10 Carbon Capture and Storage in the UK

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SUMMARY

1. About three quarters of electricity in the UK is produced using fossil fuels which in turn produces approximately one third of total UK CO_2 emissions. Carbon Capture and Storage (CCS) can reduce UK emissions rapidly, whilst renewable energy and low-carbon generation technologies are developed and built.
2. Capture of CO_2 is most beneficial at large point sources such as power stations and industrial facilities. Existing power stations can be retrofitted with carbon capture equipment and new power stations can be built to be ready for capture.
3. Capture of CO_2 is already a common industrial process, although the amount of carbon captured will need to be much greater for use on power station emissions. Transport of CO_2 is already used on a similar scale onshore in the oil industry.
4. Storage of CO_2 is feasible by injection through boreholes into deep geological formations. Many of these formations have stored oil and gas for millions of years and their natural trapping mechanisms can be utilized. Possible storage sites are old oil and gas reservoirs, unmineable coal seams and saline aquifers.
5. With well designed, selected, and managed storage sites, scientists estimate that 99% of CO_2 can be retained over a period of several thousand years. This would store the carbon well beyond the era of fossil fuel use.
6. The UK is well suited to CCS and Storage technology. A quarter of existing power plants must be replaced by 2025 and this poses a perfect opportunity for CCS to be implemented. There are a large number of suitable storage sites present in the North Sea. These could economically and safely store hundreds of years' worth of CO_2 from UK electricity generation and are located close to many potential carbon capture sites.

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10.1 Introduction

Climate change is a global problem which requires global solutions. One significant cause of recent and projected climate change is an increase in greenhouse gas concentrations in the Earth's atmosphere. These increased proportions of greenhouse gases have enhanced the Earth's natural greenhouse effect. The greenhouse gas making the largest contribution is CO_2 and it is now clear that most of the increase in atmospheric CO_2 levels are the direct result of combustion of fossil fuels and biomass since the industrial revolution of the 1850s (IPCC, 2007) (Figure 10.1). Global greenhouse gas emissions have increased by 70% between 1970 and 2004.

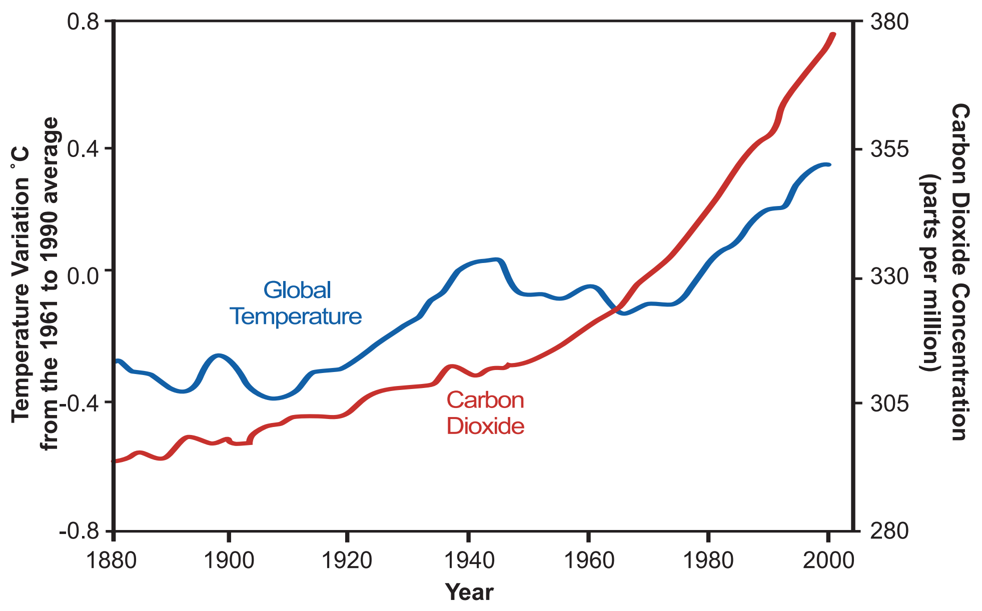

Figure 10.1 This graph shows the increase of CO_2 and the concentration in the atmosphere corresponding with the increase in global temperature since the industrial revolution. It can be seen that the biggest increase in CO_2 levels and global temperature has been since the 1970s. (Atmospheric CO_2 concentrations from IPCC Report, Climate Change 2001: The Scientific Basis, and temperature data from National Oceanic and Atmospheric Administration, Feb 2006).

10.1.1 Threat of climate change on global ecosystems

Many ecosystems around the world are, and will be, threatened by climate change and its associated disturbances (e.g. sea-level rise, ocean acidification and an increase in severe weather events such as drought, wildfire and flooding). Complex life on the surface of planet earth participates in a carbon cycle, where carbon is exchanged through natural processes between the biosphere, geosphere, hydrosphere and atmosphere. It is currently believed that net carbon uptake by terrestrial forest ecosystems is likely reach a peak within the next 50 years and then weaken or even reverse (IPCC, 2007). This is predicted to have the effect of accelerating climate change and thereby placing more species, and human civilizations, in danger.

The most recent Intergovernmental Panel on Climate Change (IPCC) report in 2007 identified that approximately 20-30% of plant and animal species studied are likely to be at an increased risk of extinction if global average temperatures rise by just 1.5 - 2.5°C (IPCC, 2007). These increased temperatures would cause major changes in ecosystem structure and function, species, ecological interactions and species' geographic ranges (IPCC, 2007). It would drastically reduce biodiversity and cause severe disruption to both the natural world and to people, due to reducing water and food supplies. Additionally, increasing atmospheric CO_2 is already leading to the progressive acidification of oceans which is expected to cause major impacts on the metabolism of invertebrates, the ecology of the shallow seabed, and marine shell forming organisms (The Royal Society, 2005; IPCC, 2007).

10.1.2 Global CO_2 emissions and fossil fuel use

Global emissions of greenhouse gases from human activity are estimated to range between 22.8 and 25.3 billion tonnes of CO_2 equivalent per year (Marland *et al.,* 2003) (CO_2 equivalent includes the contribution to global warming made by other greenhouse gases such as methane and nitrous oxide). The vast majority of these greenhouse gases are the direct result of the burning of fossil fuels for transport, heating and electricity generation.

