as renewable energy.

The Yanchang project – illustration of the CCS paradoxes

Yanchang in the coal-producing areas of northern China is to host the first industrial-scale carbon capture and sequestration system in Asia. The project is led by Yanshan Petroleum, a company owned by the provincial government of Shaanxi and the 4th largest petrol producer in China. It is to be opened in 2018 and avoid the discharge of 410,000 tonnes of CO_2 per year.

Yanchang illustrates the paradoxes of carbon capture: just like 4 out of 8 Chinese CCS projects, it is intended to capture emissions from coal liquefaction plants. The installation of these systems at the plant level does not eliminate emissions either upstream (for example fugitive emissions of methane during coal mining) or downstream (during fuel combustion). The process also consumes a large amount of water (6 to 13 tonnes of water per tonne of fuel). In addition, the catchment site and the storage site are separated by 140 km, and the transport is done by truck: more than 20,000 round trips will be needed each year. Finally, the captured CO_2 is sequestered in the Qiaojiawa oil field where it can stimulate the production of hydrocarbons.

The carbon capture and sequestration carbon is therefore part of a value chain emitting a lot of greenhouse gases which it helps to perpetuate.

Source : Financial times

TEXT BOX 4

This opposition was reinforced around the year 2010 when it became clear that CCS projects were facing many difficulties – delays, extra costs, abandonment, etc. (Markuson, 2012). This period also corresponds to a decrease in the resources allocated to research: in Europe, public and private investment in research into carbon capture and sequestration peaked in 2010 (Fiorini, 2016). In the United States, the Carbon Sequestration Initiative research programme into CCS at MIT closed in June 2016 after 16 years of existence.

In a similar fashion, some NGOs are radically opposed to carbon capture. Greenpeace believes that CCS is a dangerous waste of time, "Greenpeace opposes CCS as a dangerous distraction from the safe, secure 100 percent renewable energy future we all want." ***This position is however far from consensus: other organisations fight in favour of CCS (Bellona, ZERO, etc.), even WWF has sometimes cautiously supported this solution (WWF-UK in 2014: "Demonstrating carbon capture and storage is an urgent priority ... but the Government shouldn't plan significant investments in new fossil fuel plants today on the assumption that CCS technology will be available at an affordable cost in the future to capture emissions when we simply don't know that yet."***

• LOCAL COMMUNITIES • Carbon sequestration with its risk of leakage and induced earthquakes is worrying riverside communities. Their mobilisation has slowed or even prevented carbon capture and sequestration projects and pushed some governments to abandon on-shore sequestration in favour of more expensive off-shore sequestration.

This is what happened to the CCS project proposed by Shell in Barendrecht (The Netherlands). This project was to start in 2011 and provide storage for 10 million tonnes of CO_2 within 25 years. It was abandoned in 2010 due to opposition from the local population. Following this failure, the Dutch government decided that all CO_2 storage projects should be done at sea. Similar movements took place in Germany (Beeskow, Brandenburg) and in the United States (Greensville, Ohio and Long Beach, California).

The acceptance of carbon capture and sequestration projects by the local population is therefore a major challenge in the development of this sector. The topic has been the subject of numerous studies and scientific publications. As is often the case for emerging technologies, the first factor of acceptability is the perception of benefits, in this case the continued use of fossil fuels (L'Orange Seigo, 2014). As a result, populations heavily dependent on fossil fuels are more favourable to carbon capture and sequestration projects, even when they are otherwise hostile to emission reduction efforts. For example, in the coal state of Indiana, 80% of respondents support carbon capture and sequestration. However, this does not prevent the NIMBY effect ("not in my backyard"): 20% of respondents favourable to CCS change their minds if the project is close to their community (Krause, 2013).

The used technologies and especially the source of CO_2 are other factors likely to affect public opinion. A German study shows that CCS, which is on average perceived as relatively neutral, is supported more when it is conducted on biomass plants or industrial facilities than when it is conducted on coal plants. The mode of transport and storage also have an influence: using enhanced hydrocarbon recovery, for example, is better perceived than injecting into saline formations (Dütschke, 2016).

4 • COMMUNITIES: UNDECIDED ARBITERS

Carbon sequestration means storing a dangerous substance for an indefinite amount of time. This practice, and to a lesser extent carbon transport, has a significant territorial footprint, making communities crucial stakeholders.

For example, the 2009 European Directive on CCS provoked resistance in Germany, where the federal states challenged the sites selected for carbon sequestration. As a result of this move, the German CCS Act recognised the role of federal states by granting them a veto over carbon sequestration projects – **an unprecedented prerogative in German environmental law that does not generally give the right of scrutiny over infrastructure projects to local authorities.**

More generally, experience shows that the interest of communities can vary significantly depending on the selected technology and the equipment to be installed on their territory. In particular, they seem reluctant to accept the storage of carbon dioxide, especially when it is not associated with the construction of a new thermal power plant or with value-production (such as the production of hydrocarbons).

The implementation of the FutureGen project in the United States

FutureGen was announced in 2003, and it was conceived as the leading figure in Bush administration's "clean coal" agenda. The project was meant to demonstrate carbon dioxide capture and sequestration in a single location, bringing together the entire technology chain in a purpose-built state-of-the-art facility. This ambitious project had a budget of $1.5 billion, of which 74% was funded by the federal government.

Implementing the project was the subject of a two-year competitive process. Seven states applied for it and 12 sites were selected. The first selection round led to four finalists – two in Illinois and two in Texas. Both states have invested in the process including mobilising the general public to ensure project recognition and acceptability. In January 2008, Mattoon, Illinois was chosen as the site for FutureGen.

In mid-2009, the consortium in charge of FutureGen acquired the land in Mattoon. Laying the foundation stone of the new plant was planned for 2010. In August 2010, the project – now called FutureGen 2.0 – was restructured by cancelling the construction of the new power plant to instead retrofit an existing facility located 280 kilometres from Mattoon. In this way, Mattoon would have provided only the geological carbon storage site which led the community to withdraw support for the project. The search for a new site delayed the project for another year and was eventually abandoned in 2015.

Source : Markusson, 2011

TEXT BOX 5

CONCLUSION

Carbon capture and sequestration is an attractive option for reducing greenhouse gas emissions and could even help remove carbon dioxide from the atmosphere. A decisive advantage of CCS is that its technological feasibility has been proven and that it has been implemented on projects dating back several decades. Its main fault is that it is still too expensive and too uncertain to truly mobilise the economic actors. The reluctance of local authorities and the cautiousness of communities often complicate projects and obscure the prospects of a technology that, for the time being, remains an uncertain deus ex-machina.

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