carbon capture journal

November / December 2008 Issue 6

First oxyfuel pilot begins at Vattenfall's Schwarze Pumpe plant

Putting a value on CCS investments

Developing a risk management framework

Last Chance for Coal - Green Alliance report

Alberta Energy Minister Mel Knight on CCS in Canada

Developing a large-scale CCS network in Western Canada

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Front cover: Vattenfall officially inaugurated the Schwarze Pumpe pilot plant on September 9. The plant is the result of Vattenfall's and Alstom's combined efforts in the development of CCS technologies, and is the first pilot plant in the world to demonstrate oxyfuel combustion for carbon capture and storage

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Contents

Implementing tomorrow's technology today

Alberta is pushing forward with ambitious plans to reduce CO2 emissions by up to five million tonnes annually by 2015. This can only be done through a joint commitment from industry and government.

By The Honourable Mel Knight, Minister of Energy, Alberta, Canada

While other jurisdictions talk, Alberta acts. That's the Alberta government's approach to reducing carbon emissions, while maintaining our province's competitive, economic advantage.

In fact, the province is backing its belief that now is the time for action with a CDN $2 billion investment to kick-start large scale carbon capture and storage (CCS) projects in Alberta. This funding on CCS is unprecedented for a single jurisdiction—especially one of about 3.5 million people.

The funding is available for projects that have viable, economic plans to capture, transport and safely store the CO2.

Through this funding, the province's goal is to reduce CO2 emissions by up to five million tonnes annually by 2015.

Everyone, be it large industry or individual consumers, contributes to the CO2 challenge and that's why all need to be a part of the solution.

That is why the solution is two-fold: improved, cleaner production techniques, including the implementation of CCS technologies and wise use of energy resources. This isn't a solution government can implement on its own.

Alberta, like many jurisdictions throughout the world, has decided that CCS is the path forward. Earlier this year, the Alberta government asked industry leaders, representatives from academia and government experts to be a part of the Alberta Carbon Capture and Storage Development Council.

The Council, under the leadership of Jim Carter, former president of Syncrude Canada Ltd. who also has experience in the electricity sector, has been tasked with developing the best strategy on how to move ahead quickly and effectively with CCS projects.

Carter and the other Council members understand that Alberta is uniquely qualified and positioned to make CCS work because of large point source emitters, the abundance of disposal sites and existing expertise in compressing gas, moving it through pipeline systems and injecting it into deep reservoirs.

Alberta has been doubly blessed with the Western Canadian Sedimentary Basin, as not only does it provide the majority of the province's conventional oil, gas and oil sands resources, its depleted reservoirs are ideally suited for housing CO2 long-term.

It's also worth noting that current oil production technologies leave 70 per cent of oil in the ground. CCS is the technology that will enable oil producers to enhance recovery from existing conventional oilfields and help us increase production by up to two billion barrels.

Enhanced oil recovery (EOR) has been used in the oil patch on a small scale for about 20 years, resulting in increased recovery from existing pools, helping Alberta meet greater energy demands.

Meeting the challenges

The Council has been meeting monthly, while sub-groups meet more frequently to discuss the details around the complex regulatory issues and technology details required to move ahead with large-scale CCS projects.

The complexity of CCS reaches far beyond these technical issues. The Council is taking a collaborative approach to creating a set of best practices because of the complex interaction of the economics, technology and regulatory aspects of this emerging technology.

It is grappling with issues like long-term storage liabilities, how to close the cost gap between the implied or real cost of carbon, not to mention the cost of implementation and how to develop a monitoring, measurement and verification program.

The Council's interim progress report was released in October and members met with industry stakeholders so they could provide feedback. This input will be invaluable as the Council works to complete its final report, which it hopes to finalize by the end of the year.

My colleagues and I are looking forward to the council's recommendations on how to best implement the regulatory elements required to capture, transport and permanently store carbon on a grand scale.

While the Council has been carrying on with its efforts, the province is proceeding with the process to allocate the $2 billion fund for steel-in-the ground CCS projects.

More than 50 companies submitted an expression of interest (EOI). Government officials from a variety of ministries have closely examined the EOIs and asked for full project proposals from those applicants with end-to-end projects that are best positioned to help Alberta reach its emissions reduction goals.

"Everyone, be it large industry or individual consumers, contributes to the CO2 challenge and that's why all need to be a part of the solution" - The Honourable Mel Knight, Minister of Energy, Alberta, Canada.

Applicants selected for funding will be notified in 2009. The Council has not been involved in the selection process.

Alberta expects that its significant investment in CCS projects will pay long-term dividends for our province through the expansion of this marketable technology, and by helping to support our province's energy-based economy. CCS is an extremely costly technology and like so many emerging technologies, it is expected to become less expensive as more is learned and its use becomes more common throughout the world.

Through our investment and the projects it will support, Alberta's goal is to become a centre of CCS excellence and expertise that can then be shared with other jurisdictions to help advance this technology quickly and responsibly.

The chair of our CCS Development Council Jim Carter has likened large-scale CCS development to the building of Canada's national railroad which runs from sea-to-sea. I fully agree with that assessment.

Before it was built, it was incomprehensible to people that Canada could have one railroad running across thousands of kilometres transporting goods and people. CCS is similar, while it may be hard to imagine right now, it has the same power to transform the way our province and the world think about energy.

Through industry and government's joint commitment, CCS is well positioned to promote the long-term environmental and economic sustainability of Alberta's energy sector, while facilitating continued resource development to meet energy demands in the future.

First oxyfuel pilot plant opens at Schwarze Pumpe in Germany

Vattenfall officially inaugurated the Schwarze Pumpe pilot plant on September 9 in the presence of Brandenburg's Prime Minister, Matthias Platzeck, and the Swedish Minister for Higher Education and Research, Lars Leijonborg. The plant is the result of Vattenfall's and Alstom's combined efforts in the development of CCS technologies, and is the first pilot plant in the world to demonstrate oxyfuel combustion for carbon capture and storage.

Built next to Vattenfall's existing lignite-fired 1600 MW Schwarze Pumpe power plant in Germany, the 30 MW pulverized coal demonstration plant, for which Alstom is supplying the oxy-boiler technology, contains all the necessary components to demonstrate the complete oxyfuel chain, starting with oxygen production and ending with CO2 purification and compression.

Following an initial three-year testing programme, the plant is planned to run for at least 10 years.

It will provide the technical basis for the construction of a much larger 200–300 MW demonstration power plant to be completed by 2015.

The erection of the plant and the commissioning of the boiler have been completed and an extensive test program is now underway.

During the first test period, lignite will be the focus of the testing while bituminous coal will be used in a second test period.

The tests will yield essential data on heat transfer, combustion efficiency, emissions, dynamic behaviour, plant design, performance, cost, and economics for both greenfield and retrofit applications, said Alstom.

The oxyfuel technology

Oxyfuel firing technology is a process in which fuel is burned in a mixture of high purity oxygen (≥ 95% by volume) and recirculated flue gas, essentially eliminating the presence of atmospheric nitrogen in the flue gas.

The resulting flue gas contains primarily CO2 and water vapour, along with small amounts of nitrogen, oxygen, and gases like SO2 and NOx.

This resulting flue gas can be processed relatively easily (through rectification or distillation) to enrich the CO2 content in the product gas to more than 99% purity. The CO2 can then be used for industrial applications such as enhanced oil or gas recovery (EOR or EGR).

Alternatively, the flue gas can be dried and compressed for geologic storage, which results in near-zero gaseous emissions from the power plant. This technology is adaptable to the large fleet of existing PC (Pulverised Coal) and CFB (Circulating Fluidised Bed) power plants.

Starting in 1998, Alstom initially completed several studies to investigate the technical and economic viability of the oxyfuel firing concept compared to other CO2 mitigation technologies.

The studies involved both PC and CFB combustion systems, and considered both greenfield and retrofit applications. Concept validation work also included bench scale and pilot scale testing.

Economic evaluations show that purifying the flue gas from oxygen-fired systems can be competitive with extracting the CO2 from air-fired systems with advanced post combustion technologies and would cost less than today's commercial amine technologies.

Central to commercial scale oxyfuel firing technology is the ability to separate oxygen from atmospheric air. The oxygen may be supplied today by a cryogenic air separation unit (ASU), or in the future by more efficient processes such as oxygen transport membranes.

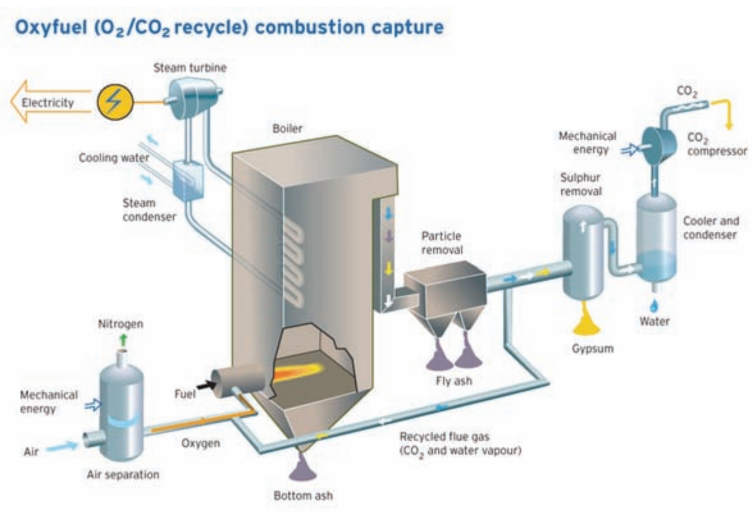
A main challenge lies in the energy required to produce oxygen on a large scale with the current generation of ASUs. Today's cryogenic air separation plants typically require electrical inputs of up to ~18% of the power plant's gross electrical output (~230 kWh/tonne of O2).

However, these figures are extrapolated from ASUs currently operating in industrial applications. Future ASUs for large power plants

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

will be much larger than any existing today; in fact, it's calculated that air separation units approximately four times larger will be required.

Due to economies of scale, these ASUs will require proportionately lower electrical inputs. In addition, new technologies are being actively developed to separate oxygen from air using much less energy, which significantly improves the economics and thermal efficiency of oxyfuel power production.



The oxyfuel process where fuel is burned in nearly pure oxygen

Operating conditions

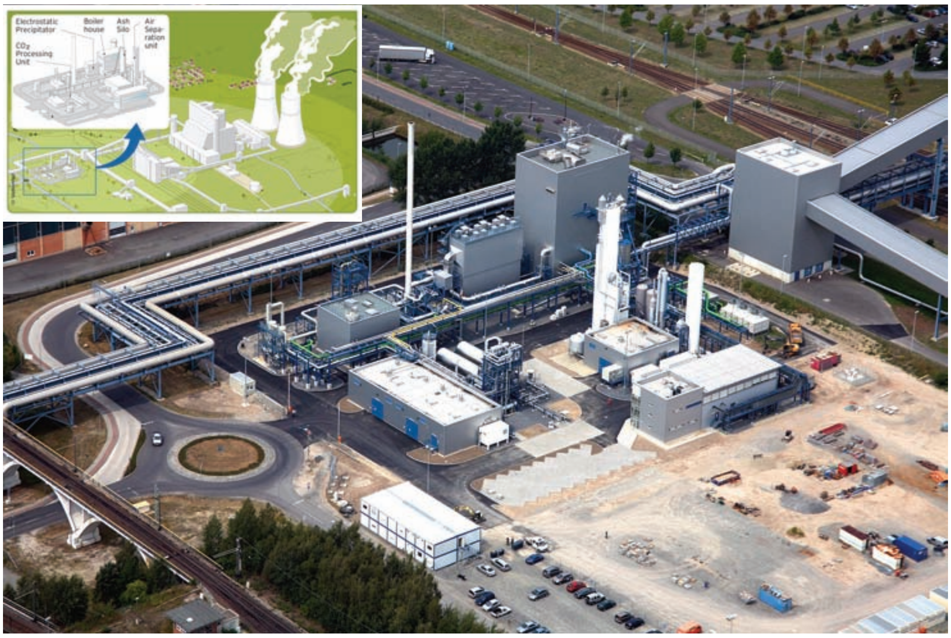
To study the specific characteristics of oxy-fuel firing, the following set of operating conditions will be investigated at Vattenfall at combustion conditions representative for a large-scale plant:

- Combustion and flame characteristics
- Recycle parameters
- Heat transfer
- Materials testing

These measurements for the combustion section and the gas treatment sections for oxygen and air-firing operation are set as validation targets.

General operating experience will also be gained, including load changes and dynamic interaction between the different systems, in particular the recirculation system operation, the ASU system and the CO2 compression and purification systems.

These results will serve as a basis for defining further equipment testing to provide the input for designing the commercial scale plant.



The pilot plant at Schwarze Pumpe in Germany, with an illustration of the component parts. (Image ©Vattenfall, Illustration ©www.kjell-design.com)

Storing the CO2

Through a cooperation agreement signed between Gaz de France and Vattenfall, the CO2 captured at Schwarze Pumpe will be used for enhanced gas recovery and storage at Europe's second largest onshore gas field, Altmark, during a 3-year trial period.

"Following liquefaction by means of pressure and temperature the CO2, at minus 28°C, will be trucked from Schwarze Pumpe to the Altmark region; a distance of around 350 kilometres," said Vattenfall.

When the CO2 has reached its destination it will be loaded into an intermediate storage facility consisting of two tanks with a storage potential of 300 m3 of CO2 each, both maintaining a pressure of 15 bar.

In order to keep the pressure in the tanks constant,evaporators and reliquefiers are installed and connected to the tanks. When the pressure in the tanks decreases, which occurs when liquid CO2 is drawn off from the tank, CO2 from the tanks will be fed into the evaporator where it will evaporate and then be fed back to the tank.

If no CO2 is drawn off from the tank for a while, there is a risk of pressure increase due to the evaporation of CO2 in the tanks because of heat absorption from the surroundings. If this occurs, the CO2 reliquefier is operated to liquefy some of the CO2 in the tank.

