

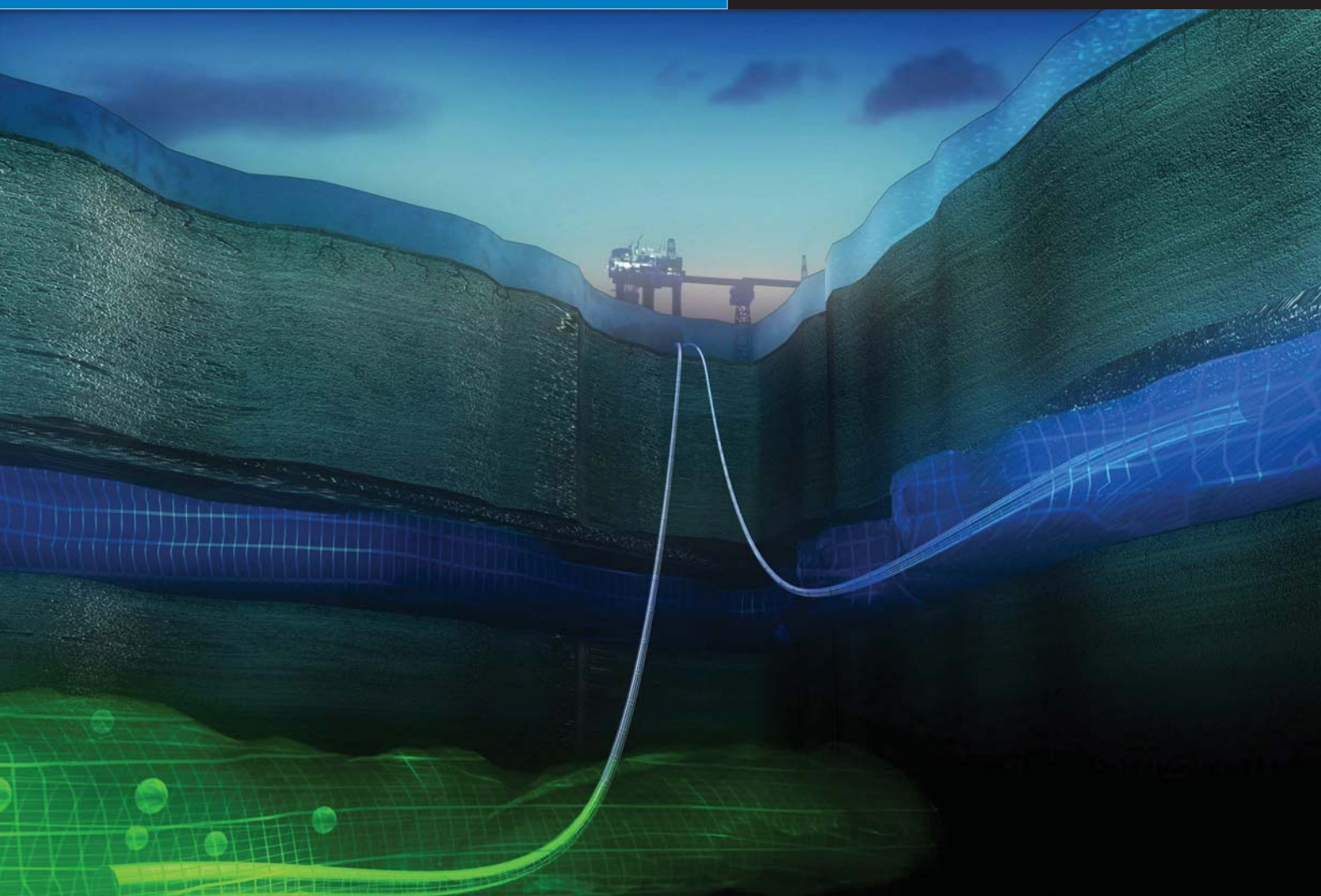
# carbon capture journal

Mitsubishi Heavy  
Industries - doing  
commercial scale  
carbon capture

Senergy -  
monitoring CO<sub>2</sub>  
storage

January / February 2008

Issue 1



Doosan Babcock - clean coal technology

The economics of industrial scale CCS

The UK's CCS demonstration project competition

The EU's CCS strategy

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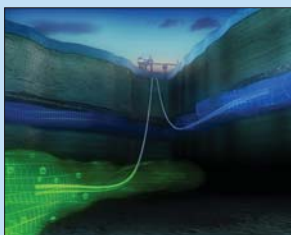
Front cover:

Carbon capture and storage at Statoil's Sleipner West field in the

Norwegian

North Sea: around a million tonnes of CO<sub>2</sub> annually is being stored 1,000 metres beneath the seabed

Photo: Alligator film / BUG / StatoilHydro



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# Letter from the Editor

Carbon Capture and Storage is the only technology that can make a significant contribution to reducing carbon emissions in a world where coal will be the fuel of choice for many decades to come. We hope to facilitate one of the most important aspects of the development of this technology - sharing of information and best practices so that CCS can be a reality by 2020

Welcome to the first issue of Carbon Capture Journal!

This is an exciting time as interest in carbon capture and storage (CCS) technologies reaches a critical mass and begins to be part of mainstream activity in the power generation industry.

I think a quote from Jan Panek, Head of Unit, Coal and Oil, European Commission at the recent Inaugural European Carbon Capture and Storage Summit in London neatly sums up why there is such a huge commercial interest in CCS.

"It does not happen too often that a multi-billion mature industry such as the one we see in energy production from fossil fuels stumbles upon a completely new business opportunity with an even bigger multi-billion potential reachable in a decade or so."

While the potential business opportunity is clear, and the core technology already exists, there are many aspects of carbon capture which are not yet mature or tested on a large enough scale.

Progress needs to be made on demonstrating the full chain of capture, transport and storage on an industrial scale.

The market needs to have confidence that there will be a revenue stream, whether from government subsidy or from market forces driven by a carbon price, that enables investment in pilot projects and research.

The regulatory environment must be clarified so that there is no confusion regarding legality and long term liabilities.

The EU will announce on 23rd January a raft of new proposals as part of a larger package on renewable energies and climate change, including a communication on CCS detailing pilot projects and clarifying the legal framework, and proposals for carbon trading after 2013. We wait to see the details.

Meanwhile in this issue you can read about some of the progress that is currently being made, including Mitsubishi Heavy Industries' industrial scale carbon capture projects around the world; UK reservoir consultancy Senergy's advice on the best way to monitor sequestered carbon; and our report from a recent meeting in London, with a range of experts explaining the best way to get the industry moving.

Jan Panek outlines the role of CCS in the

EU's energy strategy; Dr Mike Farley from Doosan Babcock explains how the UK can take a leading role demonstrating clean coal technology using CCS; and Bronwen Northmore talks about the UK's competition for post combustion carbon capture on a coal fired plant.

## Pushing forward

One of the key questions often addressed at meetings is, 'how can the industry have the confidence to make long term investment decisions when future earnings, from a carbon price or some other mechanism, are so uncertain?'

After all, the carbon price that would make CCS viable economically may not be with us until 2020 or later.

There has been talk of covering the cost of carbon capture through enhanced oil recovery (EOR), but recent experience has shown that this is not always commercially viable.

In the North Sea, which is coming to the end of its life as a producing asset, EOR can extend production for around a decade, but the potential is inevitably short term and can not form part of any sustained activity.

Undoubtedly further commitment from government is needed to bridge the gap and the best way to influence this is to gain an overwhelming public support.

In the short term, we need to explore every option to get carbon capture off the ground - innovative technology, industrial practise, some EOR, the best possible government policy and public support, with the public support probably being the hardest one of all.

## How can we influence public support?

Can we get some help from the environmental groups? They have many highly talented, energetic, engaged and motivated people with a track record of making environmental issues engaging and influencing public and government opinion.

But environmental groups don't yet trust carbon capture and storage. They think it is a 'sweep it under the carpet' solution and much work needs to be done to convince hard line activists that it is safe and will not cause undesirable side effects.

In many ways the environmentalists have an argument - no one has actually done this on a commercial scale and seen the results over many years - but right

now there's no better way of reducing carbon dioxide emissions that is within our power to implement.

We need to speak clearly and with one voice - if you believe that carbon dioxide emissions threaten life on earth (and OK, not everybody does), then CCS is the most plausible way of reducing them, in large volumes, that anybody has come up with so far.

With your support, we hope to make a modest contribution to encouraging implementation of CCS, by helping fans and foes of CCS keep up to date with new technology, projects, government policy and best practise.



Keith Forward, Editor, Carbon Capture Journal

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# Mitsubishi Heavy Industries' carbon capture technology

Mitsubishi Heavy Industries (MHI) of Yokohama, Japan, is perfecting post combustion carbon capture, with a number of pilot, demonstration and commercial scale projects, and it has developed its own special solvent. **Ronald Mitchell, manager of business development of MHI's environmental plant department, explains**

MHI has developed a commercially available, proprietary post-combustion flue gas CO<sub>2</sub> recovery system called the KM-CDR (Kansai Mitsubishi Carbon Dioxide Recovery) Process.

The technology has been developed to run on natural gas fired applications, and it can also be retrofitted to existing coal power stations.

To develop the system for coal fired gas streams, it has built and is operating a 10 ton per day demonstration facility in Matsushima, southern Japan.

The results at this demonstration facility have been critical in furthering MHI's understanding of the effects of various coal based impurities on the CO<sub>2</sub> capture process.

## Demonstration and commercial projects

By combining the commercial experiences with the concurrent research and development, demonstration projects and the expansive scale up design for larger scale, single train units (up to 5000 tpd), MHI has developed a road map which outlines a clear strategy towards providing commercially ready CO<sub>2</sub> capture solutions for coal fired power plants.

A large number of tests, from lab and bench tests to pilot and small scale demonstration tests have been conducted at a number of host sites throughout Japan.

During these significant pilot tests and demonstration operations MHI has refined and enhanced the CO<sub>2</sub> capture process and accordingly has patented many proprietary processes, solvents and equipment components.

The experience gained from the deployment of several commercial plants has been invaluable in strengthening the knowledge of CO<sub>2</sub> capture at a range of sites throughout the world.

## Commercial projects so far

In the past five years MHI has constructed four major CO<sub>2</sub> capture plants with another four currently in the pipeline.

In Malaysia it built a 200 MT/D (MAX) CO<sub>2</sub> plant capturing CO<sub>2</sub> from a natural gas steam reformer to produce urea. It has been on stream since 1999.

In Japan it has built a 330 MT/D (MAX) plant capturing CO<sub>2</sub> from a natural gas and oil fired boiler for 'general use' products. It has been on stream since 2005.

In India, MHI has supplied 2 separate 450



330 t/d (MAX) CO<sub>2</sub> Recovery Plant (Japan)

MT/D CO<sub>2</sub> capture plants utilizing natural gas to produce urea. They have been on stream since December 2006.

MHI has a 400 MT/D project under development in the United Arab Emirates, utilizing natural gas to produce urea. The FEED (Front-End Engineering and Design) is completed and it is due for start-up in 2008.

In China, a 800 MT/D CO<sub>2</sub> capture plant from a natural gas steam reformer to produce methanol is planned, the FEED is completed.

In India, a 450 MT/D plant to capture CO<sub>2</sub> from natural gas to produce urea is planned. MHI has been awarded the project and it is due to commence operation in April 2009.

In the Middle East a 450 MT/D plant to capture CO<sub>2</sub> from natural gas to produce urea is planned. MHI has been awarded the project; further details are soon to be announced.

There are also two pilot and demonstration projects running.

In Osaka (Japan), a 2 MT/D CO<sub>2</sub> capture pilot scale plant is running on a natural gas fired flue gas stream and has been operating since 1991.

In Nagasaki (Japan), a 10 MT/D, long term, CO<sub>2</sub> capture demonstration plant is running on a coal fired flue gas stream (over 4000 hrs operating experience).

These tests have helped MHI increase its understanding of the effects of several impurities



10 t/d coal fired CO<sub>2</sub> capture demonstration plant - Matsushima, Japan.

on the system (eg dust, SO<sub>2</sub>, NO<sub>x</sub>) and has helped develop countermeasures to negate the impact of these respective impurities.

## Advantages of post combustion CO<sub>2</sub> capture

The MHI KM-CDR post combustion CO<sub>2</sub> capture process offers a number of significant advantages.

It is applicable for the current, global post combustion fleet. It offers high degree of flexibility - is adaptable and cost competitive with other technologies

It operates at atmospheric pressure - so it is safe and does not require exotic materials. It produces highly purified CO<sub>2</sub> - this is an important environmental consideration for transport and disposal.

It is easy to transfer post combustion technology to developing countries - simple process and configuration. It allows for possible future zero emission use of coal

## A special solvent

The most common type of amine solvent used in the commercial market place is mono-ethanol-amine (MEA).

The main concerns with MEA and other amine solvents are high levels of corrosion and degradation in the presence of O<sub>2</sub> and other im-



purities, excessive solvent degradation rates following reaction with SO<sub>x</sub> and NO<sub>x</sub> and the large energy consumption requirements needed for regeneration.

These factors contribute to the use of large equipment, high solvent consumption and large energy losses - leading to increased operating costs.

During its comprehensive R&D phases, MHI tested more than 130 different reagents. The most efficient solvents were critically examined in the final stage of pilot plant testing.

Following this, a proprietary solvent KS-1<sup>(TM)</sup> was developed.

In parallel with the development of the solvent, the process itself has also been optimized, leading to superior, demonstrated performance of CO<sub>2</sub> recovery from the flue gases of fossil fuel combustion processes.

The development of KS-1<sup>(TM)</sup> is seen as a breakthrough because of the significant number of advantages it offers. KS-1<sup>(TM)</sup> has an exceptionally low corrosive nature and, unlike MEA, does not require a corrosion inhibitor.

This factor means carbon steel can be used for the majority of construction within the CO<sub>2</sub> capture plant. Furthermore, the process operates at atmospheric pressure (ensuring a safe work environment), has few exotic materials and a simple configuration.

Additionally KS-1<sup>(TM)</sup> offers superior CO<sub>2</sub> absorption and regeneration, lower degradation, lower circulation rate and, with other patented equipment, has less solvent loss when compared to other amine based systems.

All of these features lead to decreased operating cost. Importantly, KS-1<sup>(TM)</sup> together with the patented "improved" CO<sub>2</sub> recovery process which utilizes the heat of the lean KS-1<sup>(TM)</sup> solvent, effects a 30% reduction in steam consumption over the conventional MEA process.

## The CO<sub>2</sub> capture Process

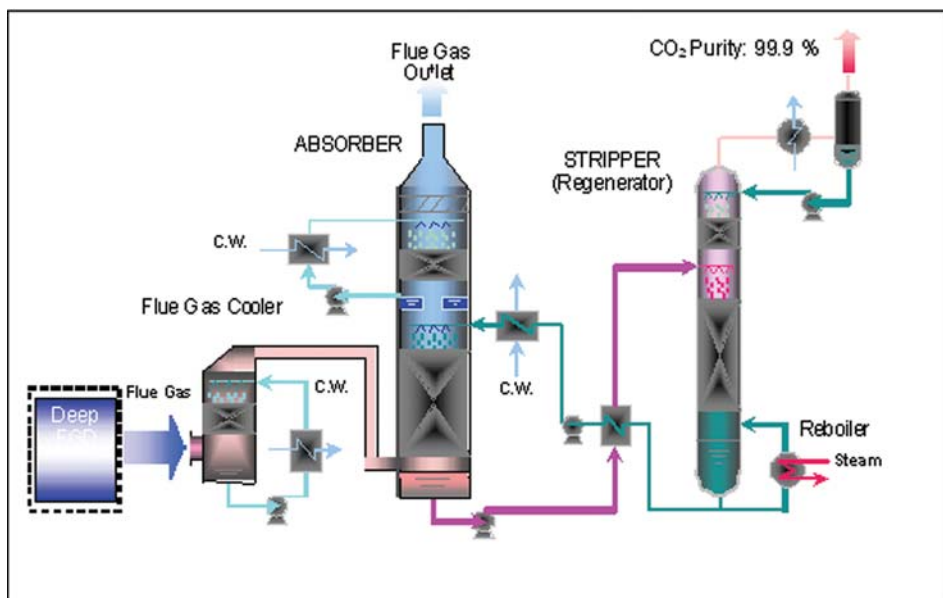
There are a number of different methods for capturing CO<sub>2</sub> from flue gas streams.

MHI has concentrated its extensive research and development programs on the use of sterically hindered amines and the post combustion, chemical absorption process in particular.

