BRIDGING TO THE FUTURE

Newsletter on Vattenfall's project on Carbon Capture & Storage | No. 11 Oktober 2008

VATTENFALL

Two important milestones have been reached

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On 9 September 2008 Vattenfall's 30 MW_{th} Oxyfuel pilot plant at Schwarze Pumpe in Germany was inaugurated. The plant is now operating and the first tonnes of CO_2, with a purity of 99.7 %, were produced a week earlier.

The construction of the pilot plant has taught Vattenfall an immense amount about the challenges involved with the Oxyfuel technology and completing this construction phase marks an important milestone.

Now the focus shifts towards the essential work on the test programme. The results of this will provide Vattenfall, the technology partners involved and, through papers and public presentations, the whole CCS community with much more invaluable knowledge. The aim with the pilot plant is to gain the necessary understanding and to validate the technology for scale-up for the approaching demonstration step.

In the shade of the inauguration at Schwarze Pumpe, another important milestone was reached outside Aalborg in Denmark. On 30 August, the seismic investigations of the Vedsted geological storage formation started. These will show whether the bedrock in northern Denmark is as suitable for CO_2 storage as earlier studies imply.

I am very proud to be a part of this development and also to be able to say that Vattenfall is not just all talk, we get things done too. Someone has to show the way, and Vattenfall is doing this now, even in a world-wide perspective. The pilot plant at Schwarze Pumpe and the ongoing seismic study outside Aalborg provide clear evidence of this. However, the project contains so much more; the pre-engineering of the two demonstration plants at Jänschwalde in Germany and Aalborg in Denmark, the cooperation on storage with Gaz de France at Altmark in Germany and our participation in the Mongstad project in Norway are further examples.

When we set our targets eight years ago, we claimed that we would reach a cost for preventing emissions of CO_2 in the future of 20 €/ton, that we would achieve a capture rate of at least 95 % and that we would be able to deliver a technical solution to eliminate the emissions from coal-fired power plants in 2020. With the latest achievements in mind, I would like to say that we are well on the way to fulfilling our ambitions.

To all my hard working colleagues, I would like to congratulate you all on these milestones, say thank you for a job well done so far, and: Let us keep up the good work!

About Vattenfall's project on Carbon Capture & Storage (CCS)

Vattenfall AB is the fifth largest electricity generator and the largest district-heating company in Europe. Its vision is to be a leading European energy company.

Vattenfall puts a lot of effort into its CCS project, as the technology is one of many methods of reducing emissions of CO_2. The capture and underground storage of CO_2 is a way of bridging over to other, renewable technology.

Vattenfall's project consists of several parts:

A full-scale **demonstration** project has started in Denmark, with Postcombustion capture at **Nordjyllandsværket**. The produced CO_2 will be transported 30 km in a pipeline to the Vedsted underground structure for storage.

A **demonstration** project has also been started in Germany. At the **Jänschwalde** power plant, both Oxyfuel and Postcombustion CO_2 capture will be demonstrated on a large scale. Different storage options are currently being investigated.

Vattenfall's **Oxyfuel Pilot Plant** in Schwarze Pumpe in Germany is now in operation. The produced CO_2 will be used for Enhanced Gas Recovery (EGR) and stored in gas fields in Altmark in Germany.

R&D to support the pilot and demonstration projects is underway for all parts of the CCS chain; Capture, Transport and Storage. Environmental issues are also covered by R&D activities. Vattenfall is an active partner in a number of EU projects.

In the **Mongstad** project in Norway, Vattenfall takes an active part in the Postcombustion R&D work.

About Bridging to the Future

Bridging to the Future is the project's newsletter and is distributed three times a year. All editions can be found on the project website www.vattenfall.com/ccs. There you can also subscribe for future issues by e-mail.

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Project manager Göran Lindgren is legally responsible for this newsletter.

Taking the step from the lab to reality:

Vattenfall inaugurates the world's first pilot plant for Oxyfuel

After almost ten years of work on Carbon Capture and Storage we have now reached a milestone: together with Brandenburg's Prime Minister, Matthias Platzeck, and the Swedish Minister for Higher Education and Research, Lars Leijonborg, Vattenfall officially inaugurated the world's first pilot plant for the CCS technology on September 9. The 30 MW_{th} plant, located in Schwarze Pumpe, Germany, carries forward the Oxyfuel-method on an entirely new scale. After a series of test rigs in cooperation with universities, the pilot plant now marks the step from the laboratory to reality.