CO2 will be injected at depths of 3000 m, and methods will be investigated for extending the natural lifetime of a gas field combined with permanent CO2 storage.

"The CO2 injection plant is designed to enable injection of CO2 of differing aggregates and characteristics," explained Vattenfall.

"This means that CO2 in the liquid, gas and supercritical phases will be injected, and at differing pressures and temperatures within these phases."

This is to see how different CO2 characteristics influence the amount of natural gas that can be recovered from the gas field.

"Using pumps and possibly the heat exchanger, the CO2 will be given the required pressure and temperature and then be injected into a closed-off underground natural-gas-bearing structure," explained Vattenfall.

At full operation about 16 tonnes of CO2 will be injected every hour. Around 100,000 tonnes of CO2 will, according to the plan, be injected into the underground reservoir during the three year test phase.

The first CO2 will be transported to the Altmark project site for injection during the first half of 2009.

Moving to commercial deployment

Alstom believes that oxyfuel firing technology is relatively low risk and can be deployed in the near term for the following reasons:

- It uses proven, reliable, commercially available PC and CFB technology.
- Oxygen can be readily produced by commercial cryogenic distillation air separation processes.
- CO2 cleanup, compression, and liquefaction also uses proven technology

Project economics are also expected to improve as the CO2 value chain is clarified and infrastructure is developed. For these reasons, the development of oxy-fuel firing is important to the electric power industry as an attractive option for carbon capture and sequestration.

Alstom ranks it as a close second to post-combustion, due to the slightly longer ramp-up period needed to validate large scale capture.

The technology also offers retrofit potential and access to difficult fuels with circulating fluidised bed technologies, which is of special interest for the high ash coals used in India, or the recovery of oil from tar sands in Canada.

Developing a portfolio of technologies

According to Alstom, post-combustion solutions such as amine or ammonia should be given a much higher priority in the funded development programs worldwide.

"These technologies are the first ones capable of ensuring the early fast ramp-up needed to achieve the necessary reduction targets to keep climate change within acceptable boundaries," said Alstom

They also have the potential to address the whole range of fuels, from hard coal to lignite to natural gas, thus making them suitable for combined cycle gas turbine units as well as coal plants.

"Other technologies must also be encouraged, as a portfolio of technologies must be developed in order to insure that the large CCS industrial challenge is addressed with the most reliable and cost effective solutions," said Alstom.

"Every effort must be made by governments worldwide to ensure that long-term policies and market regulations are put in place early enough, both for equipment suppliers to plan the necessary production capacities and for the end users to plan power fleet adaptation."

The value of captured carbon

Recent positive developments in the incentivisation of Carbon Capture and Storage are encouraging, but much more needs to be done, not least in the political leadership required to commit to large scale CCS demonstrations.

By Dr. Jim Fitzgerald, Assistant Director, Energy and Environmental Infrastructure Advisory - Renewables at Ernst & Young

The chief advantage of CCS is that it allows the continued use of fossil fuels in industry and energy production.

Most countries will continue to rely on fossil fuels, including coal, oil and gas, as energy sources. CCS is needed to supplement the future large capacity of low carbon energy sources, such as renewable and nuclear energy, as well as incentives for energy efficiency, to achieve the required reduction in carbon emissions.

The G8 group of leaders have recognised the importance of CCS at successive summits. The IEA have subsequently developed alternative energy scenarios and roadmaps to accelerate the development and commercialisation of CCS in accordance with the G8 energy minister's goal to launch 20 full-scale CCS projects by 2010.

CCS is likely to be deployed in its early stages on Enhanced Oil Recovery (EOR) projects, capturing the carbon from gas processing facilities. However, EOR will form just a small part of the large scale deployment of CCS required for future targets to be met.

Demonstration and deployment at scale on large point sources of carbon such as large industrial plants and gas, oil and coal fired power generators – the latter of which is the most carbon intensive form of energy production – is critical to achieving carbon reduction targets.

One of the key underlying drivers and differentiators between individual country roadmaps will be the extent to which they currently depend on fossil fuels, and coal in particular, in their energy mix.

Furthermore, the age of the fossil fuel fired fleet is an important consideration. Many developed countries, in particular, built most of their fossil fuel capacity in the 1970s and 1980s, which are now approaching the end of their economic lives and require replacement.

If those countries wish to maintain their existing diversity of fuel sources and also achieve reductions in carbon emissions, CCS will need to be deployed more urgently than elsewhere.

While international and national CO2 trading schemes place a price on CO2 emissions, the price is currently far below the cost of deploying CCS, which remains unproven at commercial scale. In the medium term, carbon prices are expected to increase to a level where CCS becomes cost effective.

However, in the near term, campaigners and activist investors are increasingly of the view that CO2 should not be emitted at any price and that unabated coal fired power generation capacity should not be constructed.

In Figure 1, the share of coal as a percentage of total electricity produced shows that countries have a wide range of coal dependency.

Poland relies on coal for over 90% of its electricity; China roughly three-quarters of its electricity, with France as little as 5%. In terms of total coal fired electricity produced, the US and China are the world's largest with both over 2,000 TWh of production annually.

In some countries, such as Germany, Spain and Poland the domestic coal industry is viewed as being of strategic as well as social importance and the sector still receives significant subsidy.

The origins of the EC in the 1951 European Coal and Steel Community Treaty (ECSC) (although expired in 2002) is still politically relevant and influences the stance of government on CCS in respective countries.

In Figure 2, the average age of operational coal plant shows the UK fleet to be among the worlds oldest, averaging some 36 years of age, with the newer coal fired fleets of the fast growing Indian and Chinese economies averaging just 20 and 13 years respectively. Assuming broadly consistent useful expected economic lives of 50 years,

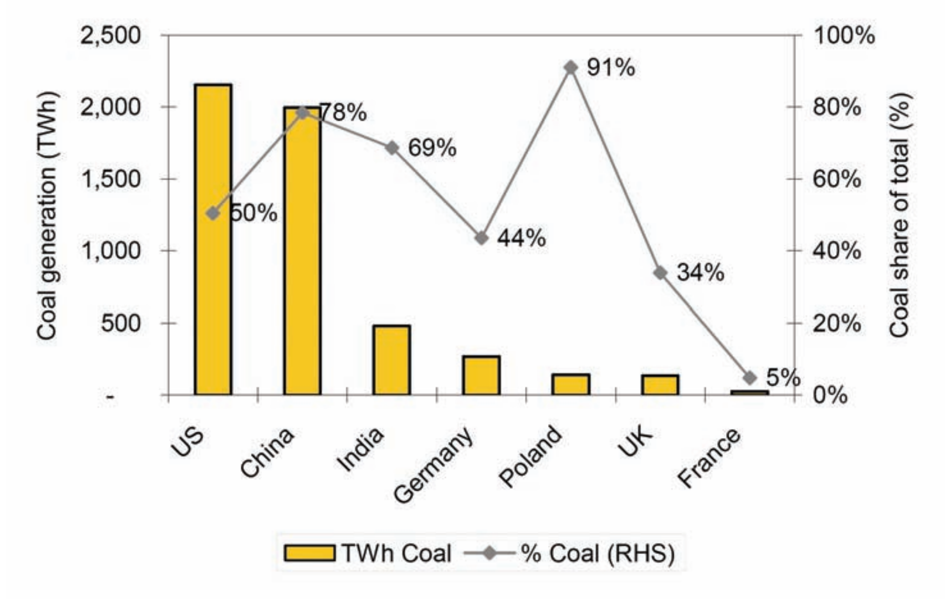


Figure 1: Coal-fired generator fleet size and importance, by country (Source: IEA, 2005)

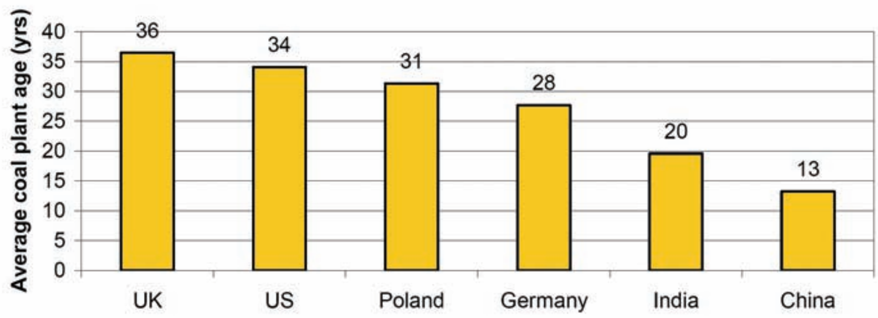


Figure 2: Average coal generating plant age, by country (Source: Platts, US DOE)

the immediacy of the need for constructing new CCS-equipped coal fired generation is therefore highest in countries with older coal fleets, such as the UK, US and Poland.

This may be mitigated somewhat by the historical or future repowering of some of those coal units, and also the impact of other environmental emission restrictions such as the Large Combustion Plant Directive.

The challenge ahead

Significant amounts of carbon-intensive fossil fuel power generators, especially coal-fired units, need to be replaced globally. An amount of this replacement is expected to be through alternative low carbon energy sources such as energy efficiency, renewable and nuclear generators.

Near Term index Rank	Country	Near term index score	Long Term index Rank	Country	Long term index score
1	USA	76	1	USA	71
2	UK	69	2	China	67
3	Canada	65	3	Russia	65
4	Australia	63	3	Germany	65
5	Netherlands	61	5	India	62
6	Norway	59	6	South Africa	60
6	Germany	59	7	Australia	59
8	France	50	8	Canada	58
9	Japan	47	8	UK	58
9	China	47	10	Japan	56
11	Poland	45	10	Spain	56
12	Spain	43	12	Norway	55
13	Russia	41	12	Netherlands	55
14	South Africa	40	14	Poland	49
15	India	39	15	France	47

Table 1: CCS Country Attractiveness Index (Source: Ernst & Young)

The remaining fossil fuel capacity replacement will need to have both increased efficiency and reduced carbon intensity using CCS. Fossil fuel generation with CCS remains unproven at commercial scale, requiring scaling of current pilot and demonstration units to enable widespread deployment. Investment is also required in the infrastructure to transport and store the captured carbon dioxide.

These investments will take time and will require external fiscal stimulus. The gradual ‘glide path’ of CCS deployment due to the long term investment horizon of the energy markets mean that, even with external stimulus, 2015 is the earliest realistic timeframe to expect commercial demonstration and 2020 for wider deployment.

The challenge is to make sure that CCS demonstration is encouraged and enabled as quickly as possible in the markets which can test actual deployment. The importance of the relative attractiveness of CCS investment over both the near and long-term is therefore important to understand.

A CCS Country Attractiveness Index

We have developed an indicative CCS Country Attractiveness Index which compares the relative attractiveness of investing in CCS across fifteen countries in both the near-term and long-term, shown in Table 1.

The Indices are based on the methodology developed by Ernst & Young for measuring the attractiveness of country’s renewable energy markets.

The Indices consider the following factors, on a weighted basis: Energy market regulatory risk; Planning and network connection issues (including public acceptability of CCS); Access to finance; Power off-take attractiveness; Tax climate; Grant/soft loan availability; Market growth potential (storage capacity); Current installed base; Emitting plant age; and Share of fossil fuel capacity (weighting coal higher than oil and gas).

The full methodology and weightings are detailed on our website www.ey.com/utilities

The Long Term CCS index considers structural aspects of the energy market in each country which are expected to impact on large scale CCS deployment beyond 2015.

The near-term CCS index takes a view until 2015 on the attractiveness of investing in CCS demonstration projects. Structural factors are less important for the near-term index and different weightings are therefore applied to the availability of government loans, subsidies and tax incentives

The US tops the list of most attractive countries for investment in CCS in both the near- and long-term. This is because of the importance of coal in the US energy mix and follows the proposed redeployment of the DOE's $1bn Futurgen program, over $300m in funding through Round 3 of the Clean Coal Power Initiative, over $300m in funding through the Carbon Sequestration Regional Partnerships, as well as various state initiatives to incentivise Enhanced Oil Recovery (EOR) using captured carbon.

The UK, Canada, Australia and the Netherlands have all announced major capital contributions to CCS demonstrators through competitions open to all investors and so rank in the top five of our near-term index.

Underpinning a potential increase in the attractiveness score for many European countries is the recent proposal to use ETS auction revenues to fund the planned 12 EU CCS demonstrators. There are also proposed amendments to EC Directives which will enable a common regulatory framework for CCS.

However, many hurdles remain for these proposals before they are implemented, and the attractiveness of investing in CCS in many European countries will not improve until those proposals are implemented.

In the long term index, the five most attractive countries for CCS investment beyond 2015 are the US, China, Russia, Germany and India, which comprise some of the world's largest and most carbon intensive economies. The exception is France which is expected to deploy significant nuclear capacity to decarbonise it's economy.

Delivering on promises

Many national governments have committed to substantial target reductions in carbon emissions by 2050 in line with their international obligations in response to climate change.

The challenging policy implications of delivering these targets are now being more fully understood. In particular, the pricing of environmental externalities such as carbon emissions, which have not historically been reflected in energy markets as currently designed, is now being explored.

For CCS, the primary method of delivery in the medium to long term is expected to be through cap-and-trade systems. However, this presents a funding gap in the near term which, unless filled by direct incentive mechanisms, will result in little or no action in developing CCS to commercial stage, and slowing its eventual deployment.

The proposed allocation of EU ETS allowances to be made available to CCS demonstration projects in a potential EUR10bn fund, together with corresponding programs in countries outside the EU, represent a critical stage in funding this gap.

Once the funding gap is addressed, government faces the challenge of working with the private sector to match investment in CCS demonstrators. Essentially, this is expected to result in the public sector procuring CCS demonstration services in exchange for funding.

This presents a significant challenge for governments to clearly establish the long term strategic objectives for investment in CCS, which vary significantly between countries.

The challenges are being increased by the credit crisis, economic downturn, and falling energy prices. However, there is a significant track record of government working with the private sector to deliver large infrastructure projects.

