

Geological methods

Carbon dioxide storage in geological formations below the German North Sea

Carbon dioxide storage in the deep subsurface of the North Sea is technically feasible and has been practised for decades beneath Norwegian waters. Under the German North Sea, there are rock formations in which large quantities of carbon dioxide could presumably be stored, too. Nevertheless, important questions remain unanswered, which are to be addressed and answered in the CDRmare research mission – with the aim of enabling carbon dioxide storage in the geological subsurface of the German North Sea in compliance with the precautionary principle.

Storage for captured carbon dioxide emissions

- > There is a consensus in climate research: Even with ambitious climate policies, Germany is still expected to release **10 to 20 percent** of current greenhouse gas emissions by the middle of the 21st century, further accelerating climate change.
- > To offset these emissions, humans will have to remove the same amount of carbon dioxide from the atmosphere. The gas must then be stored safely. Some of the residual emissions can also be avoided from the outset. To do this, fossil carbon dioxide is captured directly at the emission source and then stored underground. The gas must then be safely stored. This technique is called **carbon capture and storage (CCS)**.
- > Carbon dioxide is a long-lived gas. Its extraction and storage must therefore be **effective and permanent**. Some key CO₂ removal methods, such as direct air capture and bioenergy generation with carbon capture and storage (BECCS), rely on **deep underground storage**.

CO₂ storage in sandstone formations of the German North Sea

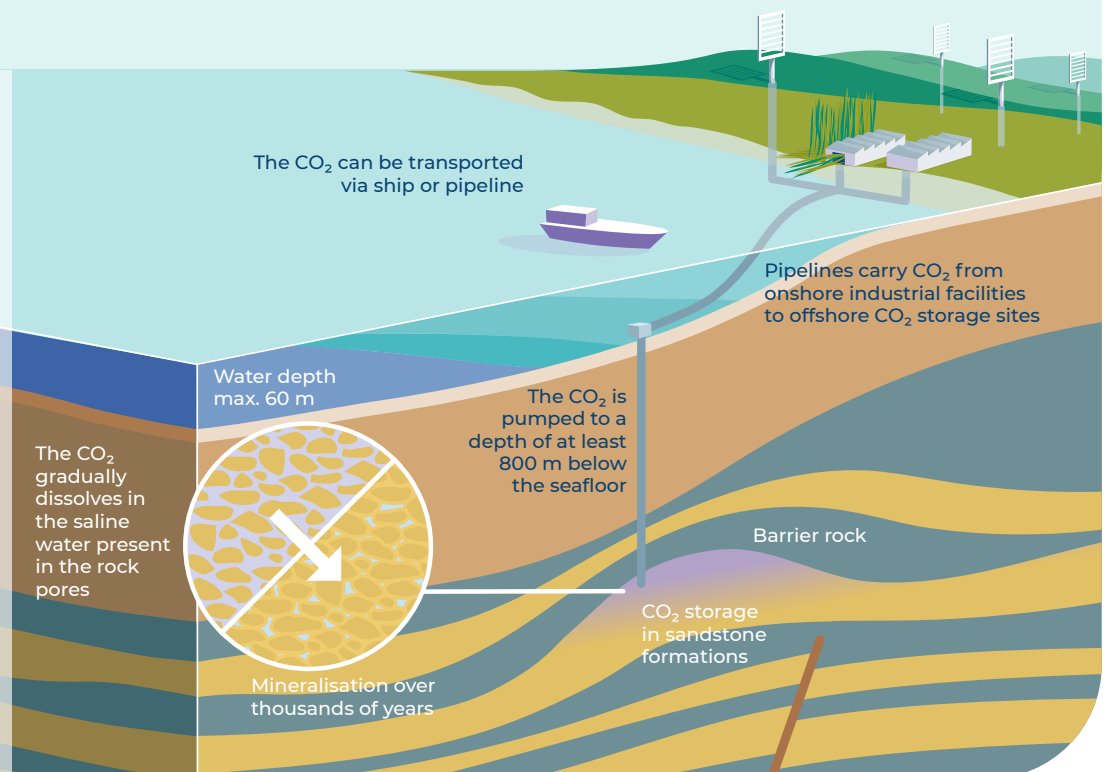
Costs associated with capture, liquefaction, transport, storage, monitoring: **approximately 150 to 250 euros per ton of carbon dioxide**