Construction succeeded by testing

The groundbreaking ceremony that had taken place in May 2006 in the presence of German Chancellor Angela Merkel had marked the start of the building phase. After two years of construction, the pilot plant now offers the possibility to test the technology on a level that is comparable to a power-plant-scale. The perspective is for the specific emissions to decrease from more than 900 to well below 100 grams of CO_2 per kWh. During a research and development stage extending over several years, the technology will be advanced via a series of phases building upon each other until it reaches a large-scale application level.

The unique thing about Vattenfall's pilot plant is that all the components of the Oxyfuel technology and the whole CCS chain, including capture, transport and storage, will be tested. The aim is to validate the technology of the different parts and to learn how they all function together. The pilot plant is one important step in our scale-up process towards a full-scale power plant with CCS.

"The pilot plant is a milestone on the way to converting coal into electricity that is almost free of emissions. It represents the first ever transition from the lab to reality. Our perspective with this step is to make a decisive contribution to global climate protection," Vattenfall's CEO and President, Lars G. Josefsson, announced on the occasion of the official commencement of operations.

Technology development also important for the region

The pilot plant is not only an important step in pushing forward the technology. It is, furthermore, a crucial component in securing the future of coal mining and electricity generation in the Lusatia region where Vattenfall is one of the most important companies.

Matthias Platzeck, Prime Minister of the German federal state of Brandenburg, stressed this importance when saying: "When the people in the Lusatia region stand by their abilities and traditions today, then they'll accomplish the technological advances of tomorrow. With today's start of the pilot plant here as well as its use of regenerative sources of energy, Brandenburg is now also at the head of this industrial development. In this way we can manage to make the region become an "innovation lab" for an environmentally-friendly and secure supply of energy. Not only does that secure jobs here, it also serves to protect our climate."

The inauguration was accompanied by a smaller demonstration by activists from German environmental NGOs. "We know that not everybody is in favour of CCS" says Staffan Görtz, project head of communication and continues, "we want to listen to what they say. CCS is new and there are still issues that are open for discussion."

Specially-designed trucks for CO_2 transport

Parallel with the official inauguration with Lars Leijonborg, Matthias Platzeck, Lars G. Josefsson and Tuomo Hatakka, the first trucks that will serve to transport the liquefied CO_2 were presented to the journalists and guests. These special trucks will commence operation as soon as construction at the injection facility in the Altmark field is finished. The start of this project is scheduled for spring 2009.

Swedish Minister for Higher Education & Research Lars Leijonborg, the CEO of Vattenfall Lars G. Josefsson, Brandenburg's Prime Minister Matthias Platzeck and Head of Vattenfall Central Europe Tuomo Hatakka together press the "red button" to officially inaugurate the plant.

Equipment for injection on site in Altmark

At the same time as the pilot plant in Schwarze Pumpe is being commissioned, the preparations for receiving the CO_2 and storing it underground are in full swing. The injection equipment and large tanks for intermediate storage of the CO_2 are being set up in Altmark.

We have written earlier about the cooperation with Gaz de France, in which the CO_2 produced in Vattenfall's pilot plant in Schwarze Pumpe will be used for an R&D project involving on-shore EGR, Enhanced Gas Recovery, see **Bridging to the Future #9**, December 2007. Besides testing the feasibility of CO_2 as an agent that facilitates the extraction of natural gas, the suitability of the largely depleted natural gas field in the Altmark region for long-term underground CO_2 storage will be investigated.

Intermediate storage in tanks

Following liquefaction by means of pressure and temperature the CO_2, at minus 28°C, will be trucked from Schwarze Pumpe to the Altmark region; a distance of around 350 kilometres. This logistics solution is the only available technology at this scale. For our demonstration and commercial size power plants, onshore CO_2 transport will be conducted in pipelines. When the CO_2 has reached its destination it will be loaded into an intermediate storage facility consisting of two tanks, both maintaining a pressure of 15 bar. The tanks have a storage potential of 300 m^3 of CO_2 each. These tanks were delivered in the middle of July.

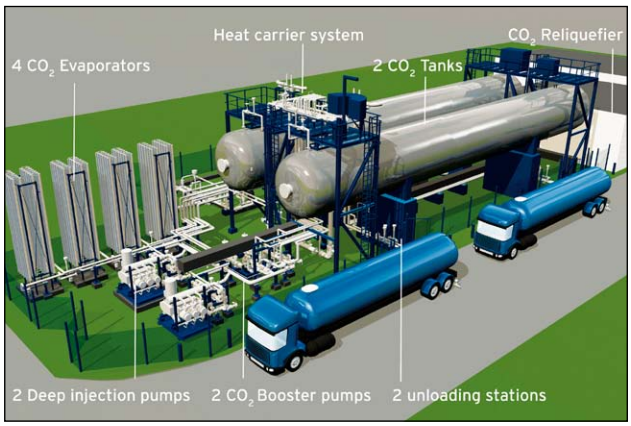
In order to keep the pressure in the tanks constant, evaporators and reliquefiers are installed and connected to the tanks. When the pressure in the tanks decreases, which occurs when liquid CO_2 is drawn off from the tank, CO_2 from the tanks will be fed into the evaporator where it will evaporate and then be fed back to the tank.