This demonstrates the benefits of adopting a structured and transparent approach in order to achieve a successful outcome and value for money.

While these Public Private Partnership principles are well established in other sectors, their use in incentivising CCS will initially prove complex and likely vary significantly between countries seeking to address the diverse drivers described earlier.

About the author

Dr. Jim Fitzgerald is an Assistant Director in the Ernst & Young Energy and Environment Infrastructure Advisory group.

Comprising a network of 150 specialists throughout the UK, our dedicated Infrastructure Advisory team focuses on Public Private Partnership (PPP) projects including the Private Finance Initiative (PFI).

The team was awarded "PPP Financial Advisor of the Year 2007" by Infrastructure Journal.

Last chance for coal - Green Alliance report

Green Alliance, an independent charity promoting sustainable development in British politics, has launched a new report, entitled 'a last chance for coal: making carbon capture and storage a reality', which demonstrates the key role of CCS in tackling the twin challenges of climate change and energy security.

Authors in the report argue that CCS gives us a tremendous opportunity to create new jobs and bring wider benefits for UK and European industry.

CCS technology appears to be ready, the report says, but it must be demonstrated quickly at a commercial scale if it is to be deployed more widely.

This demonstration requires dedicated public funding at EU level. Without such European support, the prospects for a global climate deal at the UN negotiations in Copenhagen in 2009 are severely weakened. CCS technology will be crucial for unlocking support in China and the USA.

Green Alliance urged the EU to give financial support to CCS at the crucial vote in the European parliament on 7 October 2008, as an essential step towards securing a global climate deal in 2009.

Critics argue that Europe cannot risk the construction of new unabated coal plants while CCS is being demonstrated. The publication therefore also looks in depth at how Europe can follow California's experience with emissions performance standards for fossil fuel power plants. This would provide regulatory certainty for CCS and secure the future of the EU emissions trading scheme.

Writing in the foreword to the report, former Foreign Secretary Margaret Beckett said:

"A successful outcome to current negotiations over future EU action is a pre-requisite to an effective global agreement in Copenhagen in 2009. We will only succeed if we can secure a low-carbon future for coal."

"This publication illustrates the need for Europe to agree a financial mechanism that can trigger a new wave of investment to demonstrate CCS technology within Europe and beyond. That agreement is vital to kick-starting the European and global CCS industry."

The contributing writers of the report span the political spectrum and provide perspectives from senior positions in business, unions, academia, think tanks and NGOs. Authors include former Dutch Prime Minister Ruud Lubbers, Linda McAvan MEP, Graeme Sweeney of Shell, and Frances O'Grady of the UK Trades Union Congress.

Comments from the parties

At the press launch, representatives of the three major UK political parties gave their views.

Greg Barker (Conservative Party)
"The issue of whether the lights are going out in 2015 is going to rise up the political agenda - it will be discussed at the next general election for the first time in a generation. We can't waste any more time on white papers and policy studies."

"There is scaremongering about the energy gap, but there is a real issue there; we can see this as an opportunity and take advantage of plant coming offline. The worse solution is to lock-in old technology."

"We have to redesign energy for the UK and we need to be far more supportive of CCS; if Darling (UK Chancellor) needs an example of something he should be spending money on it is CCS. We would write the cheques."

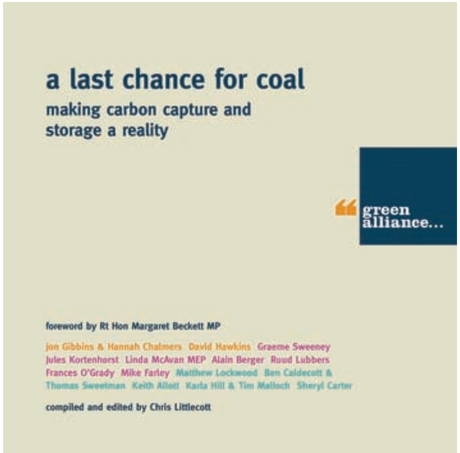
"If Darling (UK Chancellor) needs an example of something he should be spending money on it is CCS. We would write the cheques," Greg Barker, Conservative Party

Martin Horwood (Liberal Democrats)
"CCS is a critical part of our policy, it hardly hangs together without it. We would send a clear signal to industry."

"The Energy Bill is still going through parliament; the Lib Dems tabled an amendment to allow the Secretary of State just to have the power to mandate CCS and a limit on power station emissions. It was rejected."

"Effectively we have gone backwards on CCS; we are against unabated coal and we are against Kingsnorth without mandated CCS."

Elliot Morley (Labour Party; former environment minister)
"In the current financial crisis there is a real risk that climate change is pushed down the political agenda. This would be foolish and short term; it is an integral part of the financial recovery."



"We should not forget that CCS is not a long term sustainable solution; we can't pump CO2 underground forever. But it can give us a short term solution until 2050."

"Nothing will stop India and China using their coal reserves, but we can help them do it in a clean way."

"There are an awful lot of energy intensive industries that can use CCS. Corus in the UK has a furnace test rig on CCS."

"I have been talking to Yorkshire Forward about a CCS pipeline network in South Humberside and about planning permission for a coal fired power station with CCS in the region."

"We can get a first mover advantage that could bring energy intensive industry into the area."

"We should be encouraging both pre- and post-combustion not putting our eggs in one basket; it could be that gasification is a better solution for CCS, we don't know yet."

"Despite difficult financial conditions the PM has talked about spend to save in the energy industry which could create jobs and give our country commercial advantages. It's an opportunity we should not miss."

About Green Alliance

Green Alliance is an independent charity whose mission is to promote sustainable development by ensuring that environmental solutions are a priority in British politics. It works with representatives from the three main political parties, government, business and the NGO sector to encourage new ideas, facilitate dialogue and develop constructive solutions to environmental challenges.
Download a copy of the report at:
www.green-alliance.org.uk

Carbon capture - leading news

EU vote makes CCS 'mandatory' for coal power plants

www.europarl.europa.eu

The European Parliament's environment committee voted to back an emissions limit of 500 grammes of CO2 per kilowatt-hour on all new coal plants built after 2015. This effectively rules out unabated coal after this date.

The so called 'Schwarzenegger clause' will introduce an 'emission performance standard', based on average annual emissions, for new coal power plants with a capacity of more than 300 MegaWatts.

The committee also voted to allow 500 million spare emissions allowances, normally reserved for new entrants into the EU ETS scheme, to be made available as an incentive/financing measure for large-scale commercial CCS demonstration plants.

This provides a funding mechanism for the 12 European demonstration plants. The value will depend on the price of CO2 when the gas is eventually buried underground, but it could exceed €10 billion.

They also asked the Commission to strive to ensure that contracts for the construction of the 12 demonstration facilities are let before the UN meeting in Copenhagen in November 2009 (as promised by the EU Council in March 2007).

The committee has also ring-fenced 100 percent of auction revenues from the ETS, worth as much as €50 billion a year by 2020, for climate related purposes. Half of this is to be earmarked for climate protection in developing countries.

Another fund for monitoring and remediation of closed storage sides has been established. During the period when the CO2 is injected in the underground side, operators will have to pay annual contributions to a fund set up by the Member State where the storage side is located.

MEPs want this fund to cover the costs for monitoring, oversight and remediation after responsibility for a closed storage side has been passed on to the national authority.

The operator will remain responsible for a closed storage side for at least 50 years. After this time responsibility and all legal obligations for the long-term storage of CO2 will be passed from the private operator to the Member State.

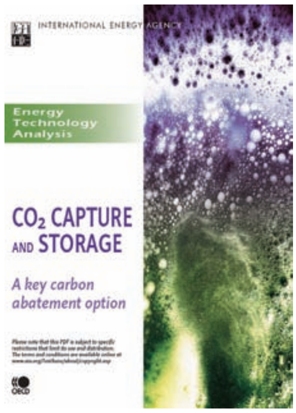
MEPs also want to give Member States more time for transposition of the directive into national law, allowing not one but two years after the directive's publication.

The report was adopted with 54 votes in favour, one against and six abstentions.

IEA releases major new CCS study

www.iea.org

The IEA has urged a quick and global push to develop and deploy CCS technologies in a new study 'Carbon Dioxide Capture and Storage: A Key Carbon Abatement Option'.



The study demonstrates that CCS can deliver cost-effective emissions reductions, but governments and industry must come forward to finance large-scale CCS demonstrations and to work together more widely.

"The window of opportunity is closing for the global community to cost-effectively address climate change. CCS technologies must play a key role, but first they must be proven in the next decade", said Nobuo Tanaka, Executive Director of the International Energy Agency (IEA), at the launch of the report in Paris.

"If we do not successfully demonstrate CCS soon, it will raise costs significantly for other climate mitigation options," he continued.

Carbon Dioxide Capture and Storage: A Key Carbon Abatement Option finds that current CCS spending and activity levels are nowhere near enough to achieve the G8 goals.

CCS technology demonstration has been challenged by a global increase in costs and a lack of suitable financial mechanisms to support it.

Foremost, the IEA believes that up to USD 20 billion is needed for near-term demonstrations, in addition to the plants base costs.

Under current energy policies, greenhouse gas emissions are projected to grow rapidly, with a major contribution coming from fossil fuel combustion in power plants and industry.

The IEA, in its 2008 Energy Technology Perspectives (ETP) study, projects that energy-related CO2 emissions would grow by 130% until 2050 in the absence of new policies. This increase would largely be a result of increased fossil fuel usage.

The 2007 Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report indicates that such a rise in emissions could lead to a temperature increase in the range of 4-7 degrees Celcius, with major impacts on the environment and human activity.

There is a large consensus that a halving of energy-related CO2 emissions is needed by 2050 to limit the expected temperature increase to less than 3 degrees. Meeting this formidable challenge will take an energy technology revolution.

The massive changes will involve enhanced energy efficiency, increased renewable energies and nuclear power, and the decarbonisation of power generation from fossil fuels.

In the power and industrial sectors alone, CCS could contribute nearly one-fifth of the reductions needed to halve back greenhouse gas emissions by 2050, and this at reasonable cost.

At the 2008 Hokkaido-Toyako summit, the G8 countries announced that 20 large-scale CCS demonstration projects must be committed by 2010, with a view to broad commercial deployment in 2020.

The Tarong Power Station in Queensland, Australia (Image ©Tarong Energy)

Ministers asked the IEA to assess how much progress will have been made in terms of implementation by that time.

It is also important to integrate CCS into greenhouse gas (GHG) regulatory and incentive schemes. While progress is underway in some countries, no country has yet developed the comprehensive, detailed legal and regulatory framework that is necessary to govern effectively the use of CCS.

Also, CCS is poorly understood by the general public with the result that there is a wide-spread lack of public support for this technology as compared to several other GHG mitigation options.

Next to an updated analysis on the potential, cost and performance of CCS technologies, the study discusses the financial incentive mechanisms that governments can use, and proposes a CCS Roadmap with the necessary technical, political, financial and international collaboration activities to achieve their emissions reduction goals.

"It is now time to act", said Mr. Tanaka. "We hope that this study helps governments and industry to take immediate steps to make a major difference on climate change with CCS."

Mckinsey report says CCS viable by 2030

www.mckinsey.com

The report says that the cost of abating CO2 emissions from a new build coal fire power station could fall to around €30-45 per tonne by 2030.

This is in line with the expected carbon price from auction of allowances in the EU emissions trading scheme, and the cost of other low carbon technologies such as renewables, meaning CCS would be a competitive solution.

However in the short term the price will be €60-90/tonne leaving an economic gap of "0.5-1,1 billion euro per project" which must be filled, through public funds or investment, if CCS is to reach large scale by 2030.

To achieve the 2030 goal, the report says the first commercial projects would have to be started shortly after the demonstration phase.

CSIRO and Tarong Energy in post combustion pilot

environment.alberta.ca

The AUS $5 million project will see the installation of a post-combustion capture (PCC) pilot plant at Tarong Power Station, 45km south of Kingaroy in Queensland, Australia.

The pilot plant is designed to capture 1500 tonnes per year of CO2 from the power station and is part of a broader research program to identify ways to reduce greenhouse gas emissions from the energy sector.

The two-year project will start immediately, with the pilot plant expected to be operational in the first half of 2009 and the research activities associated with the technology completed in 2011.

Director of CSIRO's Energy Transformed National Research Flagship, Dr John Wright, said low emission energy generation was a key research area for the Flagship.

The Tarong trial will focus on assessing the performance of an amine-based solvent. CSIRO and Tarong Energy will each contribute AUS $2.5 million to the project.

The plant is an integral part of the Asia

Pacific Partnership on Clean Development and Climate (APP) program's PCC Flagship Project.

This APP project involves trials at several power stations, including Tarong, a pilot plant installation (based on ammonia) at Delta Electricity's Munmorah power station on the NSW Central Coast and the establishment of a pilot plant at Gaobeidian Power Station in Beijing.

EU founds European Energy Research Alliance

www.eera-set.eu

The Alliance aims to expand and optimise EU energy research capabilities through the sharing of national facilities and the joint realisation of national and European programmes.

It will be a key actor of the EU Strategic Energy Technology Plan (SET Plan) and will contribute to accelerate the development of new low carbon technologies for EU to move toward a low carbon economy, says the EU.

The European Energy Research Alliance (EERA) can be seen as the SET Plan's research community pillar, covering many different disciplines and bringing a multidisciplinary approach to energy research.

It will be supported by reliable information provided by the Commission's European Energy Technology Information System (SETIS).

The founding partners of the EERA have signed a letter of intent outlining its key objectives.

