equinor

25 years of successful offshore CO_2 storage in Norway

The vast majority of energy transition scenarios, including those made by the Intergovernmental Panel on Climate Change (IPCC) and the International Energy Agency (IEA), attribute a substantial emission reduction role to Carbon Capture and Storage (CCS). CO_2 storage accounts for 15% of all emission reductions by 2070 in the IEA's Sustainable Development Scenario.

> *"In the IEA's Net Zero Roadmap, more than 7 billion tonnes of CO_2 is safely and securely stored each year by 2050, underpinning emissions reductions in virtually all parts of the global energy system. With a quarter of a century of CO_2 storage operations, the Sleipner Project is a global pioneer and an example of Norway's leadership on CCS technologies."*
>
> **Dr. Fatih Birol**, Executive Director, International Energy Agency (IEA)

CO_2 storage can mainly contribute to three areas:

Decarbonisation of industry in sectors in which CO_2 emissions are process-related (such as cement production) or where fossil fuels cannot easily be replaced by renewable electricity (such as iron and steel production);

Providing negative emissions by use of technologies such as bio-energy with CO_2 storage (BECCS) and Direct Air Capture (DAC) with CO_2 storage;

Early ramp-up of low-carbon hydrogen production, replacing fossil fuels in various applications.

CO_2 storage experience, globally and in Europe

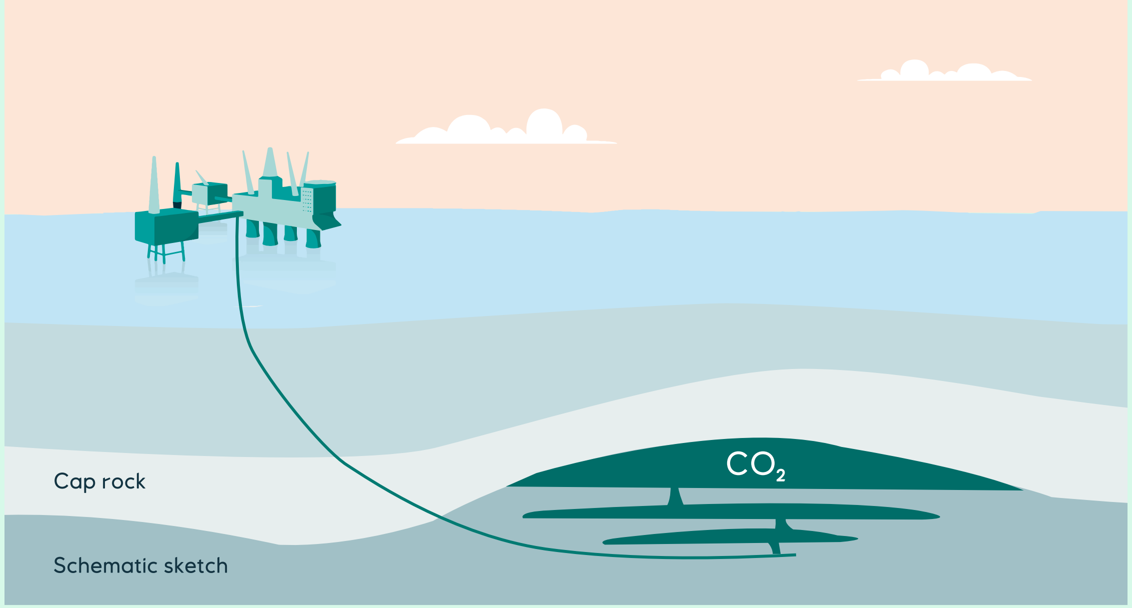
- 1970s: First CCS facilities in operation (used for CO_2-enhanced oil recovery)
- 1996: First dedicated CO_2 storage at the Sleipner field off the Norwegian coast, operated by Equinor
- 2008: Second industrial-scale CO_2 storage in Europe at Snøhvit Field, offshore Norway, operated by Equinor
- 2020: 26 commercial CO_2 storage facilities in operation globally with a total capacity of around 40 million tonnes per year (GCCSI, 2020)

Trailblazer in the North Sea: 25 years of Sleipner

The North Sea constitutes an important area for potential subsurface CO_2 storage in Europe; its total storage potential of 160 gigatons (Gt) corresponds to ca. 75 years of present European industrial CO_2 emissions. Equinor has 25 years of experience with CCS (Carbon Capture and Storage) in the Norwegian North Sea.