If no CO_2 is drawn off from the tank for a while, there is a risk of pressure increase due to the evaporation of CO_2 in the tanks because of heat absorption from the surroundings. If this occurs, the CO_2 reliquefier is operated to liquefy some of the CO_2 in the tank.

Injection at varying conditions

The CO_2 injection plant in Maxdorf in the almost depleted gas field in Altmark is designed to enable injection of CO_2 of differing aggregates and characteristics. This means that CO_2 in the liquid, gas and supercritical phases will be injected, and at differing pressures and temperatures within these phases. This is to see how different CO_2 characteristics influence the amount of natural gas that can be recovered from the gas field.

Using pumps and possibly the heat exchanger, the CO_2 will be given the required pressure and temperature and then be injected into a closed-off underground natural-gas-bearing structure. At full operation, about 16 tonnes of CO_2 will be injected every hour. Around 100 000 tonnes of CO_2 will, according to plan, be injected into the underground reservoir during the three years long test phase. The first CO_2 will be transported to the Altmark project site for injection during the first half of 2009.



Seismic investigations initiated in Denmark

During September and until mid-October, Vattenfall will undertake seismic investigations covering an area of 20 x 25 kilometres in the north of Jutland. The results of these investigations will form the basis for additional work relating to the assessment of whether the geological conditions should be investigated further with the aim of establishing a CO_2 store in the Birkelse area.

What are seismics?

Seismic investigations are based on a geophysical investigation method in which sound waves are transmitted down through the layers of the earth. This enables geologists to get an impression of the layer sequence and structure, whether it is sand, clay or chalk. The sound waves can be generated either through an explosive charge or, in the case of marine investigations, using a compressed air gun or, as will be the case in these investigations, vibrations. In these investigations, the vibrations will be generated by three vehicles, each of which is fitted with a vibrator plate that will be driven along pre-marked lines. Every 10m or so, the vibrator plate will be lowered and then vibrated for 20–30 seconds at a time. Along the lines that are to be surveyed, cables have been laid out with geophones (comparable to microphones) which capture the sound waves that are generated when they return to the surface.

Special vehicles for vibration generation

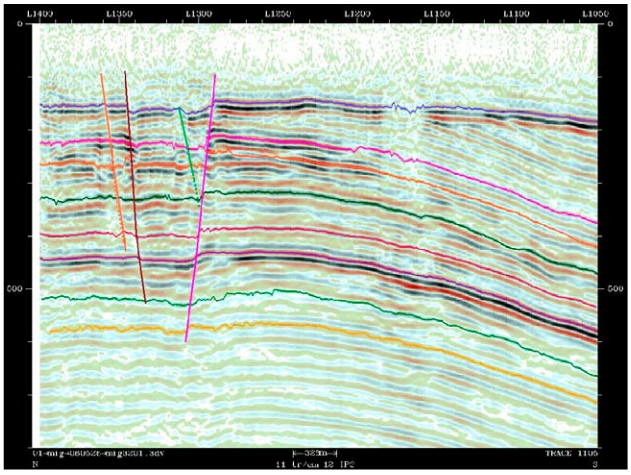
The fact that the sound waves return is due to the layered structure of the earth. The aim of these investigations is to explore the layers down to a depth of 2–3km. On their way down through the earth, the sound waves will encounter transitions between rock layers with different properties. At these transitions some of the sound waves will be reflected back to the surface. The time difference from generation of the sound waves until they are recorded by the geophones again makes it possible to form a visual picture of the layer sequence (a seismogram).

Known geology

Before any type of investigation concerning the underground is commenced, the geologist will always prepare a model of what he or she expects the underground area to be like. In the case of Birkelse, it is fortunate that oil exploration drilling was carried out in 1958, and it is because of the information provided by this drilling that we know there is a structure which could be suitable for storing CO_2. As the area has more recently been subject to further oil exploration, a number of seismic investigations have been carried out over time. Together with the earlier drilling they form the basis for the current geological model, which is being used until new and better data can be collected.