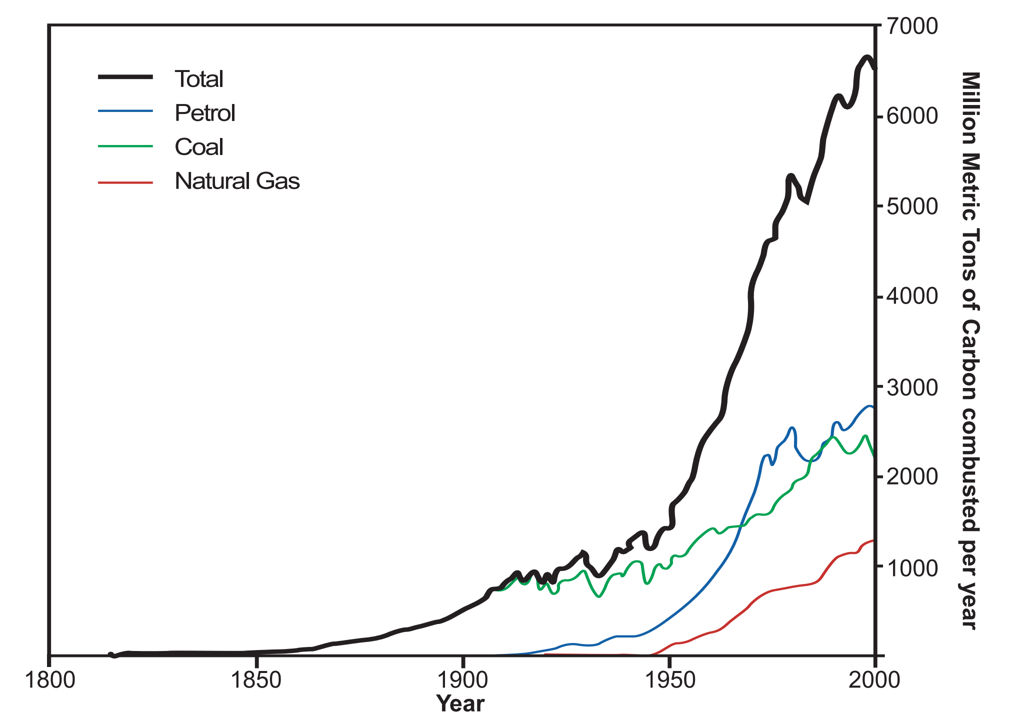

Figure 10.2 This graph shows the global carbon emissions from fossil fuel combustion since the 1850s. It can be seen that the biggest increase in carbon levels has been since the 1950s. To convert combusted carbon to CO_2 , multiply by 3.67. (Redrawn from www.globalwarmingart.com. Original data from Marland *et al.,* (2003)).

Modern industrialized society is dependent upon fossil fuels to meet its energy requirements and will be for the foreseeable future (Figure 10.3). At the present time an estimated 75% of the world's energy is produced from fossil fuels (BP, 2006; REN21, 2006) accounting for the release of more than 7 billion tonnes of carbon in 2006. In order to effectively tackle climate change and ocean acidification, the world must drastically reduce its CO_2 emissions.

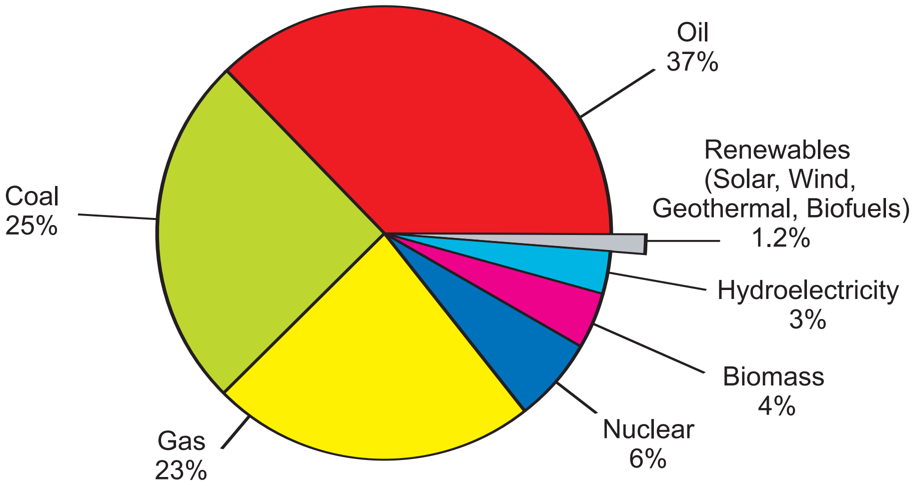

Figure 10.3 Sources of energy worldwide. It can be seen that most of the energy is produced from fossil-fuel based sources, all of which release CO_2 during combustion (Figure 10.2). (Data from the BP statistical review and REN21 global status report on renewable energy).

Even with strong development in the renewables sector, the International Energy Agency projections show that it is very probable that more than half of the industrial world's energy will still be generated by burning fossil fuels in 2050 (IEA, 2004). This is primarily because energy produced from fossil fuels is considerably cheaper, and more flexible to transport or transmit, than that produced by renewable sources. Many developing countries are unable to sustain both renewable energy development and improvements in healthcare, water and food supplies. Further pressure is created by increasing energy demands in China and India where there are no CO_2 reduction aims. The world also has the added pressure of an increasing population. China and India are predicted to become major emitters of CO_2, and in 2007 China surpassed the USA as the largest CO_2 emitter (NEAA, 2007) – some 7 years ahead of previous predictions by the International Energy Agency (IEA, 2006).

10.1.3 The UK perspective

The UK contributes about 2% of global man-made greenhouse gas emissions (IPCC, 2007), with 556 million tonnes of CO_2 equivalent in 2005.

