EUROPEAN CARBON DIOXIDE NETWORK

contributing towards a safe, secure, sustainable, climate-friendly energy supply for Europe

A "DOWN-TO-EARTH" SOLUTION TO CLIMATE CHANGE

Oil, gas and coal are extracted from the earth to provide energy. In burning these fossil fuels to liberate their energy, unwanted carbon dioxide is produced, affecting the global climate. It is possible to capture this carbon dioxide, put it into the earth's crust and keep it there. Doing this will substantially reduce greenhouse gas emissions, helps in mitigating climate change and is a key element in the transition to a sustainable energy supply.

Why capture and storage of CO_2?

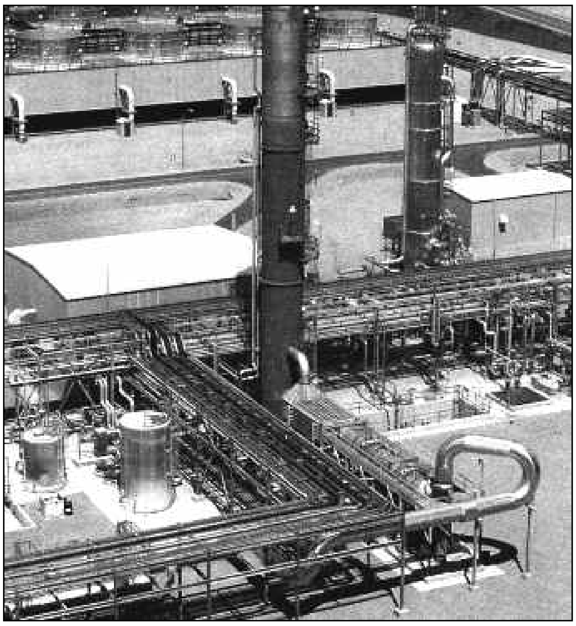
Evidence for the influence of human activities on the global climate is becoming stronger and stronger. The world-wide emissions of carbon dioxide (CO_2) in the atmosphere, resulting from the ever increasing use of fossil fuels, play a key role. Most scientists agree that the worldwide CO_2 emissions have to be reduced by more than 50%, in order to stabilize the CO_2 concentration and thereby mitigating climate change. As a first step the Kyoto protocol was adopted in 1997 to reduce the emissions by 2012 to below the 1990 level. The required reductions can be realized by means of three types of measures:

- Energy efficiency improvements and reduction in energy demand
- Use of renewable energy sources (such as wind and solar energy)
- Capture and storage of CO_2 currently emitted

It is becoming clear that the combined effect of energy efficiency increases and renewable energy sources cannot yet achieve the required reductions in emissions. The third measure, CO_2 capture and storage (CCS) may also be required to help limit global climate change. Putting CO_2 back in the ground is not new. In many countries natural CO_2 storage has existed in geological formations for millions of years. The world depends on fossil fuels and changes in our energy system cannot be done overnight but will take years. CCS will support the gradual transition of our fossil fuel based energy supply towards a diversified supply system, which will minimize the effect on the global climate. Our present energy supply system will largely remain the same in this transition period, but new infrastructures need to be realized: for example, electric power plants and large industrial plants will be equipped with capture units and pipelines to storage sites.

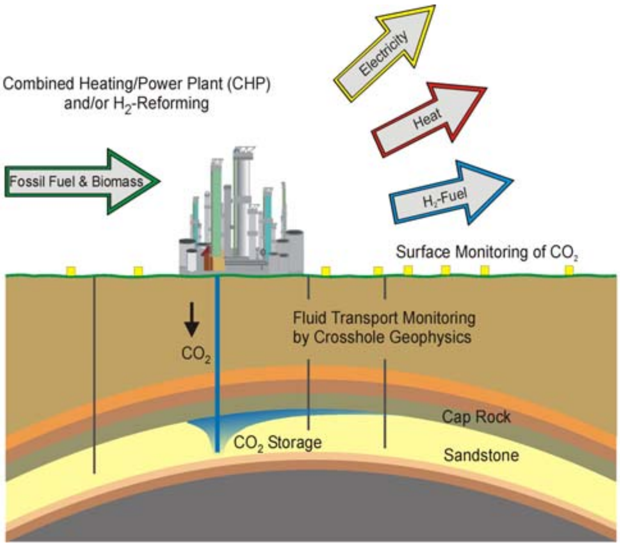
What is CO_2 Capture and Storage (CCS)?