A simplified model is based on the assumption that there is a layer of sandstone at a depth of approximately 2km which will act as a CO_2 store. Above this sandstone layer is a several hundred metre thick layer of shale, which will act as a seal that the CO_2 cannot penetrate. Uppermost in the sequence is a layer of chalk, the same that is quarried in a number of locations in North Jutland, which will trap and bind the CO_2 chemically if it were to seep through the shale cap.

The results of the planned seismic investigations will be used to confirm whether or not the various layers are present with the thickness and distribution necessary in order for work on the project to continue.



Example of computer plotted geological profile

Five common misunderstandings about CCS – Part I

All new and large-scale technologies are often met with scepticism since they seem scary and CCS, Carbon Capture and Storage, is no exception. The public debate regarding CCS has grown in recent years, which is good, but misunderstandings and misinterpretations are common in the dialogue.

Here, Vattenfall wants to straighten out some important areas of confusion and also clarify its position on five subjects. In the next issue of Bridging to the Future, you will find our thoughts on five more subjects.

1 Is there global consensus on combating climate change?

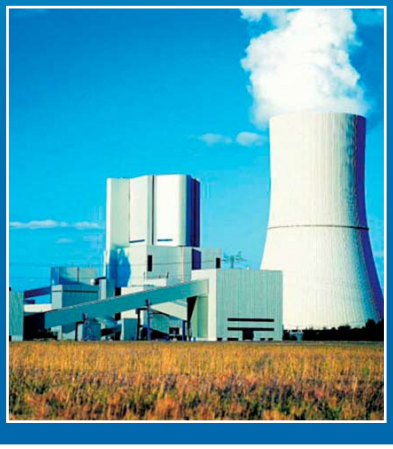
Most of the world's leaders recognise the climate change issue and are well aware of the necessity of taking action. However, there are many countries that have other more prioritised issues on their agendas. For them, the utilisation of domestic fossil resources is a means of reaching other objectives with a higher priority. CCS gives hope since it has the potential to be affordable also to economies in transition.

2 Could the world be made independent of fossil fuels within a couple of decades?

Fossil fuels have their role and will continue to play a role in global energy supply for a long time to come. There is no way that the world could make itself independent of fossil fuels within the next two decades. Fossil fuels are a far too powerful tool for reaching other important goals.

A functioning energy supply system is a cornerstone of the infrastructure and society at large – it provides added value to people. In western society we have had this for so long that we now take it for granted. In developing countries and economies in transition, improved energy supply is a tool for reaching other goals such as economic growth and improved living conditions for the population.

Today, 65 per cent of the world's electricity generation is based on fossil fuels. Fossil fuels now account for 80 per cent of the total energy supply. Fossil fuels are competitive, are found everywhere, are easy to use and can easily be transported.



3 Does CCS waste energy?

CCS plants use more energy for their own processes than traditional power plants with combustion. However, using energy to prevent CO_2 emissions to the atmosphere is not a waste of energy – it is a good use of energy. Future commercial power plants with CCS will probably be more energy efficient than the global average of existing power plants today.

Energy is needed to capture CO_2. The oxygen generation (air separation) required for both the Oxyfuel and Precombustion capture processes uses energy. Both Postcombustion and Precombustion processes need energy to re-release CO_2 after it has been absorbed by amines or other absorbents. Once the CO_2 has been captured it needs to be compressed before cost-effective transportation. This process also uses energy.

These processes use energy that otherwise could have been used to generate additional electricity. However, some of the losses in electricity generation could be used for heat production. Therefore, Vattenfall strongly believes that commercial CCS plants would achieve improved competitiveness as CHP (Combined Heat and Power) plants.

It is believed that the learning curve for CCS will be quite fast. The technology is still juvenile and there is great development potential. For example, Vattenfall believes that it would be possible to build Oxyfuel plants by 2030 with higher electricity efficiency than could be built today using the best commercially-available technology.

4 Could CCS deliver in time?

There are strong reasons to believe that CCS could deliver in time to become a powerful tool in the struggle to significantly reduce global CO_2 emissions and thereby combat global climate change. No other single measure has the same potential.

Vattenfall strongly believes that CCS could become commercial under the emission-trading scheme in Europe by 2020. Thereby, it has a potential to become a powerful tool to reduce CO_2 emissions. Other measures, such as increased energy efficiency and renewables like wind power, could deliver faster, but on a smaller scale. It is, however, important to remember that all measures are needed to handle the climate change issue.

It is also important to recognise the World's dependence on fossil fuels and that the vast majority of newly-constructed power plants, both in Europe and in the developing countries, are fired with fossil fuels, usually coal.