Nearly 75% of electricity in the UK is generated from fossil fuels (Figure 10.4) and has contributed the majority of the 208 million tonnes of CO_2 equivalent produced by the energy industries. An additional 99 million tonnes of CO_2 equivalent was produced by other industries (Figure 10.5).

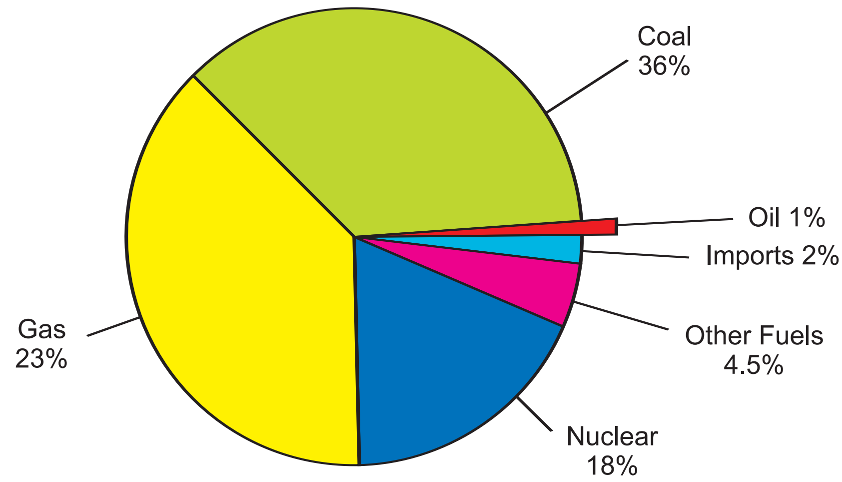

Figure 10.4 Sources of UK electricity generation in 2006. Note that fossil fuel combustion generates nearly 75% of total electricity. Other energy sources comprise hydro, solar, wind, biofuels and waste gas combustion. (Data from DBERR).

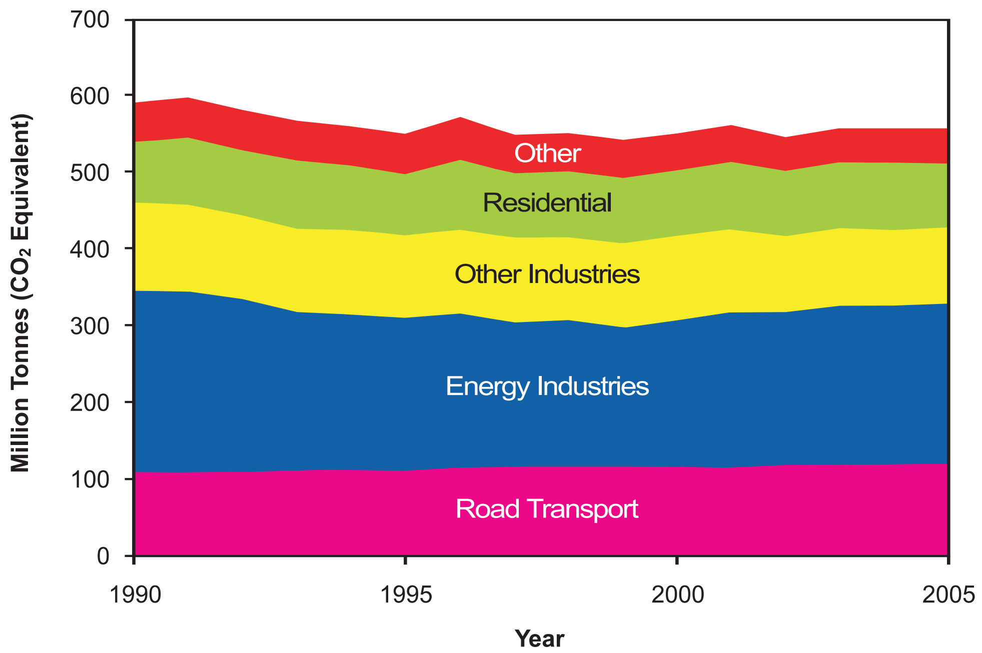

Figure 10.5 UK CO_2 emissions by source between 1990 – 2005. Overall CO_2 emissions have reduced from 1990. However, since 2003 an increase in the number, and especially the use, of fossil fuel power stations (coal and gas fired) is increasing emissions from the energy industries. The red "other" portion comprises commercial and public sector emissions (data from AEA Energy and Environment from DEFRA, 2007).

Whilst the UK is slowly reducing its greenhouse gas emissions, the government has realized the threat of climate change to both the UK economy (Stern, 2007; WWF, 2007) and the global population. For this reason the UK Government has committed to drastically reduce UK CO_2 emissions by 2050, by 60% of 1990 emission levels. The UK Parliament Climate Bill of 2007-08, will commit the UK to the world's first legally binding reduction of CO_2, with specified intermediate targets. In order for these targets to be met the UK must engage in multiple options to decarbonise energy, especially electricity. There are numerous policy and technology options, amongst these different options are:

1) **Reduce UK energy use by reducing demand.**
   This can be expressed by using less energy, and by using energy more efficiently to continue producing wealth. This is typically a cost effective method but difficult for the government to implement and to produce rapid changes.

2) **Develop low carbon and renewable energy technology, e.g. hydro, wind, tidal, solar.**
   Renewable energy is typically highly favoured by the public. However, there are significant problems in overcoming the time and high initial capital costs needed to develop reliable and cost-effective electricity.

3) **Consider the re-introduction of nuclear electricity generation**
   This can be costed as being financially attractive, however, there is no appealing solution to waste storage and it is subject to the long term availability of fuel-grade uranium resources (Sustainable Development Commission, 2006).

4) **Discover and deploy methods of low carbon transport, for individual and mass transit, air and sea travel and freight.**
   Transport fuels are the most difficult to decarbonise. Biofuels are impossible to grow nationally, in the quantities needed by the UK, and imports compete with food or forest land use. Greatly improved use of public transport is possible, but requires behavioural change by many individuals. Hybrid vehicles are a near-term improvement, although zero-carbon electric, or hydrogen, vehicles will need decarbonised supplies (from Carbon Capture and Storage).