For treating flue gasses from natural gas combustion, the CO<sub>2</sub> recovery plant consists of three main sections: the flue gas cooler, the absorber (for CO<sub>2</sub> recovery) and the stripper (for solvent regeneration).

For treating flue gasses from coal combustion, an additional component, deep Flue Gas Desulfurization (FGD) must be deployed.

When the flue gas is produced from the combustion of coal, for a power generation process, it must first pass through a deep flue gas desulfurization (FGD) unit, which lowers the sulphur dioxide (SO<sub>2</sub>) levels and cools the gas



The CO<sub>2</sub> Capture Process

stream, prior to entering the CO<sub>2</sub> capture plant.

However if the flue gas is from a natural gas fired application an FGD may not be required as the SO<sub>2</sub> content in the gas stream is minimal. Therefore, depending on the fuel type, a Deep FGD process may or may not be necessary.

The primary objective of the Flue Gas Water Cooler (FGWC) is to further cool the flue gas prior to entering the CO<sub>2</sub> absorber.

The lower flue gas temperature increases the efficiency of the exothermic CO<sub>2</sub> absorption reaction and minimizes KS-1<sup>(TM)</sup> solvent loss due to gas phase equilibrium increases.

The optimum temperature range for CO<sub>2</sub> recovery is between 95-113°F (35-45°C), however this is flexible in consideration of other factors such as water utility requirements and availability.

The FGWC is designed and constructed to not only to cool the flue gas, but to also further remove various impurities such as SO<sub>x</sub>, NO<sub>x</sub>, dust and suspended particulate matter (SPM).

The concentration of impurities and the flue gas temperature are influenced by the type of coal and combustion system. Clean-burning, natural gas typically has low concentrations of CO<sub>2</sub> and impurities, whereas coal-fired flue gas contains higher concentrations of CO<sub>2</sub> and more impurities.

The CO<sub>2</sub> Absorber has two main sections, the CO<sub>2</sub> absorption section (bottom section), and the treated flue gas washing section (top section).

The conditioned flue gas from the FGWC flows upward through structured, stainless steel packing material while the CO<sub>2</sub> lean KS-1<sup>(TM)</sup> solvent is distributed evenly from the top of the absorption section onto the packing material.

The flue gas comes into direct contact with the KS-1<sup>(TM)</sup> solvent and CO<sub>2</sub> in the flue gas is

absorbed. The CO<sub>2</sub> rich KS-1<sup>(TM)</sup> solvent (rich solvent) is pumped to the CO<sub>2</sub> Regeneration unit for steam stripping.

The clean flue gas then moves up into the treated flue gas washing section of the absorber.

This section is where vaporized KS-1<sup>(TM)</sup> solvent is removed and recycled and the flue gas is again cooled to maintain water balance within the system (the absorption of CO<sub>2</sub> in the KS-1<sup>(TM)</sup> solvent produces some rise in temperature). The clean flue gas then exits the top section of the CO<sub>2</sub> Absorber.

The rich solvent is pre-heated in a heat exchanger using heat from the hot lean solvent coming from the bottom of the CO<sub>2</sub> Stripper.

The heated rich solvent is then introduced into the upper section of the CO<sub>2</sub> Stripper, where it will come into contact with stripping steam of around 248°F (120°C). The rich solvent is then stripped of its CO<sub>2</sub> content and is converted back into lean solvent.

The high purity CO<sub>2</sub> (>99.9%) exits the top of the stripper vessel and is compressed and dehydrated, prior to transportation. Once stripped, the now lean solvent is cooled to the optimum reaction temperature of approximately 104°F (40°C) before being reintroduced to the top of the absorption section of the CO<sub>2</sub> Absorber unit.

It is expected that this technology will provide real solutions to power generation in a carbon constrained world.

*By Ronald Mitchell, manager of business development of MHI's Environmental Plant Department, based in Japan. Steven Holton from Mitsubishi Heavy Industries America, also contributed to this report.*

For further information see:

[www.mhi.co.jp/mcec/product/recov\\_co2/](http://www.mhi.co.jp/mcec/product/recov_co2/)

## MHI's Value Proposition for CO<sub>2</sub> Capture Systems

A post-combustion CO<sub>2</sub> capture system installed at your existing fossil fuel fired power plant, based on Mitsubishi Heavy Industries (MHI) world leading CO<sub>2</sub> capture technology, can be designed to capture up to 90% of your current CO<sub>2</sub> emissions. This can ensure you are compliant with any forthcoming CO<sub>2</sub> regulations and furthermore, any carbon credits generated can be banked or sold on the secondary market. The inclusion of this system may also provide an opportunity for an additional revenue stream by selling the captured CO<sub>2</sub> for various industrial applications.

MHI's technology has advanced the solvent-based capture process significantly over previously available systems to the point where it leads the world in commercially proven post-combustion CO<sub>2</sub> capture efficiency. The MHI CO<sub>2</sub> capture system will place you and your business at the forefront of the world, and you will be regarded as a benchmark for environmental efficiency in the Power Industry. Importantly, you will be able to take control of your responsibility to your customer base and the greater global environment and accordingly you shall be rewarded through the positive public exposure a project of this nature will receive on the global stage. MHI is at the forefront of providing commercial carbon solutions for power generation facilities.

Learn more about CO<sub>2</sub> capture options for your business by contacting your local MHI office:

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**KM CDR Process**

## MHI's CO<sub>2</sub> Capture Technology





# Monitoring carbon dioxide storage

One of the biggest concerns with carbon capture and storage is making sure the carbon dioxide does not leak back into the atmosphere. **Mark Raistrick, CO2 Monitoring Specialist with SENERGY in Aberdeen, explains how it is done**

In this article I will discuss the use of CO2 storage monitoring tools in the context of the emerging UK and EU CCS regulations.

A review of CCS under the Clean Development Mechanism of the Kyoto Protocol and discussions with regulatory authorities in North America where licensed CO2 (and H2S) disposal already takes place suggest that there will be broad similarities between all regulatory environments.

Though an integrated commercial-scale power generation, carbon capture, transport and storage project has yet to be built and successfully operated, secure large scale geological storage verified by monitoring has been demonstrated in a range of settings: in concert with EOR in the Midale reservoir at Encana's Weyburn field in Saskatchewan, Canada; in the aquifer zone of the Krechba reservoir by BP and partners at In Salah in Algeria; and by Statoil for 10 years in the Utsira aquifer above the Sleipner gas field.

These three big projects and a number of well-managed pilots have demonstrated the security of storage and the versatility of a range of storage monitoring techniques.

From the emerging regulations it appears that there will be obligations on CCS operators to incorporate new technologies as they emerge, so the next few years will be exciting time for all those involved in monitoring.

Before an evaluation of the effectiveness of monitoring in the context of the emerging UK and EU regulations, it is helpful to describe the fate of CO2 following injection in the subsurface.

With this knowledge the informed reader will be able to evaluate the effectiveness of any monitoring technique by asking questions like: 'what type of CO2 storage does this tool measure? what is the smallest amount of CO2 that the tool can resolve?'

## Keep this in mind

CO2 is a highly reactive molecule and storage sites are more than repositories for static volumes of inert, separate phase (i.e. pure) CO2 stored in porous rock, they are geologically heterogeneous, physically and chemically dynamic environments hosting a range of CO2-water-rock reactions.

Estimates of global CO2 storage capacity assume that both traps (in the traditional

petroleum usage of the word; closed traps with relatively static fluids) and mobile aquifer systems will be available for storage.

Though closed traps will be used initially, to realize a significant fraction of global geological CO2 storage capacity, storage in mobile saline aquifer systems will need to take place. Therefore both regulations and monitoring tools must be adaptable to a range of storage settings and storage processes.

## CO2 in the subsurface

In the following section the four fates of CO2 are described in the approximate order of their storage capacity over operational timescales (i.e. <50 years); one has the greatest short term capacity while four has the lowest capacity for storage over decadal timescales.

### i. Separate phase CO2

The buoyant injected CO2 will migrate upwards as a separate phase (i.e. probably >95% CO2) displacing fluids and filling pores towards the top of the storage reservoir. This separate phase CO2 storage is effective and securely trapped, providing the CO2 cannot overcome the capillary entry pressure or fracture pressure of the cap rock or re-enter the well bore.

In many closed traps and the majority of open aquifer systems, while the overburden will provide an effective seal, long term storage will also rely on the gradual dissolution of CO2 in water (ii, iii) and CO2-mineral reactions (iv).

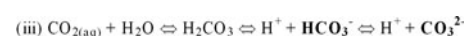
### ii. CO2 dissolves - solubility trapping of CO2 in water

Though CO2 solubility in water is much higher under subsurface conditions than at the surface, only a small fraction (often only a few %) of the injected CO2 would be expected to dissolve into the water in a closed storage trap.

However, in a naturally dynamic or engineered dynamic system with continued water circulation and down-dip migration of CO2 saturated water (which is higher density than CO2-free water) away from the injection site, the amount of the injected CO2 that ends up dissolved in the water can increase by an order of magnitude or more.

### iii. CO2 Dissolution and dissociation

Large amounts of dissolved CO2 (CO2(aq)) can be converted to bicarbonate (HCO3<sup>-</sup>) and carbonate (CO3<sup>2-</sup>) ions and stored securely in the water. Look at reaction iii though; the other product is lots of H<sup>+</sup> from carbonic acid (H2CO3) dissociation, this limits the progress of the reaction, and reduces the pH resulting in more acidic water.

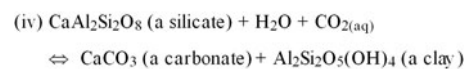


### iv. CO2 - water - mineral reactions

In response to the reduced pH resulting from CO2 dissolving and dissociating, minerals will react. If carbonate minerals are present a fraction of them will dissolve, though this is a self limiting process. In addition, some silicate minerals are likely to alter via a process that is similar to the weathering reactions that lead to soil formation.

These silicate mineral reactions are desirable as they neutralize pH and allow the formation of more bicarbonate and carbonate ions.

If dissolved metals are abundant, silicate reactions can lead to the formation of new carbonate minerals like calcite (CaCO3), providing the most secure form of CO2 storage.



While carbonate minerals react quickly enough that some dissolve during CO2 injection, silicate mineral reactions take place so slowly that they are not expected to be important over the operational life of a storage site.

However, evidence is emerging that significant silicate reactions may take place over the first few years of CO2 injection, and that this may lead to storage of injected CO2 as carbonate minerals. Watch this space!

In summary, the fate of CO2 in the subsurface is not only determined by the migration of separate phase CO2 leading to storage as a residual saturation, but by the reaction between CO2, water and minerals. We



need to understand all the other subsurface storage processes: flow of water saturated with dissolved CO<sub>2</sub>, and the rates and magnitude of dissolution, dissociation and mineral reactions.

### Emerging regulations

From discussion with the regulatory authorities it is likely that EU and UK rules for site and operational licensing will require risk based monitoring programmes constructed around (and designed to update) 3D numerical simulations of the evolution of CO<sub>2</sub> storage in the reservoir and surrounding region. A similar approach is likely to emerge elsewhere.

The expected regulations can be summarized as follows:

Monitoring data will be collected to calibrate and/or validate simulations of storage.

Monitoring and surveillance techniques will include those that can detect the location and migration of CO<sub>2</sub> in the storage site and subsurface environment.

Tools will need to have as wide an area of coverage as possible to detect previously unidentified migration pathways in the storage complex and beyond.

3D simulation will be required to provide details of the saturation distribution of CO<sub>2</sub> and must be compared with measured data and modified accordingly.

No private company could take liability for storage over geological timescales, so following the cessation of injection and site retirement, storage liability will be transferred from the operator.

For the state to assume liability for the storage site the monitoring programme must demonstrate secure storage and show that the injected CO<sub>2</sub> has stabilized.

### Monitoring techniques

#### Monitoring separate phase CO<sub>2</sub> (i)

Separate phase CO<sub>2</sub> trapped in porous rock beneath a cap rock is likely to be the long term storage result of most of the CO<sub>2</sub> injected into closed traps in the subsurface. It is sensible that major effort has been expended on developing and demonstrating techniques that monitor this type of storage.

The most powerful technique for monitoring separate phase CO<sub>2</sub> in the subsurface is time lapse 3D seismic. Time lapse seismic CO<sub>2</sub> storage monitoring relies on the seismic velocity changes resulting from the substitution of CO<sub>2</sub> for other pore fluids.

Seismic waves travel more slowly through highly compressible CO<sub>2</sub> than through the majority of subsurface solids and fluids (except from gases).

Providing baseline seismic data are collected and processed carefully, repeat surveys (time lapse data) can record the delayed arrival of seismic waves resulting from the presence of injected CO<sub>2</sub> in the storage reservoir.

This approach is sensitive to CO<sub>2</sub> at low concentrations, as little as a few % of pore volume. However, the effect of increasing CO<sub>2</sub> saturation on seismic velocities reaches a maximum at CO<sub>2</sub> saturations between 20 and 50% pore volume, so calculations of stored mass based on seismic CO<sub>2</sub> imaging will require other physical data.

With thin reservoir units the effects of the velocity reduction due to the presence of CO<sub>2</sub> may be too small to be clearly resolved by the delayed arrival of seismic waves.

In these situations the increased velocity contrast between the reservoir containing CO<sub>2</sub> and overlying units with no CO<sub>2</sub> can lead to higher reflectivity from the boundary between the two, providing an indication of stored CO<sub>2</sub>. The example below provides an illustration of this effect (Figure 1 - Guoping Li 2003).

Amplitude anomalies recorded in the time lapse 3D seismic monitoring data at Weyburn resulted from injected CO<sub>2</sub> accumulating in the thin Marly reservoir unit (<10m).

In favorable circumstances time lapse seismic monitoring can image separate phase CO<sub>2</sub> even in thin reservoir units, however if there is already another highly compressible

substance in place before CO<sub>2</sub> injection (e.g. hydrocarbon gas), or if significant amounts of CO<sub>2</sub> are being dissolved into water (or oil) other data are required to understand storage performance and the fate of injected CO<sub>2</sub>.

The following technique provides a way to trace the migrating injected CO<sub>2</sub> as it ceases to be a separate phase and begins the pathway of water and mineral reactions that lead to mineral storage.

#### Monitoring CO<sub>2</sub>-water and mineral reactions (ii), (iii), (iv)

The emerging regulations suggest that monitoring techniques and simulations must adequately characterize storage and provide information on CO<sub>2</sub> saturation, location and migration.

To understand CO<sub>2</sub> distribution we therefore not only need to monitor the separate phase CO<sub>2</sub>, but must understand the fate of the CO<sub>2</sub> that dissolves into the water.

The fate of dissolved CO<sub>2</sub> and CO<sub>2</sub> mineral storage depends on the mobility of the water and the type, rate and magnitude of reactions between CO<sub>2</sub>, water and minerals. CO<sub>2</sub> dissolved in water is very securely stored when contained within in a storage reservoir at depth, but if fluids were able to move up through the overburden and the pressure dropped, CO<sub>2</sub> would leave the water and become a mobile separate phase.

Fluid and gas samples and physical measurements (i.e. pressure and tempera-

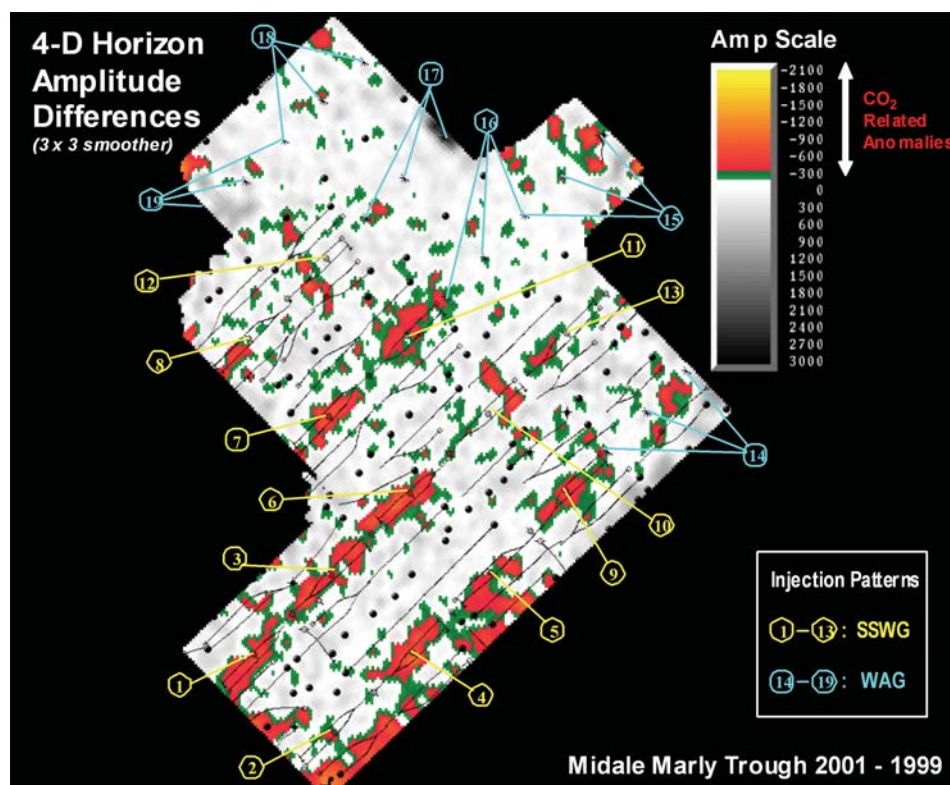


Figure 1 - Monitoring CO<sub>2</sub> - Guoping Li, *The Leading Edge*, 2003.

