Risk revealed by Lloyds:

# Carbon capture and storage

**Tuesday 15th November**

In our third *Risk revealed by Lloyd's* event, we welcomed back bp to explore the future of carbon capture and storage (CCS) and the role that it is playing in supporting decarbonisation and global net zero targets.

This post event read summarises some of the key themes and questions discussed during the event, which included:

1. How does CCS support the broader energy transition?
2. What is the current size and growth trajectory of the sector?
3. How do these technologies work in practice?
4. What are the key risks involved and what are the controls in place?

## An intro to CCS

Carbon capture and storage (CCS) continues to gain momentum as business and governments struggle to keep pace in the race to net zero. But for many years, CCS wasn't so popular, hindered by prohibitive costs and lack of political and scientific support.

In just the last ten years, we've seen a shift in favour of the technology on a global scale. Now recognised by the UN´s Intergovernmental Panel on Climate Change as a critical part of global efforts to avoid a climate catastrophe and also by US Congress, who are injecting billions of dollars into CCS efforts through tax incentives, as part of the Inflation Reduction Act passed this summer.

Today, there are more than 80 CCS projects in development in the US, all targeting production by 2030. In the UK, CCS is recognised as a must-have component of the UK's net zero strategy, with government and businesses taking geological advantage of having one of the greatest CO2 storage potentials in Europe.

In time, the International Energy Agency estimate that CCS alone could account for 15% of carbon reduction emissions. Growth and adoption of CCS technologies is happening in front our eyes, but with expediated development, we typically also see a significant change to the risk landscape and exaggerated even more so for the industries looking to reduce the hardest emissions to abate and handle them safely at an industrial scale.

If risks are not managed properly, implementing new technologies at the scale required to solve the climate crisis could create other problematic impacts for the environment. CCS is no different.

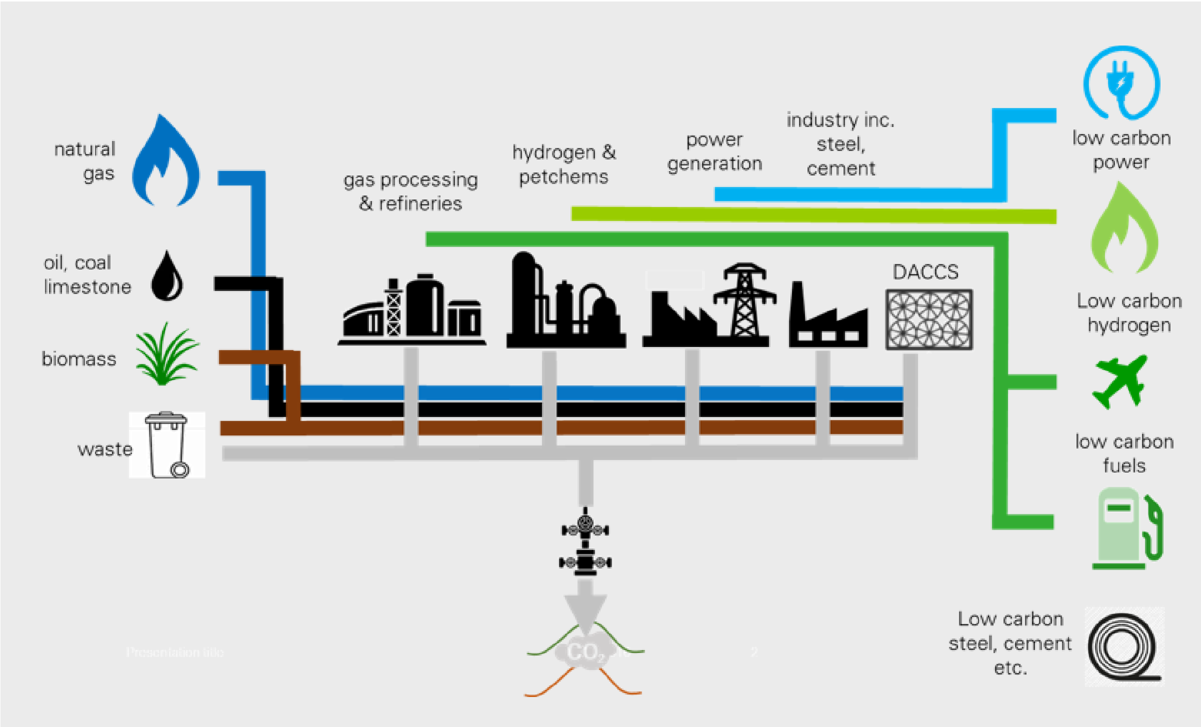
## How does CCS support the broader energy transition?

