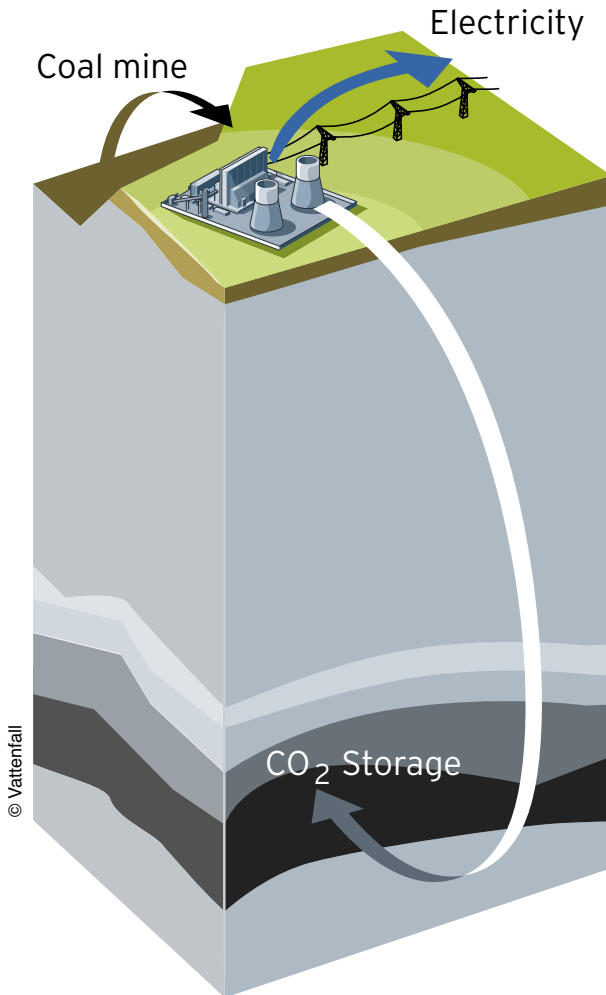


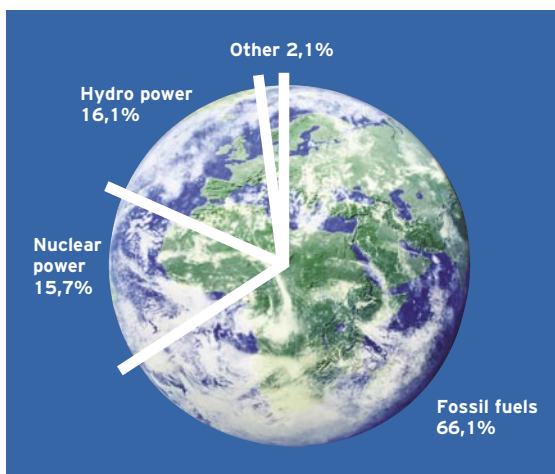
VATTENFALL & CCS – CARBON CAPTURE AND STORAGE SOON A REALITY



BRIDGING OVER TO FOSSIL FUEL INDEPENDENCE

Carbon Capture and Storage, CCS, is one of many ways of reducing emissions of carbon dioxide. For the near future, it is the most promising option for a fast and significant reduction of carbon dioxide emissions at a reasonable cost. For several years now, Vattenfall has put a lot of effort into developing a technology for capturing the carbon dioxide emitted from large coal-fired power plants and storing it safely underground.

Climate change is the greatest environmental challenge of our time and to avoid its damaging effects we need to significantly reduce the amount of carbon dioxide, CO₂, and other greenhouse gases emitted into the atmosphere.



World power generation by energy resource
Source: IEA Energy Balances (2006 Edition)

The world today is dependent on fossil fuels for its energy supply and the development of alternative sources will take time. In the meantime, emissions from fossil fuels must be significantly reduced. The capture and storage of carbon dioxide can support the transition to a low-carbon energy system in the near future.