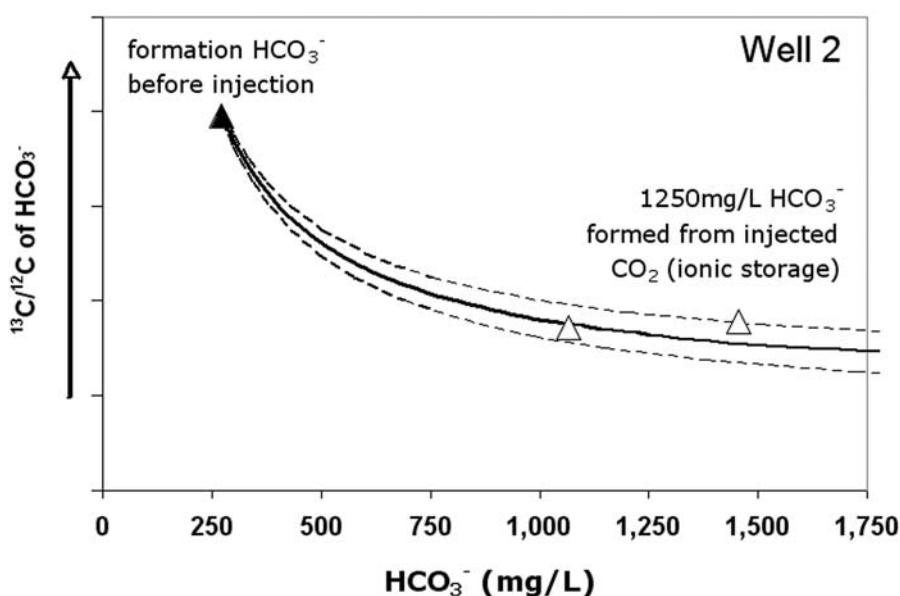


Figure 2 - storage of injected CO<sub>2</sub> as HCO<sub>3</sub><sup>-</sup>

ture) of the storage reservoir, collected from monitoring wells prior to and during CO<sub>2</sub> injection, provide information on the amount of CO<sub>2</sub> dissolved in the water, water mobility and the interactions between CO<sub>2</sub>-water and the reservoir minerals. This information can be used to calibrate simulations and both monitor and predict the fate of dissolved CO<sub>2</sub> and CO<sub>2</sub>-water-mineral reactions.

The example above (Figure 2) shows the storage of injected CO<sub>2</sub> as HCO<sub>3</sub><sup>-</sup> (bicarbonate; reaction iii). Over four years and four million tonnes of CO<sub>2</sub> injection at Weyburn, the concentration of HCO<sub>3</sub><sup>-</sup> measured in the produced fluids increased to around five times the pre-injection level.

The carbon isotope fingerprint (carbon-13/carbon-12) of the HCO<sub>3</sub><sup>-</sup> became almost identical to the carbon fingerprint of injected CO<sub>2</sub> (the solid curve on Figure 2) demonstrating that large amounts of injected CO<sub>2</sub> have dissolved, dissociated and are stored securely as HCO<sub>3</sub><sup>-</sup> in the water

These data were collected from monitoring wells and provide quantitative information about a limited part of the storage reservoir volume.

Our simulations need to integrate well and inter-well monitoring data and must be powerful enough to predict the distribution of CO<sub>2</sub> and the progress of CO<sub>2</sub>-water-mineral reactions over time in the environment far from the wells.

A detailed understanding of all the subsurface storage processes taking place throughout the storage site during CO<sub>2</sub> injection will lead to increased confidence in both storage simulations and long term site security.

## Conclusion

The examples I have given provide a brief illustration of the power of available monitoring techniques and highlight the need for an integrated approach to fulfill regulatory and licensing requirements.

It is not enough to take an image of the injected CO<sub>2</sub> plume with time lapse seismic or gravity measurements, the progress of physical and chemical reactions involving CO<sub>2</sub> must also be understood.

A range of monitoring data are needed to calibrate storage simulations and predict storage security with increased confidence.

Reducing uncertainty will save money as greater confidence in storage performance will allow continued operational and site licensing with smaller scale monitoring programmes, with less chance of any unexpected changes in storage performance and resulting lower liability and insurance costs.

## UK competition

In London on the 19th November UK Prime Minister Gordon Brown announced the launch of a competition to build one of the world's first integrated Carbon Capture and Storage (CCS) projects.

The UK project is intended be one of 10-12 demonstration projects that the EU is committed to supporting, with at least four operational by 2015. EU and UK draft guidelines on the regulation of CCS will be released for consultation in January of 2008.

The UK government has decided to support post combustion capture from a 300-400 MW coal fired power plant. Storage will be in the offshore subsurface.

Post combustion capture from coal was

chosen to complement the developing CCS projects elsewhere; e.g. the use of IGCC (integrated gasification combined cycle) for power generation at the FutureGen project in the US, and to provide the UK with experience commercializing the technology that the government believes is most likely to be employed in India and China.

The UK government has committed to providing up to 100% of the capital expenditure and operating costs incurred by the CCS project developer.

This contribution will be offset by the allocation of EU Emissions Trading Scheme (ETS) allowances for CO<sub>2</sub> stored over the lifetime of the project. It seems likely that EU CCS projects will be considered on a case by case basis for entry into Phase 2 of the EU ETS (2008-2012).

UK competition prequalifying takes place in March 2008, by this time the competitors must show they have the capabilities, capacities, technical expertise and project management skills to move to the next phase, with the winner announced by mid 2009.

## Author's note

For some monitoring techniques I have direct experience of collecting, processing and interpreting the data, having completed doctoral research on subsurface fluid and gas monitoring at Weyburn in Canada, while for others I am indebted to expert advice from colleagues within Senergy and elsewhere. However, any errors present are my own and I hope can provoke clear explanations leading to improved knowledge for all.

carbon  
capture  
journal

## Further reading

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## Carbon capture projects

### NRG / Powerspan's 125MW CCS demonstration plant in Texas

[www.nrgenergy.com](http://www.nrgenergy.com)

US power station operator NRG Energy and technology company Powerspan have announced plans to develop a "commercial scale" carbon capture and sequestration facility for a coal power station.

It will be attached to a power plant in WA Parish, Sugar Land, Texas, which ERG says is one of the largest and best baseload coal facilities in the country.

It will use Powerspan's ECO2 technology, which captures carbon dioxide post-combustion into an ammonia stream. Powerspan says that the system has simpler capital equipment design and lower energy consumption than other carbon capture technologies.

NRG says that carbon capture projects on coal fuelled power plants have only been conducted to date at a scale of 1 to 5 megawatts; this one will capture carbon dioxide from flue gas equivalent to what a 125 megawatt power plant would emit.

It will rank "among the world's largest CCS projects and potentially the first to achieve commercial scale capture and sequestration from an existing coal-fueled power plant," NRG says.

The carbon dioxide is expected to be used to enhanced oilfield recovery (EOR) in Houston, being buried in oilfields to push more oil out of the ground.

The plant is expected to capture 90 per cent of carbon dioxide from the flue gas stream and be operational in 2012.

The two companies have signed a memorandum of understanding to design, construct and operate the facility, and supply captured carbon dioxide for transportation and storage, to demonstrate the technical, economic and environmental performance of a large scale system.

### UK scientists help China's CCS efforts

[www.co2geonet.com](http://www.co2geonet.com)

The British Geological Survey (BGS) attended the launch of the Near Zero Emissions Coal (NZE) Phase 1 study in Beijing.

The aim of the study is to look at the feasibility of building coal fired power plants in China fitted with CO2 capture and storage.

NZE implements a large scale Near Zero Emissions Coal demonstration in China as agreed at the EU-China Summit in September 2005.

The geotechnical aspects of the research will involve selecting strategic sedi-



*The power plant in WA Parish, Sugar Land, Texas is among the world's largest CCS projects and could potentially be the first to achieve commercial scale capture and sequestration from an existing coal-fueled power plant*

mentary basins to be mapped for potential regional CO2 storage assessments, followed by more detailed assessment of sites potentially suitable for a demonstration of CO2 storage in China linked to a demonstration of CO2 capture from a coal-fired power station.

A Geographical Information System (GIS) linking current and planned large CO2 point sources to potential geological storage options (source-sink matching) will be constructed.

BGS and the China University of Petroleum (Beijing) co-ordinate the geological storage part of the study, which also includes working in close partnership with Heriot Watt University, BP & Shell (UK), the China University of Petroleum (HuaDong), Institute of Geology and Geophysics Chinese Academy of Sciences (CAS), Tsinghua University, PetroChina, Jilin Oilfield and others.

NZE is funded by the UK Government through Defra and DBERR and is co-ordinated by AEA Energy & Environment (UK) and ACCA21 (China).

### Luminant requests proposals for IGCC plant with CCS

[www.luminant.com](http://www.luminant.com)

Luminant, a subsidiary of Energy Future Holdings (EFH), has issued a request for proposals (RFP) from companies offering Integrated Gasification Combined Cycle (IGCC) and/or other coal gasification technologies with CCS.

This is the first step in the planning process for two commercial demonstration plants to be located in Texas, fulfilling a commitment made by Kohlberg Kravis Roberts & Co. and Texas Pacific Group during their acquisition of TXU Corp., now EFH.

Fulfilling other merger-related commit-

ments, Luminant previously terminated permits for eight planned coal-fueled generation units.

From the proposals received, Luminant expects to select two or more competing proposals for the commercial deployment of IGCC and/or solid fuel gasification technologies with carbon dioxide capture using coal and lignite as the primary fuel source.

Luminant will also give consideration to technologies that provide additional fuel flexibility (e.g., petroleum coke, biomass fuel blending).

This project will focus on driving efficiency improvements, emissions reductions and technological breakthroughs that could enable IGCC and/or gasification to meet the growing energy needs of Texas.

Companies have until January 14, 2008, to submit an Expression of Interest and Intent to Submit a Response.

### Australia and China partner for PCC plant

[www.csiro.au](http://www.csiro.au)

Australia and China have signed a partnership agreement that will pave the way for the installation of a post combustion capture (PCC) plant in Beijing next year.

Signed by CSIRO (Commonwealth Scientific and Industrial Research Organisation) Energy Technology chief executive, Dr Geoff Garrett, and Mr Li Xiaopeng, the President of China's state-owned energy enterprise, the China Huaneng Group, the agreement will see the plant installed at the Huaneng Beijing Co-generation Power Plant.

The installation forms part of the Asia Pacific Partnership on Clean Development and Climate initiative (AP6) which first announced funding for PCC research in November 2006.

CSIRO has been working on collabora-

tive projects with China for over 30 years, in areas such as minerals and mining technology, forestry, environmental sustainability, and crop science.

The AP6 program for PCC also includes a pilot plant installation at Delta Electricity's Munmorah power station on the NSW Central Coast, with additional Australian sites currently under negotiation for PCC installation and demonstration.

## RWE npower to develop first CCS pilot at a UK coal power station

[www.rwenpower.com](http://www.rwenpower.com)

RWE npower will design and build the first CO<sub>2</sub> capture pilot plant at a UK coal power station. The first phase could be fully operational by 2010 and will be located at Aberthaw Power Station in South Wales.

An initial £8.4m investment will focus on a 1MW capture plant, with further investment planned to support a capture and storage demonstration plant of at least 25MW.

This will act as a test ground for the potential of CCS technology as a means to generate low-carbon energy. Both plants will be designed using post-combustion technology, which can be applied to existing coal power plants.

The pilot will enable RWE npower to develop a full understanding of both the technical and commercial issues relating to CCS and will allow the CCS concept to be tested in as close to real operational conditions as is possible.

The larger capture and storage demonstration plant would form part of a new generation of high efficiency supercritical power stations which are currently under feasibility and planning at the company's existing sites in Tilbury, Essex and at Blyth, Northumberland.

## Utah \$88m carbon storage feasibility project

[www.sltrib.com/ci\\_7483032](http://www.sltrib.com/ci_7483032)

The state of Utah, USA, has launched a \$88m, ten year, research project to test the feasibility of storing carbon dioxide underground, according to an article in the Salt Lake Tribune.

Of the \$88m, \$67m is a grant from the US Department of Energy National Energy Technology Laboratory, and the rest is from 21 different industry partners. Other participants include the Utah Geological Survey, Questar Gas, Rocky Mountain Power, Savoy Energy, Blue Source, Pure Energy Corp., the Navajo Nation and the New Mexico Institute of Mining and Technology.

The project is led by Utah engineering professor Brian McPherson, who works for

Utah's Research, Science and Technology (USTAR) initiative, a public-private venture to commercialise technologies developed in Utah's universities.

It will inject liquefied carbon dioxide into water bearing sandstone formations one mile deep, covered with shale. The idea is that the carbon dioxide will displace the saltwater, which will flow into the surrounding rock.

The location is called Farnham Dome, and is in Wellington, 130 miles south east of Salt Lake City.

Ironically, the Farnham Dome held carbon dioxide from 10-50 million years ago until the years up to 1979, when it was pumped out to make dry ice and soft drinks.

Much of the expenditure will be on monitoring the new carbon dioxide reservoir and checking for leaks. The research could provide information about the potential of basins from New Mexico to Montana, with perhaps enough capacity to hold 100 years of carbon emissions, USTAR says.

Some of the carbon dioxide will be sourced from a coalbed methane development.

The project is part of the Southwest Regional Partnership, founded by Mr McPherson in 2003.

Southern California power company Edison may also get involved, according to the Salt Lake Tribune. It is looking for state funding for a \$50m project to explore the feasibility of a coal gasification power plant, which would produce carbon dioxide as a by product, which could be injected in Utah sandstone.

## Texas legislator explores incentives for 'clean coal' plants

[www.dallasnews.com](http://www.dallasnews.com)

Texas House of Representatives member Phil King is considering offering incentives for companies to build coal power stations in Texas with carbon capture, according to an article in the Dallas Morning News (Nov 16 2007).

Mr King leads the House Regulated Industries Committee.

He said he is looking for ways to offer tax breaks, or set up a fund for clean coal technologies, to help persuade people to invest in the unproven technology. This will enable Texas to get the low polluting power stations it needs.

"I'm aggressively looking into it," he told the Dallas Morning News.

"Wall Street's afraid to invest in clean-coal technology plants. We've got to find some way to give them comfort with that risk level. That will take some type of incen-

tive from the state until we get a few of these built."

## Dominion "has not proved it can do CCS"

[www.inrich.com](http://www.inrich.com)

Regulators in Virginia State (USA) are saying that Dominion Virginia Power needs to try harder if it is going to get extra government funding for its new coal plant on the basis of having carbon capture, according to an article in the Richmond Times Dispatch.

According to the article, regulators are saying that Dominion has not yet proved that its power plant will keep carbon dioxide out of the air.

Under state law, the plant would qualify for an extra 2 per cent return if it was 'clean-coal powered and carbon capture compatible'.

A hearing will be made on January 8 2008 with the State Corporation Commission, which could lead to Dominion losing a 1.5 per cent extra rate of return on its spending for the new plant it had been promised by the government. It will still get the 0.5 per cent for having a 'clean coal powered' plant.

A spokesperson for Dominion said that the plant is being engineered to accommodate carbon capture technology once it 'becomes commercially available'.

## Peabody Energy joins China's 'GreenGen' project

[www.peabodyenergy.com](http://www.peabodyenergy.com)



*A rendering of the US \$1 billion GreenGen project*

Peabody Energy has become the only non-Chinese equity partner in GreenGen, the first near-zero emissions coal-fueled power plant with carbon capture and storage under development in China.