The world's leading climate and energy bodies – the United Nations' Intergovernmental Panel on Climate Change (IPCC) and the International Energy Agency (IEA) – have all outlined a clear and key role for CCS in reaching net-zero emissions by 2050.

Industries, such as steel, shipping, and cement need a mix of decarbonisation methods, including CCS in their net-zero transition. CCS is also an enabler of low-carbon technologies like blue hydrogen which plays an important role in reaching a clean energy mix. Some share the view that without CCS, reaching our net zero goals is practically impossible.

It is also not just an interim technology to help us reach net zero by 2050. In the near and mid-term it can enable the rapid decarbonisation of existing energy systems and industrial processes in which carbon is an important part of the value chain. Many now also expect that delivery of the Paris goals will require permanent carbon removals and geological storage of CO2, is a key enabler of that.

According to bp and the IEA's World Energy Outlook, to play its role in reaching net-zero climate targets by 2050, carbon capture and storage will need abate around 6 gigatonnes of CO2 per year. This will require a significant scale-up of the current fleet of CCS facilities.




*Source: bp*

How CCS enables a low-carbon energy system:

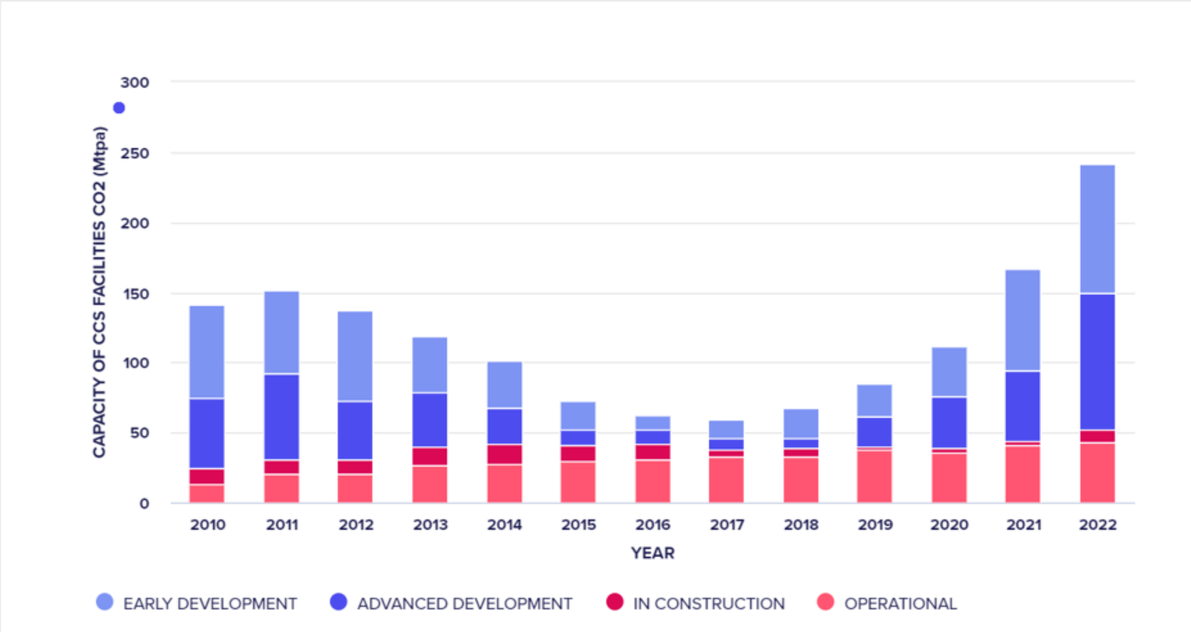
- It complements wind and solar in the decarbonisation of electricity
- It enables blue hydrogen and the production of low carbon fuels
- It can decarbonise steel, cement and other hard to abate industries
- It enables carbon removals (BECCS & DACCS)

Moreover, when delivered properly CCS can create value for local communities, particularly those reliant on historically carbon intensive industries, to reinvent themselves as thriving locations for new low carbon hubs.