5) **Capturing and storing large amounts of CO_2 from fossil fuel power stations.**
   This is the subject of active and achievable development and rapid deployment. However, the CCS process means that fuel needs to be imported, more fuel is used to generate the same net electricity, and there will be waste streams of CO_2 solvents.

Capturing and storing the CO_2 from fossil fuel power stations has the potential to be an effective tool for climate change mitigation. The majority of electricity in the UK is supplied by fossil fuels which generate approximately 37% of UK CO_2 emissions. If releasing this to the atmosphere were to be avoided through the implementation of CCS technologies, the UK would reduce its CO_2 emissions by up to 30%. The added benefit is that CCS will permit the UK continued use of fossil fuels for electricity and heat generation during the timespan that is required to develop renewables, and possibly nuclear energy, into more reliably engineered and cost-effective methods of electricity production.

10.2 Introducing Carbon Capture and Storage

Power stations and most industrial plants emit CO_2 in large volumes at individual sites. These are known as point sources and it is now possible for this CO_2 to be captured from these point sources instead of emitting it into the atmosphere. This CO_2 can then be transported and stored safely underground. This process is simply called Carbon Capture and Storage (CCS for short).

Carbon Capture and Storage therefore holds a great promise to dramatically reduce global CO_2 emissions from the burning of fossil fuels. This chapter will now provide an overview of the processes involved in CCS, and thereafter address some of the questions commonly posed regarding the benefits, costs and risks of the technology. A short discussion about what policies are needed to implement CCS concludes the chapter.

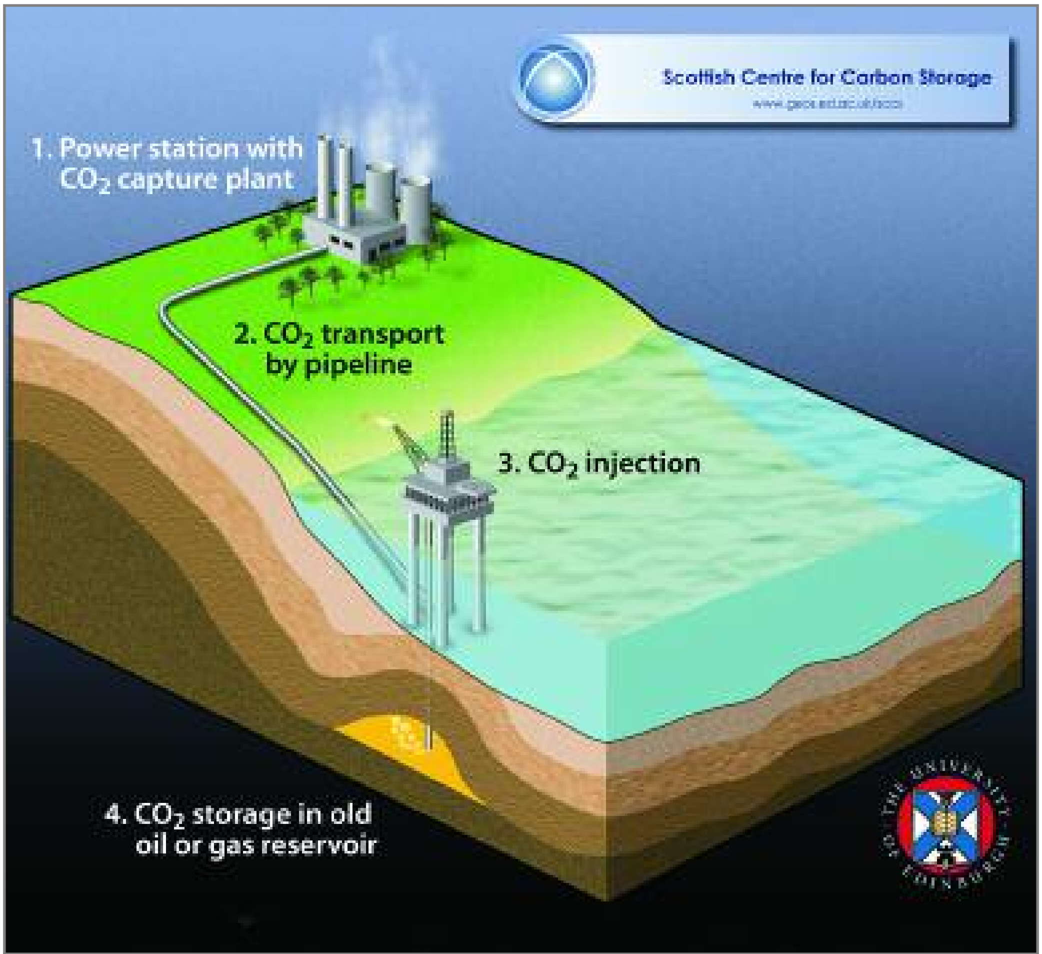

Figure 10.6 Schematic diagram illustrating the main stages of the Carbon Capture and Storage process. For the UK this will consist of a capture plant at the fossil fuel power station, transport of the captured CO_2 by pipeline followed by injection into an old oil or gas field, or aquifer offshore.

10.2.1 How does Carbon Capture and Storage work?

Carbon Capture and Storage technology has three individual steps:

(i) **Capture or removal of CO_2 from fossil fuel combustion or biofuel combustion at industrial processes, most importantly electrical power stations.**
(ii) **Transportation of the CO_2 from the point of capture to a storage site.**
(iii) **Injection of the CO_2 underground into deep geological formations for long term storage (more than 10,000 years).**

10.2.1.1 Capture of CO_2

Capture of CO_2 is a common industrial process. Nevertheless, to apply this existing technology to power plants would require an increase of size scale by a factor of 3 to 10. Capture has been used for several decades to provide CO_2 for industries, such as those making carbonated (fizzy) soft drinks, de-caffeinating coffee, or dry cleaning of clothes. The oil industry has also used CO_2 separation to purify natural methane gas, and in refineries where hydrogen gas is made from natural hydrocarbons. At present there are three different ways that can be used to capture CO_2 from a point source (IPCC, 2005) and these are:

1) Post-combustion capture
2) Pre-combustion capture
3) Oxyfuel combustion

1) Post-combustion capture

Post-combustion capture describes the capture of CO_2, which forms 3-15% of the flue gas **after** it is produced from burning a fossil fuel. Capture of the CO_2 usually occurs by passing the flue gas through an amine solvent, allowing the CO_2 to dissolve. Once dissolved the amine solvent can be pumped to a different part of the power station where it is heated to release the pure CO_2. A distinct advantage of this technology is that it could be fitted to existing power plants, such as those that burn coal, the fossil fuel that produces the most CO_2 per unit of electricity generated. This practice is called retrofitting and several sites around the UK are being considered for this.

