



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 CO₂?

Evidence for the influence of human activities on the global climate is becoming stronger and stronger. The world-wide emissions of carbon dioxide (CO₂) in the atmosphere, resulting from the ever increasing use of fossil fuels, play a key role. Most scientists agree that the worldwide CO₂ emissions have to be reduced by more than 50%, in order to stabilize the CO₂ 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:

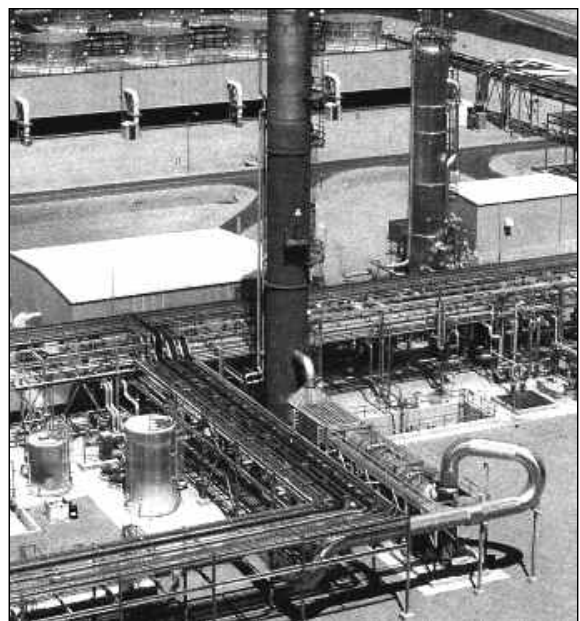
- Energy efficiency improvements and reduction in energy demand
- Use of renewable energy sources (such as wind and solar energy)
- Capture and storage of CO₂ currently emitted

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, CO₂ capture and storage (CCS) may also be required to help limit global climate change. Putting CO₂ back in the ground is not new. In many countries natural CO₂ 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 CO₂ Capture and Storage (CCS)?

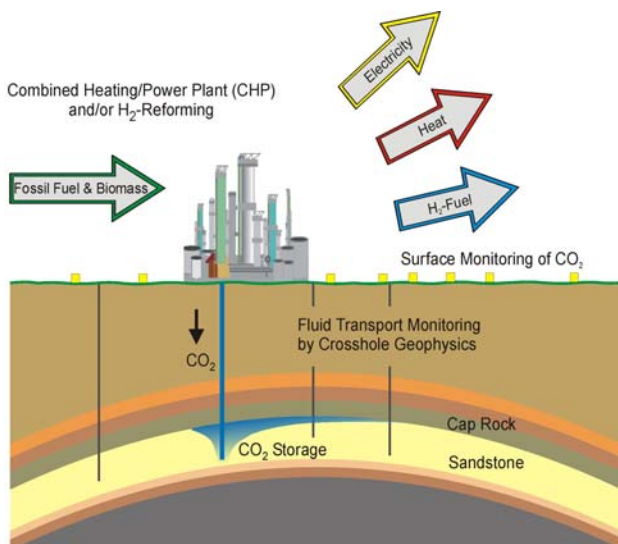
All fossil fuels contain carbon. By burning the fuel, this carbon reacts with oxygen in the air to form CO₂. By removing the carbon before or after the combustion process, for example in electric power plants, the emission of CO₂ into the atmosphere is prevented. The result is a supply of CO₂ gas, which 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).



CO₂ capture plant
(courtesy ABB Lummus Crest)

How and where can we capture CO₂?

Roughly 60% of the CO₂ 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 CO₂ (5% to 15%). One option is to separate the CO₂ from other gases in the flue gas, producing a stream which contains more than, say, 90% of CO₂. Another option is to remove the carbon before combustion, as in the case where hydrogen and CO₂ are produced from natural gas (CH₄). CO₂ capture is a well-known technology in different industrial sectors, which already separate CO₂ from other gases. At present, the resulting CO₂ is either vented or additional cleaning is performed to produce high-purity CO₂ for niche market applications, such as the beverage industry. Although some suitable technology exists, CO₂ 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, CO₂ 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 CO₂ re-use is currently limited, the majority of CO₂ extracted needs to

be stored. CO₂ can be stored in geologic formations (including depleted oil and gas reservoirs, deep saline aquifers and unminable coal seams). CO₂ 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 CO₂ emissions for tens and possibly hundreds of years.

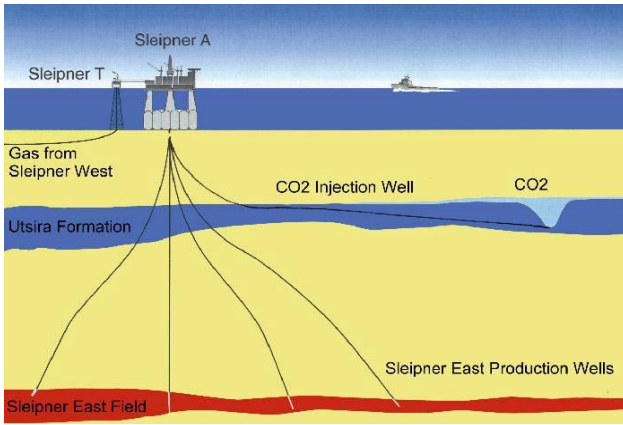
Worldwide capacity of potential CO₂ storage options (Gt = billion tonnes)

