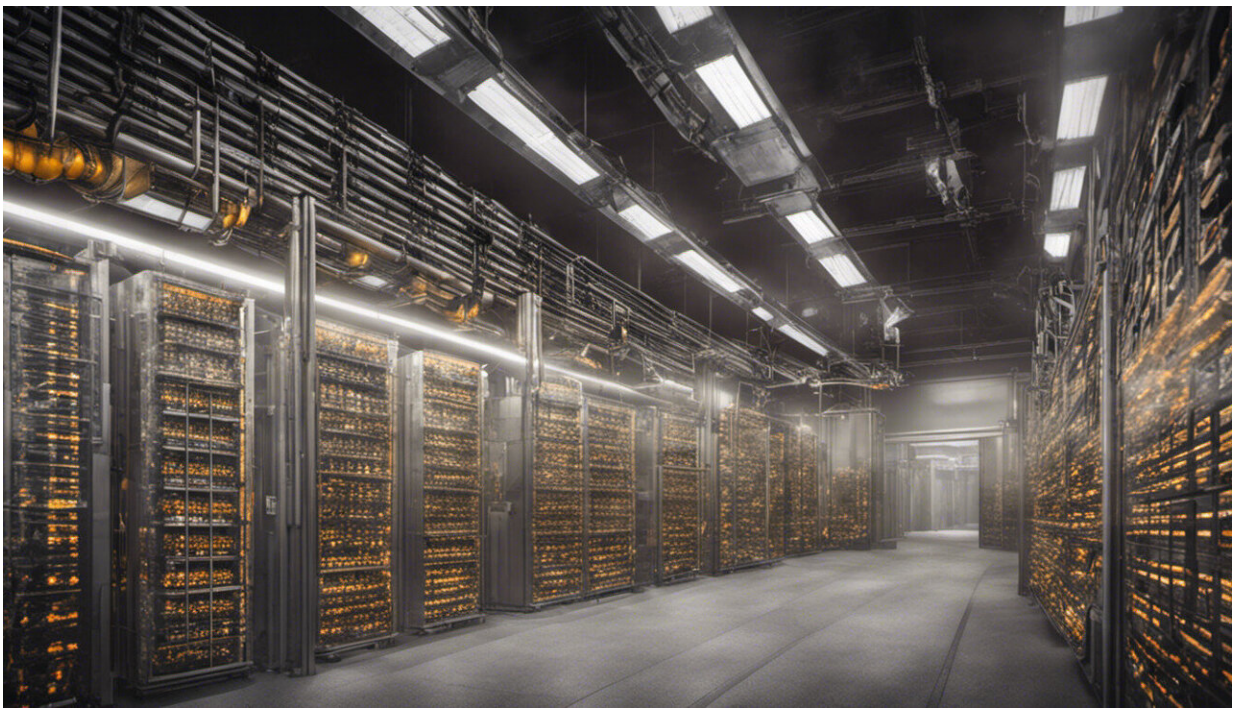
This is what you need to know about carbon capture and storage

October 8 2019, by Christina Benjaminsen



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Why is there so much talk about storing CO_2 underground? Doesn't it cost more than it's worth? Here we provide the research scientists' answers and explanations of why CCS is climate technology that we are completely dependent on. (And yes, it is perfectly safe.)

What exactly is CCS?

CCS is an abbreviation of carbon capture and storage. The carbon referred to here is the greenhouse gas carbon dioxide (CO_2), which is emitted when we, for example, burn oil, coal or gas and when we manufacture cement and other industrial products.

So, CCS is technology that can capture and transport this CO_2 and store it safely under the earth's surface. Many have therefore begun to refer to CCS as carbon recycling, since the plan is to return the CO_2 to where it came from, underground, for example in old, stable oil reservoirs that can be sealed.

Why is so-called CCS—capture and underground storage of CO_2—so important?

The reason is that all serious scenarios for the future depend on us being able to meet this challenge if the two-degree goal is to be achieved in practice. In other words, we have no choice! The reason is that we will be dependent on oil and gas for several years to come. Turning off the world's oil supplies is a far more unrealistic solution.

The International Energy Agency (IEA) and the UN Climate Panel clearly state that it is "extremely probable" that climate change is connected with our CO_2 emissions. Hence, by 2050 the world must reduce emissions of CO_2 by 5 gigatons per year. This is equivalent to the total CO_2 emissions from about ten thousand factories and power stations. CCS can contribute to eliminating fully 14-17 percent of these emissions. (Based on figures from 2015.)

Without this method it will be impossible to achieve the so-called two-degree goal, which in the opinion of an increasing number of scientists ought to be adjusted to 1.5 degrees. To be on the safe side (i.e. aiming

for 1.5 degrees) we should actually reduce emissions even further, at the same time as we implement capture and storage of CO_2.