2) Pre-combustion capture

Pre-combustion capture involves the capture of CO_2 **before** the fuel is burned. To do this the fossil fuel is gasified or 'partially' burned in a combustion chamber at a higher pressure than normal and with a controlled amount of oxygen. This produces hydrogen and a relatively pure stream of CO_2 (15-60%) that can be easily separated and captured. The hydrogen can then be burned to produce heat for electricity generation without producing any further CO_2 (water vapour is the main by-product). This capture technology is well understood and is already used in industrial applications such as the production of CO_2 during production of hydrogen from splitting hydrocarbon in oil refineries. This technology has not yet been applied to a process as large as power generation.

3) Oxyfuel combustion

Oxyfuel combustion involves burning hydrocarbon fuel in a chamber which is rich in oxygen (more than 95%), rather than air (which contains 16% oxygen). This produces water and more than 80% CO_2 as by-products. Cooling of this mixture of gases allows the water to be condensed. This leaves an almost pure stream of CO_2 which is then ready for transport to a storage site. At the time of writing (2007) this is the least developed of the three capture technologies.

10.2.1.2 Costs of capture

The capture step of CCS is the most expensive, and is the step that has been least well developed technologically. The biggest problem is that all of the capture processes require energy to separate the CO_2 from the other gases. This is known as the energy penalty and is the main expense of the process, typically comprising 75% of the costs (IPCC, 2005). As a result of the energy required for the process, CO_2 capture makes a power station less efficient, meaning more fossil fuels need to be burnt for the same amount of electricity produced. However, the technology is currently being researched extensively and at the time of writing it is believed that a power station using CCS, by any of the three capture methods listed above, will emit 85-95% less CO_2 than one which has no CO_2 capture. Additional problems are the production of wastes: ash from coal (as at present), and new streams of degraded solvents – especially from post-combustion capture.

10.2.1.3 Transportation of CO_2

Once the CO_2 has been captured, it is pressurized to greater than 70 atmospheres, when it forms a liquid. The liquid is denser than gas, and consequently allows the CO_2 to be transported, as it can easily be pumped.

Special CO_2 pipelines can be used to transport it in a similar way to natural gas which is transported to homes around the world. Transport of CO_2 is carried out extensively in the United States to to be used for Enhanced Oil Recovery (see below). Small amounts of CO_2 can also be transported in tanker ships similar to those that transport oil. Ship transport has been used for many years to supply CO_2 for the brewing and soft drink industries. However, as the tankers can only transport a limited amount at a time, pipeline transport is more efficient for distances up to 500 kilometres.

Liquefied CO_2 has already been utilized around the world for Enhanced Oil Recovery projects (EOR). This technology involves injecting CO_2 into old oil reservoirs in order to increase oil production. When the CO_2 is injected into oil reservoirs, it makes the oil less sticky, freeing it from the small pore spaces where it is trapped. The addition of CO_2 also increases the pressure acting on the oil in the reservoir and effectively pushes oil out from the pore spaces in the rock where it is trapped.

The costs and the energy required for CO_2 transport must be considered. The conversion of the CO_2 gas to a liquid requires energy, in addition to the energy required for pumping. Increased revenue from using captured CO_2 for enhanced oil recovery can be used to offset some costs. To minimize any environmental and economic costs, storage sites would ideally be located as close as possible to the power plant.

10.2.1.4 Storage of CO_2

Once the CO_2 has been captured and transported to the storage site it can then be injected. In the early stages of CCS research two distinct settings for storage were considered. They were:

1) Ocean Storage
2) Deep geological formations

1) Ocean Storage - Can CO_2 be stored in oceans?

Storage of CO_2 at the bottom of deep oceans was investigated as a possible method in the early stages of CCS research. The process would involve injecting a stream of CO_2 into the ocean from a fixed pipeline or below a moving ship.

The environmental impacts of this technique were found to be generally negative and the UK Government does not support this type of storage. Additionally, this method is currently outlawed by international marine treaties and injection of large amounts of CO_2 into the marine environment may acidify large amounts of sea water. Marine life is highly sensitive to such changes and therefore injecting CO_2 is certain to adversely affect marine life.

A final negative reason is that ocean storage is not a permanent method of CO_2 storage. There is a high risk that CO_2 will, over time, return to the atmosphere, as there is not a distinct physical barrier to prevent it from doing so. For these reasons this method of storage has been deemed unsuitable and no further research into it is being undertaken.

2) Deep geological formations – can we store CO_2 underground?

Many deep geological formations have acted as natural storage facilities for oil and gas for millions of years. It is therefore easy to appreciate why those natural trapping structures could be utilized to store CO_2 underground for many thousands of years. There are several different types of underground sites which could be used to store it:

– Exhausted oil and gas fields

Oil and gas fields consist of a layer of porous rock with a non-porous cap rock above. The oil and gas is held in the small pore spaces within the porous rock structure in a similar fashion to how the spaces in a sponge hold water. Oil and gas are trapped in these reservoirs by the cap rock, which has a dense non–porous structure with few spaces, preventing gas or oil movement through it. This acts as a lid on the reservoir, sealing the oil and gas underneath.

Once the fossil fuels have been removed, CO_2 can be injected through a well into the layer of porous, sponge-like rock. The sediment grains and clay particles which form the cap rock are too densely packed for the CO_2 to move through it, meaning that it is permanently trapped in the field.