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 CO₂ emission	25 Gt CO₂ per year

Source: IEA-GHG, 2004

Oil and gas reservoirs, which generally have been well researched, are considered to be safe sinks for CO₂ storage, since these reservoirs have held oil, gas and often CO₂ for millions of years. CO₂ 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 CO₂ storage. This process, referred to as enhanced oil/gas recovery (EOR), has been performed in the USA using CO₂ for some years, not with the purpose of CO₂ storage, but to increase oil production. In Canada, injection of acid gas (a residual product of natural gas refining consisting of mainly CO₂ and H₂S) into oil/gas fields and deep saline aquifers has been practiced for many years.

Deep saline aquifers are underground formations, typically sandstones, containing saline water. These formations offer enormous storage potential: they are present in most countries, often close to industrial CO₂ sources, are usually very large, and so have a very large CO₂ storage capacity. The injection of CO₂ into these formations is similar to injection into oil and gas fields. The Norwegian Sleipner project, the first commercial CO₂ injection project in the world, where annually circa 1 million tons of CO₂ is injected into an aquifer under the North Sea, demonstrates that CO₂ 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 CO₂ in a coal seam, it has been shown that CO₂ “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 CO₂ storage. Coal seams have held methane for millions of years, so it is quite probable that they will retain CO₂ 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 CO₂ capture, transport and storage?

When capturing CO₂ 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 CO₂ 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 CO₂ emission. CO₂ capture is presently costing between 25 and 60 €/tonne of CO₂ avoided. Ongoing research is expected to halve these costs.

Transport costs are relatively modest: transporting CO₂ over 100 km by pipeline will cost 1 to 4 €/tonne CO₂ 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 CO₂. When extra oil or gas is produced during CO₂ injection, the costs may be less than 0 €/tonne CO₂. 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 CO₂ capture and storage. The question we should ask ourselves is: (a) whether the risks of CO₂ capture and storage are acceptable and (b) whether the risks are comparable with those of alternative CO₂ mitigation options? The main risks are in transport and storage of CO₂. Any storage sites will be selected far from areas of earthquake risk to ensure that the rocks are stable.



CO₂ transport USA-Canada

In the USA, there is an extensive infrastructure of CO₂ 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 CO₂ 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 CO₂ 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 CO₂ injection with a well failure, which may result in escape of CO₂ that will migrate upwards. The likelihood of a sudden escape of CO₂ 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 CO₂ 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 CO₂ market is created by setting a maximum emission cap per country and grant permits (so-called carbon credits) to emitters of CO₂. 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 CO₂ capture and storage is developed with avoidance costs down to 20 €/tonne CO₂ and geological storage of CO₂ 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.

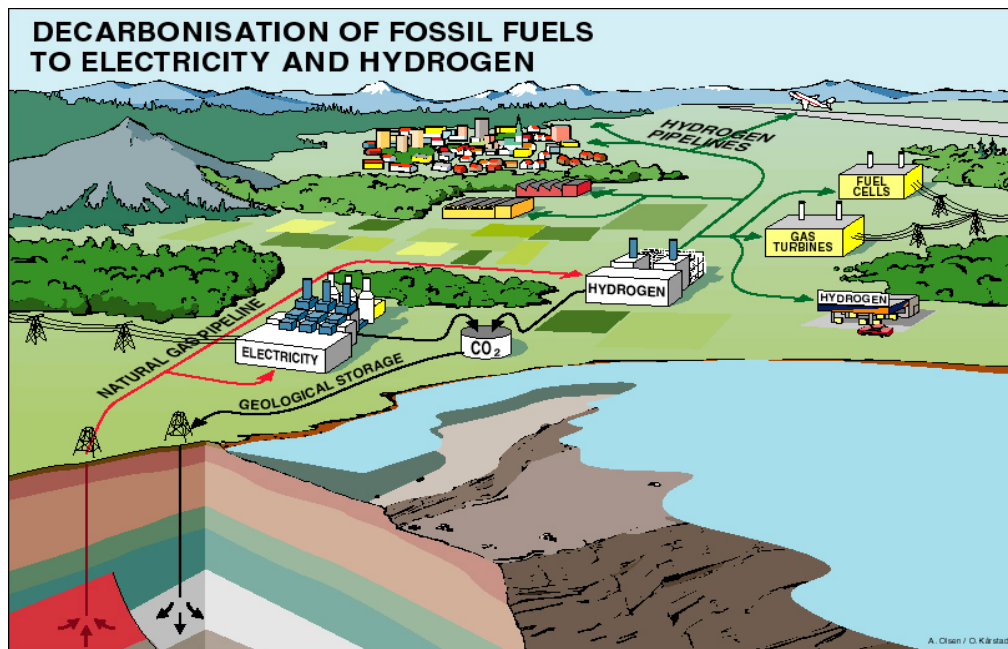
www.ieagreen.org.uk: the IEA Greenhouse Gas Programme is an international collaboration, which aims to evaluate technologies, disseminate results and identify targets for research on CCS.

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 CO₂ is captured and stored (Courtesy: Statoil)