The best Vattenfall and Europe can do is to show the rest of the world that CCS is possible and that the cost for it is affordable. If we can do this, the rest of the world will follow and a significant global reduction of CO_2 emissions could be achieved.

5 Does CCS reduce efforts to develop renewable and sustainable technologies?

Efforts to develop CCS do not reduce efforts to develop renewable and sustainable technologies. CCS is a powerful complement.

CCS is no silver bullet; it is an intermediate solution along the road to a global low-carbon or CO_2-neutral society. But, CCS does not have the potential to reduce all CO_2 emissions. It could be applied to large point sources but would be to too costly for small, outspread sources. CCS is not seen as an option for the transport sector.

Therefore, all the players in the energy sector have given high priority to the continued development of renewable and sustainable solutions. Based on the information available today, there is no hope that these technologies could become mature enough to replace the fossil fuels within a reasonable time.

EU projects with Vattenfall participation

Vattenfall is playing an active part in several European projects involving CO_2 capture, transport and storage and has done so for many years. Openness is one of our core values. We learn a great deal from this and we strongly believe that this kind of cooperation between equipment suppliers, the research community and energy companies will push the development forward for CCS to become commercial by 2020. In this article you will find a summary of the projects in which we are involved.

Increased understanding of CO_2 storage

To date, Vattenfall is engaged in five different EU projects for CO_2 storage, all of which have a different focus. One project – ECCO – is supported by the European Commission (EC) under the quite new 7th R&D framework, FP7.

The **ECCO** project kicked-off in early September, and during the three-year period to come the partners, mainly R&D providers, e.g. Norwegian SINTEF, Dutch TNO and Danish GEUS, and energy companies, e.g. Statoil and DONG Energy, will study the CO_2 value chain. This means that the partners will look closer at enhanced hydrocarbon recovery (EOR/EGR), quantify the European potential for this and evaluate the technological challenges involved. The total budget amounts to about €5.5 million.

Photo: CO2SINK/GFZ Potsdam

CO_2SINK project: The small drilling rig is set up at Ketzin.

Vattenfall is also an active partner in four projects under the 6th Framework Programme. **CO_2Remove** aims to learn lessons from existing CO_2 storage sites. This is done by developing and testing monitoring methods for base-line CO_2 storage site evaluation. New tools for storage monitoring and the prediction of long-term effects have also been in focus, as well as producing a guideline for best practice in CO_2 storage. This project has a total budget of around €15 million, started in 2006 and will last for five years.

In the town of Ketzin near Berlin, Vattenfall is involved in **CO_2SINK**, a project that concerns the in-situ testing of the geological storage of CO_2. It will advance our understanding of the science and the practical processes involved in the underground storage of CO_2 in a saline aquifer. Eighteen partners are involved in the project, which is coordinated by GFZ, the German Research Centre of Geosciences. The project started in 2004 and in June this year the first CO_2 was injected into previously examined geological formations.

In the project **CSEGR** the focus is on evaluating the potential for CO_2 storage combined with EGR, Enhanced Gas Recovery, in two German gas fields. One of the gas fields is Altmark, and Vattenfall's plans for storing CO_2 from the Oxyfuel pilot plant in Schwarze Pumpe can be seen as a result of this project. The total budget of this project is about €1 million. Vattenfall, with five collaborators, started the CSEGR project in 2005. The work will be completed in October this year, but the activity in the Altmark field is increasing day-by-day now.

In the GESTCO project that was carried out between 2001 and 2003, the potential for the geological storage of CO_2 was assessed in some parts of Europe. In the **Geocapacity** project, which is a continuation of GESTCO, several white areas on the European map are covered, including the southern and eastern parts of the continent. The project started in 2006 and will be finalised next year. The total budget of this project is around €5 million and 26 partners, mainly geological institutes and universities, are involved.

CO_2GeoNet is a European network of excellence on the geological storage of CO_2, sponsored by the EC under FP6. The aim is to promote research integration within the scientific community to help enable the implementation of CO_2 geological storage. Thirteen well-known research institutes, such as GEUS, BGR and TNO, are involved. After four years of support from the EC a scientific association has now been launched to continue the work of CO_2GeoNet also after the funding comes to an end next year.

Growing interest in the transport issue

The closer to implementation of CCS we get, the more focus can be and is directed on the transport issue. **CO_2Europipe** is a new project under the 7th Framework Programme that is currently under negotiation with the Commission. If funded, this project will start in January 2009 and last for two and a half years. The project involves 18 partners, mostly from the industry. The aim is to pave the way towards large-scale Europe-wide infrastructure for the transport and injection of CO_2.