To sum up: Such initiatives as the increased use of nuclear power and renewable energy, and changes involving the electrification of the transport industry will not be enough. We cannot manage without CCS. The world must therefore undergo change on a scale we have never seen before, and this is urgent.

Why has it come to this?

First of all: The world's climate researchers agree that CO_2 is a greenhouse gas that inhibits heat radiation and therefore causes the Earth's temperature to rise. When the amount of CO_2 in the atmosphere increases, the insulating effect of the atmosphere also increases—in other words, CO_2 contributes to the greenhouse effect. Natural emissions of CO_2 are handled by the planet itself, since trees and plants absorb CO_2 in connection with photosynthesis, resulting in the so-called "carbon cycle". However, since the industrial revolution our demand for energy has increased, and this demand has been satisfied by using coal, oil and gas, which without human interference would have remained untouched, as a natural underground carbon store. By burning coal and gas, and by establishing industry that also emits CO_2, we have released more CO_2 than nature is capable of absorbing alone, for example through the process of photosynthesis.

All the available figures and scientific measurements show that greenhouse gas emissions have increased steadily since 1890, and the emissions up to the present time have resulted in a total rise of one degree in the mean temperature at the Earth's surface.

We are already seeing the impact both on nature and on infrastructure. A further increase in temperature will lead to a rise in sea level as the polar

ice melts, to even more extreme weather, and to more acidic seawater which in turn will cause organisms such as corals and algae to die out. Species that at present form food for animals and humans will disappear. Rising temperature and drought will dramatically reduce yields of cereals, fruit and vegetables. This will cause an increase in the number of refugees.

Is it technically possible to capture CO_2?

Yes. Norwegian research scientists have been working on this since the 1980s. In those days CO_2 had already been injected for some time (since the 1970s) into American oil fields to increase oil production. Almost the same technology is used in CO_2 capture today. Since CCS commenced in 1996, more than 23 million tonnes of CO_2 have been safely stored at the Sleipner field and we have been storing CO_2 at the Snøhvit field since 2008. The storage takes place in brine-filled pores in sandstone formations (so-called salt-water aquifers). Such CO_2 accumulations are sealed by a natural geological caprock, such as shale or clay.

Norway also has the world's largest test facility for CO_2 capture technology at Mongstad. Here, large and small technology providers can present their innovative concepts for improving CO_2 capture technology and test them on an industrial scale under carefully controlled conditions.

Is it expensive?

All technology costs money, but the costs that climate change will impose on us will be far higher.

SINTEF's estimates show that the cost of large-scale (i.e. millions of tonnes per year) capture, transport and storage of CO_2 from coal-fired power plants will be approximately USD 93 per tonne (NOK 830). (See

the key facts box). This cost varies according to the country, source, transport distance and type of disposal site. Capturing CO_2 from cement factories, steelworks and incineration of waste will cost less than capturing CO_2 from power plants.

However, CCS is getting cheaper all the time: As is the case with other technology that is initially expensive, CO_2 capture has become more efficient and therefore cheaper. Research scientists expect the price to sink further, in step with the implementation of the technology. Spreading of this technology is also seen as representing major potential for industrial development.

How does CCS work in practice?

Essentially, there are two categories of CCS:

The first is to capture and store CO_2 found in power generation and other industries, such as the cement, steel and waste industries, as well as power generation from natural gas and coal. These are sources with high CO_2 emissions.

SINTEF's research facility for CO_2 -capture in Trondheim, Norway. The plant will make it cheaper to clean the exhaust gases from gas and coal power plants and the process industry for the greenhouse gas CO_2. The laboratory is used for research on chemical purification of CO_2 from exhaust gases, the method that will be used in the first full-scale plants in the world for CO_2 capture. Photo: Thor Nielsen.

This is done using various chemical processes.

This absorbtion technology (among these, amine technology) uses chemicals that bind to the CO_2 contained in the industrial flue gases before it reaches the chimney. This means that industries such as the

steel industry, fertilizer producers and cement factories can reduce their CO_2 emissions to zero.

This is extremely important as these industries produce goods the world needs, but are also set to produce CO_2 as a by-product of their activity well into the future. CCS is the only solution there is that can deliver zero emissions for these industries.

To capture the CO_2, the first step is the use of chemicals to bind to the CO_2. Then the CO_2 must be separated from the chemicals to get pure CO_2. To achieve this, the mixture is heated to release the CO_2. This process leaves two products: pure CO_2 that is easy to handle and chemicals that can be reused.

The process of separating the CO_2 from the chemicals is costly, because it requires a lot of energy. Such CO_2 purification is therefore most profitable in industrial processes that generate waste heat, because the energy from this excess heat can be used for the purification process. Norwegian researchers and Aker Solutions have developed a mobile test facility for this in the Solvit project.