Dedicated work

Vattenfall started working with CCS in 2001 with feasibility studies and GAP analyses, followed by laboratory tests. A 30 MW_{th} pilot plant will be ready in the summer of 2008 to test and validate the Oxyfuel capture technology. Plans for the construction of larger demonstration plants are currently taking shape within the Vattenfall Group. The demonstration plants, which will be ready around 2013-2015, will prove the commercial abilities of CCS. Every step is part of the preparation for the realisation of a commercially viable concept in 2020.

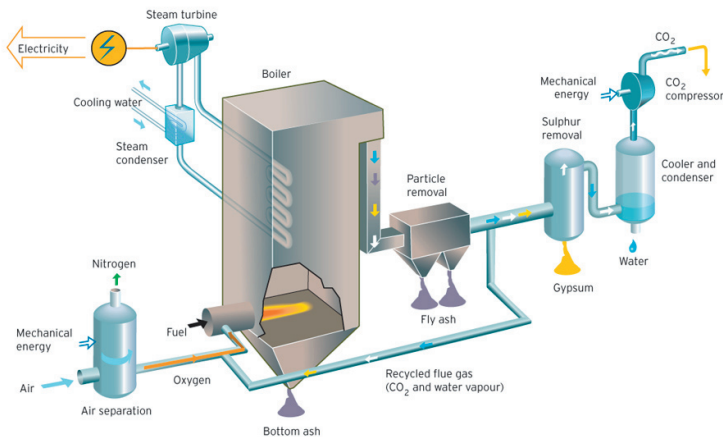
CHALLENGES

The Vattenfall CCS project covers research and development over the entire chain of capture, transport and storage of carbon dioxide and faces several challenges in developing a commercial concept.

Capture

Capture technologies aim to produce a concentrated stream of carbon dioxide that can be transported to a suitable storage site. In fossil fuel-fired power plants, CO₂ represents only a small portion of the flue gas. There are three main technology options available for capturing the CO₂ produced in large power plants.

Oxyfuel (O₂/CO₂ recycle) combustion capture



Oxyfuel combustion, where CO₂ is practically the only product following combustion in almost pure oxygen and recycled flue gas, instead of in air.

Postcombustion, where CO₂ is washed from the flue gas after conventional combustion.

Precombustion, where a gasification process removes the carbon from the fuel before the resulting hydrogen gas (H₂) is combusted.

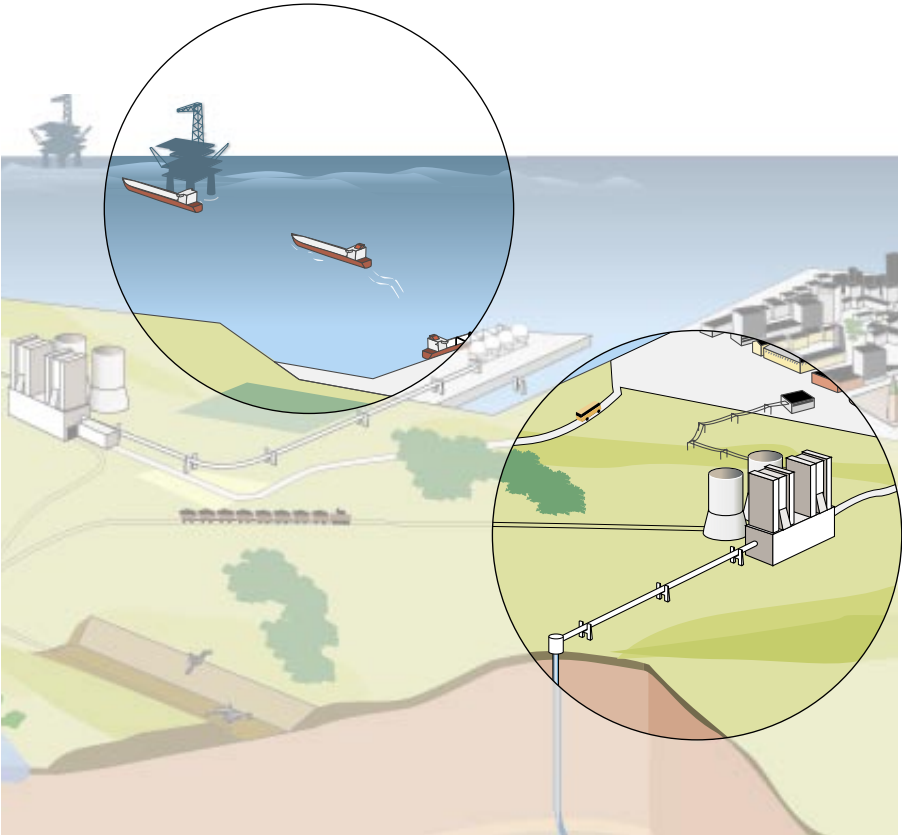
All three options need to meet the challenges of reducing the increased energy demand from the capture process and the increased equipment investment costs.