Current members of the EERA are:

- Commissariat à l'Energie Atomique (CEA), France
- Centro de Investigaciones Energeticas, Medioambientales y Tecnologicas (CIEMAT), Spain
- Centre for renewable energy sources (CRES), Greece
- Energy Research Centre of the Netherlands (ECN), Netherlands
- Ente per le Nuove tecnologie, l'Energia e l'Ambiente, (ENEA), Italy
- Forschungszentrum Jülich (FZ Jülich), Germany
- INETI - Instituto Nacional de Engenharia, Tecnologia e Inovação, Portugal.
- Risø DTU National Laboratory for Sustainable Energy, Denmark
- Energy Research Centre (ERC), United Kingdom
- Technical Research Centre of Finland (VTT), Finland
- European University Association (EUA),
- European Heads of Research Councils (EUROHORCS)

Australian carbon storage legislation released

www.premier.vic.gov.au

The Victorian State Government has released Australia's first legislation enabling the onshore injection and permanent storage of carbon dioxide.

Energy and Resources Minister Peter Batchelor said the proposed Greenhouse Gas Geological Sequestration Bill 2008 would ensure onshore greenhouse gas injection and storage were conducted safely and sustainably, and in a transparent and consultative way which met community expectations.

"This draft Bill provides investors with a clear signal that Victoria is committed to the development of carbon capture and storage (CCS), while also protecting private landholders, public health and the environment," Mr Batchelor said.

He said it would allow the government to continue to use low-cost energy through the state's brown coal resource.

"This Bill provides the legal framework for the sustainable and timely development of CCS (carbon capture storage), providing confidence for the community and it will be complemented with the proper checks and balances," Mr Batchelor said.

"Under this Bill, applications for greenhouse gas injection and storage projects can only be granted when the approving minister is satisfied the operations will pose no risk to public health or the environment."

"The Bill also includes protection measures for private landholders and provision for thorough consultation with the community, including relevant municipal councils, and public and private landholders in areas where greenhouse gas injection and storage activities are proposed."

He added that the consent of private land owners and a compensation agreement would be required for any CCS activities on private land.

"Greenhouse gas injection and storage will also be barred in wilderness areas and marine national parks and marine sanctuaries with the highest conservation values," Mr Batchelor said.

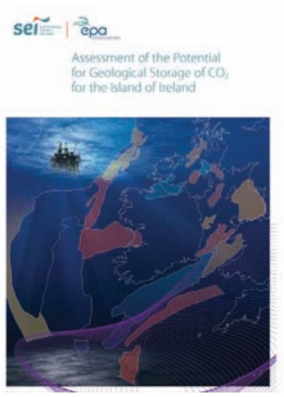
Study on CCS in Ireland released

www.slrconsulting.com

Dublin-based natural resources consultancy SLR Ireland has led a study into the potential for CCS in Ireland.

The study was commissioned by Sustainable Energy Ireland (SEI) and the Environmental Protection Agency (EPA) and is the first major carbon capture and storage study in Ireland.

"The Assessment of the Potential for Geological Storage of CO2 for the Island of Ireland" study was launched in Dublin at an event attended by Eamon Ryan, the Minister for Communications, Energy and Natural Resources, as well as Brendan Halligan, Chairman of SEI and Dr Mary Kelly, Director General of the EPA.



The study team included other international experts from BGS, CO2CRC and Byrne Ó Cléirigh.

The report identifies the large point sources of CO2 on the island of Ireland and modelled the potential geological structures where captured CO2 could be stored.

The optimal transportation infrastructure between the sources and storage locations for a number of cases were also considered.

Each scenario was modelled economically to provide reasoned cost estimates for construction of power planted fitted with carbon capture matched with appropriate storage sites.

Eni and Enel sign CO2 capture agreement

www.enel.com

The two companies are joining forces to implement Italy's first project for the capture, transport and geological sequestration of carbon dioxide.

Eni CEO Paolo Scaroni signed the agreement for Eni and Enel to work together on Italy's first CCS project.

Enel is to build a CO_2 capture and liquefaction plant in Brindisi, whereas Eni will inject the liquefied gas within the Stogit exhausted field at Cortemaggiore (Piacenza).

Eni CEO Paolo Scaroni and Enel CEO Fulvio Conti signed a strategic cooperation agreement at the Headquarters of the Ministry of the Environment.

At the same time Eni, Enel and the Environment Ministry signed a Memorandum of Understanding aimed at the verification and diffusion of CO_2 capture techniques and at the promotion of renewable sources.

Enel is currently completing Italy's first industrial CO_2 capture plant, capable of removing 2.5 tonnes of gas per hour, at the Brindisi thermal power station. The pilot plant will be ready in the autumn of 2009.

Eni has also started to implement the capture project which is aimed at injecting about 8,000 tonnes of CO_2 per year at the Stogit exhausted field at Cortemaggiore (Piacenza).

The integration of the two projects is set to start in the autumn of 2010. In order to gain experience in the pipeline transport of CO_2 as well, Enel and Eni have also decided to lay a pilot dense-phase CO_2 transport line at the Brindisi site.

The integrated project will also allow to develop skills over the whole CO_2 capture, transport and sequestration process chain, to be applied subsequently to large-scale demo projects.

In order to achieve this goal, the agreement also foresees that Enel and Eni will undertake a detailed feasibility study for the construction of a large-scale integrated demo plant for an Enel's clean-coal power station to be proposed as a candidate for the demonstrative European programme.

Enel and Eni will also prepare a joint study of the Italian CO_2 storage potential. During the implementation of these activities, Enel and Eni will also rely on the cooperation initiatives already in place with the main Italian research bodies and institutes which are already active in the field.

Norwegian government allocates NOK 1.9 billion to CCS

www.regjeringen.no

The Norwegian Government has proposed an allocation of over NOK 1.9 billion in 2009 to CCS, through projects at Mongstad and Kårstø, research and development of CCS technologies and international projects.

StatoilHydro operations at Kårstø (Photo: Øyvind Hagen / StatoilHydro)

An allocation of NOK 920 million is proposed to fund the State's share of investments in the Test Centre Mongstad, while NOK 190 million will go on planning of the CO_2 capture plant at Kårstø.

The investment decision for Kårstø is planned to be taken at the end of 2009. A budget of NOK 570 million has been proposed for the planning and preparations of the transportation and storage of captured CO_2.

CLIMIT, the national programme to fund research, development and demonstration of CCS technologies, will be allocated approximately NOK 150 million in 2009.

An allocation of NOK 20 million will go to fund the Ministry of Petroleum and Energy's work to promote CCS internationally.

Policy, company and regulation news

US government report says CCS needs national strategy

www.globalwarming.house.gov

A Government Accountability Office report says carbon sequestration technologies won't significantly advance until a national strategy to regulate carbon emissions and interagency cooperation measures are established.

"If carbon sequestration technologies are going to get off - and into - the ground, we must have national limits on global warming pollution and an administration dedicated to promoting climate-friendly technologies," said Chairman Edward J. Markey (D-Mass.) of the Select Committee on Energy Independence and Global Warming, who requested the study.

The report says a lack of a national strategy to control carbon dioxide emissions has hamstrung efforts to expand CCS technologies, saying it leaves the power sector with "little incentive to reduce their emissions . . . [and] little reason to devise the practical arrangements necessary to implement the reductions."

It also points to a lack of coordination among agencies involved in developing and regulating CCS infrastructure in the United States, for example with pipeline transportation of carbon dioxide emissions.

A national CCS program "would require an elaborate network of interstate CO2 pipelines" that would involve many agencies and jurisdictional issues, the report notes. To date, however, "no federal agency has claimed jurisdiction over siting, rates, or terms of service" for the pipelines, according to the GAO.

In addition, the report finds that a lack of clear liability and ownership rules for underground carbon dioxide injection is an obstacle to expansion of CCS technologies, but that the administration has provided little or no leadership in developing such rules.

Australian government report says CCS is affordable

www.treasury.gov.au

The Australian government has released "Australia's Low Pollution Future: The Economics of Climate Change Mitigation", a new report into how CCS would affect the Australian economy.

The report says that Australia and the world could continue to prosper while making the emission cuts required to reduce the risks of dangerous climate change.

"Even ambitious goals have limited impact on national and global economic growth."

The report found that real household income continues to grow, although households would face increased prices for emission-intensive products, such as electricity and gas.

The Australian Treasury's modelling also demonstrates that early global action is less expensive than later action; that a market-based approach allows robust economic growth into the future even as emissions fall; and that many of Australia's industries will maintain or improve their competitiveness under an international agreement to combat climate change.

The report also found that there are advantages to Australia acting early if emission pricing expands gradually across the world: economies that defer action face higher long-term costs, as global investment is redirected to early movers.

It promotes a flexible market-based approach to financing, such as emissions trading, which would allow the market to respond as new information becomes available.

Biofuels Power in biomass CCS pilot

www.biofuelspower.com

Biofuels Power Corporation will manage a pilot project in Houston to use biomass to generate electricity and store the resulting CO2 in several abandoned oil wells.

The project will use wood chips and other refuse from Hurricane Ike cleanup activities in the metro Houston area to fuel a pilot scale power generation and carbon sequestration project that will be connected to the grid and provide up to 4 MW of electricity for Houston.

The other operating partners in the project are DSMC of Humble, Texas, a waste wood storage facility owner that served as a primary disposal site for the City of Houston's Hurricane Ike cleanup effort and controls an initial source of waste wood that will serve as fuel for the project, and Texoga Technologies Corporation, a consulting firm that will provide oil well retrofit and carbon sequestration expertise.

The pilot project will be installed on a

6-acre site near Humble, Texas that is controlled by DSMC, lies on top of the Humble Salt Dome and includes several abandoned oil wells that can be retrofitted for exhaust gas sequestration.

Under the preliminary agreements, Biofuels Power will contribute a 2.5 Mw steam turbine, a 1.5 Mw diesel electric generator and transformer and grid interconnect equipment in exchange for a 30% equity interest in the project; DSMC will contribute a ten year lease on the Humble property, infrastructure and waste wood in exchange for a 30% equity interest; and Texoga will contribute oil well retrofit and carbon sequestration consulting services in exchange for a 10% equity interest. Tax credit financing partners will own the remaining 30%.

EU tenders for €1 million CCS network

ec.europa.eu

The European Commission has launched a call for tender to establish a network of projects to demonstrate the use of CC-Stechnology in power plants.

The selected contractor will assist the commission in ensuring that the network allows early-movers to exchange information and experience from large-scale industrial demonstration of the use of CCS technologies and optimise costs through shared collective actions.

The successful operation of demonstration projects is crucial for the wide-scale commercial application of CCS.

The deadline for submission of tenders is Oct 6, 2008 and the selection process should be completed by the beginning of 2009, said the commission.

UK to co-operate with UAE Masdar project

www.masdaruae.com

The UK and Masdar, the Abu Dhabi owned clean energy company, have signed an agreement to co-operate on the development of technologies including CCS.

The memorandum of understanding covers work on low carbon energy such as wind, wave and solar power, CCS and energy efficient buildings.

The Linde Group and Vattenfall form technology partnership

www.vattenfall.com/ccs

The Linde Group and Vattenfall Europe Technology Research have entered into a wide-ranging technology partnership for carbon dioxide separation in coal-fired power stations.

The aim of the collaboration is to test the oxyfuel combustion process for lignite and anthracite and to develop the technology for subsequent use in large power stations.

The tests are being conducted at the research facility for a coal-fired power station using carbon dioxide capture technology in Schwarze Pumpe in Brandenburg, Germany, recently officially inaugurated by Vattenfall.

Linde has built an air separation plant and a carbon dioxide liquefaction plant for this pilot power station. Linde is supporting Vattenfall, providing extensive scientific and technical expertise during the first trial phase to the end of 2011.

At the research facility, a variety of tests and experiments will be conducted during the operation of the pilot plant. These will create a better understanding of the entire oxyfuel combustion process and of the reaction of individual components within the process chain.

Under the technology partnership, Linde will take delivery from Vattenfall of around 4,000 tonnes of liquefied CO2 per annum from the research facility and market it.

Both companies also intend to work together to develop further possible applications for the separated liquefied CO2 which is not required for the storage projects.

Rather than being stored, the separated CO2 could be channelled into another constructive application, which would avoid expending large amounts of energy on manufacturing the product for that application, explained Vattenfall.

New report says US must make CCS mandatory for new coal plants

A new report, "Coal Power in a Warming World", from the Union of Concerned Scientists, urges the US to push forward with pilots for CCS, as well as investing in efficiency, renewable power, and energy storage.

www.ucsusa.org

The US must immediately stop the construction of coal plants that do not employ CCS technology, by implementing federal policies that include a CO2 performance standard and a cap-and trade program to render coal plants without CCS a financial liability, according to the report.

"Given the significant potential CCS technology has for reducing global warming pollution, the United States should undertake a demonstration program of 5 to 10 commercial-scale CCS projects, which will enable us to determine the technology's merits as quickly as possible."

The report goes on to say that for CCS to play a major role in reducing CO2 emissions, an enormous new infrastructure must be constructed to capture, process, and transport large quantities of CO2.

It also stresses that CCS is yet to be demonstrated in the form of commercial-scale, fully integrated projects at coal-fired power plants, and that such demonstration projects are needed to determine the relative cost effectiveness of CCS compared with other carbon-reducing strategies, and to assess its environmental safety — particularly at the very large scale of deployment needed for CCS to contribute significantly to the fight against global warming.

It also says that coal-to-liquids technology, even using CCS technology, would greatly increase CO2 emissions. Coal-to-gas technology could either increase CO2 emissions or decrease them depending on whether it displaces other uses of coal.

The key recommendations of the report are that the US should:

Increase research and development (R&D) for CCS to evaluate the technology's potential in the fastest way possible. The United States should fund 5 to 10 full-scale, integrated CCS demonstration projects at coal-fired power plants, using different types of generation and capture technologies and different types of sequestration sites.