All fossil fuels contain carbon. By burning the fuel, this carbon reacts with oxygen in the air to form CO_2. By removing the carbon before or after the combustion process, for example in electric power plants, the emission of CO_2 into the atmosphere is prevented. The result is a supply of CO_2 gas, which can then be transported to a suitable underground storage reservoir. The reservoir can be an "empty" (depleted) oil or gas field, a coal layer or an aquifer (water bearing layer).



CO_2 capture plant
(courtesy ABB Lummus Crest)

How and where can we capture CO_2?
Roughly 60% of the CO_2 emissions of mankind takes place at large stationary sources, such as electric power plants, refineries, gas processing plants and industrial plants. In the majority of these processes, the exhaust flue gas contains diluted CO_2 (5% to 15%). One option is to separate the CO_2 from other gases in the flue gas, producing a stream which contains more than, say, 90% of CO_2. Another option is to remove the carbon before combustion, as in the case where hydrogen and CO_2 are produced from natural gas (CH_4). CO_2 capture is a well-known technology in different industrial sectors, which already separate CO_2 from other gases. At present, the resulting CO_2 is either vented or additional cleaning is performed to produce high-purity CO_2 for niche market applications, such as the beverage industry. Although some suitable technology exists, CO_2 capture has not yet been optimized for large-scale application at power plants. Extensive research is being undertaken in many countries around the world to study new, promising concepts and improve existing technologies with the purpose of reducing costs and energy consumed in capture. Simultaneously, tests are planned in power plants to validate these newer technologies on a commercial scale.



Concept of a Combined Heat & Power (CHP) plant, producing electricity, heat and hydrogen, whilst capturing CO2 and storing it underground
(Courtesy CO2SINK project, GFZ, Potsdam, 2004)

Where do we store it?
After capture, CO_2 can be either stored or re-used (e.g. as resource for producing soft drinks, or in greenhouses to help plant growth). Because the market for CO_2 re-use is currently limited, the majority of CO_2 extracted needs to be stored. CO_2 can be stored in geologic formations (including depleted oil and gas reservoirs, deep saline aquifers and unminable coal seams). CO_2 can also be fixated in the form of minerals. Geologic formations offer a huge storage capacity (see table below). Despite the broad ranges in the storage capacity, it can be concluded that the capacity is sufficient to store worldwide man-made CO_2 emissions for tens and possibly hundreds of years.

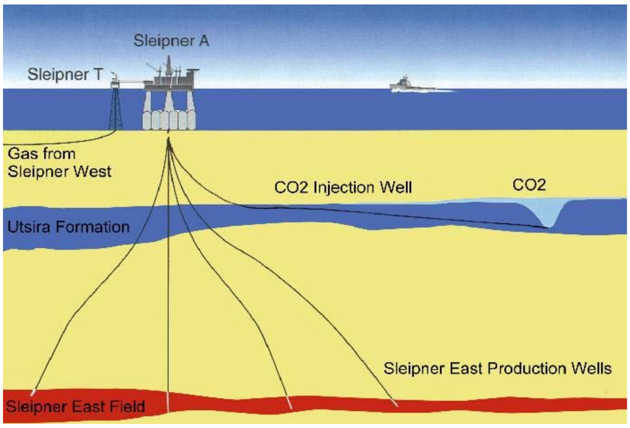
Worldwide capacity of potential CO_2 storage options (Gt = billion tonnes)

Option	Storage capacity in Gt CO_2
Deep saline aquifers (water bearing layers)	400 – 10,000
Depleted oil and gas reservoirs	930
Coal seams	30
World CO_2 emission	**25 Gt CO_2 per year**

Source: IEA-GHG, 2004

<u>Oil and gas reservoirs</u>, which generally have been well researched, are considered to be safe sinks for CO_2 storage, since these reservoirs have held oil, gas and often CO_2 for millions of years. CO_2 injection in some of these reservoirs will enable further production of oil/gas remaining in the reservoir. The revenues from this additional oil/gas could be used to offset the cost of CO_2 storage. This process, referred to as enhanced oil/gas recovery (EOR), has been performed in the USA using CO_2 for some years, not with the purpose of CO_2 storage, but to increase oil production. In Canada, injection of acid gas (a residual product of natural gas refining consisting of mainly CO_2 and H_2S) into oil/gas fields and deep saline aquifers has been practiced for many years.