Vattenfall is performing focused research on all three technologies. The Oxyfuel technology is being validated in Vattenfall's pilot plant and we are involved in several projects for the large-scale testing of the Postcombustion technology.

Transport

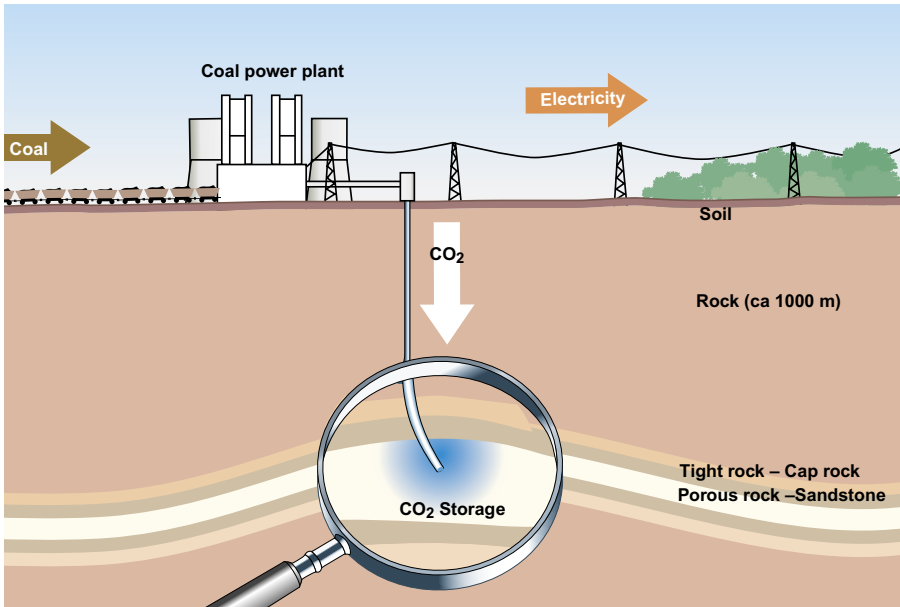
Infrastructure for transporting CO₂ is the key component that ties the capture at power plants to the storage at suitable sites. A large-scale system for carbon dioxide capture and storage has to handle CO₂ from several power plants.

One single 1800 MW lignite-fired power plant produces around 10 million tonnes of carbon dioxide each year. Pipelines and ships are the most attractive options for the transportation of these large amounts of CO₂.



Storage

In many parts of the world, CO₂ is found in geological formations where it has often been trapped between the pore spaces of sedimentary rock much in the same way as oil and natural gas. The idea behind geological storage is to replicate the conditions existing in these natural carbon dioxide accumulations.