Exhausted oil and gas fields are ideal for CO_2 storage. A great deal is known about these sites and the knowledge gained from of Enhanced Oil Recovery (see above) means that CO_2 injection has already been conducted on a range of sites and associated injection technology has been developed. However, a programme of monitoring must be undertaken after CO_2 injection, to ensure that pre-existing boreholes, which have punctured the natural cap rock seal, do not act as leakage pathways for CO_2. It is thought that oil and gas fields could hold about 30 years of emissions from UK power plants.

– Unmineable coal seams

Unmineable coal seams offer another method of CO_2 storage. Whilst underground, coal has a layer of natural gas (usually methane - CH_4) chemically attached to it. Once CO_2 is injected, it will push the methane off the coal and adsorb onto the coal in place of the methane. An additional benefit is that during CO_2 injection, the methane could be recovered and used to produce energy. This could be used to cover some of the cost of the CO_2 storage.

However, there are two problems with this technique. Firstly burning of the methane will produce more CO_2 and secondly, in order for the CO_2 to be permanently stored the coal can never be mined. The coal is 'sterilized' as a fuel resource even if the coal becomes economically worthwhile to mine it in the future. There are no coals in the UK (in 2007) where this technique has been applied.

– Saline aquifers

Saline aquifers are deep underground stores of salt water. They are an attractive option as they are commonly found offshore, could hold a very large amount of CO_2 and are of no real use to humans due to the un-drinkable water. The UK North Sea contains several large saline aquifers and their use would keep transport costs to a minimum. The current estimates indicate that several centuries' worth of total UK CO_2 emissions could be held in these aquifers.

The main problem with this type of storage is that a relatively small amount of information is available when compared to old oil and gas reservoirs. Further research needs to be completed to determine if the potential storage capacity is as large as preliminary research suggests.

10.3 How would the CO_2 be stored in the rock?

CO_2 can be trapped in four distinct ways which are explained in the following section.

10.3.1 Structural Storage

CO_2 is more buoyant than water meaning that when injected into a reservoir it will rise up through the pore spaces in the reservoir rock until it reaches the impermeable cap rock. Good cap rocks such as shales and mudstones are impenetrable to the CO_2 and will prevent it from leaking back to the atmosphere. As already mentioned, many natural gas fields around the world have stored both CO_2 and natural gas for millions of years in this way.

10.3.2 Residual Storage

The porous rocks in oil and gas reservoirs behave like a tight, rigid sponge. A sponge traps air residually and, for this reason, to soak a sponge in water it must be squeezed several times to replace the trapped air with water. In a similar fashion when liquid CO_2 is injected into a rock formation, much of it is trapped as isolated microscopic bubbles within the pore spaces of the rock and this is known as residual trapping.

10.3.3 Dissolution Storage

In the same way that sugar dissolves in hot tea, CO_2 quickly dissolves in water. This water containing CO_2 is denser than the freshwater surrounding it and will therefore sink to the bottom of the reservoir, so trapping the CO_2.

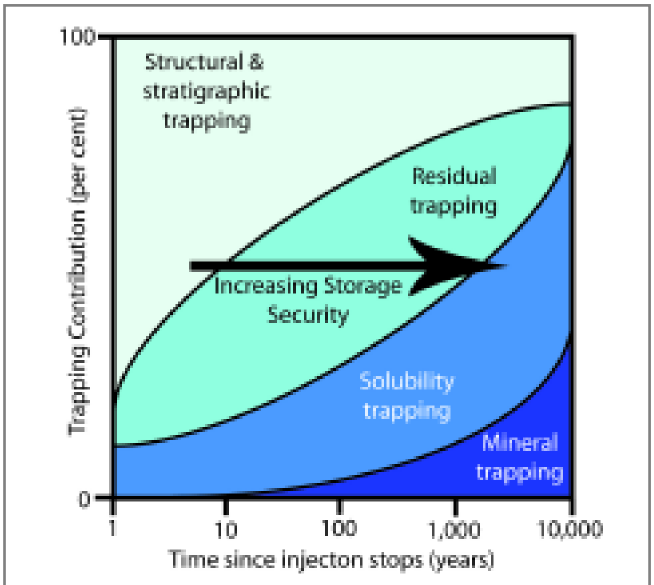

Figure 10.7 CO_2 trapping methods and time since injection stops (redrawn from IPCC Special report on Carbon Capture and Storage, 2005).

10.3.4 Mineral Storage

When CO_2 is dissolved in water it forms a weak acid (carbonic acid) which can dissolve and react with the minerals in the reservoir rock. If the conditions in the reservoir are favourable new minerals can be formed. They would coat the interior of pores within the reservoir rock and lock away the CO_2 within the rock. However, under most conditions this process is extremely slow and this is therefore the least useful storage mechanism.

10.4 Monitoring and Verification of CO_2

Verifiably measuring the quantities of stored CO_2 is essential, especially if this technology is to be used to meet national or international commitments on reducing emissions or is to be used as a basis for emissions trading. Operators of CO_2 storage sites will also need to monitor site performance to verify that there is no leakage from the storage reservoir.

CO_2 can be measured at any stage of the CCS chain, and techniques for this are already available. During the CO_2 capture process, flows of gas would be measured as a normal part of the operation. During transport, CO_2 pipelines in the USA constantly monitor large quantities of pumped CO_2. At the injection site, metering on oil rigs is established to measure oil and gas production for tax purposes, similar methods could be used to measure the amount of CO_2 injected into geological storage sites.

Oil and gas companies now have the technology to trace gas flows in underground reservoirs using a number of methods which are directly applicable to monitoring stored CO_2. Whilst all of these methods are currently in use in the hydrocarbon industry, monitoring CO_2 storage will need to be carried out accurately and cheaply over a much longer time period than current monitoring technologies will allow and hence further research is this area is required (DTI, 2005).

10.5 Commonly Asked questions

The following section briefly answers some of the most commonly asked questions asked in relation to CCS technologies.