The mobile test facility has verified capture from gas- and coal-fired power stations, refineries, waste incineration facilities and cement factories. Researchers held tests in six pilot plants in Germany, Scotland, the U.S. and Norway and evaluated 90 different chemical mixtures to find the best one.

The chemical purification method can also be used when creating hydrogen from natural gas. Using this method, the hydrogen becomes completely emission-free.

The second method is called BIO-CCS. In practice this means extracting CO_2 from the atmosphere.

The principle is to capture and store CO_2 from sources that are initially considered climate neutral, such as biological waste, wood chips or manure. What is captured is the CO_2 found in the earth's natural cycle—and not CO_2 from carbon sources such as coal, oil and gas. This way we reduce the amount of greenhouse gas that already exists in the atmosphere, because it comes from the natural, biological CO_2 cycle.

BIO-CCS can also be done by capturing and storing CO_2 from biological sources through biocarbon (charcoal) production. Biocarbon is a good soil improver and also binds to CO_2, as long as the coal is not burned and remains in the soil. The method of producing biocarbon is called pyrolysis, and is so simple that it can be done in your own garden with garden waste, for example. However, a pyrolysis furnace is needed.

In the oven, the biomass is heated to between 500 and 700 degrees with a minimal air supply in no more than 20 minutes. Biocarbon contains twice as much carbon as other organic matter. The method is smart because we only need soil or cultivated land for CO_2 storage, which makes the transport and storage of CO_2 less complicated than from industry. Of course, the method is most effective when used on a large scale in horticulture or agriculture.

According to figures from the Norwegian Institute of Bioeconomy Research (NIBIO), emissions from the Norwegian agricultural sector can be halved if 4,000 Norwegian farms produce and mix biocarbon into the soil. NIBIO is a partner in the CAPTURE+ project and are the ones that have researched biocarbon for the longest in Norway.

How do we know that transporting CO_2 in pipelines is safe?

Today CO_2 is transported in pipelines that extend over thousands of kilometres of land in North America. In Norway, there is 150 kilometres of CO_2 pipeline on the seabed from the Snøhvit field to Melkøya in

Hammerfest.

Consequently, transporting CO_2 is completely safe if all the pipelines are specifically designed just for CO_2 transport. To find out what is needed, SINTEF has developed an advanced simulation model that can predict whether a crack or other damage to a CO_2 transport pipe can be developed into a continuous breach. The tool shows how the pipes themselves can prevent cracks from growing without the need to make the pipe walls unnecessarily thick or for other costly risk-reducing measures.

Attempting to over-dimension the pipelines to control fractures by increasing the wall thickness is a costly strategy. For a 50-mile-long pipeline with a 36-inch diameter, increasing the wall thickness by just three millimetres will add NOK 250 million (GBP £22.25) to the total cost given today's steel prices.

The Norwegian oil industry has many decades of experience in pipe design and safety assessments related to natural gas pipeline transport. But CO_2 has differing properties than natural gas. Unlike natural gas, CO_2 heats as pressure decreases. If there is a hole in a CO_2 pipeline, up to ten times more energy is released compared to a leak in a natural gas pipeline.

Recently, SINTEF has used the simulation model to prepare projections for the Northern Lights project. This project is managed by Equinor with Shell and Total as partners and covers the transport and storage part of Norway's demonstration project for full-scale CO_2 handling.

How do we know that underground storage of CO_2 is safe?

To date, all research and experience suggests that storage of CO_2 can be done safely if appropriate storage areas are selected.

A good example is Equinor's pilot project at Sleipner, where 1 million tonnes of CO_2 per year has been injected into the pourous sandstone under denser layers of clay almost 1,000 metres under the seabed since 1996. SINTEF researchers many topics related to safety, but also cost-effective, storage:

One example of ongoing research is the SINTEF-coordinated Pre-ACT project, which is funded by the EU, the Research Council of Norway, Equinor, Shell and Total, among others.

In the project, researchers have access to monitoring data from important CO_2 storage demonstration plants. The data will be used to calibrate and demonstrate the value of the developed methods and to develop a "protocol" or recommendations.

The recommendations are developed as tools for operational decisions based on information about the pore pressure in the storage reservoir. This will help the operators maximize both safety and the storage capacity in a cost-effective way. The system will also be used to monitor the reservoirs.

Pre-ACT uses a large field lab for CO_2 storage: Svelvik CO_2 Field Lab. The field is located in a sand pit near Drammen in Norway and is managed by SINTEF. The lab consists of one injection well and four monitoring wells, all with instruments to measure what is happening both in the wells themselves and in the areas between the wells. This gives researchers even more unique data.

In addition, this field lab provides researchers with unique opportunities for testing new methods and equipment, such as fibre-optic sensors for CO_2 monitoring.