SCCS

CO_2 GEOLOGICAL STORAGE:

Commonly asked and critical questions

About this report

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This report contains a list of commonly asked questions concerning the safety and levels of risk associated with offshore underground storage of carbon dioxide (CO_2). The list of questions and answers is framed in the context of the UK Continental Shelf (UKCS) and was compiled by:

- Reviewing questions and concerns appearing in the public perception and NGO literature; and
- Expert review of the compiled question list.

Answers are based on the evidence base gathered and cited here.

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Commonly asked and critical questions about CO_2 Geological Storage

1. What is CO_2?

CO_2 is a naturally occurring substance that is not normally dangerous to human or environmental health. It is naturally present in human blood and the atmosphere – we breathe it out, and plants need it to grow. It also leaks naturally from volcanoes and geysers, can be found in natural underground reservoirs and dissolves in seawater as part of the natural carbon cycle. CO_2 is therefore a fundamental and essential part of nature. CO_2 does not burn and will not explode; it is only at high concentrations that CO_2 becomes dangerous. In human and animal health terms, CO_2 can be toxic and pose a threat to life through asphyxiation, but only when it displaces oxygen down to dangerously low levels. CO_2 is far more dangerous as a major greenhouse gas, the most significant environmental impact of which is to increase global temperatures, exacerbating climate change with damaging impacts on global human health and biodiversity. CO_2 captured from industrial processes may contain extremely low levels of impurities, though these are well understood and managed and are well within acceptable risk levels of current human activities.

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2. How do you store CO_2?

Geological storage is the last of the three major steps in the CCS 'chain'. It can take place both onshore and offshore. In the UK, only offshore geological storage sites are being considered. CO_2 is stored at depths of around one kilometre (and at least 800 metres) in carefully selected sites with rock formations that are both porous and permeable.

At the storage site, a borehole is drilled (or an existing one used) into porous and permeable rock, into which large tonnages of liquid CO_2 are then injected. The CO_2 displaces the salty water which normally occupies the millimetre-sized voids (pores) in the rock. The storage site is overlain by a layer of impermeable rock (caprock), which, together with other geochemical processes, acts to stop any flow of CO_2 back to the surface. These processes are the same geological forces that kept the original fluids contained and they work together to increase the storage security of injected CO_2 over time. Depending on the characteristics of the site and any monitoring requirements, as few as one or two boreholes are required to operate a CO_2 storage site, which will be offshore, deep beneath the North Sea seabed.

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3. How can we be sure it's safe?

Research and real-world experience tell us that CO_2 geological storage is safe and secure. Leakage is very unlikely to occur (see Q3), but if it did, it would be localised and temporary, and would be very unlikely to cause any significant harm to ecosystems or communities. The knowledge and understanding that we have of natural CO_2 reservoirs and real-world experience from industrial CO_2 storage projects, coupled with an extensive and ongoing research base, provide very high confidence in the safety and security of CO_2 geological storage. Hundreds of millions of tonnes of anthropogenic CO_2 have been safely transported, injected and stored in geological formations for over four decades.

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4. How do we know the CO_2 will stay there?

The long-term consequences of storing CO_2 underground are very well understood because naturally occurring reservoirs have been shown to securely contain CO_2 for tens of millions of years. The most suitable storage sites for CO_2 are at least 800 metres beneath the seabed and occur in the same geological formations as oil and gas reservoirs. The same geological structures and mechanisms that kept oil and gas securely contained for millions of years will equally ensure that the CO_2 is securely locked away and unable to return to the surface.

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5. How will we know if the CO_2 leaks?

CO_2 storage sites are carefully selected according to specific criteria designed to ensure that the CO_2 does not leak. However, comprehensive risk management strategies are a regulatory requirement of any proposed project, which means that safeguards are in place to ensure the safety and security of CO_2 transport and storage. Measuring, monitoring and verification (MMV) will be in place which means that, in the unlikely event of CO_2 starting to move towards the surface, this would be detected, and the operator would intervene to control, minimise and prevent leakage. MMV techniques and technologies that have been used in the oil and gas industry for decades are broadly transferable to CO_2 transport and storage, and a range of CO_2-specific techniques has also been developed and used successfully. Bespoke MMV strategies will be tailored to the characteristics of individual storage sites.

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6. What will happen if the CO_2 leaks?

In the unlikely event that CO_2 were to leak from a carefully selected storage site, the leak would be fixed, and any environmental damage remediated to restore the site to a safe and secure state. This would be achieved by applying measures that have been successfully applied in the hydrocarbon industry for over 50 years, as well as new techniques developed specifically for CO_2 geological storage. Measures include management of the injection process to reduce the pressure in the store that is driving the movement of CO_2, and a range of methods to plug leaks, including the use of sealants (e.g. cements, gels, foams, nanoparticles) and hydraulic, gas and chemical barriers, some of which react with the CO_2 to turn it into a stable mineral form. To date, such measures have not been required as, despite intensive monitoring, there have been no confirmed leaks from existing CO_2 geological storage projects. Corrective measures covering potential leakage pathways, which can be broadly categorised as either manmade (e.g. related to the well and injection operations) or natural (e.g. caprock failure, faults or fractures), are a key part of storage risk management. Implications of leakage for adjacent environmental uses such as fishing, aquaculture and offshore renewables are likely minimal, though this requires further study.