The US \$1 billion GreenGen project, led by managing partner China Huaneng Group, will involve the design and operation of an integrated gasification combined cycle (IGCC) powerplant near Tianjin, southeast of Beijing.

A 250-megawatt plant will be built in the initial phase, expanding to 650-megawatts in later phases. Project design



and review is complete, a site has been selected at the Lingang Industrial Park, and construction is expected to commence in early 2008, with the first phase of the plant expected on line by 2009.

GreenGen believes the site is in an optimum location near a number of chemical facilities that create opportunities to utilize the project's syngas, heat and byproducts and power, while some of The CO<sub>2</sub> will go to enhanced oil recovery projects.

China Huaneng is the majority shareholder in GreenGen while Peabody will own 6 percent of the initiative. Huaneng is one of the top 10 power companies in the world, and the largest power generator in the People's Republic of China.

Peabody opened its Beijing office in fall 2005 and began trading activities in China in 2007. It is the world's largest private-sector coal company.

## CCS not commercially feasible until 2017 - Las Vegas testimony

[www.lasvegassun.com](http://www.lasvegassun.com)

According to an article in Las Vegas Sun representatives from power companies Sierra Pacific Resources, LS Power Associates and Sithe Global Power, have testified that carbon capture and storage technology will not be commercially feasible until 2017.

The three companies, which want to build new coal power plants in Nevada, have signed memorandums of understanding (MOUs) with Nevada Division of Environmental Protection, saying they will capture carbon dioxide "once the technology becomes commercially feasible".

The Nevada Division of Environmental Protection (NDEP) has already rejected a petition from local environmental groups, Sierra Club, Citizen Alert, the Nevada Conservation League, Western Resources Advocates, the Bristlecone Alliance and the Progressive Leadership Alliance of Nevada, saying that the three companies should only be able to construct the plants if they can control carbon dioxide emissions.

Charles Benjamin, president of the coalition of environmental groups, questioned whether the MOUs were legally enforceable, and how it will be determined whether or not carbon capture and storage is economically feasible.

Leo Drozdoff, administrator of NDEP, said that the MOUs "go well beyond good faith efforts and require real commitments and actions by the companies."

According to the Las Vegas Sun, NDEP said that it could have rejected the request from the environmental groups to get involved, because their request came seven

weeks after NDEP said it wanted to complete the process by late October. However a spokesperson for the environmental groups said they had only been given one week to review the complex documents.

## Xcel Energy IGCC plant delayed - Denver Post

[www.denverpost.com](http://www.denverpost.com)

The Denver Post has reported that Xcel Energy is delaying a decision on building a IGCC power plant for at least two years.

The reasoning was that the plant would be too expensive to build "without a partner" and the additional power is not required, according to quotes from chief executive Dick Kely, speaking at a conference "New Energy Economy" in Denver.

Xcel is the largest electric and gas supplier in Colorado.

It proposed the plant last year to demonstrate its commitment to address carbon dioxide emissions and play a leadership role in the utility industry.

The company does not need the additional power because it has so much growth in wind generating power, Mr Kelly said. A decision will be made sometime between 2009 and 2011.

"We're not abandoning (the IGCC plant)," he stressed, "we're just delaying (a decision) for a couple of years."

The proposed power plant would have been the first IGCC plant where the carbon dioxide is separated and buried.

Mr Kelly said that costs would have been "way over \$1 billion," and the additional costs (compared to a normal coal fired plant) would have been more than 20 per cent, the company's initial estimate.

"I will continue to work with Xcel, other public and private utilities and the state of Colorado to determine how we can bring an IGCC demonstration project to Colorado," said local senator Ken Salazar.

## Tampa Electric defers use of IGCC beyond 2013

[www.tampaelectric.com](http://www.tampaelectric.com)

Tampa Electric of Florida no longer plans to meet its 2013 need for baseload generation through the use of integrated gasification combined-cycle technology (IGCC), the company has announced.

Primary drivers of the decision include continued uncertainty related to carbon dioxide regulations, particularly capture and sequestration issues, and the potential for related project cost increases.

Because of the economic risk of these factors to customers and investors, the company believes it should not proceed with an

IGCC project at this time.

However, the company remains steadfast in its support of IGCC as a critical component of future fuel diversity in the US and believes the technology is the most environmentally responsible way to utilize coal.

The company also believes that IGCC technology offers the best platform to capture and then sequester CO<sub>2</sub>.

As the owner of the first and largest commercial IGCC generating facility, Tampa Electric anticipates that its Polk Unit 1 could be a central part of the research needed to advance the technology, in partnership with government agencies and others.

With the deferment of the IGCC plan, the company will further study how it plans to meet its needs for more than 600 megawatts of generation in early 2013, evaluating other technologies and fuel options, including natural gas, as well as the impact of expanded energy-efficiency and conservation programs and renewable resources.

## Washington State power plant permit revoked

[seattlepi.nwsources.com](http://seattlepi.nwsources.com)

A permit application for a new coal power plant near Portland, Washington State (USA) has been revoked because the builder did not address how it would bury the carbon dioxide, according to an article in Seattle Post and Intelligencer (Nov 28).

The application to build the power plant was made by Energy Northwest, and it was suspended by Washington State Energy Facility Site Evaluation Council.

A law was passed earlier this year in Washington, stating that utilities cannot sign long term contracts with coal fired power plants that produce 'excessive' carbon dioxide.

New power plants would have five years to sequester carbon dioxide emissions, or they would have to offset their emissions through more drastic measures than buying carbon offsets - such as buying a dirtier plant and closing it down.

Energy Northwest had argued that carbon sequestration is still 'unworkable in real world practise', according to Seattle Post and Intelligencer, and wanted to pay to offset emissions until it considered it to be workable.

This was not good enough for the Council, which said that Energy Northwest had a plan to implement carbon sequestration at 'some indefinite later date', not today, as required by the legislation.

The proposed plant was 793 megawatts and was going to gasify coal and burn the gas to make power.

# Saskatchewan moves from CCS to nuclear

The Canadian province of Saskatchewan has shifted policy from carbon capture and storage to nuclear power, according to our North American correspondent Stephen Salaff

Saskatchewan Power Corporation (Saskpower) has recently changed its position from promoting coal power generation with carbon capture, to promoting nuclear power, following a change in Saskatchewan state government.

Earlier, Saskpower pioneered and vigorously promoted carbon capture sequestration technology, with a plan to capture carbon dioxide at a lignite coal fuelled electricity generation station in southeastern Saskatchewan.

It would then transport liquid CO<sub>2</sub> for use in enhanced oil recovery operations (EOR) at nearby oil fields.

Saskpower has already had profitable experience with CCS, using the carbon dioxide for EOR.

The project was planned to be part of the International Energy Agency greenhouse gas (IEA GHG) Weyburn-Midale Greenhouse Gas Monitoring and Storage project, managed by Petroleum Technology Research Centre of Regina, Saskatchewan.

However, SaskPower's interest in this project waned during mid 2007, during the final months of the New Democratic Party government of Saskatchewan (this party is no longer in power).

The main reason for the loss in interest was the time it was anticipated that it would take to build the coal power station with car-

bon capture, and the rising local electricity demand.

Former New Democratic Party Minister John Nilson stated on September 1 2007 that the proposed 300 MW coal power station with CCS "could not be built in time to meet rising electricity demands at a competitive cost".

"It would have been premature to proceed with construction at this time," he said.

On November 7th 2007, a new party was elected, the Saskatchewan Party, under Premier Brad Wall. The party, which holds 65 per cent of parliamentary seats, prefers nuclear power over coal power with carbon capture.

Saskatchewan Party's view is probably connected to the fact that the world's largest uranium producer is based in the province.

Mr Wall advised the Chamber of Commerce in Saskatoon, Saskatchewan's northern metropolis and headquarters of uranium producer Cameco Corp, that "a Saskatchewan Party government would immediately develop and implement a uranium value-added plan for possible nuclear power production in Saskatchewan.

"The largest producer of uranium in the world, yet the NDP government is content to simply ship it away," he said.

A nuclear power company, Atomic Energy of Canada, has also been extensively

lobbying the government to buy one of its Candu 3 reactors for Saskatchewan.

Editorials in the Saskatchewan Star Phoenix have supported the change in policy from coal / CCS to nuclear.

"Rather than being the first jurisdiction to develop clean-coal technology, which entails paying for all the mistakes until the bugs are worked out, Saskatchewan could be developing proven nuclear technology, not only for its own needs, but to become a major electricity exporter, as are Manitoba and Quebec," the newspaper said on Aug 10 2007.



Stephen Salaff - freelance writer

**Stephen Salaff is a freelance energy and environment writer based in Toronto, Ontario**

## Policy and regulation

### Hillary Clinton - would fund 10 large CCS projects

[mysilverstate.com](http://mysilverstate.com)

If elected as US president, Hillary Clinton would "put immediate funding towards 10 large-scale carbon capture and storage projects," according to her written answers to questions posed by Nevada democratic blog mysilverstate.com.

These projects would "utilize a range of coal types, power plant types, and storage locations," she wrote.

"I also believe that we need to take swift action to spur the development and deployment of technology and practices that will enable us to capture, store and safely se-

quester carbon dioxide from coal-fired power plants," she wrote.

"To accelerate the development of this important technology, I would put immediate funding towards 10 large-scale carbon capture and storage projects that I will move quickly to develop the regulatory framework to ensure that carbon sequestration can be done safely and reliably.

"I will move quickly to develop the regulatory framework to ensure that carbon sequestration can be done safely and reliably," she wrote.

"And I will require all new coal plants to be capable of adding capture and storage technology when it becomes commercially

available."

"I know that coal plays a major role in America's energy mix - it powers 50 percent of the country's electricity generation and we still have enormous coal reserves - but I also know that coal-fired power plants are the largest contributors to U.S. greenhouse gas emissions. If we continue to build new coal plants in the same way that we have done so in the past, we will not be able to meet our climate change goals," she wrote.

"I recently announced a comprehensive plan to address global warming and move our country toward energy independence that would reduce the need for new power plants."



"I would direct state utility commissions to ensure that before approving an application to build a coal plant, there is an evaluation of whether the energy services provided by that plant could be met by cost-effective investments in energy efficiency."

"Under my plan, I will create a Strategic Energy Fund that would jumpstart a clean energy future by injecting \$50 billion over ten years into research, development and deployment of renewable energy, energy efficiency, clean coal technology, ethanol and other homegrown biofuels."

"My plan has three big goals: to reduce greenhouse gas emissions by 80 percent from 1990 levels by 2050 to avoid the worst effects of global warming, cut foreign oil imports by two-thirds from projected levels by 2030, and to transform our carbon-based economy into an efficient green economy."

## US carbon capture association formed

Fortune 500 and leading energy, power system, paper/packaging/forestry, pipeline, financial & management consulting companies join to form the North American Carbon Capture & Storage Association.

Founding member companies include: BlueSource, LLC, Halliburton, International Paper, Keener Oil & Gas Company, Kinder Morgan, MissionPoint Capital Partners, Occidental Petroleum Corporation, Peabody Energy, PetroSource Energy Company, Ramgen Power Systems, Schlumberger, ScottMadden Inc., and Shell.

The NACCSA and its members will work to educate stakeholders in the United States and Canada about the technological readiness of CCS with the goal of helping to create a framework that supports the development of a CCS industry, including CO<sub>2</sub>-EOR where those opportunities exist.

The association will also work closely with its members to inform them about policy, legal, regulatory and technical developments related to CCS through information sharing and analysis.

## Australia moves on CCS

Professor Ross Garnaut, an economist who is drawing up a climate change strategy for the new Australian government, has said that coal fired power has no future in Australia unless ways are found to reduce carbon emissions, speaking to The Australian newspaper.

This means that the future of Australian coal power depends on how successful it is at implementing carbon capture and storage.

"If we can make it work at a reasonable cost then coal has an expanding future," he said.

Citigroup has already stated in a report (Dec 3) that there could be a surge in construction of low emission coal powered stations in Australia, which could be an industry worth \$10bn a year in Australia.

Citigroup did its calculations on the basis of 100 to 200 million metric tons per year of CCS storage capacity being required, which would need a capital investment of \$16bn to \$31bn.

Meanwhile the Australian Construction, Forestry, Mining and Energy Union has called for a target of 5 per cent of electricity to be generated from low emission coal technology by 2020, in order to protect the coal power station industry and coal miners' jobs.

Tony Maher, president of the Union, told Australian newspaper The Age that coal companies would not invest in the technologies unless they were guaranteed a market for them.

The Union suggests that the coal industry increases its levy for new technologies from AUD \$0.20 per tonne of coal (USD \$0.17) now to AUS\$1 (USD \$0.88) per tonne.

In a separate development, Steve Thomas, shadow environment minister for the state of Western Australia, complained to local newspaper Collie Mail that Western Australia was only going to get 1.8 per cent of the Australian National Clean Coal Fund, despite having 10 per cent of the national population.

The total Clean Coal Fund is AUS \$500m (USD \$439m) and Western Australia has AUD \$5m (USD \$4.4m).

## G8 workshop backs CCS technology

Governments, industry, environmental NGOs and scientific representatives from over 15 key countries have agreed to recommendations to accelerate the early global deployment of CCS.

The workshop in Calgary, Canada, concluded with an urgent call for the development of at least 20 industrial scale CCS projects worldwide by 2020.

There was also broad consensus by participants that market mechanisms, like emissions trading, will not be sufficient to mobilise early CCS projects and government assistance will be required to address the current financial gap to accelerate commercial deployment of CCS.

The recommendations also highlighted the inclusion of CCS under the Clean Development Mechanism (CDM) by December 2008 as an important priority.

The recommendations will go before the International Energy Agency (IEA) before they are presented to G8 Leaders in Ju-

ly 2008 in Japan.

The recommendations on near-term opportunities for CCS to the G8 Summit Hokkaido, Japan, July 2008 in full are as follows:

"G8 heads of government are urged to recognise the critical role of CCS in tackling global climate change and demonstrate the political leadership necessary to act now to initiate widespread deployment of this technology."

"CCS can achieve substantial reductions in CO<sub>2</sub> in a world faced with increased demand for fossil fuels. With CCS, fossil fuels will become part of the solution, not part of the problem."

"The IEA has estimated that, in addition to other mitigation options needed to combat climate change, CCS must be installed on the equivalent of 630 coal fired power plants by 2030."

Expeditious deployment of CCS requires the following immediate actions:

### 1. Demonstrating CCS

The G8 must act now to commit by 2010, to a diverse portfolio of at least 20 fully integrated industrial-scale demonstration projects (>1 Mtpa), with the expectation of supporting technology learning and cost reduction, for the broad deployment of CCS by 2020.

### 2. Taking Concerted International Action

G8 governments and international financial support, build capacity and share information for large scale integrated CCS demonstration projects and near term opportunities to accelerate wider deployment of CCS in developed and developing countries.

An early priority should be to include CCS in the Clean Development Mechanism (CDM) in December 2008.

### 3. Addressing the Financial Gap

Governments should address together with the private sector, the financial gap and risks facing early CCS projects in order to accelerate the commercial deployment of CCS, recognising that market mechanisms alone will not be sufficient for the early deployment of CCS.

### 4. Establishing Legal and Regulatory Frameworks

By 2010, it is essential that governments have established the appropriate legal and regulatory frameworks that are needed for safe, large-scale geological storage of CO<sub>2</sub>.

### 5. Raising Public Awareness

Public education and support is critical to CCS deployment. The link between CCS, continued global economic development and environmental protection must be emphasised. Governments and stakeholders must dedicate resources to advance this message.

## CEZ proposes new source for CCS finance

[www.cez.cz](http://www.cez.cz)

Czech power company CEZ Group is proposing that the Czech Republic use part of its emission credits, assigned according to the Kyoto Protocol, to design and build a CO<sub>2</sub> capture and storage unit.

According to CEZ, a demonstration project for CO<sub>2</sub> separation and storage can be supported by using surplus AAU (Assigned Amount Unit) emission credits, which the Czech Republic has at its disposal.

The Czech Republic can sell the units to countries that lack them.

AAU units are emission credits allocated to a country under the Kyoto Protocol that represent that country's obligation to reduce emissions. In the case of the Czech Republic, this amounts to emissions at the level of 1990 minus 8%.

They should not be mistaken for CO<sub>2</sub> emission allowances traded within the European Emissions Trading Scheme.

CEZ has already launched a dialogue with state administration authorities. Because the sale of some of the AAU credits is unlikely to generate enough funds, more sources of funding will have to be identified.