The Sleipner Project west off the Norwegian coast was the first subsurface CO_2 storage project in Europe - and the first offshore CCS project ever. It temporarily became the world's largest project, capturing and storing up to 1 million tonnes CO_2 per year, through one single well. Until the end of 2020, more than 19 million tonnes of CO_2, equalling the yearly emissions of more than 10 million cars - have been successfully stored. The Sleipner Project paved the way for CO_2-storage-application on an industrial scale.

Credit: IKM, Pål Ørke.



How CCS works?

In the carbon capture and storage (CCS) process, CO_2 is separated from gas mixtures such as chemical process streams, exhausts, or even air, and is subsequently permanently stored.

The captured CO_2 is compressed and pumped deep down into the subsurface – for example offshore – to isolate the greenhouse gas from the atmosphere.

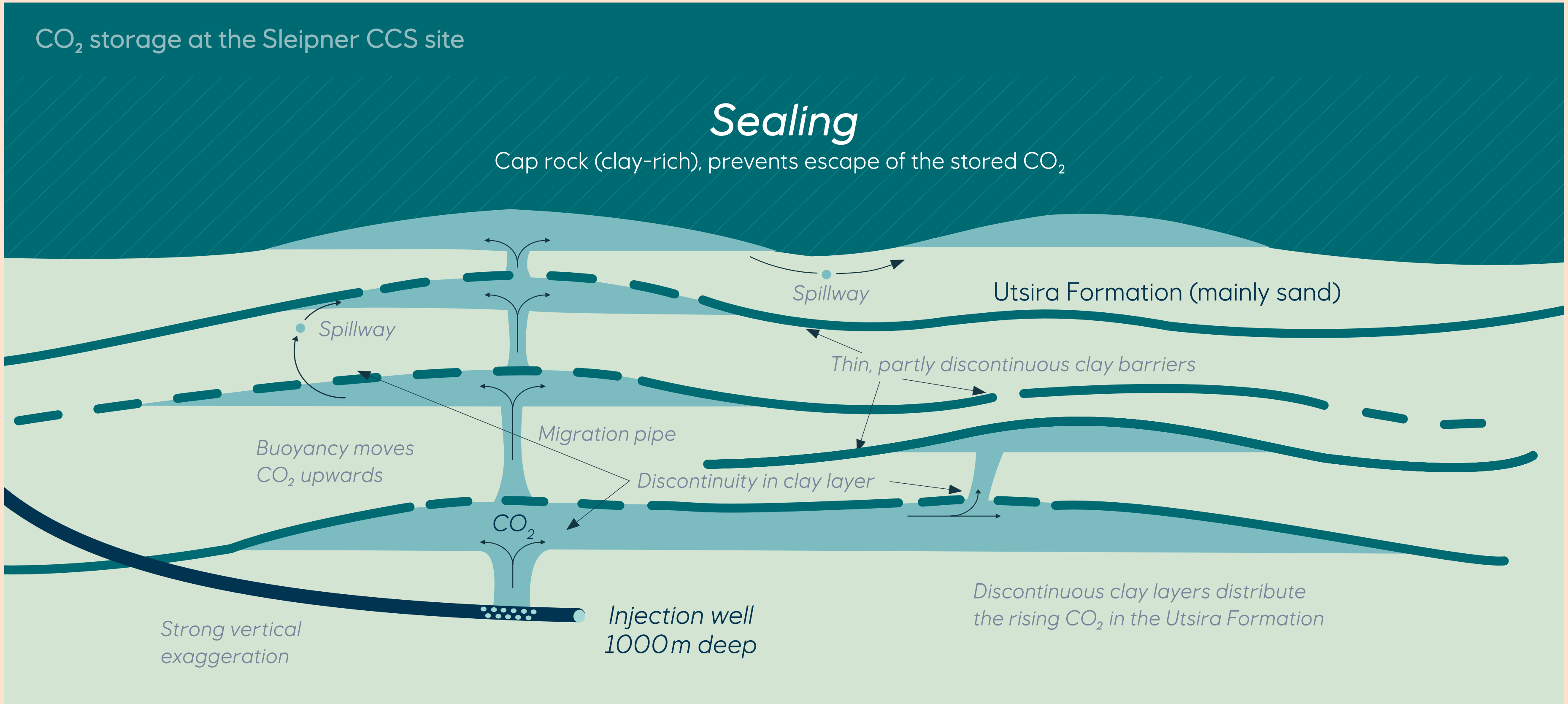
Finding a suitable site

Subsurface CO_2 storage requires two key elements: presence of a porous and permeable storage rock formation and a caprock that seals it. The rock formation can be either depleted oil and gas fields or salt water-filled rock formations, so-called saline aquifers.

A suitable formation must form a 'trap' with the caprock, which in most cases means an upwards closed structure like a helmet or an upside-down bowl, which keeps the CO_2 securely in place.

The structures that keep CO_2 in place are very similar to those in oil and gas fields, where hydrocarbons have stayed in the subsurface for many million years.

The evaluation of the integrity of a storage site is a complex exercise that requires expert knowledge and development of conceptual and digital models of the subsurface based on seismic and well data. This process is being regulated in the EU CCS Directive and storage plans are subject to by national authorities.



Monitoring