Three alternatives for storage of CO₂ are regarded as especially interesting:

Existing oil and gas fields where CO₂ can be injected to enhance the recovery of oil and gas from existing production. The oil industry has a lot of experience of this after many years of activity. Today, more than 70 enhanced oil recovery (EOR) projects are underway around the world. Most of the carbon dioxide used in these operations is recycled, but some projects are adapted to permanently store the CO₂.

Depleted oil and gas fields which have demonstrated their ability to hold oil and gas over millions of years and therefore have great potential to serve as long-term storage sites for CO₂.

Deep saline geological formations containing salty water are potential storage options for CO₂. Suitable formations are typically located at least 800 metres underground and contain salty water that is not fit to drink. The carbon dioxide partially dissolves in the water and in some cases slowly reacts with minerals to form carbonates, thereby permanently trapping the carbon dioxide underground.

Regardless of the option selected, an impermeable layer of rock, known as cap rock, covers the reservoir, thus preventing leakage upward or escape into the atmosphere. All storage alternatives can be applied both onshore and offshore.

Vattenfall is currently locating, quantifying and evaluating suitable storage sites. Estimates indicate that Europe has more capacity than required to store all carbon dioxide emissions from its coal-fired power plants.

VATTENFALL'S OXYFUEL PILOT PLANT

The construction of the Oxyfuel pilot plant started in 2006 and it will come into operation in the summer of 2008. The pilot plant is an important milestone in the effort to achieve the goal of a commercial concept for CCS by 2020. It will be the first plant in the world to test the Oxyfuel combustion technology on this scale and to include the full CCS chain.



The 30 MW_{th} pilot plant is the first visual sign of Vattenfall's CCS efforts and is located near the existing 1 600 MW_e lignite-fired power plant in Schwarze Pumpe, south of Berlin in Germany.

The purpose of the pilot plant is to validate and improve the technology relating to the Oxyfuel capture of CO₂. A wide range of tests will be performed at the pilot plant and a first test period will last for three years.

CO₂ storage in the Altmark

The CO₂ produced at the Schwarze Pumpe pilot plant will be transported to the Altmark gas field in northern Germany for storage. Altmark is owned by Gaz de France and the CO₂ injection is part of a joint project with the aim of testing the EGR technology (Enhanced Gas recovery) and the use of a depleted gas field as a long term carbon dioxide reservoir.

IMPLEMENTATION IN DEMONSTRATION PLANTS

A demonstration plant is the link between the pilot plant and the commercial concept that is to be developed. In the pilot plant the technology itself and the process will be validated, whereas in a demonstration plant the technology's commercial abilities will be proven. Initial studies for demonstration plants have already begun within the Vattenfall Group and two sites have been chosen so far.

Nordjylland Power Station

In northern Denmark, Vattenfall will investigate the possibility of storing CO₂ at the Vedsted Structure, which is a geological reservoir at a depth of between one and two kilometres below the surface.

If storage proves to be feasible here, the intention is to establish a full-scale CO₂ capture plant at Nordjyllandsværket, the most efficient coal-fired power plant in the world. The CO₂ will be captured using the Postcombustion technology and then, in liquid form, be transported to the storage facility through a 30 km-long pipeline.

Based on the results of investigations of the geological structure, an investment decision is planned for 2010 and a CCS demonstration plant at Nordjylland would be ready for commissioning in 2013.

Jämschalde

In Germany, Vattenfall has started investigations for turning the Jämschalde power plant into a CCS demonstration plant. Both the Oxyfuel and Postcombustion capture technologies are being studied.

The lignite-fired 3 000 MW_e power plant at Jämschalde consists of six blocks, each composed of two boilers producing steam for one joint steam turbine section that generates about 500 MW net electricity.

In the feasibility study, the reconstruction of one out of six blocks at Jämschalde will be investigated. One new Oxyfuel boiler would be built and one of the two existing boilers in the block would be retrofitted with a Postcombustion capture unit. This double-demo project could be realised in 2015.



Nordjylland Power Station

Read more about Vattenfall's
project on CCS at:
www.vattenfall.com/ccs