Responsibility for corrective measures would lie with different parties at different stages over a site's lifetime: the operator would likely be responsible during the operational phase and the post-closure period up until the point at which the operating licence expires; at this point, responsibility would likely transfer to the competent authority, i.e. Scottish or UK Government, depending on the location of the storage site. More work is required to establish this issue of transfer of liability more clearly, particularly given the regulatory transition associated with the UK's exit from the EU.

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7. What will happen to the sea and marine life if the CO_2 leaks?

Impacts of CO_2 leakage on the sea and marine life are likely to be small compared to the impacts of ongoing processes such as bottom trawler fishing and ocean acidification. Should CO_2 leak from the seabed, any impacts will be highly localised (radius of tens of metres) and the risk of significant harm being caused to the sea or marine life is very low. There would be impacts on the immediate ecosystem, but the recovery from these is expected to be rapid - within one growing cycle or season – although the impacts on specific plants or animals will depend on their stage of development.

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Pearce, J., et al. (2014). "A Guide for Assessing the Potential Impacts on Ecosystems of Leakage from CO_2 Storage Sites." Energy Procedia **63**: 3242-3252. (Pearce, Jones et al. 2014)

8. Will drinking water be affected if the CO_2 leaks?

The risks to drinking water from a CO_2 leak from an offshore storage site are very low. CO_2 can mobilise trace elements already in the subsurface, which can have an adverse effect on drinking water, though the risk of this happening is very low with levels falling within the normal range for existing oil and gas activities.

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9. What will happen if there's a seismic event?

CO_2 storage sites are normally situated away from earthquake zones or high-risk areas. The North Sea basin is a tectonically stable area and, while seismic events do occasionally occur, there has been no significant impact on oil and gas operations to date, providing confidence in the low likelihood and degree of potential impacts on CO_2 geological storage operations. Evidence from two demonstration projects in Japan (the Nagaoka pilot project in 2004 and the Tomakomai CCS demonstration project in 2018) - one of the most seismically active regions in the world - confirmed that no leaks were detected following large earthquakes, with CO_2 injection continuing safely once investigations had concluded.

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10. Will storing CO_2 underground cause seismic events?

It is possible, but unlikely: the injection of CO_2 into the porous rock causes an increase in pressure in the reservoir, which could cause a small seismic event (induced seismicity). This is likely only during the active injection phase and near aftermath. The risks and consequences of induced seismicity, however, are very well understood and managed, because other human activities, such as mining and oil and gas operations, can also cause seismic events if not properly managed. Experience gained from these industries, along with careful site selection; mandatory comprehensive risk management and monitoring strategies; the suite of existing seismic monitoring technologies; and measures to control the injection rate and reservoir pressure, will help to reduce any risk of induced seismicity from storing CO_2 underground.

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11. What is the difference between Enhanced Oil Recovery and CO_2 storage?

Enhanced Oil Recovery (EOR) is the term for a range of techniques that oil producers can use to improve the recovery rate of oil wells. These can involve thermal, gas injection or chemical injection approaches. The injection of CO_2 is one approach that has been used to improve oil production. CO_2 EOR has been used in a number of studies as an analogue for CO_2 injection in dedicated storage sites. However, the nature of CO_2 injection in each of these cases may differ for several reasons, limiting the usefulness of this analogy. There are no known current project proposals in Scotland to combine EOR activity with CO_2 storage.

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12. Is storing CO_2 the same as fracking?

No. These two activities do share some similarities in approach, but their applications and end results are quite different. Fracking is for carbon extraction; CCS is for carbon storage.

Fracking involves drilling a borehole into organic rich mudrock (shale) and injecting large volumes of water, sand and chemicals at high pressure. The process is designed to form thousands of cracks (fractures) in the shale, which contains gas and oil, to allow these hydrocarbons to escape from the rock and flow up a borehole to the surface. Fracturing the rock in this way causes small earthquakes (induced seismicity). Many tens of boreholes are typically needed to undertake a fracking development on land.

CO_2 geological storage involves drilling a borehole (or using an existing one) into porous and permeable rock and injecting large tonnages of liquid CO_2. The injected CO_2 displaces the salty water which normally occupies the millimetre-sized voids (pores) in the rock. The storage site is overlain by a layer of non-permeable rock (caprock), which, together with other geochemical processes, acts to stop any flow of CO_2 back to the surface. Depending on the characteristics of the site and any monitoring requirements, as few as one or two boreholes are required to operate a CO_2 storage site, which will be offshore, deep beneath the North Sea seabed.

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