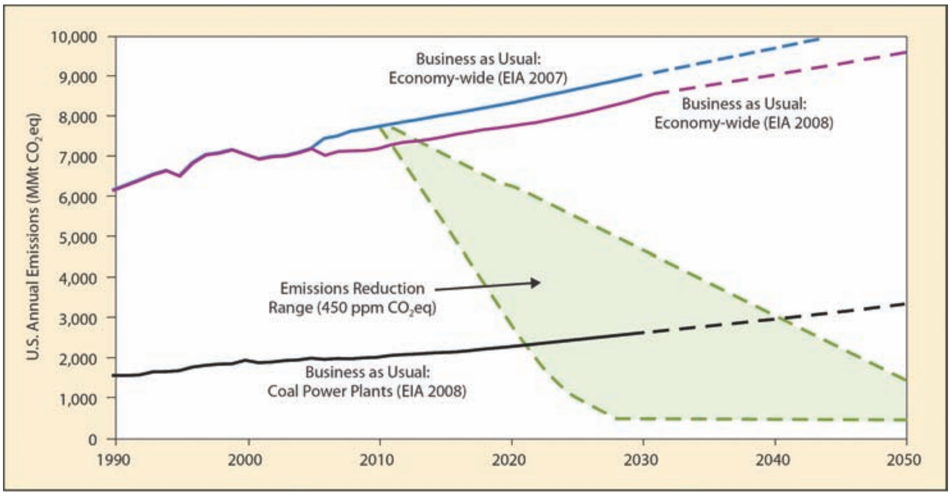
Investing in demonstration projects is warranted given the promise this technology holds and is needed to determine whether wider deployment is appropriate, but it is premature to provide incentives for widespread deployment.

These demonstration projects (and a detailed survey of possible sequestration sites) should be funded initially by a modest fee paid by operators of existing coal plants

and later by a small portion of the revenue generated by auctions of pollution allowances under a cap-and-trade program.

Support should be focused on CCS demonstration projects that actually reduce emissions from existing coal plants. In addition, the demonstration program should include the development of regulatory protocols for selecting and monitoring sequestration sites.

As the technology becomes proven at commercial scale, it should be eligible to compete against other carbon-reducing technologies for funds intended to accelerate deployment.



Rising Coal Emissions Compared with Needed U.S.Economy-wide Emissions Reductions by 2050
If CO2 emissions from coal-fired power plants continue to rise at rates projected by the U.S. Energy Information Administration, it will be impossible for the United States to achieve the steep economy-wide emissions reductions it needs to have a reasonable chance of avoiding the worst effects of climate change. In fact, projected emissions from coal plants alone could exceed the level of total global warming emissions we can afford for the entire economy—including the transportation, residential, commercial, industrial, and agricultural sectors—between 2020 and 2040. The United States would need to reduce its total emissions at least 80 percent below 2000 levels by 2050 to achieve the range of reductions shown in the figure, says the report.

Stop building new coal-fired power plants without CCS.

Each new coal plant built without CCS represents a major long-term source of CO2. It is not safe to assume that new coal plants built today without CCS could cost-effectively add it later, because the cost of CCS (considerable even when included in the plant's original design) would be much higher if added as a retrofit.

The federal government should therefore adopt a strong performance standard limiting CO2 emissions from new coal plants, which will prevent the construction of any plant not employing CCS from the outset.

Until such a policy is put in place, state regulators should evaluate proposed plants using a projected range of prices those plants would likely have to pay for their CO2 emissions under a cap-and-trade program.

Stop investing in new coal-to-liquid plants and reject policies that support such investments.

Coal-to-liquid technology cannot reduce CO2 emissions (compared with petroleum-based fuels), but it could greatly increase those emissions. It should not, therefore, have any part in our energy future.

All transportation fuels should be held to a low-carbon performance standard that limits global warming pollution and provides safeguards against other environmental damage.

Ensure that any coal-to-gas plants employ CCS and that the resulting fuel is used to offset coal use rather than natural gas use.

Because coal-to-gas plants could either help or hinder our efforts to fight global warming, regulations are needed to ensure that this technology leads to CO2 reductions, not increases.

Significantly increase both deployment of and R&D for energy efficiency and renewable energy.

States and the federal government should adopt policies such as renewable electricity standards, energy efficiency programs, and appliance efficiency standards that would accelerate the deployment of energy efficiency and renewable energy technologies.

The federal government should also greatly expand its R&D and demonstration funding for these technologies (including energy storage technologies). Federal research money has long focused disproportionately on coal and nuclear power, greatly underfunding inherently cleaner technologies despite their tremendous potential. Given the urgency of the threat posed by global warming, this underfunding must be corrected.

In combination, these deployment and R&D investments in energy efficiency and renewable energy will minimize the near-term cost of reducing carbon emissions, buy time until the cost-effectiveness of CCS can be demonstrated at commercial scale, ensure a diverse set of long-term low-carbon options, and avoid perpetuating the undue advantage coal has long had over cleaner energy technologies.

Adopt statutes and stronger regulations that will reduce the environmental and societal costs of coal use throughout the fuel cycle.

The use of coal, from mining through waste disposal, has serious impacts on the safety and health of both humans and our environment. Policies are needed to reduce these impacts and place coal on a more level playing field with low-carbon alternatives.

This would include a ban on mountaintop removal mining and tougher standards for mercury emissions, mine safety, and waste disposal. Any federal policy that promotes coal use, including ongoing or expanded CCS subsidies, must be accompanied by such measures.

Put a price on CO2 emissions by adopting a strong economy-wide cap-and-trade program

This, in concert with other policies, will drive emissions reductions from existing coal plants and help ensure that the price of coal reflects its true costs.

The revenues generated by the auction of pollution allowances under this cap-and-trade program should be used to 1) augment deployment of the most cost-effective low-carbon technologies and 2) provide assistance to communities and workers affected by any coal plant or mine closures.

Ensure the transfer of low-carbon technologies to other countries

Especially developing countries such as China and India to reduce the serious threat posed by the world's expanding use of coal without CCS.

The United States should also provide financing for the international deployment of low-carbon technologies such as integrated gasification combined cycle (IGCC) and CCS (where such technologies are cost-effective relative to other low-carbon alternatives).

Developing a large-scale CCS network in Western Canada

In his recently completed master's thesis, Christian Bang concluded that the implementation of a large-scale CCS network in conjunction with EOR represents the most cost-effective technology for dramatically reducing Canada's GHG emissions in both the short and long term, while at the same time allowing development of the vast oil sands operations in Alberta. In this article, he summarises the principal findings, highlights potential hurdles, and presents possible solutions.

Niels Christian Bang, Roskilde University, Department of Environment, Technology and Social Studies

The Western Canadian Sedimentary Basin (WCSB), an area consisting of Alberta, Saskatchewan and parts of Manitoba and British Columbia is ideally suited to long-term CO2 sequestration, with total potential storage capacity within this area thought to be in the neighbourhood of 1 000 gigatonnes (Gt).

At current emission rates the WCSB would thus have enough storage capacity for Canada's cumulative emissions well into the year 4000.

While the vast majority of this capacity is within 'non value added' sites such as deep saline aquifers, of greater interest are the 'value added' sites which refer to CO2 storage options with a negative cost; that is sites where the injection of CO2 results in an economic payout such as via Enhanced Oil Recovery (EOR).

Using EOR as a driver

Depending on the report relied on, the CO2 storage capacity from oil reservoirs with EOR potential in the WCSB has been estimated to be between 560 and 639Mt.

Within Alberta there is also 800-900Mt of capacity in so-called 'depleted reservoirs' ,which is relevant because it is difficult to gauge at what point a 'depleted reservoir' becomes a 'reservoir with EOR potential'.

When CO2 is pumped into an old oil reservoir some oil is likely to be recoverable and thus as the price of CO2 for the purchaser goes down, and/or oil prices go up, an increasing number of depleted oil reservoirs will become economical.

Thus while the current EOR CO2 capacity figures are in the 600Mt range, it is worth bearing in mind that changes in CO2 and oil prices could see the total EOR CO2 sequestration capacity within Alberta rise to well over 1000Mt.

To put this figure into perspective, the 2007 annual upstream emissions from oil sands were in the neighbourhood of 40Mt, and as such, a potential storage capacity of 1000Mt or greater would provide enough sequestration capacity for over 20 years, even allowing for increases in annual oil sands emission rates.

EOR CO2 technology is relatively mature as there are EOR projects within the WCSB that as of 2004 were storing more than 2Mt of CO2 a year.

At appropriate sites CO2 EOR can boost oil extraction rates by an average of 50% of the recoverable reserves (this average is the result of an expected 8-15% extraction increase of the total resources in place).

The most prominent of these is the project located in Weyburn Saskatchewan, which has shown EOR projects of its kind can pay C$30 per tonne of CO2 and be profitable at oil prices of just C$30 per barrel.

The Weyburn project produces approximately 6 barrels of oil for each tonne of CO2 purchased and is therefore regarded as one of the fields best suited to EOR.

While most EOR projects will instead produce 3-5 barrels of oil per tonne of CO2 purchased, future oil prices are likely to be much higher than C$30 per barrel and as such it is not unreasonable to assume that similar EOR projects could support significantly higher CO2 purchase prices of greater than C$50 per tonne.

Based on an extensive literature review and interviews with leading experts within the field, it is evident that costs of capture in Western Canada vary greatly.

However an extensive amount of CO2 is reportedly available for capture and transport in the $C25 - $50 tonne range, and would therefore be attractive to CO2 EOR project developers.

While the above conclusions appear to indicate that the CO2 supply, demand and price variables are in place for a functioning CCS network within the WCSB, there are a number of potential hurdles to the establishment of such a network.

The following section will thus list what the major hurdles are to making this a reality, and how these hurdles may be overcome.

Hurdles and Suggested Conclusions

Public Acceptance

One potential hurdle is that of public acceptance, because the general public may be leery of pumping CO2 into the ground due to fears that this could result in potentially fatal leaks under poor monitoring situations.

This is likely less true of populations living in traditional oil producing areas as they are accustomed to the pumping of various solvents into the ground, however even the inhabitants of such areas may become nervous when made aware of the potential scale of larger projects whose goal may be to sequester 10 million tonnes of CO2 a year.

By investing in public awareness campaigns and ensuring that proper sequestration and monitoring criteria are in place, this is unlikely to be a major issue moving forward.

This is supported by the findings of a study carried out via surveys conducted in 2004 and 2005 which indicated that the majority of Canadians see CCS as an appropriate technology for reducing GHG emissions, particularly if appropriate regulations are in place.

However it is worth noting that the majority viewed it more as bridging technology to be used until other solutions such as renewables are developed.

EOR projects are more sensitive to price fluctuations than conventional projects

EOR can both bring the costs of CCS down considerably, as well as provide additional income for government in the form of additional royalties.

However, relative to conventional oil projects EOR projects are more vulnerable to oil price fluctuations and this has contributed to the limited number of such projects undertaken to date.

There are a couple reasons for this, firstly EOR projects generally have higher operating costs than conventional oil projects and thus a fall in oil prices will harm them first.

Secondly, to secure contracts for the delivery of CO2 the buyer generally gets a lower price if they agree to purchase a fixed amount each period.

Thus while a conventional oil field can simply turn off the pumps if a substantial fall in oil prices renders project revenues less than operational costs, EOR projects have the additional cost associated with the CO2 it has agreed to purchase.

While a reduction in oil prices below

$50 does not appear likely at this point, the extreme price fluctuation exhibited within the last six months is evidence that oil price volatility is a factor that EOR firms must consider before both committing large amounts of capital for the necessary infrastructure to undertake EOR, as well as entering into contracts for the purchase of CO2.

To help minimize this risk one possible solution would be to provide tax or royalty breaks for EOR projects when prices dip below a certain WTI price.

The taxpayer costs of implementing such breaks would likely be quite low as they would be similar to existing royalty arrangements that levy varying tax rates depending on the oil price.

On the off chance that the government should experience some revenue losses during periods of low oil prices this would most likely be offset by the additional revenue generated via projects that may not have been initiated if not for the legislation.

As such, this represents a low cost, low risk solution for government that could result in more EOR projects getting off the ground.

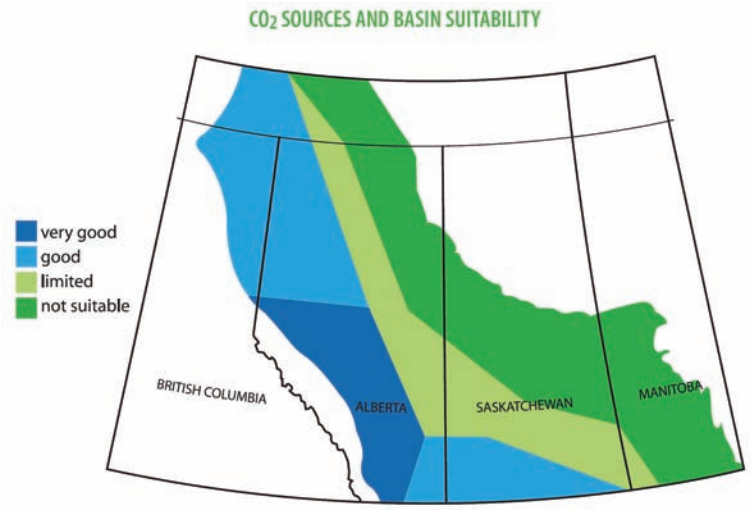
Upfront Costs

The most prominent hurdle facing the establishment of a large scale CCS network are the significant upfront costs that must be undertaken to capture and transport CO2, and therefore creative and innovative ways of bringing these costs down must be explored.

The Weyburn project mentioned above is in part so successful because it received a favourable royalty rate from the Saskatchewan provincial government similar to that which helped encourage early oil sands development in Alberta.

The assurances of a preferable royalty regime for EOR projects in the WCSB would help spur investment in EOR projects and in the long-term such a decision may even prove to be tax neutral as additional EOR projects would likely to be undertaken.

In the short-term the government could more then offset this small revenue loss by raising royalty rates on oil sands development as these projects have now reached maturity and are experiencing record profits.



The suitability of potential storage sites in the Western Canada Sedimentary Basin.

The Weyburn project has proved very successful in demonstrating the technical and economic viability of both EOR and CCS, and has thereby drawn global interest from parties interested in investing in similar technologies.