If the CCS unit becomes profitable, CEZ will be prepared to return the state contribution, or to participate in further CO<sub>2</sub> emission reducing measures together with the state.

CEZ has already reported this proposal draft to the representatives of the Ministry of Industry and Trade and the Ministry of the Environment which consider it to be a promising solution.

Moreover, the suggestion is in accordance with the government's decision of November 2007 on the use of AAU credits for up-to-date technologies in the power industry.

"This concept has several advantages - the surplus of the Czech emission credits is large enough to support both a CCS demonstration project and other measures that are already being prepared by the respective ministries," said Martin Cmíral, Head of the Environmental Department at CEZ.

"In addition, these means do not burden the state budget or any other public funds."

Although several countries are considering the sale of surplus AAU credits, none of them has yet presented a specific proposal for its practical implementation.

Implementation of the CO<sub>2</sub> storage



*The power plant in Ledvice being considered for CCS could be financed by the sale of surplus AAU emission credits*

project in the Czech Republic would send a strong signal to the research and development sector as well as technology manufacturers, as a significant amount of such technologies would be produced under foreign licenses.

The power plant being built in Ledvice could possibly be suitable for the application of CCS technology. Captured CO<sub>2</sub> would be stored in deep sediment basins in the Northern Bohemian region.

## Only 34% confidence in clean coal - climate decision makers

[www.iucn.org](http://www.iucn.org)

A survey of 1,000 "climate decision makers and influencers" from around the world found that only 34 per cent were confident that clean coal technology - retrofitting existing power plants - could reduce atmospheric carbon over the next 25 years without unacceptable side effects.

36 per cent were confident that clean coal technology with new build plants could deliver as a low carbon technology.

This compares to 74 per cent thinking solar hot water could deliver, 62 per cent for offshore wind farms, 60 per cent for land wind farms, 51 per cent for combined heat and electricity plants, 44 per cent for tidal energy, and 40 per cent for next generation nuclear power.

28 per cent were confident in bicycles ('human powered vehicles'), 26 per cent in large scale hydroelectric and 21 per cent in first generation biofuels from agricultural crops.

Groups surveyed included senior

government officials, scientists, business leaders and civil society leaders. The survey was conducted by GlobeScan, the World Conservation Union, IUCN and the World Bank.

The respondents said they thought half of their organisations' reductions of carbon emissions over the next decade would come from efficiency improvements, not carbon capture.

## World Coal Institute new CCS report

[www.worldcoal.org](http://www.worldcoal.org)

The World Coal Institute has published a 12 page brochure on carbon capture, in association with the IEA Greenhouse Gas R&D Programme.

The reports aims to cover aspects of CCS as comprehensively as possible, including to answer the questions: Can CO<sub>2</sub> Be Stored Deep Underground? How Can CO<sub>2</sub> Be Captured From Industry? Where Can CO<sub>2</sub> Be Geologically Stored? Why Does CO<sub>2</sub> Stay Underground? Where Are The Good Geological Storage Sites? Where is CO<sub>2</sub> Geological Storage Happening? What Is The Future Of CO<sub>2</sub> Geological Storage?

The report should be easily readable for people who are not technical specialists (and do not have any prior knowledge of carbon capture).

Technical specialists might also find aspects of it interesting, for example the World Coal Institute's view about which areas of the world are most suited for carbon storage.

There is also a map of current carbon capture and storage projects.



[www.world-CTL2008.com](http://www.world-CTL2008.com)

# First World Coal-To-Liquids Conference

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# Clean coal technology

Coal based power generation will be part of the world's energy mix for decades to come and the UK can take a leading role demonstrating clean coal technology using carbon capture and storage, but greater commitment from government is needed. **By Dr Mike Farley, Director of Technology Policy Liaison, Doosan Babcock**

Rather than being phased out, today coal is being used in increasing quantities for power generation, particularly in parts of the world including the USA, China, India and Europe, which have large resources.

There has also been widespread recognition of the necessity of clean coal as part of a balanced energy portfolio, recently reinforced by international bodies such as the International Energy Agency and the European Commission, as well as publications such as the Stern Review.

The UK 2007 Energy White Paper and the EU Energy Package each point to the need for a diverse portfolio of energy sources for power generation to achieve security of supplies.

Both emphasise the vital importance of coal in the generation mix and recognise the integral role that cleaner coal plays alongside energy efficiency, renewables, and nuclear in reducing emissions.

The UK government has further demonstrated its commitment to coal by setting up the Coal Forum with the objective "to help find solutions to secure the long-term future of coal-fired power generation and UK coal production".

The Government has announced its Carbon Capture and Storage (CCS) competition, focussing on pulverised coal. In addition, the Government needs to address the issue of how CCS can be implemented quickly and globally.

While some remain sceptical about the feasibility and economics of CCS, the process is proven; already millions of tons of carbon dioxide have been permanently stored underground. In addition, studies have shown that electricity from power plants with CCS will be less expensive than electricity from renewable sources.

The phased introduction of carbon-abated clean coal is the lowest risk approach to meet all three Energy Review objectives relatively quickly.

If the UK is to avoid the impending energy gap, a large number of new or replacement carbon-abated power plants will need to be operational by 2015 and need to be started between 2006 and 2011.

Whilst in the past, clean coal was considered to be synonymous with gasification or Integrated Gasification Combined Cycle (IGCC), it is now seen to include a number of conversion technologies (including advanced supercritical boilers, fluidised beds and gasification) and a number of CO<sub>2</sub> capture technologies (including post-combustion solvent absorption, oxyfuel firing and pre-combustion).

All of these technologies are likely to have

a role in the plant mix because clean coal technologies are needed for existing plant (including recent plant in China, USA and Europe) as well as future plant.

It is now widely anticipated that any new plant in Europe will be required to be capture-ready. Alongside capture-ready plant, a number of first-of-class CCS projects (often referred to as demonstration projects) are planned.

The EU Directorates for Transport and Energy, Environment and Research are each backing an industry strategy, published by the European Technology Platform "Zero-emissions Power Plant" (ETP ZEP) [2], for ten-to-twelve such demonstrations around Europe, to be operational by 2015.

DG Environment and DEFRA/DTI in the UK are pushing ahead with the necessary regulations for CCS and clarification of the London Convention (now implemented) and OSPAR to allow storage beneath the ocean floor.

### New plants

To maintain a diverse portfolio, it is necessary that a significant proportion (a third to a half) of the plant to be built in the UK for operation by the end of 2015 is coal and, to meet CO<sub>2</sub> reduction targets, it will need to be suitable for CO<sub>2</sub> capture.

Many projects have to start soon before the best options for CO<sub>2</sub> capture are finalised, and it is therefore likely that the plants will be in two groups:

(i) A small number of new build (or retrofit) plants with CCS fitted from the start. These demonstration projects would allow the best CCS options to be understood by 2012 to 2015. Ideally, these projects would include the three capture technologies and three different types of storage site (oil-field, gas-field and saline aquifer). The BERR competition winner will be one of these projects. It is recognised that incentives will be necessary to make all these projects happen. The current Emissions Trading Scheme does not provide the long-term certainty of carbon price to justify investment.

(ii) 5 to 8 GW of "capture-ready" new build or retrofits. These will bring short-term CO<sub>2</sub> reductions, security of supplies, economic electricity and options for fitting CCS from 2012/2015 onwards.

In combination, this scenario would meet all three Energy White Paper (EWP) objectives. The technologies used would be capable of being used globally for existing plant (including capture-ready) and future new build.

If Britain builds power plants (coal and gas) designed for CCS and demonstrates the technologies full scale it will set an important example to the world and, just as importantly, will be at a competitive advantage.



*"More urgency and ambition is needed by the government," Dr Mike Farley, Doosan Babcock.*

The Prime Minister and the government have recognised this and should now back their ambitions with a support for a comprehensive programme of CCS projects which will prove engineering solutions capable of much larger scale carbon emission cuts than the "ethical consumerism" which many promote.

The Government has recently announced a new ambition for wind power that would give Britain 33 Gigawatts of offshore wind by 2020. While renewable energy is vital as part of a balanced portfolio, it will not deliver sufficient power to fill the generation gap.

If CCS is fitted to all of the new power plants to be built in the UK up to 2016, the reduction in carbon dioxide emissions would be around 80 million tonnes per year, about 45% of present emissions from power plant. Later as other plants are replaced the reduction would move up to around 85%.

If the generation gap is to be averted, more urgency and ambition is needed by the government.

Positive high level endorsement of the future role for coal must be given, including a target for the proportion of coal in the portfolio and timescales for the achievement of near-zero emissions for coal and gas generation.

Incentives should be set for CCS sufficient to drive forward three or four demonstration projects covering the range of capture technologies and storage sites.

More positive and consistent support must be given for research, development and demonstration on a scale commensurate with the global potential for clean coal technologies.

Companies like Doosan Babcock are investing heavily in the necessary R+D and will roll out the technology as fast as the market and governments allow.



# UK CCS Demonstration Project

Bronwen Northmore, Director, Cleaner Fossil Fuels Unit, Department for Business, Enterprise and Regulatory Reform, talked about the launch of the UK's competition for a post-combustion demonstration project

Ms Northmore began by addressing the criticism that the UK government had been too slow to act.

"It has taken us 2.5 years to launch this competition," she said. "Many people think that is very slow, but in the light of what Jan [Panek see pg. 20] has just said I think it is not too bad. This all really kicked off in 2005 when the UK simultaneously had G8 and EU presidency."

"Tony Blair at the time concluded that he wanted to focus very heavily on climate change and that brought Cleaner Fossil Fuels into focus and particularly what was happening in China and India."

"That was the start of a pretty swift curve upwards in the level of interest politically and, indeed, nationally."

"That year also, we launched our Carbon Abatement Technologies (CAT) Strategy, which was a document that looked at various technology options for reducing emissions and using fossil fuels, particularly coal more cleanly and, obviously, one of those options was CCS."

"At the time, we received £25 million, which was subsequently increased to £35 million; a small fund to demonstrate some assembly components relating to carbon abatement technologies."

"In 2006, there was still great interest in CCS, so we moved on and Government moved on to consulting on barriers to deployment of CCS. That looked at various things such as regulatory barriers; it also looked at cost penalties and the funding gap."

At that time in the UK there were a number of potential projects, around six or seven, she said, and project costs were evaluated taking into account the generic costs produced by the IEA and others and the UK's own consulting efforts.

This resulted in the Prime Minister [Gordon Brown] launching the competition on 19 November 2007, as part of a major climate change speech.

## The Project

Ms Northmore said there were two overarching objectives for the project: the successful demonstration of the full chain of CCS technologies on power plant at commercial scale; and the demonstration of technology that is relevant and transferable to key global markets, particularly in emerging economies such

as China and India.

The government is prepared to fund up to 100% of the incremental CCS costs, she said, although it was expected that the competition process would result in the winning company bidding to fund some of the costs itself.

This would not include the power plant, but the capex and opex that are necessary to run the demonstration, taking account of the carbon price.

"Everybody always says, 'Well, what is your budget for this?', and in fact one of the objectives of running a demonstration is to find out what the cost of a CCS plant is, because nobody really knows," she said.

"All I can say is that ministers did look very closely at the range of cost and it was a wide range that came from the consulting engineers for the very different types of project in the UK that were being mooted at the time."

"However, ultimately, of course, the project we do fund and support will have to be affordable."

## Project parameters

The high-level project parameters are:

It does have to be in the UK; it needs to demonstrate the full chain of CCS technology by 2014 at commercial scale; it must use post-combustion technology (includes oxyfuel); around 90% capture; offshore storage; information sharing essential.

Phasing will be considered, so provided there was a substantial proportion of capture, around 50-100MW ready by 2014, the rest could be phased in as fast as possible after that.

"2014 is very important to us," she said. "Because if CCS is going to make a difference it needs to be starting to be deployed widely by about 2020."

"You therefore need a number of demonstration projects that have been up and running for a sufficient time by 2020 for the first level of learning to feed into the second generation of more widely deployed plant."

Commercial scale has been defined as demonstrating capture of about 300-400MW, which would most likely mean partial capture on a larger, 600 or 800MW unit.

"We looked at whether it was worth going above that and concluded that the learning we would receive from the demonstration would be no greater if we funded capture on an entire unit."

## Why Post-Combustion on Coal?

Ms Northmore said that they had looked at the project in Norway, which is post-combustion on gas, and in the USA, the FutureGen project which is an integrated gasification combined cycle (IGCC), pre-combustion on coal and concluded there was a gap in the market for a demonstration project on post-combustion on coal.

"We also looked at the IEA's projections for new build and the preference of generators the world over to go for pulverised fuel supercritical plant [suitable for post-combustion capture]."

"Thus, the international overall landscape pointed us in the direction of post-combustion on coal."

"Furthermore, what is happening in the UK also pointed us in that direction. We have a number of potential coal generation projects on the books coming forward from the generators and the vast majority of those are, again, supercritical pulverised fuel."

"Therefore, basically, we would need post-combustion capture on coal in our own backyard sooner or later and it makes sense to go for that technology."

She said that did not mean the UK had taken a choice on a preferred technology.

"We have no idea as to what ultimately will be the technology of choice; nobody can tell at this stage, but for the purposes of our demonstration project we made the decision on policy objectives with a view to speeding deployment of CCS."

## Information sharing

"Information sharing is absolutely key and is the main reason why we are doing this. It is a demonstration; we are doing it to encourage the fastest possible deployment of CCS as a technology."

"Picking up what it is like to build one of these and what it is like to operate, the impact on the power plants, how reliable they are, what it costs, all those issues are very important to us so we will be looking for bidders to come up with good proposals for information sharing."

carbon  
capture  
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**For the full project description with details of the pre-qualification process (deadline 31 March 2008) visit:**  
[www.berr.gov.uk](http://www.berr.gov.uk)



# The Economics of Exploiting CCS on an Industrial Scale

Industry experts discuss the likely financing options for CCS plants including the structure of the European Emission Trading Scheme and the potential for income from enhanced oil recovery in the North Sea

### Setting the carbon price

Paul Zakkour, principal consultant, ERM, began by pointing out that there is a great deal of talking going on around the world with this meeting about CCS following another meeting last week and another the week before.

"Everyone has a big appetite for industry to do these projects," he said. "The policymakers are scrambling to create the regulatory frameworks and enabling frameworks for CCS, but still project finance guys cannot get a business case put together right now to invest in CCS without any kind of perspective on what the revenue stream is going to be."

"That is the biggest fundamental problem we face: there is no long-term carbon price."

"The Commission's announcement about a 20% reduction target maybe gives us a 12-year window if you are very bright and you can create some kind of clever pricing model that can give you a price of carbon in 2018 or 2019."

"I still do not think we are in a position where business is ready to sign off FIDs (Final Investment Decisions) on carbon capture and storage projects until we have a clearer, stronger carbon price signal or where we have a guaranteed carbon price being underwritten by government."

"You can cost a project with some degree of certainty and you can finance a project if you have friendly backers or a good credit rating, but what you cannot do is forecast long-term revenues and that is really the challenge."

Lars Stromberg, director, Vattenfall, said that the most important part of the whole story is that we are operating in a deregulated power market.

"We are working in a system where car-

bon dioxide costs, electricity prices, fuel prices are all connected in the future," he said. "Of course, if there are unknown factors in this equation then we have problems."

"The extra cost of a demonstration plant will constitute something around €400-600 million, which has to be covered in some way or another."

"It was also said that it is necessary that we do believe in a future where electricity prices will bring that money back into the system in some way or another. If we do not do that, we have a problem, nothing will happen and the power companies will not move."

### Enhanced Oil Recovery (EOR)

Bert Metz, co-chair of the intergovernmental panel on climate change working group III talked about the findings contained in the IPCC special report on CO<sub>2</sub> capture and storage that was published two years ago.

"There was a comprehensive assessment made of all the aspects," he said. "Including the economics, and it is very clear and no big surprise that CCS is not cheap."

"It is much more expensive than many other options to reduce emissions, but in the longer term it may be very important to achieve deep reductions. The cost estimates basically are in the range of US\$20-80/tonne of CO<sub>2</sub> avoided for a power plant and there are some smaller options with gas treatment that may be cheaper."

"However, that cost goes down significantly when you combine it with enhanced oil recovery (EOR). These analyses were done with oil prices lower than \$50/barrel."

"With the current price being close to \$100/barrel, it might be even more attractive and costs can basically come down to zero."