10.5.1 Will the CO_2 escape?

As outlined in the previous section of this chapter there are several ways in which CO_2 is held within the rock structure. The initial means is structural storage, where the CO_2 is trapped beneath a non-permeable (no flow) cap rock. This is the same mechanism by which most of the oil and gas fields around the world trap oil and gas. Many of these fields have stored oil and gas for hundreds of thousands to many millions of years and provided that the man-made CO_2 is placed in a similar geological site which has been adequately characterized and well chosen, long term storage can be achieved.

As well as oil and gas, around the world there are many sites that have naturally contained CO_2 from natural sources for millions of years. Hence, with thorough planning, research and testing of storage sites, CO_2 can be reliably trapped underground for thousands and possibly millions of years. One of the conclusions of the latest IPCC (the UN Inter-governmental Panel on Climate Change) report states that more than 99% of the CO_2 could be retained over 1000 years with well designed, selected and managed sites (IPCC, 2005). This would store the CO_2 well beyond the era of extravagant fossil fuel use by humans.

10.5.2 Has Carbon Capture and Storage been used before?

As of 2007, only a handful of industrial scale projects are in operation world wide. Sleipner in the North Sea has been operating since 1996 and is the world's oldest CO_2 storage project injecting over 1 million tonnes of CO_2 per year into a saline aquifer. In Salah in Algeria has been operating since 2004 and injects about 1 million tonnes of CO_2 per year into the saline aquifer beneath a gas field. Weyburn in Saskatchewan is a commercial Enhanced Oil Recovery operation where CO_2 has been stored and monitored. Smaller injection sites are in the Lacq region in France, and a range of Enhanced Oil Recovery and CCS test sites in the US and Canada. Large commercial injection sites are planned to be operational during 2007 at Snøhvit in Norway, and 2008 in Western Australia (Figure 10.8).

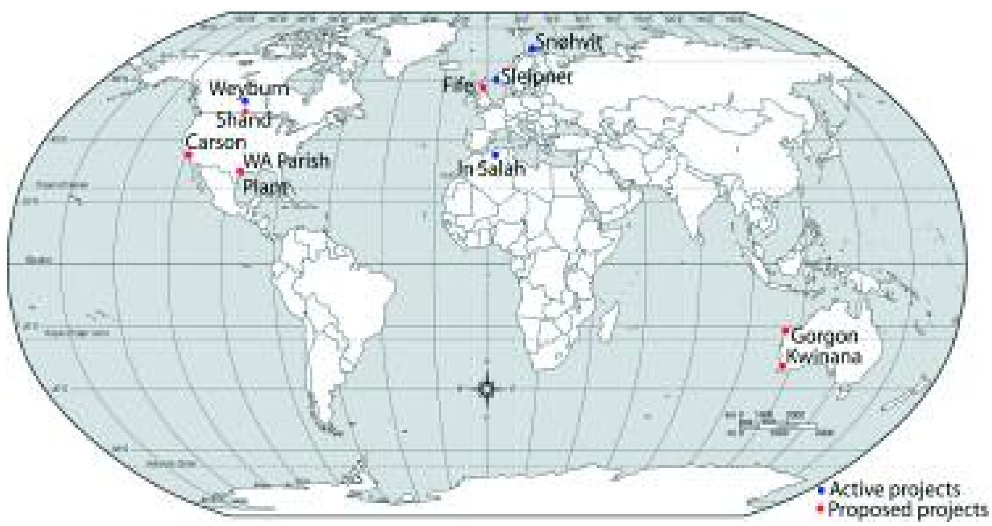

Figure 10.8 World map illustrating the location of commercially active and proposed storage sites which inject or intend to inject over 700,000 tonnes of CO_2 per year.

