Carbon capture

Tackling climate change

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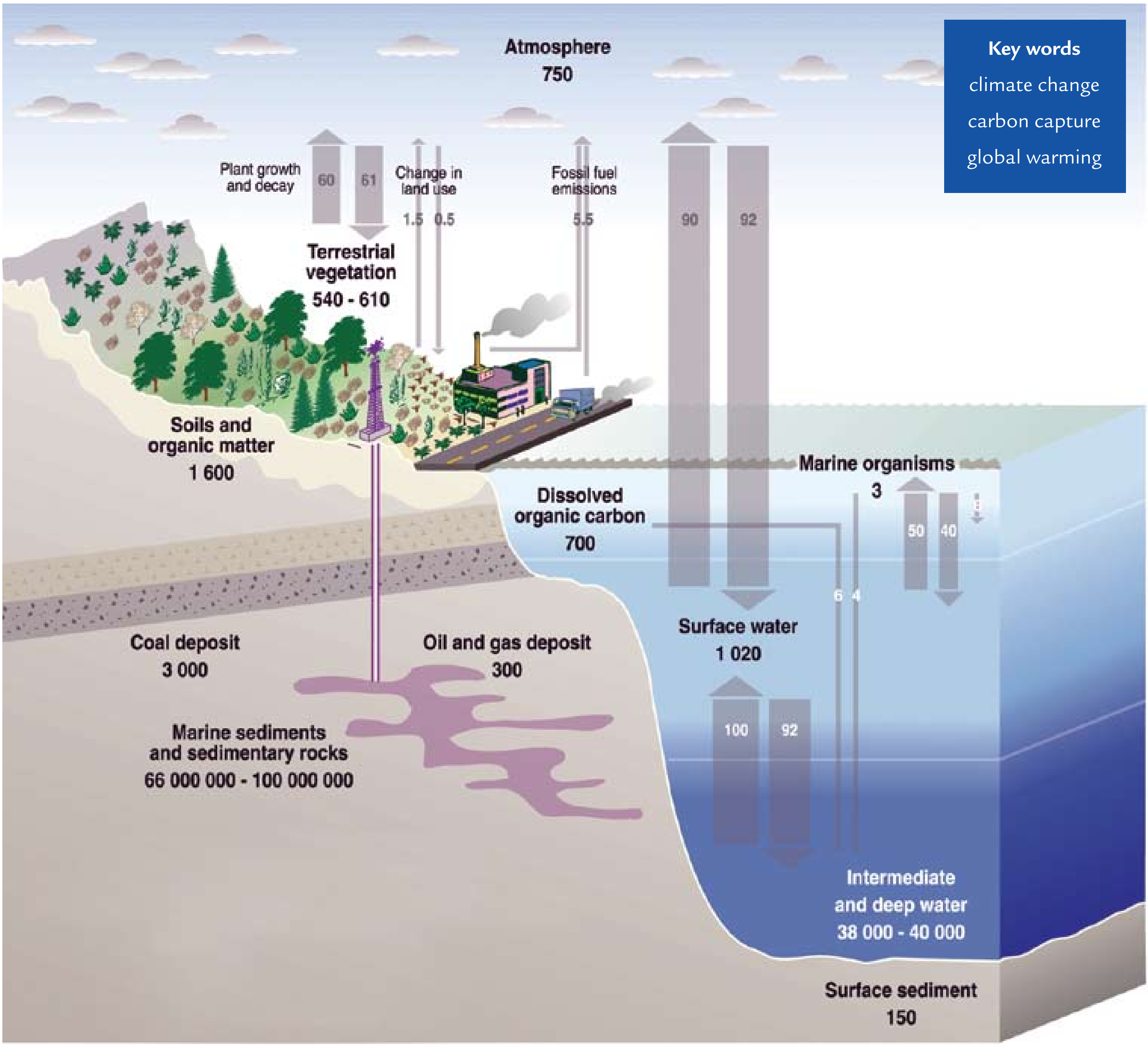

Figure 1: *The carbon cycle explains the exchange pathways of carbon and shows CO_2 is increasing in the atmosphere. The figures give amounts of carbon in gigatonnes of carbon; a gigatonne is a billion tonnes.*

Burning fossil fuels releases carbon dioxide into the atmosphere. This is a major contributor to climate change. Can we capture and store that CO_2 as it is produced? Sarah Mackintosh of Nottingham University describes progress in the science and technology of carbon capture.

