Carbon capture and storage (CCS) – Frequently Asked Questions

General questions about CCS

What is CCS?

CCS involves capturing carbon dioxide (CO_2) that would otherwise be emitted into the atmosphere from industrial sources, such as coal-fired power stations, and storing it deep underground in geological structures. The CCS process usually involves four stages:

1. CO_2 is captured and separated from industrial emissions;
2. CO_2 gas is compressed into a liquid-like form;
3. CO_2 is transported along a pipeline to a suitable storage site; and
4. CO_2 is injected deep underground into secure geological formations for long-term storage – a process known as geosequestration.

Why do we need CCS?

CCS has the potential to significantly reduce greenhouse gas emissions by removing large quantities of CO_2 that would normally be released into the atmosphere and instead storing it deep underground.

There is currently no single technology available that will reduce greenhouse gas emissions to the levels needed to avoid worsening climate change. However, along with developing renewable energies and improving our energy efficiency, CCS is part of a portfolio of solutions that will help Australia and the world achieve large cuts in emissions while satisfying everyones energy needs.

It does not replace the need to convert to renewable and other clean energy technologies, but while these technologies are still being developed and improved we will continue to rely heavily on fossil fuels for our future energy needs.

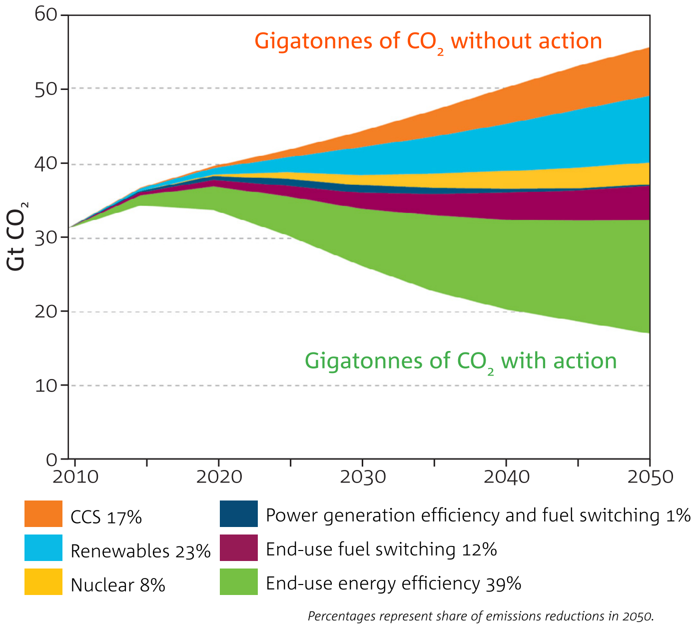


Figure 1: A wide range of technologies, including CCS, will be needed to achieve a substantial reduction in CO_2 emissions globally (Data from the International Energy Agency's Energy Technology Perspectives 2012 report shows that a wide range of technologies, including CCS, will be needed to achieve a substantial reduction in CO_2 emissions globally).

Is CCS a proven technology?

Many of the CCS technologies used are well developed and have been used for decades by the petroleum industry. Experience with geological storage projects across the world has also shown that CO_2 can be stored securely with a very low risk of leakage.

What is now being investigated is the use of CCS for capturing and storing industrial emissions at a large scale that is also commercially viable.

As at September 2012, the Global CCS Institute identified 75 large-scale integrated projects worldwide, 16 of which are operational or under construction, capturing around 36 million tonnes of CO_2 per annum. The eight large-scale integrated CCS projects currently in operation are:

- Sleipner CO_2 Injection, Norway;
- In Salah CO_2 Injection, Algeria;
- Snøhvit CO_2 Injection, Norway;
- Great Plains Synfuel Plant and Weyburn-Midale Project, Canada;
- Shute Creek Gas Processing Facility, USA;
- Enid Fertilizer, USA;
- Val Verde Natural Gas Plant, USA;
- Century Plant, USA.

For further information on these projects please visit www.globalccsinstitute.com

In March 2013 the European Commission released a draft energy paper suggesting that the EU increase its emissions reduction target to 40% by 2030, and the paper has placed CCS technology at the heart of future EU energy policy.