### What is the current size and growth trajectory of the sectors?

The first CCS projects were in the US Permian Basin (West Texas) in the 1970s when CO2 was used to enhance oil production but resulted in CO2 storage as CO2 displaced oil and water in the reservoir. In 2022, 61 CCS facilities were added to the global project pipeline.

Currently there are 30 operating facilities, with a cumulative capture capacity of ~42 million tonnes per annum (mtpa), and around 90 facilities across all stages of development with a capacity of ~200 mtpa. But much more needs to be done to reach net zero.



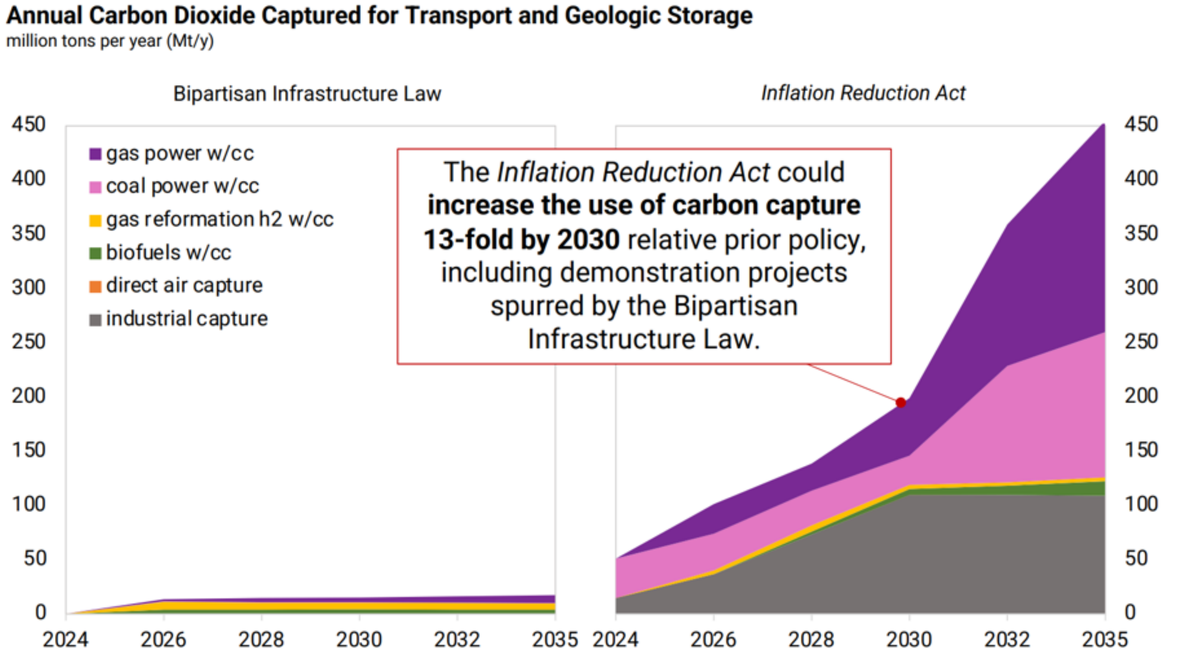

Source: Global CCS Institute, Global Status Report, 2022

Most operational plants are located in the US and Canada, but also in Norway, UAE, Saudi Arabia, Brazil, Australia and China. The UK, Netherlands, and Indonesia are also showing progress in their adoption of CCS facilities.

In 2022, CCS has become more popular through the development of strategic partnerships in CCS clusters and policy incentives that are expected to boost its growth.