Improved CO_2 capture always in focus

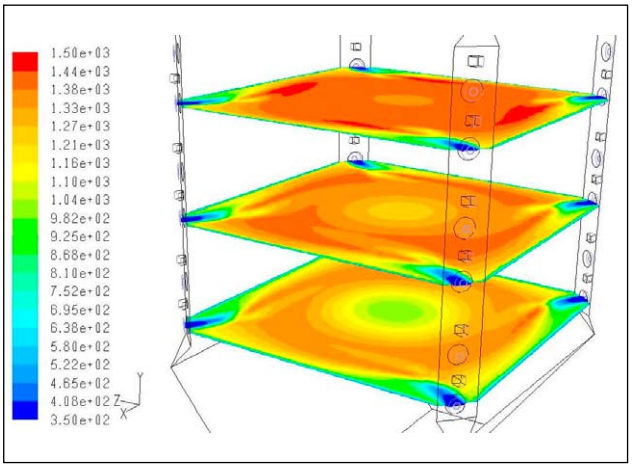
The project that Vattenfall has been, and still is, mostly involved in over the last couple of years is the **ENCAP** project, **En**hanced **Cap**ture of CO_2. We act as coordinator of the whole project and have the leading role in Subproject 3, where the development of Oxyfuel combustion is in focus. This project has been extremely important to Vattenfall and has increased our knowledge concerning the Oxyfuel, Precombustion and Chemical Looping capture processes, as well as alternative high-temperature technologies for producing oxygen.

ENCAP is a very large project involving 24 European energy and power companies, leading European equipment suppliers and high-ranked research providers. The project started in 2004 and will end in 2009. The total budget is around €22 million.

The Postcombustion capture process is in focus in the new **Cesar** project, which we wrote about in issue #10 of Bridging to the Future, April 2008. Cesar, and its predecessor Castor, aim to reduce the energy requirement in the Postcombustion capture process by means of large-scale testing in the Esbjerg pilot plant. The project will last until 2011, has a budget of €7 million and involves 19 partners. The project is coordinated by TNO.

Oxymod is a project with the purpose of developing, and by means of experiments validating, mathematical modelling methodology for Oxyfuel combustion. Six partners have developed CFD models (Computerised Fluid Dynamics) to be used as a tool for optimisation and analysis of the combustion process and have supported the project with experimental data for validation purposes. The project started in 2005 and has recently come to and end. The total budget was around €2 million. The project was coordinated by Vattenfall.

The **Dynamis** project has its focus on the Precombustion capture process and its role in a hydrogen society. The project also covers transport and storage issues. Twenty-eight partners are involved in this project, which started in 2006 and will finish in February next year. The original idea was that the project would support the preparation of a demonstration plant. The total budget is almost €7.5 million.



CFD simulations performed within the ENCAP project

Characteristics of carbon dioxide

Carbon dioxide (CO_2) is the fourth most abundant gas in the earth's atmosphere, accounting for approximately 380 ppm (0.0380 %). In the past, however, the atmospheric concentration was lower. Since the industrial revolution, levels have increased by about 100 ppm. There are several contributing factors that determine the CO_2 concentration in the atmosphere, but most researchers agree that the main cause of the increase in concentration is the release of CO_2 previously bound in fossil fuels.

CO_2 is, at atmospheric conditions, a colourless gas. It is also odourless, non-poisonous, non-flammable and not explosive. CO_2 is denser than air, which means that CO_2 has a tendency to sink into depressions and low-lying areas. At most times, atmospheric turbulence prevents any accumulation of CO_2.

Carbon dioxide is an integral part of the carbon cycle and is produced by most living organisms during respiration. Exhaled air from humans consist of about 4 % CO_2 (40 000 ppm). CO_2 is also a part of the photosynthesis process, in which plants use CO_2 and sunlight to grow. CO_2 concentrations in a greenhouse vary substantially over a 24-hour period. During the day, concentrations may sink as low as 150–200 ppm due to plant uptake. At night, plant respiration increases when uptake drops in the absence of solar energy, and the CO_2 concentration can increase to about 500–1000 ppm. The CO_2 concentration in greenhouses is often increased through the addition of CO_2 in order to increase plant growth.

Effects well investigated

The physiological effects on human health and safety due to elevated CO_2 concentrations are well understood and a considerable amount of research has been conducted in this field. (The research has been based mainly on healthy adult males, and the effects on children and weak individuals may differ to some extent). Exposure studies have not revealed any adverse physiological effects for humans chronically exposed to CO_2 concentrations below 1 % CO_2 (10 000 ppm).