"In order to allow fossil fuels to remain an integral part of the energy mix and the EU to offer a potential for a green re-industrialisation of Europe's declining industries, early deployment of CCS technology at a large scale is needed," reads the document.

The Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC) Otway Project is Australia's first operational storage demonstration project. In Stage One of the project, approximately 65,000 tonnes of CO_2-rich gas was safely injected into a depleted gas reservoir, two kilometres deep underground. A comprehensive monitoring program has verified that the injected CO_2 is securely contained, which is in keeping with models made of the storage reservoir and the movement of CO_2. The second stage of the project is now looking at injecting CO_2 into a saline aquifer.

There are also a number of other proposed CCS demonstration projects in Australia.

Current and/or proposed carbon storage projects in Australia include:

- Gorgon Gas Field, Barrow Island, Western Australia;
- Fairview Project, Queensland;
- International Power Capture Plant, Hazelwood Power Station, Victoria;
- Latrobe Valley Post Combustion Capture Project, Victoria;
- Callide Oxyfuel Project, Queensland;
- CarbonNet Project, Victoria;
- South West Hub Project, Western Australia;
- Coolimba Power Project, Western Australia;
- Galilee Power Project, Queensland;
- Munmorah PCC Project, New South Wales;
- Tarong PCC Project, Queensland;
- Wandoan/Surat Basin Project, Queensland.

Is CCS safe?

CO_2 is a naturally occurring gas that is released into our atmosphere every day from respiration by all animals, fungi and microorganisms. We breathe it out, plants use it as a part of photosynthesis. It is not toxic, flammable or explosive. In fact, low levels of CO_2 are necessary for all life.

CO_2 is also produced as a by-product of the combustion of fossil fuels (coal, oil and natural gas) or the burning of vegetable matter, among other chemical processes. CCS involves storing large quantities of industrially produced CO_2 deep underground in naturally occurring geologic formations. Some of these formations have already trapped oil and gas deposits, as well as naturally occurring CO_2 gas, for millions of years. With proper engineering design and monitoring, the same kinds of seals that originally trapped oil and gas will ensure that the injected CO_2 is highly likely to remain securely stored for thousands of years.

The possibility of leakages is something that has to be taken very seriously, although in reality failures of wells, pipelines or other surface CCS facilities is very unlikely, and such failures would be easy to detect as any leakage of CO_2 into groundwater or the atmosphere would be very gradual.

Is CCS economically viable?

When mobile phone technology was first introduced in the USA in the 1940s, the lack of radio channels meant that only three customers in any given city could make telephone calls at one time, paying very high rates per call.

Fast forward 60 years and there are six billion mobile phones in use around the world- almost one per head of population- with a range of competitive prices on offer.

As CCS is a new industry, initial costs will be high. However, future costs are likely to decline with advances in technology and once it is used on a large-scale. In terms of power generation, estimated costs for using CCS technology are comparable to other low emission technologies such as wind, and significantly cheaper than solar.

Alarmingly, however, the International Energy Agency (IEA) estimates that without the widespread global deployment of CCS technology, the cost of halving CO_2 emissions by 2050 would be 70% higher.

Questions about the geological storage of CO_2

Injection of CO_2

HOW IS CO_2 INJECTED UNDERGROUND?

After capture the CO_2 is compressed into a dense, fluid-like state, before being injected under pressure to a depth of at least 800 metres. At this deep level the pressure and temperature is sufficient for the CO_2 to remain in a supercritical state.

WHAT WILL THE INJECTION SITE LOOK LIKE?

Onshore storage of CO_2 will require minimal infrastructure and will generally include:

- **Wells:** usually consisting of a two-metre long pipe protruding from the ground, equipped with valves and metering equipment. Monitoring equipment will be placed around the area to test the air, soil or aquifers for CO_2 contamination.
- **CO_2 compressor:** housed in a small shed. Noise from the compressor will meet noise regulations.
- **Pipelines:** to transport the liquid CO_2 to the injection site. These are likely to be buried underground and will have no visual impact.