Carbon dioxide, released by human activities such as burning fossil fuels and deforestation, is the major greenhouse gas to cause manmade global warming. The current concentration of CO_2 in the atmosphere is 379 parts per million (ppm) compared with a pre-industrial level of 270 ppm. It is estimated that the level of CO_2 is currently rising by 2 ppm annually. Annual emissions of CO_2 grew by approximately 80% between 1970 and 2004. The current global emission from fossil fuels is 5.5 gigatonnes of carbon per year (GtC/yr) (see figure 1).

However, with the war on how to tackle future sustainable fuel demands still raging, it has become clear that a relatively short term 'band-aid' solution is urgently required to slow the current and potential effects of global warming.

Phasing out fossil fuels

Can you imagine trying to phase out the world's current fuel supply? It will take the UK a few years just to phase out the traditional filament light bulb!

Carbon Capture and Storage (CCS)

A viable option currently being explored to counteract rising atmospheric CO_2 levels is CO_2 capture and storage. In this process CO_2 is separated from industrial and energy-related sources, transported to a storage location and stored in a way which isolates it from the atmosphere for a long time. Figure 2 demonstrates the potential effect on levels in the atmosphere of storing the CO_2 over a number of years.

Oil out, carbon in, what's the problem?

Although in principle the idea of storing CO_2 in ready made geological structures seems relatively straightforward, the reality is very different. There are many different aspects and implications to storing CO_2; for example, how do we remove other gases associated with fossil fuel burning from the CO_2, and how do we transport the CO_2 to the storage

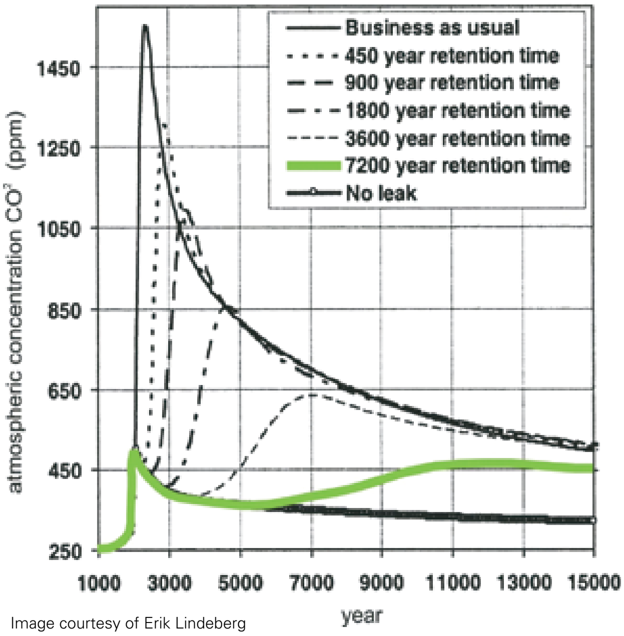

Image courtesy of Erik Lindeberg

Figure 2: Acceptable 'retention' times of CO_2 stored. Even storing CO_2 for just 450 years has a positive effect on the atmosphere.

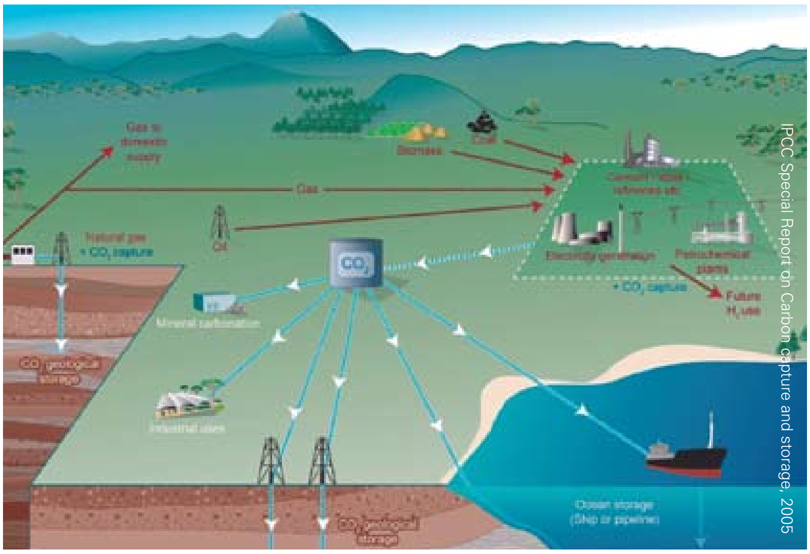

Figure 3: *Carbon capture and storage processes*

Where can we store captured carbon?

Biological Sequestration – CO_2 stored in forests and soils.

Biological sequestration has many limiting factors as its storage form is often volatile and subject to subsequent release through changes of land use, harvesting, fires, or other disturbances.