Once CO_2 is pumped into the storage reservoir it is closely monitored. The monitoring process is also regulated via the EU CCS Directive and monitoring analyses are shared with responsible authorities who also regularly supervise and inspect the sites.

Monitoring of the cap rock and the overburden is key to ascertain successful containment and to enable immediate mitigating measures in case of observed breach of site integrity. The stored CO_2 is monitored as follows:

Continuous pressure monitoring

For any storage site, maximum allowable pressures are determined and continuously monitored. If pore pressure approached the pre-set limit, injection would be reduced or stopped, and the storage strategy adjusted. At the Sleipner storage site, no pore pressure increase has been observed despite almost 20 million tonnes of CO_2 injected.

Regular seismic CO2 monitoring

Not only pressure within the site but also the movement of CO_2 is monitored. CO_2 has different acoustic properties than water thus seismic properties of a rock with water in its pores change when quantities of such water are displaced by CO_2. With seismic monitoring – by comparing data sets from before and during the injection (so called time-lapse seismic data) – the distribution of CO_2 in the subsurface can be shown.

This method can detect already small fractions of injected CO_2 that would leave the site in case of leakage. At Sleipner, no leakage has been observed with 10 seismic time-lapse surveys conducted over the last 25 years.

Monitoring after active injection phase

When storage capacity in any given reservoir is reached and/or CO_2 injection ended, monitoring continues for at least 20 years by the operator of the site. When all monitoring data shows that the CO_2 will remain completely and permanently contained, site responsibility is transferred to authorities as stipulated in the EU CCS Directive. The costs for continued monitoring rest with the operator.

