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Carbon Capture and Storage (CCS)

The key to cleaning coal

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"The UK faces a massive challenge over the next decade. We need more power for our homes and businesses, and we need to deliver this in a way which minimises our impact on the environment and keeps energy as affordable as possible.

"On a global level, we believe that the development of carbon capture and storage (CCS) technology is critical if we are to tackle the threat of climate change, and we hope to play a key role in its development."

What is CCS?

CCS is a process that allows carbon dioxide (CO_2) to be captured from power stations to prevent it from entering the Earth's atmosphere. It's a technology that is developing all the time and could well make fossil-fuelled generation a viable low-carbon option for the future.

The UK Government is holding a competition to build a CCS plant on an industrial scale with the aim of demonstrating the capture, transportation and storage of carbon dioxide from a power plant. E.ON has been shortlisted to participate in the competition.

Why do we need it?

It is now widely accepted that our planet is undergoing climate change, with man-made gases produced from fossil fuels, such as coal, gas and oil, being one of the major causes of global warming.

At the same time, demand for electricity from the UK's homes and businesses continues to rise, placing pressure on companies such as E.ON to generate more power while also reducing its emissions of greenhouse gases.

While some of the answer comes from increasing use of renewable technologies such as onshore and offshore wind, biomass and marine power, we also have to clean up traditional forms of generation from fossil fuels.

Globally, many countries such as China and India do not have access to large gas reserves so coal-fired generation is the only viable source for much of the power needed to support their populations. It is with this in mind that we believe the UK must take a position of leadership in the development of low carbon technologies.

One of the ways that we have of doing this is to fit carbon capture and storage technologies to new and existing power stations – particularly to coal-fired units. By doing that, we hope, in the future, to be able to capture 90% of carbon dioxide before it is released into the atmosphere and to store it underground.

The technologies to do this have been tested on a number of small scale projects across the world. The next step is to take the technology forward and demonstrate carbon capture, transportation and storage on a large scale. When we get there, we'll have a real chance of being able to cater for the global population's energy needs at the same time as protecting our planet from damaging carbon emissions.

How does CCS work?

Carbon capture technology is being developed to play an integral part in large-scale power stations.

The first step involves stripping out the carbon dioxide from the other gases produced in the power generation process. It is important that the CO_2 stream that goes away for storage is as pure as possible.

There are currently three techniques for capturing carbon dioxide:

1. Post Combustion

Post combustion capture is designed to capture the carbon dioxide after the fossil fuel has been burned but before it is released into the atmosphere. The most common way to do this is to use chemicals, generally amines, to get the stream of virtually pure carbon dioxide that can then be transported and stored.

This process sees the flue gases – which are the product of burning the coal or the gas used to produce steam for the power station's turbines – passed through an 'absorber' that is then 'scrubbed' by the amine, which clings onto the carbon dioxide. The 'carbon dioxide loaded' amine is then heated which has the effect of both freeing the carbon dioxide and also cleaning the amine to allow it to be re-used.

The carbon dioxide is then dried to remove any excess water and it is ready for transportation and eventual storage.

By using this method, around 90% of carbon dioxide is captured, with the carbon dioxide stream also having a very high purity – of around 99%.

The main advantages to this technology are that it can be retrofitted to existing power stations and that it is already in use in a wide range of processes around the world.

However, it also has its disadvantages, notably that it reduces both the efficiency and the output of the power station because of the amount of steam and power required to run the systems.

2. Pre-Combustion

The main concept behind pre-combustion capture is to capture the carbon dioxide before you burn the coal. This leads to a situation whereby a coal-fired power station is actually run on gas – hydrogen.

In pre-combustion, the coal is converted into a synthetic gas – mainly hydrogen and carbon dioxide – with the hydrogen used to run the power station and the CO_2 streamed off. This method is more usually called Integrated Gasification Combined Cycle (IGCC).

The major factor in favour of IGCCs is that the carbon dioxide is at a very high concentration and under pressure, making it much easier to capture. The downside to this technology is that it cannot be retrofitted to existing power stations.