- In the UK, bp is leading the CCS East Coast Cluster developing CO2 transport and storage infrastructure for the Tees and Humber regions. The project includes onshore pipelines, compressors, offshore pipelines, subsea manifolds, injection wells and deep saline formations for geological storage with monitoring

- In the US the Inflation Reduction Act could increase the use of carbon capture 13-fold by 2030 relative to prior policy, including demonstration projects spurred by the Bipartisan Infrastructure Law




Source: Princeton University, 2022

But to unlock the full potential of CCS in the journey to net zero, the view of most experts is that more governments need to create the right policies and enabling regulation for the private sector to take action with robust business models.  Governments can also enable access to finance from investment and infrastructure banks to make project finance more widely available. Local government can play an important leadership role in the development of CCS clusters.

## How do these technologies work in practice?

Carbon capture and storage involves different technologies to capture, transport, and store CO2 safely underground. The capture can be done in two ways, capturing CO2 from large emission sources known as ‘point-source capture’, and directly from the atmosphere known as ‘direct air capture’.

Point-source capture is when large emission sources, such as steel mills, cement plants, and petrochemical facilities are equipped with technology allowing the capture of CO2, preventing it from being emitted to the atmosphere. With direct air capture, it is possible to remove historical CO2 emissions, those that are already in the atmosphere.

### Capture

There are several methods to capture the CO2 based on the emission source:

> **Post-combustion** capture involves removing CO2 using from flue gases, with liquid solvents (amines) currently leading the market. This is commonly performed in gas processing operations and is now being deployed on flue gases from power stations

and industrial processes. Solid adsorbent technologies are developing rapidly and are likely to become competitive over time.

**Pre-combustion** capture involves reforming natural gas to produce hydrogen, and capturing the resultant CO2. The main techniques are Steam Methane Reformation (SMR) and Autothermal Reformation (ATR)

**Oxy-fuel combustion** capture involves burning hydrocarbons in pure oxygen, as opposed to air. The CO2 is separated from water in the exhaust.

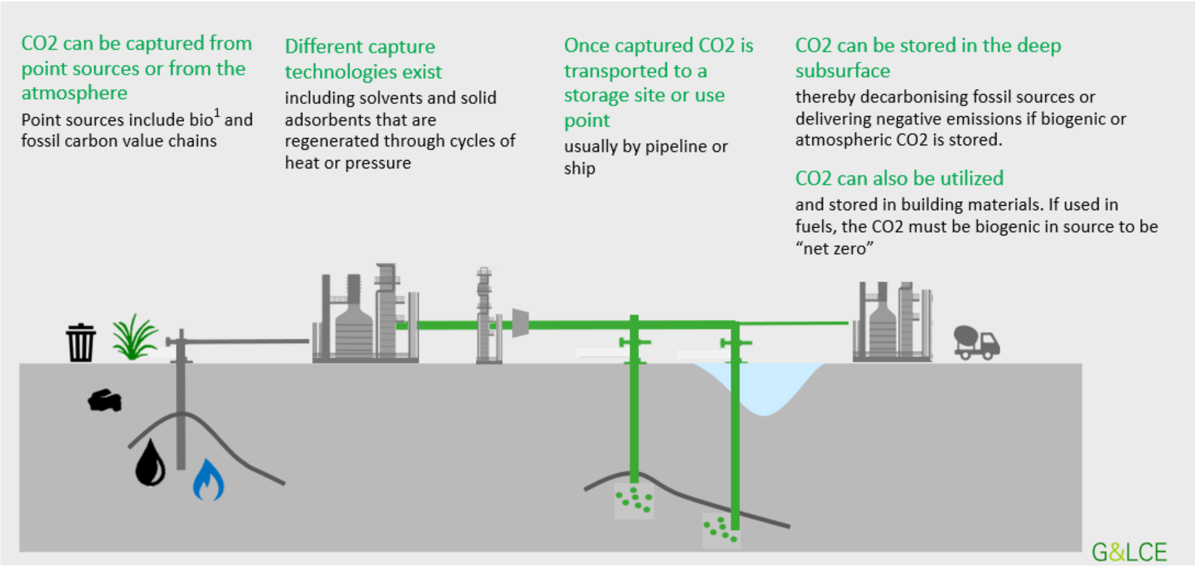
**Direct Air Capture** involves extracting CO2 from the atmosphere. There are many technologies in development and early deployment stages.