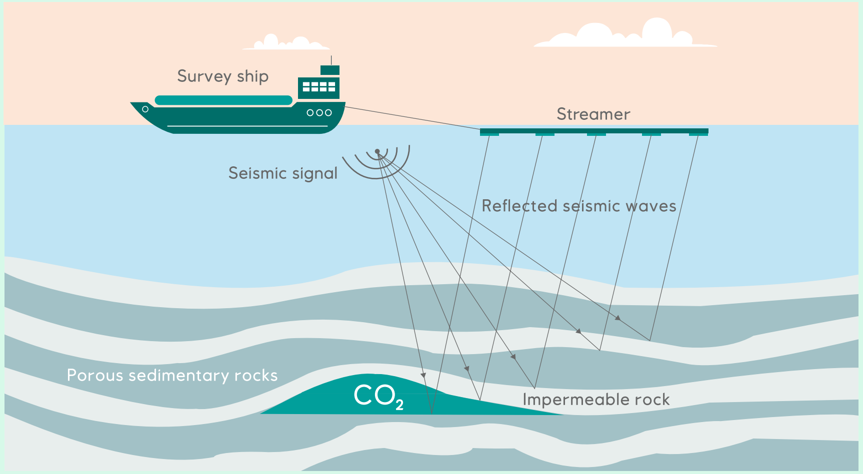
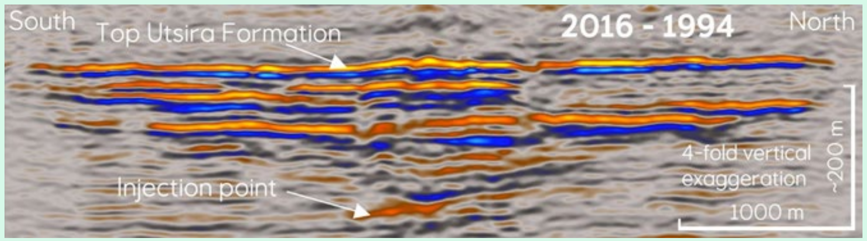


Image provided by Sleipner licensing partners



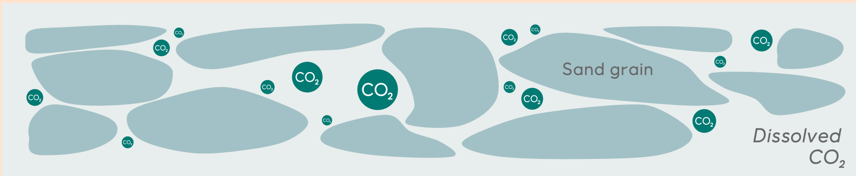
Seismic section through the Sleipner CO_2 reservoir: seismic time-lapse data (amplitude difference) of the 2016 and 1994 campaigns. The intense colours (especially yellow, blue) show the presence of CO_2 accumulating beneath thin clay layers and under the tight caprock seal.

Increasing safety over time

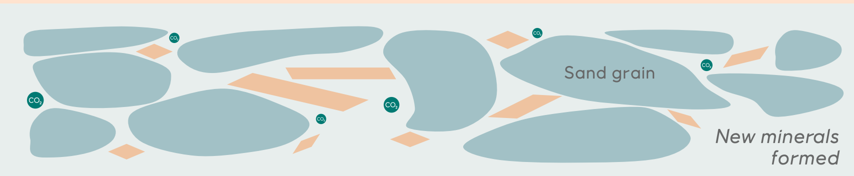
In addition to capillary sealing by the caprock, three physical and chemical mechanisms contribute to safe storage by progressively reducing the amount of mobile CO_2.

1. The injected CO_2 occupies pores between the sand grains of the storage formation. Capillary forces are the cause for typically ca. 20 to 35% of the injected CO_2 being permanently trapped as microscopic bubbles in the pores.

2. CO_2 dissolves in the subsurface water. Over time, all the injected CO_2 will dissolve in the salt water in the reservoir, which will become denser and tends to sink down, further reducing the risk of spills.