CO_2 storage sites

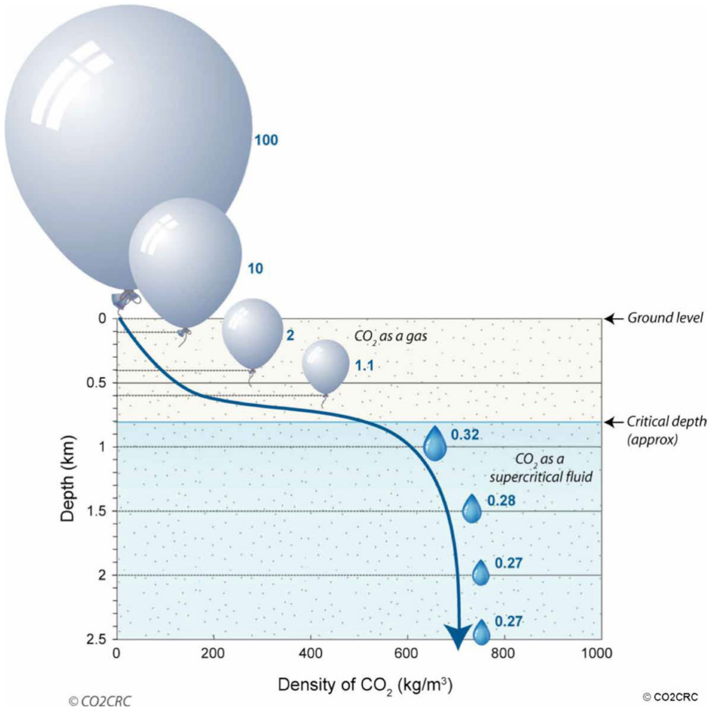
WHERE CAN CO_2 BE STORED UNDERGROUND?

CO_2 can be stored in geological rock formations deep underground.

Suitable geological formations are typically areas of porous rock lying beneath thick layers of impermeable rock. The spaces in the porous rock trap the CO_2, while the thick impermeable layers act as a 'cap rock' to create a seal.

There are currently three main storage options:

- **Depleted oil and gas fields:** the removal of oil and gas from a reservoir creates space in porous rocks that can be refilled with injected CO_2. These sites are attractive because their natural trapping mechanisms have often securely held oil and gas, as well as naturally occurring CO_2 gas, for thousands to millions of years.



How CO_2 is changed during injection from the surface. As the combined temperature and pressure increase with depth, the CO_2 gas transitions into its most dense phase as a supercritical fluid. This means that any volume of CO_2 gas at normal atmospheric pressure can be condensed into much less volume (about 400 times smaller) for storage in deep underground reservoirs.

- **Deep saline aquifers:** injected CO_2 can be stored in unusable saline water residing in porous rocks several kilometres down, trapped below sealing layers of impervious clay and mud. The CO_2 dissolves into the saline fluids over time and remains trapped in the pore spaces of the rocks.
- **Coal seams unsuitable for mining:** injected CO_2 can enter very small pores within the coal, where it is held so tightly it will remain there even without cap rocks. Some coal seams already hold gases, such as methane. In some instances the injected CO_2 displaces the methane, which can then be recovered and used as fuel.

WHAT MAKES A STORAGE SITE SUITABLE?

The main geological conditions needed to securely store CO_2 are:

- Adequate capacity to store the injected CO_2.
- Reservoir rock that is both porous and permeable. The rock must have pore spaces in which the CO_2 can reside and have links between pore spaces (permeability) to allow the CO_2 to move through it.
- A trapping mechanism to prevent the CO_2 migrating from the target geological structure. There are four basic mechanisms that keep the CO_2 in place: stratigraphic/structural, residual, dissolution and mineral trapping.
- An impermeable cap rock to prevent the CO_2 from migrating upwards.

Suitable storage sites must be at a depth of at least 800 metres so that the pressure and temperature is high enough for the injected CO_2 to remain in a dense, fluid-like (or supercritical) state.

HOW ARE SUITABLE STORAGE SITES IDENTIFIED?