## Transport

Once the CO2 is captured, it is compressed for transportation. The compression increases the density of CO2 causing it to behave like a liquid. For large quantities of CO2, pipelines are the most common mode of transport. Transporting CO2 by ship, trucks and rail are also viable alternatives but typically more expensive.

## Storage

Following transport, the CO2 is injected into deep underground rock formations where it is safely and permanently stored in geological structures. The rock formations are similar to those that have held oil and gas underground for millions of years. CO2 has been safely stored underground in enhanced oil recovery projects since the 1970s using mature technologies for its injection and monitoring, and since 1996, CO2 has been commercially stored in saline formations.




Source: bp

## What are the key risks involved and controls in place?

### Transport

Although $CO_2$ isn't flammable, releases of $CO_2$ if not quickly dispersed can create the potential for asphyxiation.

Buried pipelines usually offer the lowest cost, lowest risk solution to transporting $CO_2$. Historically, there have been very few incidents, but even buried pipelines can be ruptured, for example by landslides, resulting in releases. When transported by pipelines, risks are managed by strict standards for pipeline materials and wall thickness, the use of staged isolation valves, sensible pipeline routing, and appropriate inspection and maintenance regimes. Transporting $CO_2$ by pipelines is a technology already tried and tested. The USA alone already has about 5000 miles of $CO_2$ pipelines in service. As with all potentially hazardous substances, good design, controlled handling protocols and strong regulation are key to mitigating risks.

### Storage

The risks involved and controls in place in geological storage can be dissected in three main components – containment, capacity and injectivity.

**Containment** refers to $CO_2$ staying within the rock formations selected for storage and not migrating into formations where it could cause issues with other geological operations such as freshwater extraction. Containment risk is principally addressed through site selection, knowledge of local and regional geology and previous development activity. For instance, sequences of impermeable rocks such as shales or salts prevent vertical migration of $CO_2$ out of the storage complex. Also, avoiding faults and natural fractures that can provide routes for unplanned $CO_2$ migration. Storage sites that contain heritage must ensure these wells are appropriately plugged to avoid the potential for them to become future leak paths.

Containment risks are monitored throughout the life of a field, usually using observation wells, surface sensors, and remote sensing techniques such as micro seismicity. This data is used to calibrate calculations to predict future behaviour of the stored $CO_2$. If the data indicates the potential for $CO_2$ to move outside its target zone, appropriate action can be taken, for example by extending the storage site, or reducing its target storage volume.

**Capacity** risk refers to how much $CO_2$ a storage site can hold relative to plan. If a storage site's capacity is smaller than plan, the unit cost for storing $CO_2$ might rise, and plans to develop successive storage sites may need to be accelerated.

**Injectivity** risk refers to the actual performance of an injection well versus plan. This is often difficult to predict exactly for an individual well but has lower compound uncertainty at a field or regional level. If wells outperform their injection target, fewer wells may be needed in the development. If wells underperform, then more may be needed, which increases project cost.

After injection operations cease, containment risk continues to be managed through ongoing monitoring. A jurisdiction may specify how long this activity should continue. In some jurisdictions, subject to a review process, state authorities may decide to take on long-term stewardship of the CO2 that has been safely and permanently stored.

## How can I get involved in future events?

Thank you to those that spoke at and attended this event. Through collaborations like these, along with the continued work of Lloyd's Futureset we can deliver on Lloyd's commitment to be a catalyst for action, to empower innovation and to convene leading experts to address today's most pressing challenges – including the climate crisis.

We will be running more workshops on these issues and there will opportunities over the coming months to play your part in joining the reset. Sign up to our mailing list to see our latest insight or reach us directly to get involved – contact futureset@lloyds.com