"Therefore, I think in the economics about bringing CCS to the market this combination with enhanced oil recovery will be very important, because it will have much, much better economics and will have an earlier chance to get into the market which does not sustain this kind of carbon price at the moment."

"We have an EU ETS (Emission Trading Scheme) system of around €20, but it remains to be seen how stable that is, so I think the carbon signal from the market is not strong enough."

"One thought I would like to put on the

table in terms of how you could close the gap between what it costs in fully-fledged form and the current carbon prices is that one way would be to combine with enhanced oil recovery."

"An-

other way might be to use the proceeds from auctioning allowances under the ETS. That could generate substantial amounts of money and might be a way to come up with the funds needed to bring these technologies to the market."

Ian Phillips, Director CO<sub>2</sub> Infrastructure, CO<sub>2</sub> DeepStore said that as an ex-oil industry employee he had difficulty with EOR as a CCS concept because the whole thing is the CO<sub>2</sub> goes in, dissolves into the oil and comes out again.

"Therefore, it creates a store in the long-term, but in the short-term I do not regard it as a CO<sub>2</sub> storage concept. It is relevant, but it seems to me there is a big time-lag which is missing."

"It is technically not a big thing to ensure that the CO<sub>2</sub> is not going into the air," said Mr Metz. "You separate it and you pump it back. Over time, you store more and more CO<sub>2</sub> and when the oil filter is finished you close the tap. That is the idea."

"I agree completely that it would be very, very good if we could have the help of EOR or a value on the CO<sub>2</sub> for EOR," said Mr Stromberg. "Unfortunately, the North Sea is not very suitable for this, so we are facing a situation where we inject CO<sub>2</sub> in a well to get more oil out of that well for a couple of years."

"The CO<sub>2</sub> then starts coming back, perhaps, and you pump it down again. This means that this well cannot take more CO<sub>2</sub>, or less and less CO<sub>2</sub> from the power plant, so you have to move to the next one."

"If this situation continues for all your



*"The most important part of the whole story is that we are operating in a deregulated power market" - Lars Stromberg, Director, Vattenfall*

### References

From a panel discussion at the Inaugural European Carbon Capture and Storage Summit, London, November 28, 2007

#### The panel included:

**Paul Zakkour**, principal consultant, ERM

**Bert Metz**, co-chair of the intergovernmental panel on climate change working group III

**Lars Stromberg**, director, Vattenfall

different wells, there is just a short window of a couple of years or five years in a well which really gives a value to the CO<sub>2</sub> from the power plant, which makes the system unworkable. Therefore, we have stopped hoping for EOR to help us."

"We said 'fix the storage, with luck in the North Sea, but do not fiddle around with EOR'; we do not believe it will make a positive contribution up here in northern Europe," he concluded.

## Structuring ETS

Ian Phillips asked if any of the panelists had any words of advice for the EU on how to structure phase III of the ETS, both in concept and in duration, so that it delivers an incentive to industry to do something about carbon.

"The only signal from phase III is the two-degree communication which, if there is a post-Kyoto agreement, could be a 30% reduction by 2020 with 20% coming in the EU," said Mr Zakkour.

"Presumably, that would have to be implemented into policy measures through something like auctioning to restrict the pool of auctioning and now you have to go away and somehow integrate that into your business planning to come up with a price of carbon."

"I am sure there are plenty of people who will happily sell you some kind of forecasting tool that could do that, but at a price and with a great deal of unreliability. However, it only still gives you a 12-year window and it does not really mean much beyond 2020."

"One thing I forgot to add was there are lots of longer term commitments coming out, such as 60% reduction targets by 2050; Florida has a bill saying they are going to cut CO<sub>2</sub> emissions by 50% by 2050. You can send out a long-term signal like that, but it does not mean anything."

"Thus, it is about trying to strike that balance properly between some kind of aspirational target and something you can operationalise into near-term policy objectives that business can operate. However, that is a difficult balance to strike."

## Cost

"The most important thing is that everyone believes that CO<sub>2</sub> will have a cost," said Mr Stromberg. "The critical issue is if the world cannot agree after 2012 on something new."

"We hope to know by 2010, 2011 what is coming up after 2012, but if we do not believe in such a development, nothing will happen and then we will not believe in the system as such and then we will not invest. This is the issue we are facing."

"Regarding cost, as Bert mentioned, we believe in a cost level of €20/tonne of carbon dioxide. At this level we are competitive with

almost any other means of reducing carbon dioxide, but if we have a technology which costs €80/tonne we will not use it."

"It is like saying tomorrow in my home city of Stockholm the temperature outside will probably be between minus 11 and plus 14. That is probably true, but it does not help me much. Thus, again, it is the €20-25/tonne we are looking for and those are the technologies which will survive, not the others."

Nick Riley, Head of Science:Energy and Co-ordinator of CO<sub>2</sub> GeoNet, British Geological Survey, said that governments have already decided to support very expensive options for reducing CO<sub>2</sub> emissions. In this country [UK], there is £1 billion a year spent trying to achieve the renewables obligation for electricity supplied from renewable sources.

"Therefore, I think you are selling yourself short by saying that CCS is very expensive," he said. "It is no more expensive than what governments are already prepared to support."

"Also, it is the only technology which deals directly with the problem. We have to have something that deals directly with fossil fuels. Energy efficiency is very cheap, it makes sense and we must do it, but it does not deal with the emissions necessarily."

"There is a very good report that has just been published by the UK Energy Research Centre showing the rebound effect from energy efficiency. It is not reducing demand, people just use more efficient gadgets and we still have the emissions."

"Therefore, I think we need to be selling the message differently about CCS. Yesterday, I was at the UN meeting and there it was recognised that there is a bias towards fossil fuels and it does not help overcome that bias if we do not really get the message clearly across that if you do not deal directly with fossil fuels we are not going to reduce emissions," concluded Mr Riley.

"I have said CCS is not cheap relative to other options and that is true," replied Mr Metz. "I do not say it is too expensive, because in the longer timeframe if you really want to bring emissions down significantly, you will

reach the price level that you need, so you need it and since fossil fuel and particularly coal is not going to go away, we will certainly need that."

"The problem is that in a rational policy you would do the cheaper things first before going on to the more expensive ones. I agree politics is not always rational and sometimes people do very expensive things because it is politically more attractive, but in general it is wise to follow the rational approach of least cost."

"That is also how the market works. The carbon market looks for the cheapest thing around first and therefore the price goes up gradually and that is where the problem is."

"The price that would make CCS viable economically will not be with us until maybe 2020, 2025 and in all that time nothing will happen unless other things are happening and governments step in and bridge that gap."

## Pricing

Mervyn Rice (BP) asked why there was such a contrast between Lars Stromberg's view of the cost of carbon capture and storage and the IPCC's views.

"Let just me say, the IPCC is the best we have. A huge amount of work has gone in there," said Mr Stromberg.

"It is excellent to have put all these different information pieces together to something that people understand and can read."

"However, it does have a drawback and that is that they are based on academic papers, which are peer reviewed."

"The second thing is that it takes some time. Since the development curve is extremely steep at this very moment, some of the information which has gone into the IPCC report - especially concerning the capture technologies - is yesterday's assumption by a number of academic people."

"However, in some cases they are perfectly right. In other cases, things have moved on so we might find a considerable gap between what we believe today in industry and what was actually written in the IPCC report."

"I have criticised some of these figures many times, and have said that a cost between 20 and 80 dollars or euros per ton is like saying the temperature is between minus 11 and plus 14 outside in Stockholm. It is correct, but it does not help us much."

"We will not use technologies at the higher level. We will use the low-cost technologies in the future, so we should have real deep cuts of around 85%."

"Of course, there might be more and more difficult situations to handle with increasing cost in time. However, we are at the very beginning and we are talking about almost 20 years."



*"CCS is no more expensive than what governments are already prepared to support" - Nick Riley, Head of Science:Energy, British Geological Survey*

# CCS' Role in the EU's Energy Strategy

Jan Panek, Head of Unit, Coal and Oil, European Commission, outlines how the EU is pursuing new technologies, developing the regulatory framework and constructing an energy market that will put CCS at the forefront of its efforts to reduce CO<sub>2</sub> emissions.

Mr Panek said that 2007 had been a year of landmark events in the energy field.

"We have taken two major steps forward this year," he said. "One is in a commitment to cut greenhouse gas emissions; the other is in completing the construction of a truly integrated and competitive internal energy market. Clearly, these are ambitious goals."

"We try to always argue that as much as they are ambitious they are also necessary and, we believe, achievable."

"It is obvious that to meet our climate objectives an increased penetration of renewable sources of energy is necessary and to make energy supplies more competitive barriers to competition need to be erased."

"However, renewable energies alone will not allow us, at least not in the short or medium term, to provide enough energy for continued economic growth."

"Likewise, competition alone will not ensure integral and sufficient supplies at all times with a sustainable carbon footprint."

## CCS

"Besides renewables we need a well balanced and diversified energy mix," he continued. "A strong presence of low-carbon energy sources and this is where fossil fuels, particularly coal, come in and this is where CCS comes in. CCS is, indeed, the name of the game."

CCS has yet to prove its merit in practice, he said. "It is understandable that not everybody is giving it the amount of trust which in our eyes it deserves."

"Clearly, we do have to be aware of the shortcomings of CCS, which are typical for emerging technologies of this type. At the moment, indeed, CCS is expensive. It is not fully known and therefore all sorts of risks are being evoked and feared."

"It is associated also predominantly with coal and that is a fuel that is seen traditionally as dirty or not clean and certainly not futuristic. However, we are convinced that these shortcomings are of a temporary nature and are certainly not inherent to the concept of CCS."

"Therefore, CCS can be one of the cor-

nerstones of our fight against climate change. It can deliver the dual benefit of removing a significant part of greenhouse gas emissions without removing coal and gas from the energy mix."

"We believe it can be done in 10-15 years, but it will not happen unless we all make a leap of faith and give it a serious try, with all the initial costs this will entail."

## Overcoming the Challenges

Earlier in the year, the Commission outlined a number of challenges ahead, the main being substantial R&D requirements, lack of demonstration, high costs and legal uncertainty.

"The Commission is addressing the issue of the legal framework for CCS and within a month or two will take action towards resolving all major CCS-related issues of a legislative nature."

"A comprehensive regulatory framework will be tabled in January, designed to ensure public confidence in the safety of CCS deployment as well as to provide legal certainty to operators."

These will complement recent changes to the OSPAR Convention and London Protocol.

## Strategic Energy Technology Plan

CCS has been included in the Strategic Energy Technology (SET) Plan, a document identifying several key directions in which European R&D in energy should be concentrated in the interest of achieving a low carbon energy supply.

The SET plan has been adopted by the Commission and the heads of states of the EU member governments will make a decision at the Spring Summit 2008 on whether to endorse it.

In the SET Plan CCS is highlighted as one of the ways of delivering a decarbonised electricity base load, and there are also concrete suggestions about what should be done on CCS in the future.

It sets two time horizons, 2020 and 2050, 2020 being an interim target by which time all the necessary steps should have been taken so that new technologies allowing pro-



*"We believe it can be done in 10-15 years, but it will not happen unless we all make a leap of faith and give it a serious try" - Jan Panek, Head of Unit, Coal and Oil, European Commission*

duction of low carbon energy could be deployed on a wide scale.

This would result, by 2050, in a fully decarbonised energy base load.

It also outlines for 2020 a concrete target of a demonstration of the commercial feasibility of the whole CCS chain, capture, storage and injection, in large-scale power plants running on fossil fuels.

## Demonstration projects

The EU is cooperating with industry to see around 12 large-scale CCS demonstration projects for coal and gas-fired power plants being launched by 2015.

This will verify the economic viability of CCS technologies in a Europe-wide demonstration exercise.

"It will not be done by 2015," said Mr Panek. "But as the Director-General of my Department likes to quote eastern philosophies, he has a very special line here from Confucius saying that even a long trek starts with the very first step and that is the one across the threshold of your house and I think this is what we are trying to achieve by putting together a set of demonstration projects to be on stream by 2015."



## Financing

The initial projects face the challenge of substantial up-front investment costs, which are large not only in absolute size but also in comparison with non-CCS plants.

"It is obvious that the major challenge of the CCS demonstration projects is in financing," he said.

Operating costs will also inevitably be higher, up to 25% or 30% more by some estimates.

"The Commission expects the industry to be the first volunteer. We trust the industry predictions that CCS in power generation can commercially be feasible in 10-15 years and if this is a correct prediction it offers all involved a strong promise of great gains in the not too distant future."

"Indeed, it does not happen too often that a multi-billion mature industry such as the one we see in energy production from fossil fuels stumbles upon a completely new business opportunity with an even bigger multi-billion potential reachable in a decade or so."

While industry stands to gain from commercialisation of CCS, support from public funds will be needed before the European Trading Scheme provides a market-driven mechanism rewarding low CO<sub>2</sub> practices over carbon intensive ones.

"We do not know yet whether any public funds can be committed at the EU level," he said. "In any case, there first needs to be clarity on several issues: how much money is needed, what is the financial commitment of the industry, in what form should the public money possibly come, and where will the public money come from?"

"Each of these four questions is a tricky one and the Commission can be legitimately expected in due time to have answers to only one or two of them. No one should be tempted to conclude from it that the Commission alone will or can do the trick."

Decisions needed to be taken with relative urgency, he said. "If Europe does not keep the momentum on CCS, others may steal the march on us and Europe may find itself in one or two decades buying CCS technologies from others."

"This would be a shame considering the amount of expertise available in Europe and the effort and resources already spent on early actions by EU administrations and industry."

## Actions to be Taken

A January Energy Package which is to be tabled by the Commission will contain several different initiatives targeting renewables, the burden-sharing concept of propor-

tioning which country should do what in order to achieve the collective 20% target, and also some CCS related documents.

These include a draft objective for geological storage of CO<sub>2</sub>; a communication from the Commission on the ways of supporting CCS demonstration projects; a document on general state aid rules for assistance from public funds to environmental projects which will mention CCS.

"We hope by January to facilitate the process of obtaining state aid clearance for demonstration projects in CCS," said Mr Panek. "We also hope to highlight the importance of financing and the limited resources that may exist at the moment in the EU budget and the way to make up for that."

**"Public acceptance is an issue that is almost as dire as financing and it will become more and more critical as we try to implement the projects"**

This will be done in-sync with the SET Plan, where the Commission has committed to produce a document in 2008 looking at possible innovative ways of finding new funds for low-carbon energy technologies.

He said the ETS should be the first line of incentivisation for everybody to think twice before implementing an emitting technology rather than a non-emitting one. However probably ETS alone will not be enough to ensure the demonstration projects go ahead, so they will need some additional assistance.

"We will also try to take some very early steps within the limited means available in the Commission budget," he continued. "This would be in the form of the creation of a network of projects where we hope to be able to provide some value by a pan-European approach to link the different demonstration projects that may be happening."

"We have every reason to believe that with a little bit of a push and some enabling initiatives, such as the clarification of the legislative framework or the further signals on financial assistance or state aid clearance, we could incite a few more EU countries to come forward within a short period of time and put their own support schemes forward as well."

## Working together

All the projects resulting from the national initiatives could be put into a common ring of projects so that they could exchange in-

formation, share best practices, and avoid common mistakes.

The issue of public acceptance, he said, could also be well addressed in a coordinated or collective manner on behalf of all the projects.

"Public acceptance is an issue that is almost as dire as financing and perhaps it is not recognised yet, but it will become more and more critical as we try to implement the projects," he said.

The collective grouping of the projects could also be used as a way to discuss or engage with foreign partners in a better way than if individual projects went around the world trying to speak in a disjointed manner.

## Capture ready power plants

Making sure newly built power plants can do CCS in the future is about intelligent planning, he said. It comes down to making sure that the design allows for retrofit and can be as simple as allowing space on the site for a capture plant.

"We strongly advise or we expect companies making investments in new power installations to consider capture-readiness as a very important and crucial precondition for the long-term existence of the power plants after the period when CCS becomes commercially viable," he said.

"We certainly want to avoid a situation where CCS is able to be applied with commercial logic after 2020 and we have a host of power plants in existence by then for just five or seven years telling everybody 'sorry, we cannot do CCS because we only built it five years ago and it will be operational for another 30 years and at that stage CCS was not an option commercially, so we did not allow for it.'"

"Clearly, it would be very difficult at the moment to mandate capture-readiness, but you just want to take precautions so that if you build a power plant now you will be able to retrofit in 10 years in case either the commercial logic or the political or regulatory environment obliges you to do so."

carbon  
capture  
journal

## References

From a talk given at the Inaugural European Carbon Capture and Storage Summit, London, November 28, 2007.