The potential health and safety effects associated with CO_2 mainly relate to CO_2 being an asphyxiant, that is, if it replaces oxygen in the air to such a degree that there is a risk of suffocation. CO_2 is to some extent also physiologically active, in that it at higher concentrations can affect circulation and breathing.

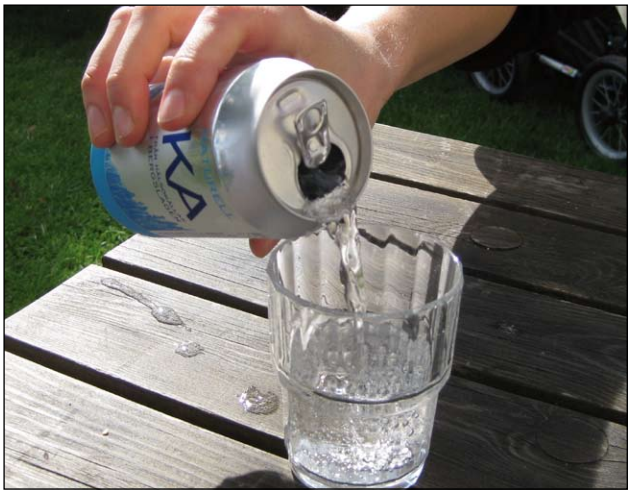
Headache because of poor air quality

Most people have probably felt the effects of poor air quality after spending some time in poorly ventilated areas. Typical office levels are 600–1200 ppm. CO_2 concentrations in tightly packed conference rooms with poor ventilation may reach levels around 2 000 ppm. However the effects then felt, such as poor ability to concentrate, headache or fatigue are to a large extent due to other residual products that form during respiration.

At concentrations above 3 % (30 000 ppm) the respiratory rate is significantly affected, the blood pressure is increased and some discomfort is experienced. At concentrations above 5 %, mental and physical abilities are impaired, and loss of consciousness can occur. Exposure to concentrations above 10 % may in the worst case be fatal.

There is substantial experience on how to handle CO_2. It is one of the most thoroughly mapped substances there is – CO_2 has been used in industrial applications, for example in the chemical industry, for a long time. This experience is now being utilised to ensure the safe operation of CO_2 capture and storage facilities.

Standard applications of CO_2: Fire extinguisher...



... and sparkling water

On the other side of the bridge

Vattenfall's strategy for fighting climate change is made up of three prongs, of which capture and storage technology is one. The other two are the optimisation of existing technology and the increased use of energy sources without emissions of fossil-fuel carbon dioxide.

In every issue of Bridging to the Future, we present work performed within the Vattenfall Group that aims to reduce emissions of greenhouse gases. The topic for this issue is our work with the first part of our strategy for combating climate change: improving the efficiency of our existing plats.

Better efficiency in thermal power plants

The coal and lignite-based thermal power plants in the Vattenfall Group generate around 80 TWh annually. An efficiency increase of only one or two per cent in a power plant would give several extra GWh every year. Increasing the pressure and temperature of the steam generated is a measure for increasing the efficiency and output.

This modern technology is realised in Vattenfall's new power generating block in Boxberg, Boxberg R, which is currently under construction. A live steam temperature of 600 ºC and a pressure of 285 bar will be utilised and the net power efficiency in Boxberg R will be more than 43 %.

More power from the Luleälv River

Earlier this year, the decision to refurbish the Akkats hydro power station was taken by the Vattenfall board. Akkats is one of fifteen power stations on the Luleälv River in the very north of Sweden and together they generate almost 14 TWh annually. The first power station along the river was inaugurated already in 1914.

The planned refurbishment of Akkats includes replacing the old 150 MW turbine with two smaller machines of 75 MW each. The old inlet tunnel will remain and feed one of the new turbines with water. A second inlet tunnel will be built to supply the second turbine. Stones and other material from incidents in the past in the outlet tunnel will be removed, which will facilitate the water discharge.

Akkats hydro power plant

The work will result in an increase in the electricity generated of around 25 GWh annually and Akkats will then generate around 590 GWh of totally CO_2-free electrical power each year. The cost of the project is estimated at €100 million. The project will start in the autumn of 2008 and run for around 5 years.

Ringhals nuclear power plant

Increased output in the nuclear power plants

In total, about 50 TWh of nuclear power is generated annually in Vattenfall's nuclear power plants in Sweden and Germany. In the Swedish plants, Ringhals and Forsmark, work to increase the generation in the existing plants is ongoing.

Ringhals' four reactors, both boiling water and pressurised water reactors, produce around 28 TWh in a normal year. The first reactor came into operation in 1975 and with the modernisation work that is currently underway we will be able to run the facilities for many years to come.