Government assistance for a clean coal power plant project that incorporates CCS with EOR could provide the necessary incentive for first movers to demonstrate the feasibility of this technology and thus bring additional private funds to the table.

What is really needed to facilitate large-scale use of CCS in the WCSB is a backbone pipeline connecting the large emitting sources with the vast potential storage areas. For the oil sands producers to be brought into the mix, a pipeline would therefore have to be constructed from the Fort McMurray region to central Alberta.

The Alberta government has recently announced that it will soon be implementing intensity targets for the largest industrial emitters requiring them to reduce their GHG emissions by 12%. Those that are unable to meet the targets have the option of buying carbon offsets or paying a $15/tonne charge into a climate change fund.

One option would be for the proceeds of this fund going towards the building of the backbone pipeline thus bringing down the cost of CCS via private sector funds.

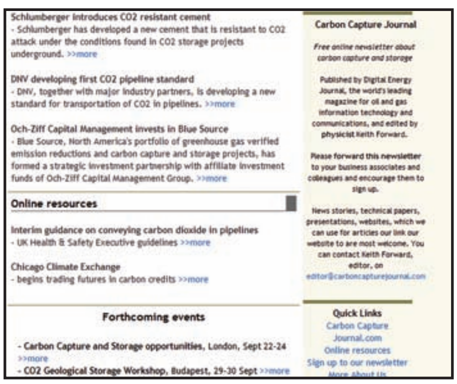
This option represents a win/win situation for the Alberta government as the private sector emitters will either be reducing their emissions directly today, or helping to pay for infrastructure the can help reduce emissions in the medium-long term.

Lack of regulation

What really exacerbates the above cost problems are issues regarding lack of regulation. Companies are particularly unwilling to proceed with large capital outlays if they don't know what the regulatory framework will look like in a few years time.

What is therefore needed is long-term certainty in the regulatory framework which matches the long-term nature of the CCS investments. When industry makes long-term strategic investment decisions, particularly regarding the large initial outlays involved in CCS, they need a degree of price certainty and regulatory stability.

Industry needs to know what the costs and incentives of producing CO2 will be, and



without this, industry is not likely to invest in the costly infrastructure associated with CCS.

Conclusion

During the course of my research, it became evident that some of the very largest CO2 emitters in Alberta are willing to retrofit their plants (at their own expense) so they can capture and sell their CO2.

The major obstacle preventing them from doing so is the lack of long-term rules and regulations upon which to base their negotiations with EOR project owners.

Thus while the implementation of all the above solutions would be helpful in establishing a comprehensive CCS network in Alberta it is the opinion of this researcher that the two most important government actions would be:

1) Implementing a royalty regime which gives EOR producers royalty relief for a fixed period of time, thus encouraging more EOR projects.

2) At both the federal and provincial levels, implementing regulation with respect to CO2 emission reduction targets, as well as setting out precise fines for breeching these targets.

This should be coupled with legislation highlighting any other incentives or penalties that firms may encounter, and of equal importance is the requirement that all such legislation should be long-term in nature so that private industry can plan accordingly.

The governments in Canada are currently presented with a real opportunity to spur private investment into expensive CCS infrastructure. With the proper incentives and regulatory framework in place, a number of EOR companies would be willing to invest in a technology that will provide them with viable projects and reduce GHG emissions.

These projects will contribute to CCS infrastructure, greatly reduce Canada's GHG emissions, and if implemented correctly this can be accomplished at little or no additional cost to the taxpayer.

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Carbon Capture and Storage: risk management framework as a key challenge

There is an urgent need to develop risk management solutions to remove the uncertainty facing investors that is acting as a barrier to commercial deployment.

By Olivier Poupard, head of geosciences branch, OXAND, France

CCS technology is available today, offering a clean and reliable form of electricity supply. However, full-scale demonstration projects are urgently needed to address issues of scale-up and integration, and help shape the necessary policy and regulatory frameworks.

As with other new technologies, the early deployment of commercial-scale CCS projects will involve substantial costs and risks. They are long-term in nature, requiring potentially long periods of operation (30-50 years) and abandonment (more than hundreds of years).

Therefore, there is an urgent need to establish a set of solutions that will deal with the risks and remove the uncertainty that represents the barrier to their commercial-scale deployment.

CCS and risk management as decision making support

CCS processes create a suite of technological and non-technological risks causing impacts on facilities, environment and/or public health and safety. CCS project life-cycle comprises three distinct phases, each of which has the potential for risks:

Phase 1: Carbon Dioxide Capture

Improper venting of CO2, leakage at the capture point, other technological failures or catastrophic weather events may result in ecological, human health, supply chain interruptions and property-related consequences.

Phase 2: Carbon Dioxide Compression and Transport

The potential for leaks during the transport of carbon dioxide from the point of generation (capture) to the sequestration (storage) site exists.

Eventual transportation networks likely will travel through a combination of heavily populated areas, as well as potentially ecologically sensitive areas.

Further, the corrosive nature of carbon dioxide when mixed with water under certain conditions such as colder climates may contribute to the risk of pipeline fractures. Such leaks may result in ecological, human health, and property-related consequences.

Phase 3: Carbon Dioxide Geological Storage

Storage of carbon dioxide involves a series of four main steps:

(1) site characterisation/feasibility/design;

(2) operation (carbon dioxide compression and injection);

(3) closure/post-closure;

(4) abandonment.

Possible local impacts resulting from injection operations or leakage include but are not necessarily limited to:

(i) Acidification of potable aquifers and/or soils;

(ii) Accumulations of gaseous CO2 at the surface affecting human health and/or the environment;

(iii) induced seismic activity or uplift.

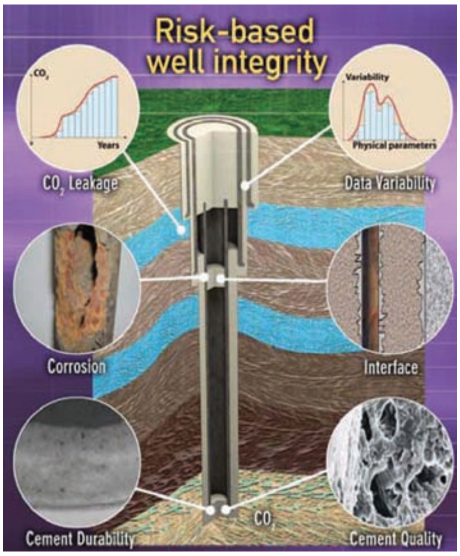


Figure 1: Illustration of well integrity key indicators

Compared to the capture and transportation phases, the underground nature of the containment zone includes large uncertainties implying more difficulties to define means by which the facility can monitor and evaluate operational conditions and the continued integrity of the containment zone.

Indeed, the capture and transport processes span over relatively short periods

of time, enabling an accurate simulation and precise evaluation of their performance.

The storage on the other hand spans over long (5000-10000 years) periods of time and predicting the outcome is a difficult task.

If in many cases the geology can be reasonably assumed to ensure its confining role by definition (exhausted oil and gas reservoirs, deep saline aquifers), a similar evaluation cannot be made for the wells unless a clear understanding of the ageing and chemical aggression processes of their components are well understood. Moreover, an important level of uncertainty always remains.

Risk management processes

The risk management process represents the process of assessing, monitoring, mitigating and communicating risks during the lifetime of a CO2 capture and storage facility.

Risk management provides an efficient tool as decision making support for project managers and/or stakeholders involved in CCS projects by taking into account the uncertainty and its effect on achieving objectives and assessing the need for any action.

OXAND proposes solutions for structuring and implementing a Risk Management framework based on the Draft International Standard ISO/DIS 31000 circulated from the European Council (2008) that includes 5 activities:

- establishment of the context
- risk assessment
- risk treatment
- communication and consultation
- monitoring and review

Well integrity assessment in CCS projects

For a commercial scale deployment of CCS technologies, barriers remain to be overcome in relation to the specificities of CO2 geological storage:

(i) storage must be ensured over a very long time frame;

(ii) physical properties of CO2 may change rapidly along a leakage path, due to phase changes;

(iii) uncertainties will always remain in the description of the geological environment. CO2 storage will be designed for no leak over the project lifecycle, which implies maintaining sealing through wells.

The well appears as one of the main technological problems as this man-made intrusive object can directly connect CO2 to water resources, biosphere, or atmosphere. In a CO2-based environment, casing corrosion and cement leaching processes will affect well integrity.

The performance of the well to confine CO2 gas within the reservoir may be impacted and risks associated with CO2 leakage over the storage time period may increase.

Figure 2 : Workflow of the P&R™, the data collection and interpretation is made in collaboration with Schlumberger Carbon Services

The fundamental questions we need to answer are:

- Can wells be a CO2 leak path to targets (atmosphere, potable water, fauna, flora, saline aquifer...)? What are the weakness points in well system to ensure well integrity performance (i.e. CO2 leakage)?
- What are the key indicators of long term performance for well integrity in a CCS project?
- What are the risks associated to well integrity for CCS projects?
- What are the possible options to mitigate risks to an acceptable level?
- What could be the recommendations for the monitoring well integrity during injection period?
- How can a strategy for well abandonment be adapted to CO2 storage?

To answer these key questions, OXAND has developed a risk-based approach for well integrity performance management. The approach, based on Performance and Risk methodology (P&R™), serves as a decision making support tool.

This methodology is based on experience in material aging and risk assessment of complex systems, like nuclear structures, where probabilistic simulations are performed.

It accounts for the main stakes involved in well integrity management (economic, pollution, safety and health, corporate image, public opinion …) and enables the full integration of uncertainties as part of risk estimation.

The methodology greatly improves common approaches based on "Features, Events, and Processes" as it quantifies risk levels. It provides useful and reliable tools to support decisions for well integrity management strategies or emergency plans.

Moreover, updating risk assessment with incoming data allows for an evolving vision of risk levels to optimise interventions in time.

A P&R™ analysis requires 3 major steps, presented in the Figure above:

- Risk-based foundation including data collection, system description, functional analysis and consequence grid
- Performance and risk assessment: static model, failure mechanism identification, dynamic model, scenario identification,

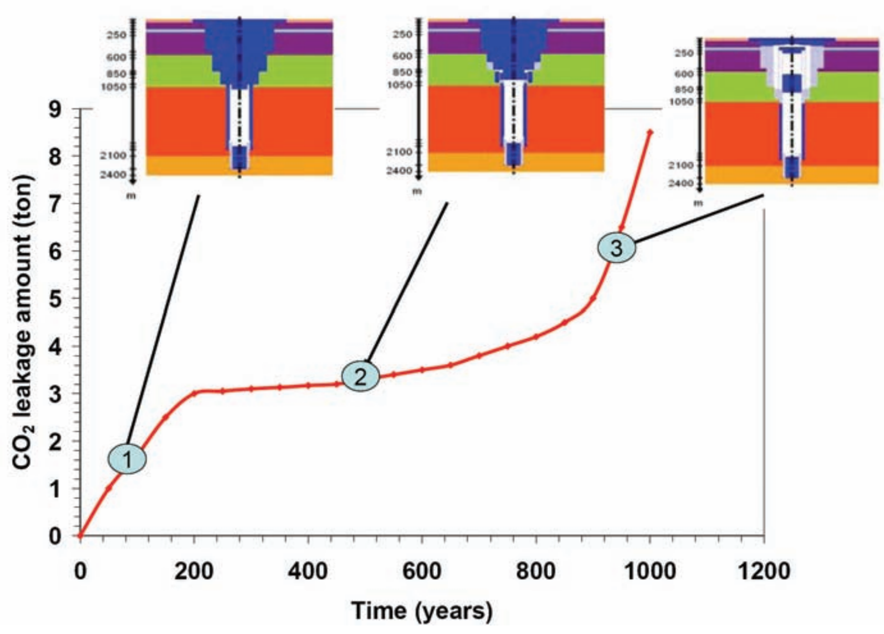


Figure 3 : CO2 leakage mass vs. time for a given scenario (Simeo™ Stor), including leakage pathways over time (CO2 is colored in white)

leakage simulations and risk estimation

- Risk treatment: risk evaluation, risk sources identification, recommendations for reducing unacceptable risks

Leakage simulations are performed from a coupled modelling integrating 2-phase flow and ageing models. This coupled model uses boundary conditions provided by a reservoir simulator of CO2 saturation and pressure.

Model parameters, such as corrosion rates and cement degradation can be calibrated through laboratory tests, including accelerated testing and time-lapse well integrity monitoring measurements.

Figure 3 shows a curve representing CO2 leakage mass vs. time for a given scenario (Simeo™ Stor). Some illustrations of CO2 leakage pathways over time from water saturation of well components within well system are also represented.

Quantifying the risk level for all scenarios gives a map of all risks, a process called risk mapping. It gives a general picture of the risks at any given time of interest (injection, post-injection, abandonment).

Such risk mapping constitutes a powerful support for the operators to predict and communicate on the well integrity performance. Practically, the risk mapping is performed by filling a color coding grid with each couple (frequency of occurence, severity) corresponding to all scenarios which lead to CO2 leakage. Figure below gives an example of such an output for a well integrity project over long term.

By defining a Risk Acceptable Level, it is possible to identify which risks needs to be mitigated. For these unacceptable risks, the identification of the components characteristics that contributes to the highest risk scenarios (i.e. risk sources) will be the basis for the risk mitigation plan.

Risk mitigation actions can either contribute to lowering the probability of occurrence, the severity of a CO2 leakage, or both. Risk mitigation actions are of four types:

- Characterisation/inspection actions
- Workovers
- Operational best practices
- Monitoring to control the evolution of the system and allow identification of a potential hazard before it occurs

Conclusion

CCS is an available technology to contribute to limit greatly the problem of climate change. The difficulties embedded in the full scale application are related to risk management.

We are talking about risk management for the injection period and also for long term safety demonstration of the storage.