The European Union Strategic Energy Technology (SET) Plan can be downloaded at:

[ec.europa.eu/energy/res/index\\_en.htm](http://ec.europa.eu/energy/res/index_en.htm)

## Capture Technology

### HTC Purenergy to launch new capture technology

[www.htcenergy.com](http://www.htcenergy.com)

HTC Purenergy, an energy technology company that is commercialising CCS technologies for enhanced oil recovery (EOR), will launch a new modular, pre-engineered CO<sub>2</sub> capture system.

Purenergy CCS 1000 is a stand alone carbon capture system that will capture CO<sub>2</sub> from the flue gas exhaust of power plants and large industrial emitters.

It will be capable of capturing 1000 tons per day of CO<sub>2</sub>.

The system is pre-engineered, pre-built and modularly constructed in Saskatchewan by HTC's strategic partner

Pinnacle Industrial Services of Regina using technologies developed and validated at the University of Regina.

The company believes, because of its modular design, that it will be able to be manufactured, shipped and erected at the emitter sight at a much lower cost than other systems that have to be custom built on site.

HTC Purenergy is globally commercialising this product through its head office in Regina (Canada), and commercial offices in Sydney (Australia), Beijing (China), and Vermont (USA).

### EESTech acquires CCS technology from HTC Purenergy

[www.eestechinc.com](http://www.eestechinc.com)

EESTech has acquired the rights to HTC Purenergy's CO<sub>2</sub> capture technology outside Europe and the Americas.

EESTech bought 100% of the shares in CO<sub>2</sub> Technologies Pty Ltd, a wholly owned subsidiary of HTC Purenergy, giving EESTech the exclusive rights to commercialise the CCS technology in China, India, Japan, Australia, New Zealand, Malaysia, Indonesia, Brunei, Thailand, the Philippines and Singapore.

EESTech has co-developed a patented HCGT (Hybrid Coal Gas Turbine) technology with an Australian Government Research facility. The HCGT uses waste coal, ventilated air methane or biomass to produce electricity and steam.

When the HCGT is integrated with HTC Purenergy's CCS technology the combined system can capture CO<sub>2</sub> from power stations and other industrial flue gases.

According to the company, the integration of both technologies forms the world's first stand-alone Hybrid CCS System that is non-disruptive to industry, which it says can reduce the cost of CCS by up to 40%.



*HTC Purenergy CCS 1000 - a stand alone carbon capture system capable of capturing 1000 tons per day of CO<sub>2</sub> from the flue gas exhaust of power plants*

### RWE Power, BASF and Linde co-operate on CCS research

[www.basf.com](http://www.basf.com)

[www.linde.com](http://www.linde.com)

RWE Power, BASF and The Linde Group have teamed up on the development of new processes for CO<sub>2</sub> capture from combustion gases in coal-fired power plants.

The co-operation will comprise the construction and operation of a pilot facility at the lignite-fired power plant of RWE Power AG in Niederaussem to test new developments and solvents from BASF for the capture of CO<sub>2</sub> by CO<sub>2</sub> scrubbing. Linde will be responsible for the engineering and the construction of the pilot facility.

The purpose of the planned pilot facility is the long-term testing of new solvents with a view to gaining an understanding of processes and plant engineering to improve CO<sub>2</sub> capture technology.

The goal is to apply CO<sub>2</sub> capture commercially in lignite-fired power plants by 2020. After the pilot tests, a subsequent demonstration plant will be designed to provide a reliable basis for the commercialisation of the new process in 2010.

RWE Power has earmarked a budget of approximately EUR 80 million for the development project, including the construction and operation of the pilot facility and demonstration plant.

Apart from the CO<sub>2</sub> scrubbing method, RWE Power is also developing the first carbon neutral coal-fired power plant with CO<sub>2</sub> transport and storage, based on the integrat-

ed gasification combined-cycle process (IGCC).

This large-scale 450-MW plant is due to come on stream in 2014, although no decision has yet been taken as to where it should be located.

### Praxair and Foster Wheeler form alliance

[www.fwc.com](http://www.fwc.com)

[www.praxair.com](http://www.praxair.com)

Praxair and Foster Wheeler have signed a multi-year agreement to pursue demonstration projects that will incorporate clean coal technologies and integrated oxy-coal combustion systems into coal-fired electric generating plants.

The two companies have agreed to share technical information to ensure successful integration of the combined systems.

Under the agreement, Foster Wheeler will develop and supply steam generators using oxy-coal combustion technology that can be installed in new or existing coal-fired power plants.

Foster Wheeler expects that its first applications of oxy-coal combustion technology would involve the company's circulating fluidized-bed (CFB) steam generators, and expects that the technology will be applicable to pulverized-coal (PC) steam generators as well.

For this project, Praxair will provide the upstream oxygen-supply facilities and the downstream CO<sub>2</sub> capture and gas-processing technologies and equipment.





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# Separation and Capture

The companies expect that their first joint commercial effort will be the previously announced demonstration project being pursued by the Jamestown (New York) Board of Public Utilities.

## RWE to join AEP in validation of carbon capture technology

[www.rwe.com](http://www.rwe.com)

[www.aep.com](http://www.aep.com)

American Electric Power and RWE, will collaborate with Alstom during a validation of commercial-scale application of carbon capture and storage technology on an existing AEP coal-fired power plant.

AEP and RWE have signed a memorandum of understanding (MOU) on the collaboration. RWE will join a project AEP announced in March when it signed an MOU with Alstom, for post-combustion carbon capture technology using Alstom's Chilled Ammonia Process.

RWE will also participate in an associated project for deep geological storage of captured CO<sub>2</sub>.

The Alstom technology will be installed on AEP's 1300-megawatt Mountaineer Plant in New Haven, West Virginia, where it will capture CO<sub>2</sub> from a slipstream, or portion, of flue gas from the plant.

The slipstream will be equivalent to 20 megawatts of generation, an increase from the 10 megawatts included in the March announcement.

The Alstom chilled ammonia system is expected to capture up to 200,000 metric tons of CO<sub>2</sub> per year, which will be injected for geological storage in deep saline aquifers at the site.

Battelle Memorial Institute, a global science and technology enterprise and a leader in carbon storage research, is serving as the consultant for AEP on geological storage.

In 2002, Battelle, AEP, the U.S. Department of Energy and others sponsored the world's first site-specific investigation of carbon storage capabilities at the Mountaineer plant.

During the investigation, an approximately 9,000-foot exploratory well and seismic studies determined that the site was suitable for deep geological storage of CO<sub>2</sub>.

The validation project at Mountaineer will begin in 2009, or after successful completion of a small-scale pilot demonstration of the technology by Alstom and the Electric Power Research Institute on a Wisconsin plant.

Once commercial viability of the technology is validated at Mountaineer, AEP plans to install Alstom's chilled ammonia



*AEP's 1300-megawatt Mountaineer Plant in New Haven, West Virginia where Alstom's chilled ammonia process will be used to capture CO<sub>2</sub> from a slipstream*

technology on one of the 450-megawatt coal-fired units at its Northeastern Station in Oologah, Oklahoma.

Plans are for this commercial-scale system to be operational at Northeastern early next decade.

It is expected to capture about 1.5 million metric tons of CO<sub>2</sub> a year. The CO<sub>2</sub> captured at Northeastern Station will be used for enhanced oil recovery.

In addition to this carbon capture and storage collaboration agreement, AEP and RWE are members of the e8, a non-profit international organisation composed of the nine leading electricity companies from the G8 countries.

The e8 promotes sustainable energy development through electricity sector projects in developing nations worldwide.

## AEP, SemGreen agree CO<sub>2</sub> delivery deal

[www.aep.com](http://www.aep.com)

American Electric Power and SemGreen have signed a memorandum of understanding regarding the delivery and use of carbon dioxide captured by a planned commercial-scale carbon capture system.

AEP and SemGreen have agreed that CO<sub>2</sub> captured at Public Service Company of Oklahoma's (PSO) Northeastern Station will be transported to SemGreen through pipeline and technology provided by SemGreen.

The CO<sub>2</sub> would then be used or sold by SemGreen for enhanced oil recovery. SemGreen is SemGroup's business unit dedicated to emerging technology and opportunities that create sustainable energy alternatives,

enhance energy resources and mitigate damage to the environment.

In its March announcement, AEP said it would pursue the first commercial use of carbon capture technologies on existing coal-fired power plants, with installation of a commercial-scale system planned for one of the 450-megawatt coal-fired units at Northeastern Station in Oologah, Oklahoma.

Plans are for the commercial-scale system to be operational at Northeastern early next decade. It is expected to capture about 1.5 million tons of CO<sub>2</sub> a year.

The March announcement followed the signing of an MOU with Alstom for post-combustion carbon capture technology using Alstom's chilled ammonia process.

The Alstom technology will be installed for product validation on AEP's 1300-megawatt Mountaineer Plant in New Haven, West Virginia, where it will capture CO<sub>2</sub> from a slipstream - or portion - of flue gas from the plant.

The chilled ammonia system is expected to capture between 100,000 and 200,000 metric tons of CO<sub>2</sub> per year, which will be injected for geological storage in deep saline aquifers at the site.

## Powerspan licenses coal based capture technology from US DOE

[www.powerspan.com](http://www.powerspan.com)

Powerspan, a clean energy technology company, has exclusively licensed a patent for post combustion capture of CO<sub>2</sub> from conventional coal based power plants.

Patented by the U.S. Department of Energy's (DOE) National Energy Technology

Laboratory (NETL), the post-combustion, regenerative process uses an ammonia based solution to capture CO<sub>2</sub> from flue gas.

Under a cooperative research and development agreement (CRADA), Powerspan and NETL have been collaborating on the development of the CO<sub>2</sub> capture process since 2004.

The patent granted to the DOE represents the only patent issued in the US to date covering a regenerative process for CO<sub>2</sub> capture with an ammonia based solution.

Recently, Powerspan and NRG Energy announced a memorandum of understanding to demonstrate at commercial scale the CO<sub>2</sub> capture process at NRG's WA Parish plant near Sugar Land, Texas.

The demonstration is expected to be operational in 2012 and will be conducted on a flue gas stream equivalent to a 125 megawatt unit, equating to approximately one million tons of CO<sub>2</sub> captured annually.

The 'ECO2' process is a post-combustion CO<sub>2</sub> capture process for conventional power plants that is suitable for retrofit as well as for new coal based plants.

According to the DOE the technology has simpler capital equipment design and lower power consumption than comparable processes.

The regenerative process can also be

integrated with Powerspan's patented Electro-Catalytic Oxidation (ECO) process for multi-pollutant control of sulfur dioxide (SO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>), mercury and fine particulate matter from power plants.

The CO<sub>2</sub> capture takes place after the ECO process. Once the CO<sub>2</sub> is captured, the ammonia based solution is regenerated to release the CO<sub>2</sub> in a form that renders it ready for geological storage.

The ammonia solution is not consumed and can be recovered and sent back through the scrubbing process.

## Carbon capture under \$20 per ton?-

### Sargas

A new carbon capture technology has been developed for coal fired plants which could reduce the cost to \$20 per ton according to a Reuters article.

The catch is that the technology requires the flue gas to be under pressure to work, so it cannot be used with existing plants where exhaust gases are at atmospheric pressure.

However it can be used with new pressurised fluidized bed combustion systems, which are currently used in Sweden, June and Germany, and it can be used with any new natural gas plants, Reuters says.

It uses a system of pressurised filters,

absorbers and condensers.

The technology, developed by Sargas Technology Group, can also remove 95 per cent of carbon dioxide from a flue gas stream, more than the 90 per cent of most carbon capture technologies, the inventors claim.

A 5m tall prototype handling 60 kg exhaust gas / hour has been running since October this year on a power plant in Stockholm, run by Finland energy company Fortum.

"A competitive coal-fired power plant with carbon dioxide capture could be built today with this technology and produce energy at competitive costs," Sargas chief executive Henrik Fleischer told Reuters.

"For future plants it could be interesting ... Theoretically you don't need so much energy," Eva-Katrin Lindman, head of research and development at Fortum Varme, told Reuters.

The company wants to build a 400 megawatt coal fired power plant to supply electricity for metals smelters in Norway, working together with aluminium company Alcan, Norwegian oil company Norsk Hydro, French metals producer Eramet and Norwegian group Tinfos.

Mr Fleischer said that the plant could be running by 2012.



## WORLD RESOURCES INSTITUTE

The World Resources Institute Climate and Energy program, based in Washington, DC, seeks a Senior Associate/Project Manager to manage the Carbon Capture and Sequestration (CCS) project.

The Senior Associate will manage an initiative to develop and test environmental, technical, and social guidelines for CCS projects. This will involve coordinating input and feedback from a multi-stakeholder group of government, industry, research, and NGO participants.

The individual selected must have the following key competencies:

- Masters degree and at least 5-10 years of professional experience in the energy and climate field, at least 2 of which are in CCS.
- Understanding of and demonstrated interest in climate change and CCS.
- Knowledge of and/or experience with geology, oil and gas, coal and power generation activities preferred.
- Strong organizational skills, excellent English-language written and oral communication skills, and a demonstrated ability to work effectively in teams and to assert initiative and leadership as appropriate.

Further information and how to apply is online at <http://archive.wri.org/joblist/job.cfm?jid=297>

# DOE awards first three large scale sequestration projects

U.S Deputy Secretary of Energy Clay Sell announced that the Department of Energy (DOE) has awarded the first three large-scale carbon sequestration projects in the United States.

The three projects - Plains Carbon Dioxide Reduction Partnership, Southeast Regional Carbon Sequestration Partnership and Southwest Regional Partnership for Carbon Sequestration will conduct large volume tests for the storage of one million or more tons of carbon dioxide (CO<sub>2</sub>) in deep saline reservoirs.

DOE plans to invest \$197 million over ten years subject to annual appropriations from Congress for the projects, which are the first of several sequestration demonstration projects planned through DOE's Regional Carbon Sequestration Partnerships.

The newly awarded projects kick off the third phase of the program. During the first phase, seven partnerships - consisting of organizations from government, industry and academia, and extending across the United States and into Canada - characterised the potential for CO<sub>2</sub> storage in deep oil-, gas-, coal-, and saline-bearing formations.

When Phase I ended in 2005, the partnerships had identified more than 3,000 billion metric tons of potential storage capacity in promising sinks. This has the potential to represent more than 1,000 years of storage capacity from point sources in North America.

In the program's second phase, the partnerships implemented a portfolio of small-scale geologic and terrestrial sequestration projects. The purpose of these tests was to validate that different geologic formations have the injectivity, containment, and storage effectiveness needed for long-term sequestration.

The formations to be tested during this third phase of the regional partnerships program are recognised as the most promising of the geologic basins in the United States. Collectively, these formations have the potential to store more than one hundred years of CO<sub>2</sub> emissions from all major point sources in North America.

Plains CO<sub>2</sub> Reduction Partnership, led by the Energy & Environmental Research Center at the University of North Dakota,

will conduct geologic CO<sub>2</sub> storage projects in the Alberta and Williston Basins.

The Williston Basin project in North Dakota will couple enhanced oil recovery and CO<sub>2</sub> storage in a deep carbonate formation that is also a major saline formation.

The CO<sub>2</sub> for this project will come from a post-combustion capture facility located at a coal-fired power plant in the region.

A second test will be conducted in northwestern Alberta, Canada, and will demonstrate the co-sequestration of CO<sub>2</sub> and hydrogen sulfide from a large gas-processing plant into a deep saline formation. This will provide data about how hydrogen sulfide affects the sequestration process.

Southeast Regional Carbon Sequestration Partnership, led by Southern States Energy Board, will demonstrate CO<sub>2</sub> storage in the lower Tuscaloosa Formation Massive Sand Unit.

This geologic formation stretches from Texas to Florida and has the potential to store more than 200 years of CO<sub>2</sub> emissions from major point sources in the region.

The partnership will inject CO<sub>2</sub> at two locations to assess different CO<sub>2</sub> streams and how the heterogeneity of the formation affects the injection and containment. Injection of several million tons of CO<sub>2</sub> from a natural deposit is expected to begin in late 2008.

The project will then conduct a second injection into the formation using CO<sub>2</sub> captured from a coal-fired power plant in the region.

Southwest Regional Partnership for Carbon Sequestration, coordinated by the New Mexico Institute of Mining and Tech-



*The Plains CO<sub>2</sub> Reduction Partnership map showing various types of CO<sub>2</sub> storage sites*

nology, will inject several million tons of CO<sub>2</sub> into the Jurassic-age Entrada Sandstone Formation in the southwestern United States.