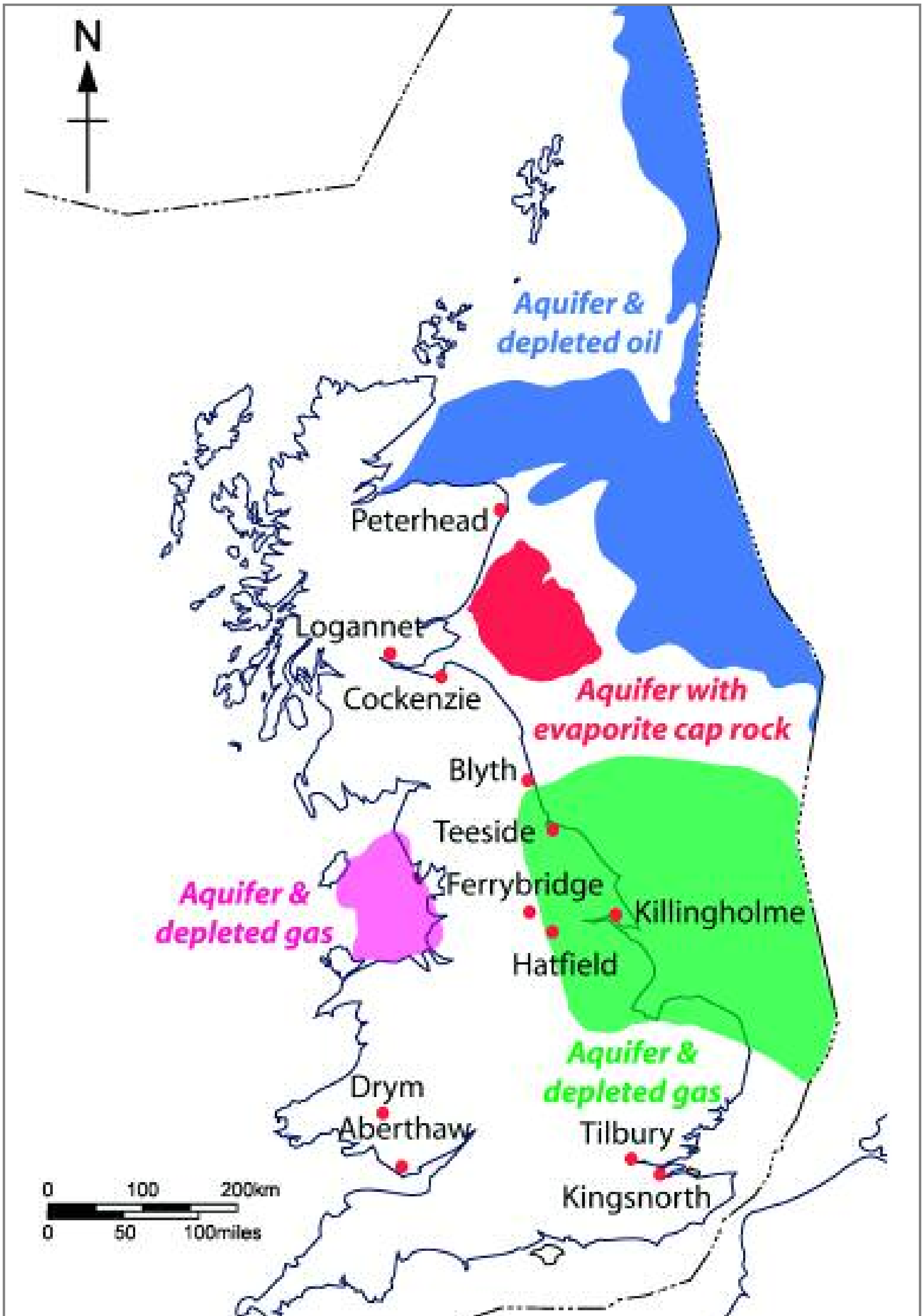

Figure 10.9 Map of Great Britain illustrating potential offshore sites for CO_2 storage and proposed sites where CO_2 capture is being planned to take place.

The UK is a good location for CCS. The UK has a large number of exhausted oil and gas fields and a large number of saline aquifers offshore (Figure 10.9). Coal and gas fired power plant are within tens to hundreds of kilometres of a wide range of geological storage sites (Figure 10.9). There is extensive expertise within the country in pipeline engineering and offshore oil and gas production. This expertise could be readily applied to CCS.

10.5.3 Will Carbon Capture and Storage be expensive?

The costs of CCS technologies depend on a number of factors including the type of power station, the type of capture technology used, transport distances, whether Enhanced Oil Recovery could be used to offset initial costs and future oil prices. The main cost factor is that CO_2 capture plants require more energy to operate. This reduces net plant efficiency and more fuel is required to create the same amount of energy. Electricity prices will therefore increase. This is widely estimated to increase by 1.0 p/kWhr, from 3.0 to 4.0p/kWhr wholesale price. If this is passed on to UK domestic consumers without additional profit, this is only about £30-£50 extra per average household per year.

Oil production in the UK North Sea is nearing the end of its life and Enhanced Oil Recovery could postpone abandonment of the old oil fields. However, Enhanced Oil Recovery has never yet been used for oil fields under the sea. Several evaluations have been made of Forties and of Miller in the UK North Sea, Gullfaks, Draugen and Heidrun in the Norwegian North Sea, but all have been rejected on economic reasons.

The high initial costs of new plant for CCS technologies, and extra operating cost, do mean that governments will have to provide financial incentives and support to help implement the capture and storage technologies for the first plant(s). In 2007 the UK government announced a competition to build the first joined up CCS system in the UK from power plant to storage (DBERR, 2007). This is intended to be operational at a 300 MW scale by 2014. The EU plans to encourage the build of 12 CCS plants to be operational by 2015. These will lead to improved plant built before 2020. After 2020, the EU ambition is for all new fossil fuel plants to be using CCS.

As with all new developments, building commercial scale plants will help to bring costs down. Therefore companies must be encouraged by government to incorporate CCS technologies into their new build and existing power stations. Governments must make clear statements on the importance of CCS on the future economy, clear subsidies must be given to develop cheaper capture technologies. CO_2 storage in Norway's Sleipner field was encouraged by the Norwegian CO_2 emissions tax and many US Enhanced Oil Recovery projects are financially viable due to tax incentives.

The UK requires 80 Giga Watts of electricity generation at peak load. Before 2020, 25 GigaWatts of this generation capacity (including nuclear) needs to be replaced because it is out of date or polluting. This rebuild of a number of plants is the perfect opportunity for CCS to be implemented. Planning consent granted for new power plants during 2007 started to reflect this, to require that CCS equipment can be retrofitted later.

10.5.4 Shouldn't the UK be investing more money into renewables rather than Carbon Capture and Storage?

Even with above average estimates (IEA, 2006 Alternative scenario) on the deployment of renewable energy, fossil fuels will still be the main source of electricity for the UK for at least another 40 years. No single renewable technology is currently deployable in that timescale to meet the UK electricity needs, and fossil fuels will need to fill the energy gap. Carbon Capture and Storage offers the UK the window to store carbon whilst renewables or other low carbon technologies are being developed and deployed.

10.5.5 Is the UK ready to demonstrate this technology?

The UK has the technical and business ability to start CCS immediately. The different technologies that make up CCS are now mature enough for full-scale demonstration. Delays mean that CO_2 in the atmosphere and ocean continues to increase and the effects of climate change and ocean acidification will increase. Many of these changes, and poorly known feedbacks, are irreversible on human timescales. The industrial world will simply run out of time. Carbon Capture and Storage has the potential of significantly reducing UK emissions very soon. As early as 2020, CCS offers emission cuts of 5-10Mt CO_2 per year on each coal or gas plant with commercially functioning sites. An aggressive programme could decarbonise all the UK fossil power plant fleet by 2025, by a combination of retro-fits onto existing power plants, and as part of new-built plants. This would reduce UK CO_2 emissions by over 150Mt/yr. This is a small part of worldwide CO_2 emissions, but the key point here is that, once a technology has been proven to work – then the technical and commercial risk greatly decreases and other industries and nations can confidently replicate that system. Before the first aeroplane, flight could be a theory. The first flight proved that machines heavier than air could fly. The first CCS challenge is to build a handful of power plants. The second challenge is to spread that learning globally. Five years saved from UK emissions by rapid CCS development, could mean five years saved from Chinese emissions soon after.

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