Choosing and characterising the geological storage site is the most critical part in mitigating the risk for storing CO_2 underground.

A number of tests and analyses are conducted to determine whether a site is suitable including geological site descriptions, seismic surveys, formation pressure measurements and water sampling.

WHAT HAPPENS TO THE STORED CO_2 OVER TIME?

After injection and due to its buoyancy, the CO_2 moves through the porous reservoir rocks. The amount and speed of migration depends on the amount of CO_2 injected, the nature of the rocks and geological structures and pressure. The CO_2 may slowly migrate up towards the base of the sealing rock formation. This natural seal will block the CO_2 from migrating towards the surface (structural trapping) and prevent its release into the atmosphere.

The CO_2 may also gradually dissolve in the saline water in the pores (dissolution trapping) or be trapped in rock pores along the migration route (residual trapping), enabling all the CO_2 to be securely dispersed. The CO_2 may also react with other minerals underground and form new rocks such as calcium carbonate (mineral trapping). When this occurs it will be permanently trapped. Over time, a combination of trapping mechanisms is likely to take effect, making the CO_2 more securely stored.

HOW MUCH CO_2 CAN BE STORED UNDERGROUND?

The amount of CO_2 that can be stored underground depends on the type of geological formation used to store it. Because of this, estimates of global geological storage capacity are highly variable. Nevertheless, most studies have indicated that the storage capacity for CO_2 in geological formations is equivalent to many years of global annual CO_2 emissions.

A preliminary estimate by scientists at the United States Department of Energy's Pacific Northwest National Laboratory (PNNL) indicates there is nearly 11 trillion tonnes of potential global deep geological storage capacity, which should meet the storage needs for this century. A more conservative estimate by the Intergovernmental Panel on Climate Change (IPPC) has identified a technical potential of at least 2 trillion tonnes of worldwide CO_2 storage capacity. In Europe, the EU project GESTCO estimated the region around the North Sea could contain 37 billion tonnes, enough for the injection of CO_2 for several decades.

COULD STORED CO_2 LEAK TO THE SURFACE OR CONTAMINATE GROUNDWATER?

The government will only grant licences for CO_2 injection at storage sites proven to be geologically stable with an appropriate seal or trapping mechanism suitable for CO_2 containment.

The geology, sequence of rock formations and saline aquifers, as well as the presence of the cap rock, ensure that the CO_2 remains securely stored away from groundwater and the atmosphere. CO_2 injection is typically much deeper (at least 800 metres underground) than usable sources of groundwater, so the risks to water supplies are minimal.

Comprehensive monitoring of the migration patterns and behaviour of injected CO_2 is an integral part of CO_2 storage. The aim is to provide an early warning of any migration beyond the expected zones, allowing corrective action to be taken.

HOW COULD A CO_2 LEAK BE MANAGED?

In the rare event that a CO_2 leakage occurred, comprehensive monitoring and verification regimes would be in place to detect it at an early stage. Migration into overlying rock formations (due to inadequacies in the seal or in the well completion) would be detected by repeat geophysical techniques, while a variety of monitoring methods would be in place to detect leakage into the atmosphere that exceeds the natural background levels.

Leaks from surface facilities, such as wells and pipelines, would be readily detectable, and could be dealt with by the types of procedures that the petroleum industry already uses for oil and gas facilities. In the unlikely event that CO_2 was to permeate to the surface, a gradual escape of CO_2 would be expected and would be dissipated by the wind, as normally occurs when CO_2 is vented naturally in volcanically active areas.

Further reading

If you would like to view a video version of our frequently asked CCS questions, please visit the National Geosequestration Laboratory (NGL) website, www.ngl.org.au

Further information on CCS can be found at any of the following websites:
www.globalccsinstitute.com
www.co2crc.com.au

KEY CONTACT
Mr Eamonn Bermingham
Communications Advisor
t +61 8 6436 8627
e eamonn.bermingham@csiro.au

CONTACT US
t 1300 363 400
+61 3 9545 2176
e enquiries@csiro.au
w www.csiro.au

CESREfs003-13 CCS