The Entrada formation stretches from Colorado to Wyoming and is a significant storage reservoir in the region. The partnership will inject CO<sub>2</sub> into the formation after extensive baseline characterisation and simulation modeling.

The project will test the limits of injection and demonstrate the integrity of the cap rock to trap the gas. Information gained from the project will be used to evaluate locations throughout the region where future power plants are being considered.

Over the first 12 to 24 months of these projects, researchers and industry partners will characterise the injection sites and then complete the modeling, monitoring, and infrastructure improvements needed before CO<sub>2</sub> can be injected.

These efforts will establish a baseline for future monitoring after CO<sub>2</sub> injection begins. Each project will then inject a large volume of CO<sub>2</sub> into a regionally significant storage formation.

After injection, researchers will monitor and model the CO<sub>2</sub> to determine the effectiveness of the storage reservoir. These three projects will double the number of large-volume carbon storage demonstrations in operation worldwide.

[www.fossil.energy.gov](http://www.fossil.energy.gov)



## Transport and storage projects

### Gorgon LNG with CCS project go-ahead

[www.chevron.com](http://www.chevron.com)

Chevron's Gorgon LNG project in Barrow Island, off Western Australia, has been given the go ahead by the Australian government.

The project will produce about 10 million tons per year of natural gas.

About 3 million tons per year of carbon dioxide, produced with the gas, will be separated out and re-injected into a reservoir formation, while the gas will be liquified for shipping.

The sequestration of the carbon dioxide was required by the Australian government.

Chevron was asked to implement a number of other environmental plans for the project, including a plan to protect threatened species on Barrow Island, a protection regime for the Flatback Turtle.

The project was originally budgeted at AUS \$11bn (USD \$10bn) but costs have now risen to over AUS \$15bn (USD \$14bn), with the cost of carbon storage alone expected to be AUS \$850m (USD \$770m) in the first ten years.

Western Australia company Cool Energy has developed a new process to liquify the carbon dioxide on the surface before pumping it underground, according to Australian news service ABC.

### Botswana reluctant about Sasol CCS plant

[www.gov.bw](http://www.gov.bw)

The government of Botswana is not very keen to let South African oil company Sasol build a carbon capture and storage plant in Botswana due to concerns about water pollution, according to an article by Botswana Press Agency (December 12).

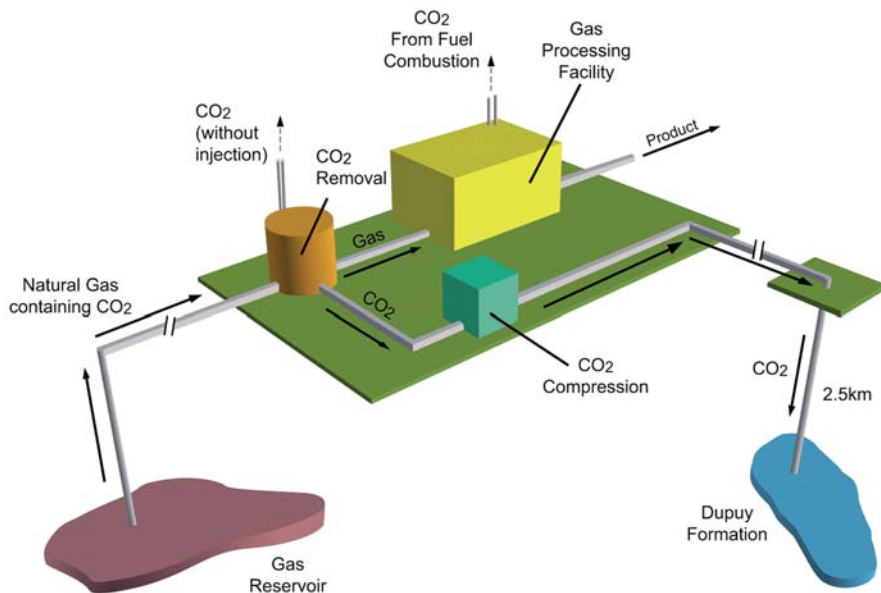
Sasol has approached Botswana's ministry of Wildlife, Environment and Tourism to discuss the issue.

"We have emphasised that all stakeholders need to meet in one forum where this issue and its likely impacts would be discussed," head of the ministry Meteorological Services Department Phetolo Phage was quoted as saying.

"So far it would be too risky to embark on such a project before we know its pros and cons, what if the gas eventually leaks from underground, and what happens to our water?" said Steven Monna, director of Environmental Affairs.

Botswana is also cynical about why Sasol wanted to store the carbon dioxide in Botswana rather than South Africa.

"South Africa has been mining for ages and as such has many big underground caves where they could store their gases."



The Gorgon LNG sequestration project will store around 3 million tons of CO2 per year

### Michigan carbon storage project postponed

[www.kalamazoo Gazette.com](http://www.kalamazoo Gazette.com)

A project by Michigan University to store carbon dioxide 2600 feet underground has been postponed due to objections of a local landowner, according to reports in local paper Kalamazoo Gazette.

The landowner is concerned that the carbon dioxide could migrate to rock under his property.

The landowner complained during the initial permitting process. The US Environmental Protection Agency determined that the objections did not warrant stopping the project, but the landlord then appealed. A response to the appeal is due in early November 2007.

A professor of geosciences at Michigan University said that the carbon dioxide would move a few metres per hundreds to thousands of years.

The University received nearly \$300,000 in government Department of Energy grants for the project.

### Funding commitment for Moomba carbon storage

[www.santos.com](http://www.santos.com)

Australia's Coalition Government will commit \$10 million to fast track development of the Moomba Carbon Storage (MCS) concept.

The project has the potential to become the world's largest CO2 storage facility.

Santos and its joint venture partners will match the federal funding commitment by also contributing \$10 million to advance

what is known as the Front End Engineering and Design (FEED), or project definition, phase of MCS.

FEED would then inform the Final Investment Decision, expected in mid 2008. A positive Final Investment Decision in 2008 would enable CO2 injection to commence in 2010 at a rate of approximately 1 million tonnes per annum.

The initial phase of MCS is a \$700 million project designed to demonstrate the technical and commercial feasibility of securely storing carbon dioxide in depleted oil and gas reservoirs in the Cooper Basin in northeast South Australia and southwest Queensland.

The FEED process will harness extensive knowledge derived through Santos' existing operations to provide enhanced definition around the one billion tonnes of CO2 storage potential in the Cooper Basin.

This funding will also extend that mapping into the carbon storage potential of the depleted oil and gas reservoirs in Santos' south west and eastern Queensland operations.

Subject to the success of the demonstration phase, MCS would then be scaled up to serve as a regional, multi-user carbon storage hub serving eastern Queensland and NSW's Hunter Valley coal fields.

It is projected that these volumes could exceed 20 million tonnes per annum of CO2 for over fifty years.

Moomba's central Australian location, proven geology and connection to existing infrastructure make it uniquely positioned to become a major near-term carbon storage solution for eastern Australia.

## Petroleum Technology Alliance Canada starts

[www.ptac.org](http://www.ptac.org)

Petroleum Technology Alliance Canada and the Alberta Energy Research Institute (AERI) have begun the PTAC CCS Project, to provide design and cost estimates for a CO<sub>2</sub> collection system from different sources in the Fort Saskatchewan area of Alberta, and CO<sub>2</sub> transportation through a common pipeline system.

PTAC has initiated collaboration among 17 producers, transportation companies, and provincial governments which have provided funding for this project and will oversee its implementation through a Steering Committee.

The project will provide design and cost estimates for a CO<sub>2</sub> collection system from different sources in the Fort Saskatchewan area of Alberta, and CO<sub>2</sub> transportation through a common pipeline system.

The project scope will only include the required pipeline infrastructure to aggregate CO<sub>2</sub> to a common location. The study does not include pipelines to enhanced recovery fields at this time.

The Steering Committee believes that sufficient CO<sub>2</sub> exists or will exist in the Fort Saskatchewan area to support commercial scale enhanced recovery of conventional oil

in Alberta.

Conducted by SNC-LAVALIN, the study will evaluate at least three representative CO<sub>2</sub> sources in order to understand what is required to aggregate different quality types of CO<sub>2</sub>.

Several companies have agreed to provide CO<sub>2</sub> quantity and quality information in support of this study. Process design may include CO<sub>2</sub> purification, dehydration and compression requirements.

The project will review the merits of a common compression site to achieve system pressure required for pipeline transport to major oil pools.

Findings of this study will be presented at the PTAC Towards Clean Energy Production - Managing GHGs While Minimizing Costs and Maximizing Recovery Conference, February 27-28, 2008 at the Telus Convention Centre.

## Stavanger - Gassco carbon transport study

[www.gassco.no/sw9407.asp](http://www.gassco.no/sw9407.asp)

Norwegian international pipeline operator Gassco is pursuing two carbon dioxide projects funded by the Ministry of Petroleum and Industry (MPE) relating to future transport of CO<sub>2</sub> from plants in western Norway.

One of these studies involves a gas-fired power station at Kårstø north of Sta-

vanger, operational autumn 2007, where the target is to have a carbon capture facility in place by 2011/12.

It also covers a similar capture plant to be built by 2014 for a gas-fired power station planned at the Mongstad industrial complex north of Bergen.

The study on the full-scale capture facilities at Kårstø and Mongstad will provide the basis for establishing carbon transport and storage solutions from these plants.

The company's preliminary findings on transport opportunities indicate that a ship-based solution will not be pursued further in this study. Further studies are due to be completed in the spring of 2008.

Another study focuses on a test centre for carbon capture due to be established at Mongstad and scheduled to become operational in 2010. In that connection, the MPE has initiated a separate project to establish a decision base for carbon transport and storage from the test centre.

The solution currently under consideration involves taking carbon dioxide from the Mongstad centre to the Hammerfest LNG plant at Melkøya in northern Norway.

This would link with the existing subsurface carbon storage system which forms part of the Snøhvit gas development in the Barents Sea.

## Transport and storage research

### Research shows faster reactions for injected fluids

[reporter.leeds.ac.uk/press\\_releases/current/carbon\\_dioxide.htm](http://reporter.leeds.ac.uk/press_releases/current/carbon_dioxide.htm)

University of Leeds research shows that porous sandstone, drained of oil, reacts with injected fluids more quickly than had been predicted.

Such reactions are essential if stored CO<sub>2</sub> is not to leak back to the surface.

The study looked at data from the Miller oilfield in the North Sea, where BP had been pumping seawater into the reservoir for enhanced oil recovery (EOR).

As oil was extracted, the water that was pumped out with it was analysed and this showed that minerals had grown and dissolved as the water travelled through the field.

Significantly, PhD student Stephanie Houston found that water pumped out with the oil was especially rich in silica. This showed that silicates, usually thought of as very slow to react, had dissolved in the newly-injected seawater over less than a year.

This is the type of reaction that would

be needed to make carbon dioxide stable in the pore waters. The study gives a clear indication that carbon dioxide sequestered underground could also react quickly with ordinary rocks to become assimilated into the deep formation water.

The work was supervised by Bruce Yardley, Professor in the School of Earth and Environment at the University, who explained, "If CO<sub>2</sub> is injected underground we hope that it will react with the water and minerals there in order to be stabilised."

"That way it spreads into its local environment rather than remaining as a giant gas bubble which might ultimately seep to the surface."

"It had been thought that reaction might take place over hundreds or thousands of years, but there's a clear implication in this study that if we inject carbon dioxide into rocks, these reactions will happen quite quickly making it far less likely to escape."

### DECARBit project to investigate cheaper capture technologies

[www.sintef.no](http://www.sintef.no)

New EU-funded research on pre-combustion

carbon capture technologies for gas and coal fired power plants is about to begin.

The four-year DECARBit project, supported by the Seventh Framework Programme (FP7), will be coordinated by the independent Norwegian research organisation SINTEF and involve 14 partners from eight different countries.

SINTEF forms part of the Norwegian branch of the European Innovation Relay Centre Network, assisting companies and research organisations in areas of technology transfer, license agreements, intellectual property rights (IPR) and in identifying sources to finance innovation.

It is involved in various EU-funded projects, including five in the area of CO<sub>2</sub> handling, but also in other fields of research.

Norway has been a major player in the development of carbon capture and storage (CCS) technologies and according to SINTEF, it is thanks to this experience, as well as intense national collaboration between itself, StatoilHydro and the Norwegian University of Science and Technology (NTNU), that Norway has been highly successful in gaining EU support for research.

## Bureau of Economic Geology receives funding for large scale U.S. storage test

[www.beg.utexas.edu](http://www.beg.utexas.edu)

The Bureau of Economic Geology at The University of Texas at Austin has received a 10-year, \$38 million subcontract to conduct the first intensively monitored, long-term project in the US studying the feasibility of injecting a large volume of CO<sub>2</sub> for underground storage.

The project is designed to build public assurance about the use of carbon sequestration. The project is a phase III research program of the Southeast Regional Carbon Sequestration Partnership (SECARB).

It will study the feasibility of injecting large volumes of CO<sub>2</sub> at high rates into deep brine reservoirs.

The project has been designed to develop best practices for future large-volume injections by gathering a greater variety of subsurface data than any previous experiments.

Key issues include estimating the CO<sub>2</sub> storage capacity of brine reservoirs, understanding the effects of injection pressure and developing methods for documenting retention of CO<sub>2</sub> in the injection zone.

The project will use the Tuscaloosa-Woodbine geologic system that stretches from Texas to Florida. The region has the potential to store more than 200 billion tons of CO<sub>2</sub> from major point sources in the region, equal to about 33 years of U.S. CO<sub>2</sub> emissions overall at present rates.

Beginning autumn 2008, the project will inject CO<sub>2</sub> at the rate of one million tons per year, for up to 1.5 years, into brine up to 10,000 feet below the land surface near the

Cranfield oil field about 15 miles east of Natchez, Mississippi.

Monitoring equipment will measure the ability of the subsurface to accept and retain CO<sub>2</sub>. The study will be supported by Denbury Resources' CO<sub>2</sub> enhanced oil recovery operations at Cranfield. Denbury Resources will supply CO<sub>2</sub> from its Jackson Dome.

The bureau's Gulf Coast Carbon Center, an industry-academic partnership, has been developing expertise to design and conduct carbon sequestration tests since 1998.

Gulf Coast Carbon Center sponsors include KinderMorgan, BP, Chevron, Praxair, NRG, Entergy, Schlumberger, Marathon Oil Corporation, Shell, Luminant, Lower Colorado River Authority, Austin Energy and the Jackson School of Geosciences at The University of Texas at Austin.

The project will involve 20 research partners worldwide, including the University of Mississippi, Mississippi State University, Schlumberger, Advanced Resources International, Southern Company and four national labs.

## £2.3m UK government funding for Edinburgh research

The UK government is providing "the bulk" of £2.3m funding for an Edinburgh University and ScottishPower research project into carbon capture beneath the Firth of Forth, Scotland, according to a BBC report.

The project will look for the best sites for storing the carbon dioxide, which will come from the Longannet power station, Scotland's largest source of greenhouse gas.

The carbon dioxide will be pumped into sandstone under the Firth of Forth, and tests made to see if it stays there.

## French-Norwegian research cooperation

[www.france.no/co2/welcome.html](http://www.france.no/co2/welcome.html)

As a result of an expert seminar 22-24 November 07, Norwegian and French researchers will now cooperate more closely on developing solutions for the capture and storage of CO<sub>2</sub>.

A number of project proposals were defined which will allow companies and organisations from the two countries to have more impact in the EU research programs.

Norway's goal is to reduce emissions by 30 per cent by 2020, while France, like the rest of the EU, is aiming for a 20 per cent reduction by 2020. By 2050, Norway intends to be climate neutral, while France aims to reduce its emissions to a quarter of their current level.

The most important proposals are:

- The launch of a forum to discuss the suitability of various CO<sub>2</sub> capture technologies

- A possible EU project to look into transporting CO<sub>2</sub> from Normandy to the North Sea for storage

- Various forms of cooperation between large scale demonstration projects in France and Norway

- Mutual participation in projects to develop technology or industry standards

- A common research seminar to discuss CO<sub>2</sub> to be arranged by IFP and NTNU (Norwegian University of Science and Technology) in the spring of 2008.

The seminar was held in Alstom Norway's offices in Oslo and was organised by the French embassy in Norway in cooperation with Alstom, Det Norske Veritas (DNV), the Research Council of Norway, the French-Norwegian Foundation (FNS) and Total, with support from StatoilHydro and Gaz de France (GdF).

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