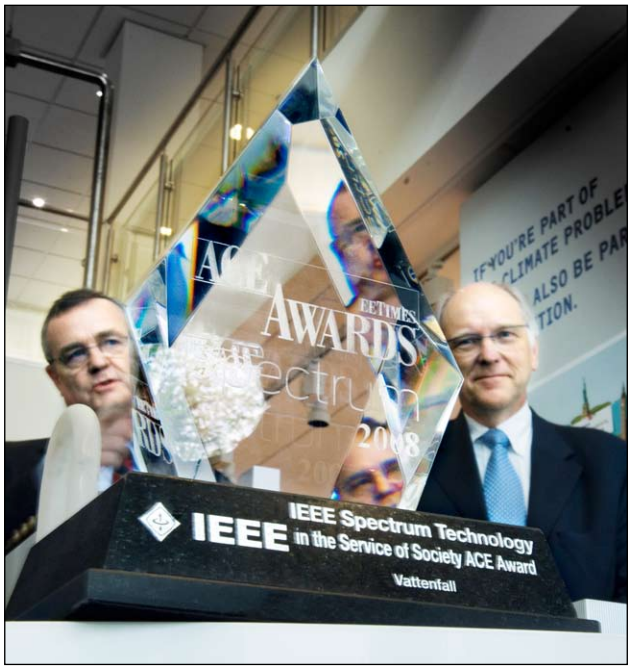
An investment programme was initiated in 2002 and in the period up until 2012, € 1.4 billion will be invested in regeneration, improved safety, reduced environmental impact and increased output. The programme consists of 300 different projects, involving among other things new turbines and generators, a new digital control room and new cooling water systems. The investments will increase the power output from Ringhals by 4 TWh per year.

Vattenfall receives award for the Oxyfuel Technology

Vattenfall's CCS project is at the vanguard of development. In the spring of 2008, Vattenfall received an Emerging Technology Award for its Oxyfuel pilot plant project in Schwarze Pumpe from the Institute of Electrical and Electronics Engineers (IEEE), the world's leading organisation for electrical and electronics engineers.

Dr. Lars Strömberg, former project manager of Vattenfall's CCS project and now head of R&D at Vattenfall, and Dr. Helmar Rendez, Head of Strategy at Vattenfall, received the award at a gala in San José on the American west coast in April this year. The prize was shared with Alstom Power Inc., as the developer and supplier of the Oxyfuel boiler in the Schwarze Pumpe pilot plant. Alstom Power was represented by Steve Orsini at the gala in San José.

Of all the new innovations that have been developed over the past year, this project is considered to have "the potential to provide the greatest social benefit", according to IEEE.



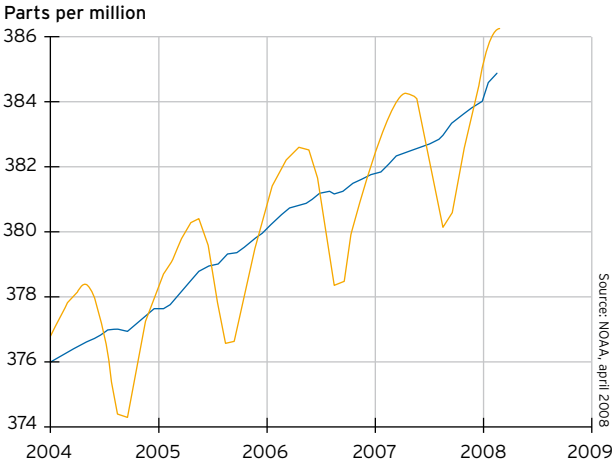
Lars Strömberg and Lars G. Josefsson together with the IEEE award

Did you know?

- The cost of 1 tonne of CO_2 is € 23.5 (average August 2008, see left diagram).
- The global concentration of CO_2, adjusted for seasonal variations, is approaching 385 ppm, see right diagram. (Source: NOAA).
- 91% of Poland's electricity generation is based on coal (2005; Source: Euracoal).

CO_2 certificate prices 2008

Recent global monthly mean CO_2



"The cost of seriously limiting greenhouse gas emissions will be high. According to the Stern Report, extensive climate action will annually cost at least 1 % of global GNP. This can be compared with the additional cost of about 5% of global GNP that energy consumers have been forced to accept between 2005 and 2008 because of the increased cost of fossil fuels."

Professor Marian Radetzki, Member of the Royal Swedish Academy of Engineering Sciences, IVA, and the IVA-project Energy crossroads (Vägval energy, www.iva.se/energi).