Ocean Sequestration

The ocean already stores a great deal of CO_2 (see figure 1), but it has been proposed that we could accelerate this process by fertilising the ocean with iron to promote growth of carbon fixing plankton – an unpopular choice with most people. An alternative is to inject CO_2 into the ocean at depths greater than 1000m at which depth it should form an impermeable hydrate seal which would prevent it escaping. This idea is being further researched in Japan where other types of storage are limited.

Geological Storage

Injection of CO_2 into stable geological structures such as oil and gas fields, unminable coal beds and deep saline formations (see figure 3). These structures are already well-researched and understood as we have been using them to extract fossil fuel for over 100 years, so it makes understanding the processes involved in storing the CO_2 easier. Depleted oil and gas reservoirs are estimated to have a storage capacity of 675–900 $GtCO_2$. Deep saline formations are very likely to have a storage capacity of at least 1000 $GtCO_2$.

The In Salah CO_2 project is in Algeria. Since 2004, 1.2 million tonnes CO_2 per year has been captured and stored there. Compare this with world annual production of 5500 million tonnes.

site? Is it possible that the storage site could leak and, if so, what are the consequences? CO_2 is not toxic at normal levels, but it is heavier than air and at high concentrations it can cause suffocation. How much extra energy will CCS processes cost? These are just some of the science questions – just imagine how complicated it becomes when lawyers, land owners and governments become involved! Despite the many hurdles that have had to be addressed, we are now at the stage where some demonstration carbon storage sites have already been or are due to be set up.

CCS – the current status

There are a number of different projects being carried out across the world (see figure 4), some projects are focused on CO_2 capture and some are more focused on CO_2 injection and storage. Current capture projects include Boundary Dam and CASTOR. Boundary Dam is a power station in Canada which has a centre that has been set up to develop new capture technology and perform long term tests on a semi-industrial scale. They are experimenting on the waste gas from the Boundary Dam power plant. The CASTOR project is based at a coal-fired power plant in Denmark. Its specific goals involve: halving the cost of capturing and separating CO_2; developing storage efficiency, safety and security while limiting its environmental impact; and testing in real-life, industrial-scale facilities.

Figure 4: *A variety of storage projects have been set up across the world.*

The Sleipner field is in the North Sea (see figure 5). It produces natural gas and light oil from sandstone which is about 2 500 m below sea level. Here, CO_2 is injected into a 200m-thick sandstone layer about 800 m beneath the bottom of the North Sea. Like most rocks deep underground, this sandstone is filled with salt water. It is very porous and permeable, so the CO_2 moves rapidly sideways and upward through the rock layer, replacing the water between the sand grains.

Figure 5: *The Sleipner oil field, where CO_2 is pumped into underground rocks.*

Teapot Dome is an experimental facility in Wyoming USA run by the US Department of Energy. Many universities and industrial partners carry out experimental work there to try to develop techniques to monitor the stored CO_2 and gain a greater understanding of what happens to the CO_2 underground (see figure 5).

The UK

In 2007 the government launched a competition for companies to compete to win funding to develop the UK's first full scale CCS demonstration. The

Figure 6: *Experimental work being carried out at Teapot Dome.*

winner is due to be announced this year (2010) and it is expected that the demonstration plant will be up and running in 2014.

Research at the Centre of Innovation in Carbon Capture and Storage

Here at the University of Nottingham there is a great deal of exciting and novel research. Just some of the projects being done here at the moment include:

- A number of projects using minerals (rocks) to store CO_2 in a permanent, solid and stable form. Experiments are carried out in high pressure rigs shown in figure 7. Ground minerals are placed in the rig and heated. High pressure CO_2 is then passed into the rig. Experiments continue to optimise the process.

Figure 7: *Mineral carbonation experiments at Nottingham.*

- Studies into how other reactive gases (impurities) change the properties of carbon dioxide during capture, transport and storage.
- Establishing reliable monitoring of environmental impacts by testing gases released by the soil.
- Research into artificial photosynthesis: using light and catalysts to turn CO_2 into fuels or chemicals.

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Look here!

Find out more about CCS research in Nottingham at: *http://tinyurl.com/yzs5joq*

Global 'Warming'?

Although, as you would expect, the planet will get warmer if CO_2 continues to increase in the atmosphere, it is possible that Europe will in fact get colder. This is because Europe is currently warmed by the Gulf Stream which is diverted past Europe by global ocean circulation (warm, less dense waters flowing in one direction at the sea surface and cold, dense waters flowing in the opposite direction in the deep ocean). More CO_2 in the atmosphere could slow down or even stop this circulation, reducing or slightly redirecting the Gulf Stream and making Europe a colder place to live!