Frequencies \ Severities	Minor 1	Low 2	Serious 3	Major 4	Critical 5	Extreme 6
6	12	0	0	0	6	0
5	22	6	31	45	23	9
4	13	277	151	24	10	5
3	5	306	45	12	15	0
2	0	36	87	46	5	0
1	0	0	21	14	0	0

- - - Acceptable risk level

Figure 4 : Illustration of a risk matrix for a risk-based well integrity analysis A thousand of scenario has been estimated. In each box the number of scenario that have the same frequency and severity.

These concerns are close to the ones faced by the nuclear industry.

OXAND has successfully applied its know-how and technologies to CCS applications worldwide. One of those technologies is the P&R™ methodology integrated in the Simeo™ Stor simulator platform. It provides risk-based solutions from predictive CO2 leakage modelling tools for well integrity performance over short term (tens of years) and long term (hundreds of years and more.

Risk-based solutions present an important growth in practice because of their capability to communicate recommendations considering owner stakes. Risk-based approaches offer a great opportunity to risk managers to anticipate their risk and to engage relevant programs and demonstrate long term safety.

References

"Managing the Risk Associated with well Leackages over Long Timescales":, Y. Le Guen, L. Jammes, J. Le Gouevec, R. Chammas, B, Gerard, O. Poupard, SPE 116424, SPE Asia Pacific, 2008.

Preliminary probabilistic study for risk management associated to casing long-term integrity in the context of CO2 geological sequestration - Recommendations for cement plug geometry: Y. Le Guen, O. Poupard & J.-B. Giraud, M. Loizzo, ESREL 2008.

About the company

Olivier Poupard, head of geosciences branch, OXAND

OXAND group is an independent international consulting company providing innovative services in expertise and risk management for Oil&Gas CCS or EOR activities.

OXAND group operates its own innovative tools and databases (Simeo™) for diagnosis and prognosis of ageing infrastructures.

With an experience in decision-making criteria based on performance and risk™ assessment methodologies (P&R™), coming from its nuclear experience, OXAND group develops its activities worldwide and its services are successfully acknowledged by oil&gas operators.

Training for the future of CCS

The Scottish Centre for Carbon Storage will begin teaching the first Masters in CCS in September 2009.

Dr. Mark Wilkinson, Scottish Centre for Carbon Storage, University of Edinburgh

The challenges and opportunities offered by a career in CCS are substantial, and while the technology has yet to be proven on a truly industrial scale, there is now a unique opportunity to get in 'on the ground floor'.

Many commentators are openly stating that the future CCS industry will be on a scale comparable to the present-day oil industry, and that implies many thousands of career opportunities worldwide.

It is common knowledge that the oil industry offers interesting and exciting careers for those who choose to follow a career within it. It might be predicted that the CCS industry will offer similar challenges and opportunities, but of a greener colour which will appeal to a more environmentally conscious generation.

Opportunities to interact with developing counties will be a natural offshoot of CCS development within the developed world, with the chance of cultural exchange and cooperation for those employed within the industry.

Implementing CCS on an industrial scale will require a highly trained workforce. Because much of the technology involved in CCS is already established, there are numerous people with expertise in individual fields, but a notable lack of people with a good knowledge of how the different aspects of CCS link together.

The problem is exacerbated by the different disciplines involved - engineers and geologists find working together to be challenging, because of the different approaches the disciplines teach, the specialist jargon and the complex concepts involved.

Such cultural differences must be overcome for the successful design and implementation of a CCS scheme. The same issue is faced by many companies, whereby an individual company may have world-class expertise in one aspect of the CCS value chain, but no experience of the other key components.

First Masters in CCS

The Scottish Centre for Carbon Capture plans to teach the world's first MSc in CCS from September 2009.

The aim is to enrol numerate graduate engineers and geoscientists, who are already trained in their respective fields, or professionals wishing to re-train into a different specialism, and educate them in the skills required to successfully work on and collaborate with other disciplines on CCS projects.

Each student will learn sufficient about the entire CCS value-chain to be able to engage in meaningful dialogue with all involved professions, reducing the problems of specialised jargon, concepts and working practices.

Within the framework of a one year course, it is not possible to turn, for example, an engineer into an expert geologist. However, it is possible to teach sufficient relevant material so that the students can read, understand and assess technical reports, and make substantial contributes to a multi-disciplinary team aimed at CCS roll-out.

At the time of writing, we believe that the MSc course is unique. The MSc will be based in the School of GeoSciences, University of Edinburgh. Teaching contributions will come from expert geoscientists, engineers, social scientists, business and legal experts in this School and the Institute of Petroleum Engineering, Heriot-Watt University, also in Edinburgh.

The Scottish Centre for Carbon Capture currently has 13 Academic staff, 12 Research Assistants, 15 Doctoral students and 5 MSc dissertations engaged in CCS-related research, and is at the forefront of CCS technological development in the UK.

Syllabus

Principal modules within the MSc course will cover: carbon management, CO_2 capture, transport, storage, and regulation. Other MSc-level courses within the Universities can be chosen to specialise in specific areas, or to produce a broader final spread of knowledge.

Because of the emphasis in inter-disciplinary working, parts of the course work will be undertaken in small groups with a mixture of engineers and geoscientists working on common problems, with a jointly written report to be produced for assessment – a dry run for a working life in industry!

Classroom based teaching will take place from September to May, with the remainder of the year spent on individual dissertation projects leading to the submission of a report. Several leading companies have indicated interest in offering internships for students to perform their research projects, which will be allocated competitively.

Dr. Mark Wilkinson Scottish Centre for Carbon Storage, University of Edinburgh

In summary, CCS offers world-wide opportunities for graduates with relevant skills, especially the ability to work in multi-disciplinary teams to achieve the establishment of CCS schemes, with a direct impact on climate change mitigation and positive business profit. An MSc in CCS from the world-leading Scottish Centre for Carbon Storage will be a passport to career opportunities within the developing industry, enabling individuals to reduce global CO_2 emissions , maintaining established lifestyles, and hopefully raising living standards worldwide.

Further information

www.geos.ed.ac.uk/sccs

The Scottish Centre for Carbon Storage (SCCS), established in 2005 with funding from The Scottish Funding Council, is a partnership between the British Geological Survey, Heriot Watt University and The University of Edinburgh, and is the UK's largest academic grouping of CO_2 Storage researchers.

The centre combines world-class expertise based on established and advanced carbon capture, policy assessment, petroleum and hydrocarbon geoscience in 3D regional and field scale geological modelling, geophysics, geo-engineering and subsurface fluid flow.

The Centre also has expertise across the full Carbon Capture & Storage chain, and frequently provides media assistance (print, radio, and TV), advice to UK and Scottish Government, and Policy advice and opinion.

Further reading

Carbon Capture and Storage in the UK
Chapter in 'Energy and the natural heritage', prepared by Bushby, Y., Gilfillan, S., and Haszeldine, S., Scottish Natural Heritage, June 2008

UK University wins carbon capture award

The University of Greenwich has won a Times Higher Education Award for an innovation which turns contaminated land into harmless material while capturing CO2.

www.gre.ac.uk

Dr Colin Hills and Dr Paula Carey from the Medway-based School of Science have developed a technology which converts contaminated land and industrial waste into harmless pebbles, capturing CO2 in the process.


Dr Colin Hills and Dr Paula Carey collecting the Times Higher Education Award

If trials are successful, the UK could benefit from 500,000 tonnes of CO2 being captured through the carbonation of household waste alone, the scientists said.

The solution, known as Accelerated Carbonation Technology (ACT), is patented and has been commercialised through a company called Carbon8 Systems.

According to Carbon8, ACT is a controlled accelerated version of the naturally occurring carbonation process, which results in an improvement in the chemical and physical properties of the treated materials.

The technology can use waste CO2 emissions from local sources, creating an end product that can be used as a secondary aggregate, engineering fill or for specialist construction materials.

Several companies have used the solution to treat wastes, including BP and Shell for North Sea oil drill cuttings and E.ON for APC (Air Pollution Control) residues and bed material from a CHP (Combined Heat and Power) plant.


The technology can convert waste material into pebbles that can be used as aggregate by reacting it with CO2.

Capture news

University of Calgary scientists remove CO2 from air

www.ucalgary.ca

University of Calgary climate change scientist David Keith and his team are working to efficiently capture carbon dioxide directly from the air, using near-commercial technology.

In research conducted at the U of C, Keith and a team of researchers showed it is possible to reduce CO2 using a relatively simple machine that can capture the trace amount of CO2 present in the air.

"The thermodynamics suggests that air capture might only be a bit harder than capturing CO2 from power plants. We are trying to turn that theory into engineering reality," said Keith.

The U of C team has devised a new way to apply a chemical process derived from the pulp and paper industry to cut the energy cost of air capture in half, and has filed two provisional patents on their end-to-end air capture system.

Energy-efficient and cost-effective air capture could play a valuable role in complementing other approaches for reducing emissions from the transportation sector.

Keith and his team showed that they can capture CO2 directly from the air with less than 100 kilowatt-hours of electricity per tonne of carbon dioxide.


David Keith at the University of Calgary is developing technology to remove CO2 from the atmosphere.

A custom-built tower was able to capture the equivalent of about 20 tonnes per year of CO2 on a single square metre of scrubbing material – the average amount of emissions that one person produces each year in North American

"This means that if you used electricity from a coal-fired power plant, for every unit of electricity you used to operate the capture machine, you'd be capturing 10 times as much CO2 as the power plant emitted making that much electricity," said Keith.

Norwegian mobile CO2 capture facility opened

www.akercleancarbon.com

HRH Crown Prince Haakon has opened Aker Clean Carbon's mobile carbon capture facility at Rikavisa in Rogaland, Norway.

It is the first advanced Norwegian capture unit, according to the company.

"With this facility we move from the drawing board to real testing on our own facility," said Jan Roger Bjerkestrand, chief executive of Aker Clean Carbon. "This unique test unit will give us valuable information that we will use to further develop andimprove our technology, in order to build full scale capture facilities."

The facility is based on compact modules, making it easy to transport by road, rail and at sea. Hook-up is fast and simple and the unit can be restarted in days, said Aker.

The design is flexible so the mobile facility can be deployed on different emission sources, including coal and gas-fired power

stations. It can process about 25,000 m3 flue gas per day.

The test unit, which is a complete capture facility, was constructed by Aker Solutions at Aker Verdal in Norway, before it was driven to Risavika.

RWE npower commissions CCS testing facilities at Didcot

www.rwe.com

RWE npower is completing new facilities at Didcot Power Station in the UK designed to test CO_2 capture post combustion and with oxyfuel firing.

RWE npower is building CCS test facilities at Didcot Power Station in the UK

The company said it would also press ahead with plans to start work next year at Aberthaw in South Wales on the country's first CO_2 pilot plant capturing flue gas direct from a commercially operating power station.

Responding to the Government's consultation, "Towards Carbon Capture and Storage", which closed recently, RWE npower called on Government to address significant challenges such as CO_2 transportation and storage which are currently not in the proposals.

It urged government to avoid regulatory and policy pitfalls that would add unnecessary delays to vital investments. RWE npower CEO Andrew Duff said: "The consultation proposals focus on the carbon capture-readiness of power stations but the Government should also be providing the strategic and regulatory framework to underpin a CO_2 transportation and storage network."

"It should also be prioritising an efficient regulatory system for storage sites. This process mustn't create further delays to electricity investment. The country needs to develop at least 25 GW of new generation facilities by 2020 and draw on a range of sources like renewables, gas and combined heat and power. Coal will play a reducing, but vital, part to keep supplies secure, reliable and affordable."

Alcoa's Kwinana aluminium refinery in Australia (Image thanks to Alcoa of Australia)

Alcoa recognised for carbon capture project

www.alcoa.com

Alcoa's Kwinana aluminium refinery in Australia was named 'Minerals Processing Plant of the Year' at the annual Australian Mining Prospect Awards sponsored by Australian Mining.

The award was given largely for its carbon capture technology that mixes waste CO_2 with bauxite residue, a by-product of the aluminium refining process.

The process reduces the alkalinity of the residue and opens the way for it to be reused in the future, as well as permanently storing the CO_2.

The Kwinana plant is capturing around 70,000 tonnes of C2 each year from a nearby ammonia plant.

The company is also investigating options for deployment of the technology across all three of its Western Australia refineries, which could lead to CO_2 savings of 300,000 tonnes per year.

Alcoa says it is making the technology available to others under suitable agreements, in opposition to normal commercial considerations, as the project has such wide ranging community benefits.

Carbon Sciences developing prototype for CO2 to fuel technology

www.carbonsciences.com

Carbon Sciences anticipates the completion of a prototype that will demonstrate its biocatalytic CO_2 to fuel process, which can produce liquid fuels such as gasoline, by Q1 2009.

Carbon Sciences' technology is based on emulating certain metabolic strategies employed by living organisms where fuel molecules (hydrocarbons) are assembled from CO_2 and H20 through low energy biocatalytic processes.

These natural biocatalytic processes occur under mild conditions of low temperature and low pressure. The company's technology allows these processes to operate on a very large industrial scale through advance nano-engineering of the biocatalysts and highly efficient process design, it said.

According to Dr. Naveed Aslam, inventor of the company's technology and chief technology advisor, the prototype under development is a flexible laboratory scale setup comprising three primary sections:

(1) Gas treatment section;

(2) Biocatalytic reaction chamber;

(3) Fuel separation and collection chamber.

"It is also equipped with in-line sampling and analysis equipment to provide real-time information of process streams. We expect that the stream of CO_2 can be transformed into a flammable liquid fuel."

"Our novel innovation is in the biocatalytic formulation and process that induce the biocatalysts to perform their natural function of assembling hydrocarbon molecules from CO_2 and H20," he continued.

"The commercial viability challenge is lowering the manufacturing cost of the fuel by enabling the biocatalyst to go through many cycles before replacement. To address that challenge, we are developing a proprietary nanoparticle structure around the biocatalysts, which we expect to be available in the second version of the prototype."

The company claims that its CO_2-to-fuel process is linearly scalable, which means that it can be scaled up for large industrial uses.