<u>Deep saline aquifers</u> are underground formations, typically sandstones, containing saline water. These formations offer enormous storage potential: they are present in most countries, often close to industrial CO_2 sources, are usually very large, and so have a very large CO_2 storage capacity. The injection of CO_2 into these formations is similar to injection into oil and gas fields. The Norwegian Sleipner project, the first commercial CO_2 injection project in the world, where annually circa 1 million tons of CO_2 is injected into an aquifer under the North Sea, demonstrates that CO_2 can effectively be stored in large quantities.



The Sleipner project - 1 million tonnes of CO2 are stored annually in an aquifer under the North Sea
(Courtesy: Statoil)

Underground coal layers sometimes cannot be mined, being too thin or too deep. They usually also contain certain amounts of methane gas. When injecting CO_2 in a coal seam, it has been shown that CO_2 "sticks" better to coal than methane does, so it sets the methane free. This means that the coal layer becomes a producer of natural gas, which can be sold to offset the costs of CO_2 storage. Coal seams have held methane for millions of years, so it is quite probable that they will retain CO_2 for at least thousands of years. This storage technology is being tested in the EU RECOPOL project, with a field experiment in Poland.

What are the costs of CO_2 capture, transport and storage?

When capturing CO_2 at power plants, this will consume extra energy, so the cost of electricity will increase. The increase depends on the type of power plant (coal fired, gas fired) and the costs of the fuel. Various studies, among others by the Greenhouse Gas R&D program of the International Energy Agency, indicated that CO_2 Capture increases the electricity generating costs with between 1.3 to 3 Euro-cents per kWh. Another way of expressing these extra costs is in terms of the avoided CO_2 emission. CO_2 capture is presently costing between 25 and 60 €/tonne of CO_2 avoided. Ongoing research is expected to halve these costs.

Transport costs are relatively modest: transporting CO_2 over 100 km by pipeline will cost 1 to 4 €/tonne CO_2 avoided.

Storage costs depend strongly on the type of reservoir into which it is injected. In aquifers and depleted oil and gas fields, costs vary from 10 to 20 €/tonne CO_2. When extra oil or gas is produced during CO_2 injection, the costs may be less than 0 €/tonne CO_2. In other words: the benefits compensate the costs, making this a profitable option.

What are the risks of carbon capture and storage?

Like all technologies, there are risks involved with CO_2 capture and storage. The question we should ask ourselves is: (a) whether the risks of CO_2 capture and storage are acceptable and (b) whether the risks are comparable with those of alternative CO_2 mitigation options? The main risks are in transport and storage of CO_2. Any storage sites will be selected far from areas of earthquake risk to ensure that the rocks are stable.

CO_2 transport USA-Canada

In the USA, there is an extensive infrastructure of CO_2 pipelines (3100 km). The accident record for these pipelines shows ten incidents from 1990 to 2001 without any injuries or fatalities. Although an incident in principle can occur when CO_2 is transported on a large scale, the consequences can be minimized by means of control safety measures and is not likely to be larger than the risk of a failure in a natural gas pipeline, present in many European countries. Moreover, since CO_2 is not explosive or inflammable, as natural gas is, the consequences in case of any leakage are expected to be smaller than for natural gas.

The main risk associated with storage is at the site of CO_2 injection with a well failure, which may result in escape of CO_2 that will migrate upwards. The likelihood of a sudden escape of CO_2 stored in an underground reservoir is extremely small and comparable to an escape of natural gas from a gas well, which are very rare.