For storage in the ocean's subsurface, liquid carbon dioxide is transported by pipeline or by ship to the relevant ocean site and injected through one or more boreholes into deep porous sandstone formations. In the rock pores, the carbon dioxide then spreads and collects at the highest point of the reservoir under the barrier layer. Over time, the carbon dioxide dissolves in the formation water and reacts with minerals contained in the surrounding sandstone. In this process, minerals (carbonates) are formed in which the carbon dioxide is permanently bound. However, several centuries pass before this happens.

Scalability: CO₂ storage at industrial scale is possible

Duration of storage: permanently possible, monitoring required

Technical level of development: The method is **feasible** and is **already being used successfully** outside Germany



Technically feasible, planned in many locations

- > The safe and permanent storage of large quantities of carbon dioxide in the deep subsurface of the North Sea is **technically feasible** and has already been successfully practiced under Norwegian waters for more than two decades.
- > In the Netherlands, Denmark, Great Britain as well as in Norway, various companies are currently planning **further large-scale projects in the North Sea** because the capture and storage of carbon dioxide in the seabed is now economically viable due to the rising prices for CO₂ emission certificates.

The geological subsurface of the North Sea offers great CO₂ storage potential

- > The North Sea has massive sandstone formations in its deep subsurface and thus offers good **geological conditions** for carbon dioxide storage. Its shallow water depth also facilitates the installation of the necessary technical infrastructure.
- > It is estimated that around **150 billion metric tons** of carbon dioxide could be stored in the deep subsurface of the entire North Sea. The potential storage reservoirs in German waters would account for 3.6 to 10.4 billion metric tons. To put this into perspective, it is estimated that Germany will produce residual emissions of 0.06 to 0.13 billion metric tons of carbon dioxide per year in the future.

Risks are known, but strategies for solving them are missing

- > The **risks** of the technology to humans and the environment are well known. They include:
 - > the unintentional **escape of the stored carbon dioxide** from the reservoir rock (leakage) and the resulting acidification of near-bottom water masses;
 - > **contamination of the marine environment** by very salty formation water, as well as by **heavy metals and other substances harmful to the environment** that could be contained in the formation water displaced from the reservoir rock in the course of carbon dioxide injection;
 - > **seismic events** at depth, which could threaten the functionality and stability of seabed-anchored infrastructure; and
 - > **noise disturbance** to marine organisms during the search for suitable storage structures, construction of the facilities, and long-term monitoring of the carbon dioxide storage facilities.

Monitoring and mitigation concepts have been developed for CCS projects in neighboring countries, but they must now be adapted to conditions in the German North Sea and, if necessary, supplemented. In addition, **strategies for dealing with possible conflicts** of use in the North Sea (e.g. offshore wind farms) are needed.

Germany's legal position on carbon dioxide storage in the seabed is in need of clarification

- > International agreements allow coastal states to store carbon dioxide in the geological subsurface of marine areas under their jurisdiction. In Germany, however, **the legal situation requires clarification** and makes CO₂ storage projects difficult. In order to be able to carry out such projects, it would be necessary, among other things, to **amend the Carbon Capture and Storage Act**. In addition, experts recommend that German marine spatial planning be extended to the deep subsurface.

CDRmare provides answers, and concepts for safeguarding and action

- > As part of the research mission CDRmare, **solutions and options for action** are developed for open geological, technical and legal questions of CO₂ storage in the deep subsurface of the German North Sea. **Monitoring and precautionary concepts for risk mitigation** are also investigated. Moreover, the researchers estimate the **costs** involved. By doing so, they create the scientific basis for a comprehensive demonstration project.

All research activities described here are carried out within the CDRmare consortium »GEOSTOR – Submarine Carbon Dioxide Storage in Geological Formations of the German North Sea«.