3. Oxyfuel Combustion

Simply put, oxyfuel involves burning coal with an oxygen-rich gas rather than in air, which leads to a flue gas that consists largely of carbon dioxide and water.

The great advantage of oxyfuel is that a capture rate of 97% is possible, together with a purity of 99.9%. However, firing in oxygen produces very high temperatures, which means the gas has to be 'diluted' to ensure that there are no problems. In addition, an oxyfuel power station is much less efficient than a traditional air-fired plant because of the need to produce oxygen and to then dilute it, although there are a number of pilot projects in existence.

What happens after the carbon dioxide is captured?

The next step is transportation of the carbon dioxide to a suitable location for storage.

There are two main ways of doing this:

1. Pipeline Transport

Where the gas can be stored relatively close to the power station, pipelines are the most obvious way to transport the gas to the storage site. In actual fact, large-scale transportation of carbon dioxide in pipelines has been going on for over 30 years in the United States, where the gas is used to recover oil from nearly depleted fields.

In fact, in our back yard in the North Sea, the Snøhvit project came on stream in 2007. This scheme transports approximately 700,000 tonnes of CO_2 a year a distance of 145km from an LNG facility to the Snøhvit oil and gas field.

2. Ship Transport

The shipping of carbon dioxide would be very similar to shipping liquefied petroleum gases (LPG), which already happens around the world. The properties of liquefied CO_2 are similar to those of LPG, and the technology could be scaled up to large CO_2 carriers if required.

In order to liquefy CO_2, it is necessary to both cool and pressurise the CO_2, typically to around -50ºC and 7 bar. However, the carbon dioxide would have to be temporarily stored onshore until such time as a boat came available, when it would be transferred to the ship's tanks. Once on site, the CO_2 would be offloaded and heated to allow injection into the storage site.

What are the options for storage?

The CO_2 would be stored in porous rock, such as sandstones, underneath an impervious cap rock. In nature, such rock structures usually contain salty (undrinkable) water, in much the same way that sand on a beach contains seawater. These are called saline aquifers. In some cases, oil or gas has become trapped inside the structures, resulting in an oil or gas field. And in rare cases, they already contain naturally occurring carbon dioxide.

There are three main ways of storing carbon dioxide:

1. Storage in depleted gas/oil fields

Our proximity to North Sea gas fields means the UK is particularly well suited to this type of storage. It's also, in many ways, the most attractive option because we already know so much about such fields.

Further, we would be able to use a number of existing pipelines and rigs, so reducing costs. It is also true that, until we came along, millions of tonnes of gas and oil had been effectively stored under the sea in these fields and so we would be confident that there would be few problems in keeping the gas stored.

2. Enhanced Oil Recovery

This process is already in use, notably in West Texas, and sees the carbon dioxide injected into an oil reservoir to increase the amount of oil recovered while also storing the CO_2.

3. Storage in aquifers

An alternative to depleted oil and gas fields would be to store the gas in deep saline formations, known as aquifers. These can be either on- or offshore and have the advantage of a much larger capacity. The Sleipner Project in the North Sea, 250km off the coast of Norway, is already in operation, where around a million tonnes of CO_2 is removed from the Sleipner West Gas Field and is injected into an aquifer 800m below the seabed every year.

Will the carbon dioxide stay where it's put?

It is believed that, over 1,000 years, storage would be at least 99% effective. For such storage projects, the vast majority of the CO_2 will gradually be immobilised by a combination of physical and geochemical trapping mechanisms which could retain the gas for millions of years.

The most effective storage sites are those where the CO_2 is physically immobilised because it is trapped permanently under a thick, low-permeability seal or cap-rock. This is the case in the majority of the North Sea oil, gas and aquifer formations.

Should any carbon dioxide leak from the initial rock formation, it is likely that it would be trapped well before reaching the surface. Furthermore, it is predicted that over time, much of the CO_2 will dissolve in the water present in the rock formation. This increases the density of the water, at which point it will tend to sink, preventing any further escape of carbon dioxide. Finally, when dissolved in water, carbon dioxide forms a weak acid which would react with the surrounding rock to form solid carbonate minerals, making it even more secure.