3. Some dissolved CO_2 will form minerals, thus becoming completely immobile.



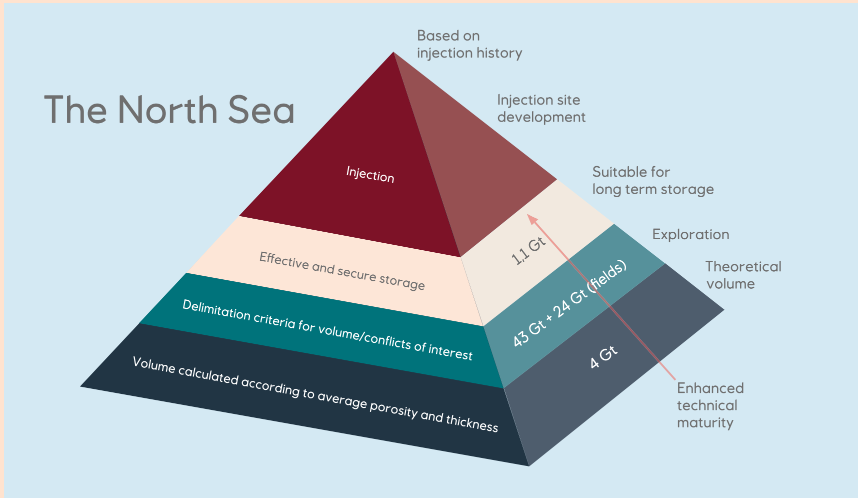
In combination, these trapping mechanisms result in progressively less CO_2 being present in a separate, mobile phase and reduce the risk of leakages.

Storage resources in the North Sea

The Norwegian Petroleum Directorate (NPD) has mapped and evaluated potential storage formations on the Norwegian Continental Shelf and estimated total storage resource of approx. 72 (Gt) of CO_2 in saline aquifers and in abandoned or to-be-abandoned oil and gas fields of the Norwegian part of the North Sea alone.

The total mapped storage resource under the whole North Sea of ca. 160 Gt corresponds to ca. 75 years of present European industrial CO_2 emissions.

However, these storage resources cover a range of economic and technical viability, thus probably not all of them will be utilized. Given that only a few percent of today's annual CO_2 emissions in Europe are intended to be handled through CO_2 storage and additional storage resources exist in other areas of Europe (e.g. the Mediterranean and Black Sea), the resources are deemed sufficient for large-scale CCS in Europe.



Storage resources in the Norwegian part of the North Sea, mapped by the Norwegian Petroleum Directorate.
Source: Norwegian Petroleum Directorate, CO_2 Atlas for the Norwegian Continental Shelf.

Sleipner– a laboratory for learning and technology development

The Sleipner Project has proven invaluable in advancing CO_2 storage research. The empirical data gained has informed other projects around the globe and constituted key input for the EU CCS Directive and regulation. The project served as a full-size laboratory, its data has been made available for academic and industrial research around the world. With its help, new modelling and monitoring technology has been developed. Since 2021, a Sleipner CO_2 storage dataset can be freely downloaded from co2datashare.org.

Learn more: http://www.equinor.com/en/sustainability/climate.html

> *"Equinor, former Statoil, shared their experiences from Sleipner and Snøhvit openly with GFZ and its Ketzin CO_2 pilot storage project. This was invaluable input for the technical success of our project."*
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> **Dr. Cornelia Schmidt-Hattenberger**, Group Leader Geological Storage, Helmholtz Centre Potsdam – German Research Centre for Geosciences (GFZ)

Outlook

Carbon capture and storage (CCS) at Sleipner has been a pioneer project and demonstrated that CO_2 storage can successfully be done offshore, in a safe and sustainable way and on an industrial scale. The project has proven that CO_2 storage can indeed serve as a viable tool in combating climate change.

For Equinor, offshore CO_2 storage is an important piece of the puzzle to reduce residual industrial emissions and an integral part of our low-carbon hydrogen strategy where we for example aim to provide climate-friendly blue hydrogen for the steel and chemical industry.

In cooperation with the Norwegian state, who provides substantial funding, and partnering with Shell and Total, we are developing the first open-source CO_2 transport and storage infrastructure for industrial emitters across Europe: The Northern Lights Project, which is planned to begin operation by 2024.

Learn more: http://youtu.be/pAAb1S4bqks

http://www.equinor.com

Credit: Kjetil Alsvik