Transport and storage news

DOE releases CO2 storage estimation methodology

www.fossil.energy.gov

The U.S. Department of Energy (DOE) has released its Methodology for Development of Geologic Storage Estimates for Carbon Dioxide, a document that details the procedures used to produce the geologic resource estimates for CO2 storage potential.

The methodology has been used in the forthcoming 2008 Carbon Sequestration Atlas of the United States and Canada (Atlas II). DOE expects to release the updated version of its atlas later this year.

The methodology document outlines the procedures for estimating CO2 storage potential in three types of geologic formations found in the United States and Canada: saline formations, unmineable coal seams, and oil and gas reservoirs.

"This important document represents more than a year's worth of work by researchers at the Office of Fossil Energy's National Energy Technology Laboratory and members of DOE's regional carbon sequestration partnerships to reach a consensus on the methodology," said Acting Assistant Secretary for Fossil Energy James Slutz. "We believe it will provide a sound explanation for geologic resource estimates in our upcoming carbon sequestration atlas."

The methodologies presented in the document are based on widely accepted assumptions associated with fluid distribution and displacement processes commonly applied in petroleum and groundwater science, the DOE said.

A subcommittee called the Capacity and Fairways Subgroup, which was convened by the regional partnerships' Geologic Working Group in 2006 to develop the first carbon sequestration atlas, provided leadership for this methodology document.

The methodology document will be presented as an appendix in the forthcoming Atlas II.

Vattenfall reports positive results on CO2 storage potential in Denmark

www.vattenfall.com/ccs

Vattenfall has recently concluded a series of seismic investigations in the area around the towns of Birkelse and Arentsminde in Denmark.

Large trucks with seismic vibrators have been working within an area of 20 x 25 km around the area and are now on their way back to Germany.

Vattenfall is investigating the possibility of storing CO2 at the Vedsted structure, a geological reservoir between one and two kilometres below the Earth's surface. If the site proves suitable for CO2 storage, the Nordjylland Power Station in Denmark (pictured) will be equipped with a full-scale unit for CO2 capture using postcombustion

Vattenfall said the first results showed promise and it has decided to conduct a second phase of the survey, to chart the bedrock in more detail. Vattenfall's main objective is to guarantee that the area is suitable for storing CO2.

In the first phase, measurements were performed in two dimensions, length and depth. The next phase consists of three-dimensional seismic within a smaller area, to determine the size of the storage site in detail.

Vattenfall estimates that it will have sufficient results to start test drilling and examine geological qualities in summer 2009.

Unit 3 at Nordjyllandsverket will, if the investigations show a suitable result, then be equipped with post-combustion technology for capturing CO2.

If seismic conditions prove to be as favorable as they seem this far, the rebuilding of unit 3 will be ready in 2013, the company said.

Alberta begins CCS field tests

www.alberta.ca

Three test wells will soon be drilled for a long-term, large-volume CO2 sequestration project in Alberta, Canada.

The Government of Alberta, through the Alberta Energy Research Institute (AERI), is providing $6.6 million in funding for the three year $20 million project near Shell Canada's Scotford facility.

The funding is separate from Alberta's $2 billion carbon capture and sequestration fund. Information from the field tests will inform Alberta's Climate Change Strategy.

The wells will examine the CO2 injection capability and storage capacity in three different types of formation beneath the surface.

The field test phase is expected to be completed by June 2010.

ScottishPower investigates North Sea storage potential

www.scottishpower.com

A consortium led by ScottishPower is investigating the possibility of using a rock formation in the North Sea that could potentially store all of Europe's C02 emissions for the next 600 years.

The consortium, which is currently developing the technical aspects of its entry into the UK CCS competition, consists of Marathon Oil Corporation, Aker Clean Carbon and Aker Solutions.

It aims to implement CCS technology at Longannet Power Station in Fife, one of four entries that have been shortlisted in the Government competition.

Engineers are working on plans to adapt two of the four burner units at Longannet - the largest power station in Scotland - to use CCS technology built by Aker, a Norwegian engineering group.

In situ carbonation of peridotite for CO2 storage

In a paper published in the Proceedings of the National Academy of Sciences, Peter B. Kelemen and Jürg Matter from Columbia University describe how the natural process of carbonation of a mineral, peridotite, could be enhanced to capture and store billion of tonnes of CO2 every year from the atmosphere.

Peridotite is a naturally occuring rock formation present in Oman, as well as other locations around the world including Papua New Guinea, New Caledonia and along the east coast of the Adriatic Sea.

The researchers found that hundreds of thousands of tonnes of CO2 are naturally stored in Oman alone every year, and suggest ways in which this process could be enhanced to store more than a billion tonnes.

"Peridotite carbonation can be accelerated via drilling, hydraulic fracture, input of purified CO2 at elevated pressure, and, in particular, increased temperature at depth," said Professor Kelemen.

"In fact, after an initial heating step, CO2 pumped at 25 or 30 °C can be heated by exothermic carbonation reactions that sustain high temperature and rapid reaction rates at depth with little expenditure of energy."

This means the reactions would be self-sustaining, and could potentially store all the CO2 emissions from power stations around the world.

Enhancing the capture process

The rock formations in Oman store CO2 as magnesium and calcium carbonate and dolomite (a mineral composed of calcium, magnesium, carbon and oxygen) in a network of underground veins.

Olivine ($(Mg,Fe)_2SiO_4$) one of the main constituents of peridotite, reacts with groundwater containing dissolved CO2, forming carbonates that increase the volume of the rock by up to 44%, causing fractures to appear.

The fractures allow more water to penetrate and increase the speed of the reaction.

The authors propose that fracturing techniques used in the oil and gas industry to allow oil to flow more easily could be used to increase the volume of rock exposed to CO2 and allow more of the gas to react.

Another key factor that affects the rate of carbonation is the temperature of the rock. The authors calculate that the optimal temperature for carbonate formation is 185 °C.

After fracturing, the rock could be heated to this temperature by injecting hot fluid. This could increase the rate of carbonation by up to a million times, the authors say.

As dissolved CO2 in surface water cannot be supplied rapidly enough to keep pace with the enhanced carbonation rates, a pure stream of CO2 or a CO2 rich mixture of fluid would then be injected.

As the carbonation reaction is exothermic, the scientists calculate that an initial heating step is all that would be required to maintain the higher rates of CO2 capture at depth.

This method could store over a billion tonnes of CO2 in a cubic kilometre of rock, the authors say.

Capturing CO2 from seawater

An alternative process could avoid prolonged pumping of fluid and the use of purified CO2.

In Oman, New Caledonia, and Papua New Guinea, peridotite is present beneath a thin veneer of sediment offshore, beneath the sea bed. Here, peridotite could be drilled and fractured, and a volume could be heated using the method described above.

Little heating would again be required, as the temperature at the bottom of a 5km borehole is already 100 °C.

Seawater could then be pumped into the well, where it would heat up and the dissolved CO2 would react with the peridotite raising the temperature further.

The seawater could then rise back to the surface through another well, several kilometres from the first, through convection.

The CO2 depleted seawater would absorb more CO2 from the atmosphere, reducing overall world concentrations of the gas.

The authors calculate that this method could store only around ten thousand tonnes of CO2 in a cubic kilometre of rock, due to the limited concentration of CO2 in seawater, but at relatively little cost.

Conclusion

The authors have described a process that provides a way to permanently store CO2 in mineral deposits available in several locations around the world.

One method involves transport and injection of concentrated CO2, in a similar way to currently proposed plans to store CO2 in aquifers or depleted oil and gas fields.

A type of limestone called travertine is deposited near springs as water rich in carbonates emerges to the surface. White carbonate veins in peridotite can be seen inthe background.

The other method could provide a way for CO2 from the atmosphere to be extracted and stored without the energy penalty of capturing from point sources such as power stations.

Although this method would store considerably less CO2 by volume of rock, it would be relatively cheap to implement, and since the rock does not have to be heated, could be employed on a very large scale.

Further studies needed

According to the paper, the reactions studied are virtually impossible to replicate in a lab. More elaborate models combined with field tests will be required to evaluate and optimise the method.

For example, it is difficult to predict the consequences of hydraulic fracturing of peridotite, plus cracking associated with heating, hydration, and carbonation, in terms of permeability and reactive volume fraction, say the authors.

"Large-scale field tests should be conducted, because the proposed method of enhanced natural CO2 sequestration provides a promising potential alternative to storage of supercritical CO2 fluid in underground pore space," said Professor Kelemen.

South Africa to publish CO2 storage atlas

The Council for Geoscience (CGS) in South Africa is leading an eighteen-month investigation into a CO2 Geological Storage Atlas for the country.

www.geoscience.org.za

The project is sponsored by Sasol, Eskom, PetroSA, Anglo American and the South African National Energy Research Institute (SANERI).

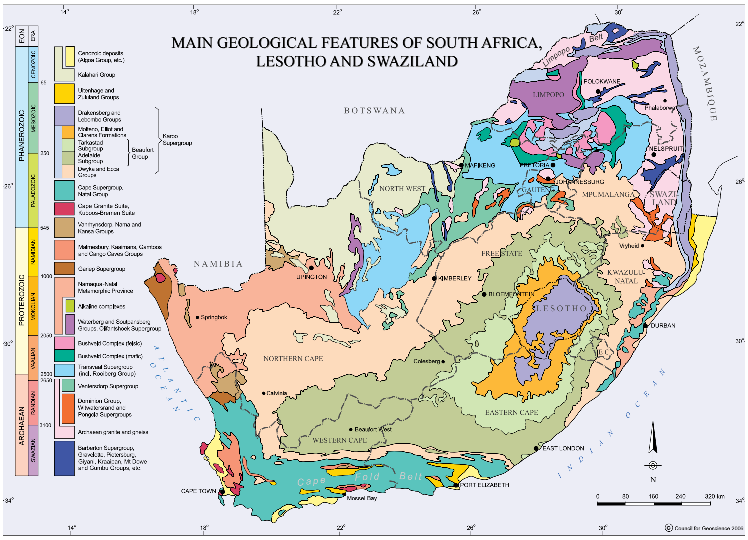
The CGS, along with the Petroleum Agency of South Africa, has been appointed to compile and publish the resulting CO2 Geological Storage Atlas.

The atlas, which will be completed by December 2009, will report methodologies and the results of the storage potential evaluations for all the onshore and offshore basins of South Africa.

It will provide ranking of the basins according to risk and tectonic settings, and will discuss storage options. It will also contain illustrated maps showing the geographic distribution of the basins and relevant geological and seismic profiles to support salient findings.

Additional data, such as the estimated CO2 storage capacities of basins, the main emission sources, location of industrial complexes and transport issues will also be included.

The production of the atlas will involve a CO2-storage prospects assessment, which CGS says will most likely lead to further research, the development of a pilot project and potentially large-scale pilot CO2 storage ventures in South Africa.



The new CO2 atlas will show the storage potential for onshore and offshore basins in South Africa (map © Council for Geoscience)

Norway begins seismic survey of possible subsea storage site

A seismic survey of the subsurface has been initiated at the Troll field in the North Sea to determine whether the site is suitable for storage of large volumes of CO2 from carbon capture facilities at the industrial plants at Mongstad and Kårstø.

www.npd.no

The Norwegian Petroleum Directorate (NPD) and Gassnova SF have ordered 3D-seismics to survey whether the Johansen formation at Troll is suitable for permanent storage of CO2.

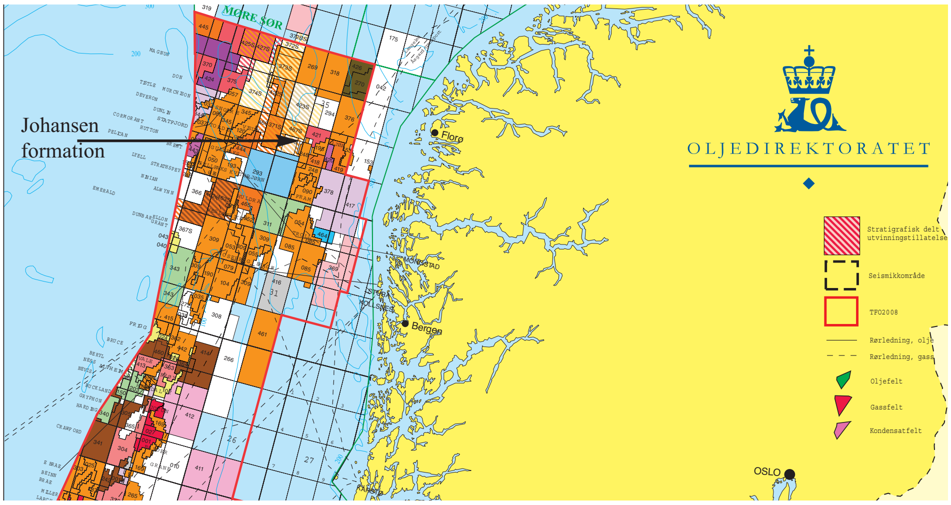
StatoilHydro is responsible for the seismic data acquisition, and is using the vessel M/V Ramform Challenger, owned by PGS, for this activity.

Gassnova, the state-owned enterprise for handling CO2, is responsible for implementing the Government's CCS project for CO2 capture from Mongstad and Kårstø.

Another objective of the survey is to determine where the CO2 injection wells should be located.

"The survey is an important part of our work to achieve the goal of storing carbon dioxide in the subsurface," says Odd Magne Mathiassen, research coordinator in the NPD.

The NPD has studied three potential storage sites for CO2 – the Johansen formation and two sites connected to the Utsira formation in the Sleipner area.



The Johansen formation, one of the most suitable areas for carbon storage, is located south of the Troll area in the North Sea (map ©Norwegian Petroleum Directorate)

The Johansen formation is located south of the Troll area in the North Sea at a depth of approximately 2500 metres, below the Troll oil and gas reservoirs.

The plan calls for the acquisition activity to get underway sometime in September.

Processing and interpretation of the 3D-seismic data will probably be completed early in 2009.