Research is being carried out in many institutes throughout the world, covering the following subjects related to risks:

- Study of the detailed physical and chemical processes in reservoirs

- Site selection procedures including seismic (earthquake) activity analysis
- Tools to predict the long term behaviour of CO2
- Monitoring and verification techniques
- Risk assessment methods and risk management procedures
- Best Practices and norms
- Well Integrity

Incentives

In order to realize significant market penetration of CO_2 capture and storage technology, incentives are required to stimulate the required large investments in this additional technology by power companies and industries. Therefore, carbon prices must be established, which can be either in the form of a carbon tax or a trading system.

In a trading system, a CO_2 market is created by setting a maximum emission cap per country and grant permits (so-called carbon credits) to emitters of CO_2. The European Union Emissions Trading system specifically includes the use of Carbon Capture and Storage (EC decision 29 January 2004) to enable this technology to be added to the other low emission energy sources and ensure that Europe has a secure and sustainable supply of energy for the foreseeable future.

If CO_2 capture and storage is developed with avoidance costs down to 20 €/tonne CO_2 and geological storage of CO_2 is proved secure as a viable Greenhouse Gas mitigation technique, the technology could be introduced commercially within a decade, providing that fiscal and regulatory regimes are also aligned.

Further information:

www.co2net.com: CO2NET is a European Thematic Network geared towards educating and providing information for policy makers and stakeholders.

The following site provides detailed information about technology and projects: www.co2captureandstorage.info.

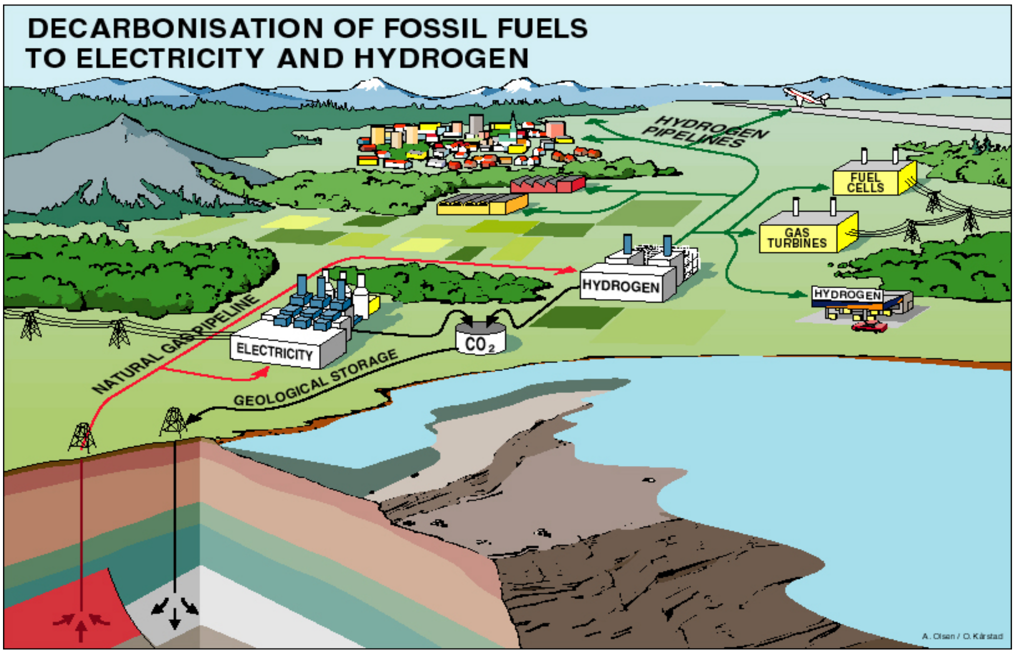
www.ieagreen.org.uk: the IEA Greenhouse Gas Programme is an international collaboration, which aims to evaluate technologies, disseminate results and identify targets for research on CCS.

www.co2captureproject.org: CCP is an international project funded by eight of the world's leading energy companies.

www.clsforum.org: The Carbon Sequestration Leadership Forum is an international climate change initiative at government level.

www.ipcc.ch: The Intergovernmental Panel on Climate Change (IPCC) plans to issue a Special Report on CCS.

www.climnet.org/CTAP: CAN, the Climate Action Network of environmental NGO's, held a special workshop on CCS



Possible future situation: fossil fuels generate electricity and hydrogen, and CO_2 is captured and stored (Courtesy: Statoil)