

carbon capture journal

May / June 2009

Issue 9

Developing the full
CCS chain in Dutch
'Energy Valley'

HTC Pureenergy -
Canada's CCS
'national champion'

Why assuming CO₂-EOR will 'oil the wheels' of CCS is dangerous
Financing CCS projects - where will the money come from?
A transatlantic dynamic for CCS policy - US visit to London and Brussels
The UK's low carbon strategy - no new coal without CCS
Recent development on solid sorbents for CO₂ capture
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International Test
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Capture,
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research,
demonstration
and engineering
facility. The HTC
Purenergy CCS
Capture System™
is based on
technology
developed here



Leaders

Spectacular developments in Dutch 'Energy Valley'

In the northern Dutch 'Energy Valley' regional governments, energy companies and research institutes work together on the creation of a Silicon Valley for the energy sector. One of the goals: the development of a full blown CCS chain. German energy supplier RWE is a major player in the region

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By Maarten van der Schaaf, freelance journalist specialized in (sustainable) energy issues

Energy Valley

"Name me one other region in Europe where similar investments are being made in the energy sector?" asks professor Catrienus Jepma, director of the Energy Delta Institute (EDI) a joint venture of Gasunie, Gazprom and the Rijksuniversiteit Groningen. "There is probably none. In five years, 15 billion euros will be invested in energy-related projects in the northern provinces of the Netherlands. This is spectacular."

The provinces of Groningen, Friesland, Drenthe and Noord-Holland have a traditionally strong energy profile: natural gas was found here in the 1950's. In recent years the idea has risen of creating a so-called Energy Valley.

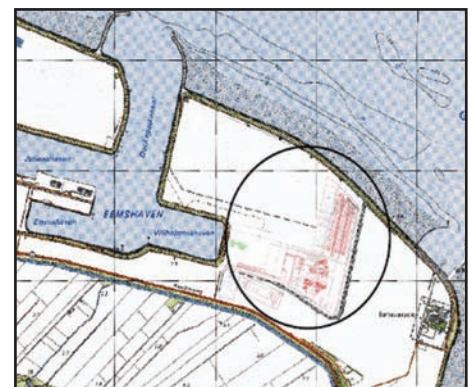
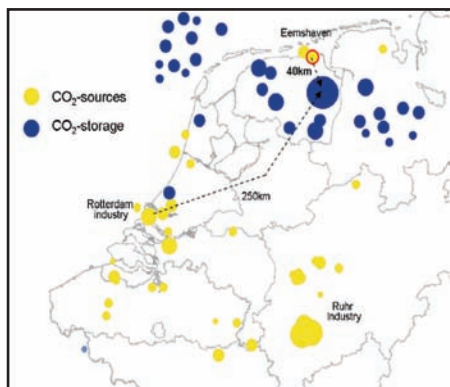
Jepma: "The energy sector gives the region the opportunity to excel. I have noticed in recent years that things start to develop very fast here. Knowledge centers focus on energy issues, regional governments powerfully promote the energy valley concept and big energy companies have come in."

CCS chain

Carbon capture and storage (CCS) is only one of the aspects of the developments in the energy sector in the north of the Netherlands, acknowledges Jepma. "However, CCS is of strategic importance. We cannot miss out on developments in CCS technologies. Whether you like it or not, fossil fuels will remain the major source of energy on a global level for years to come. Without using CCS it will be very hard to control CO₂ emissions worldwide and fight climate change."

Regional governments agree. They are trying to facilitate the creation of a CCS chain that includes capturing, transporting, storing and reusing CO₂ gasses in the region. "We want the region to be a leader in CCS," says Desmond de Vries, CCS project manager of the province of Groningen.

"CCS will not only help us to capture CO₂, it will also stimulate the economy and provide jobs. Therefore we do not focus on one CCS project in particular. In



Eemshaven is an attractive location for CCS, the harbor is centrally located in northwest Europe and the region has a good pipeline infrastructure (top image Copyright Groningen Seaports)

fact, we see the development of a CCS chain as one big project."

The active engagement of the northern Dutch provinces is unique in Europe, says De Vries. "Whenever I am on European conferences on CCS, there are hardly any representatives of regional governments."

The interest of the province of Groningen for CCS started to blossom in

2007 when German energy supplier RWE and Dutch energy company NUON expressed that they had serious plans to build new power plants in Eemshaven in the province of Groningen. De Vries: "We wanted the new factories to be as safe and clean as possible and they wanted to demonstrate CCS at their plants. It matched."



RWE: Major driver of CCS in Northern Netherlands

The German energy supplier RWE currently prepares the construction of a hypermodern coal and biomass fueled power plant in Eemshaven. It will be the biggest construction project in the Netherlands. The factory will be operational in 2013 with an output of 1600 MW. Latest 2015, RWE aims to have a demonstration capture unit in place with access to transport and storage infrastructure.

“Choosing for CCS is an obvious thing to do,” says Laut van Severter, business developer at RWE. “The construction of a new highly efficient power plant contributes to 20% emission reduction as it replaces older less efficient power plants. Also, the plant can produce green electricity for 300.000 households by 10% biomass co-firing. CCS will allow the Eemshaven plant to reduce its carbon footprint even further.”

Last year, RWE signed an Memorandum of Understanding with Gasunie, the national Dutch gas distributor, to do a pre-feasibility study for CCS infrastructure. “This is only one of many aspects that come with



“The construction of a new highly efficient power plant contributes to 20% emission reduction as it replaces older less efficient power plants. CCS will allow the Eemshaven plant to reduce its carbon footprint even further.” - Laut van Severter, business developer at RWE



RWE is currently preparing the construction of a hypermodern coal and biomass fueled power plant in Eemshaven. It will be operational in 2013 with an output of 1600 MW and a planned CO2 capture demonstration unit will be completed by 2015 (close up above left)

the development of CCS,” says Van Severter. “Apart from technical challenges, good communication about developing CCS is of vital importance. One should start with this well before official planning procedures. By discussing our initiative with relevant stakeholders we create the right project definition and necessary subsequent support during planning, construction and operation.”

RWE participates in various CCS research programmes and investments around the world. There are plans for a demonstration project of amine-based post-combustion CO2 capture technology in the Eemshaven. In July a pilot version of the amine technology will be commissioned at RWE’s site in Niederaussem, Germany.

Attractive location for CCS

It is not surprising that RWE regards the Dutch energy valley as a good location to develop CCS. “Eemshaven is an attractive location for CCS,” says Van Severter. “The harbor is centrally located in northwest Europe and the region has a good pipeline infrastructure. There is a lot of experience with gas extraction, storage and distribution. The existing hydrocarbon reservoirs, both off-shore as well as on-shore, offer excellent possibilities for large CO2 storage. Most of them will be depleted in the next 10 years.”

Another reason for choosing Eemshaven is the broad and sustained political support for CCS in the Netherlands. Environment minister Jacqueline Cramer and minister of Economic Affairs Maria van der Hoeven seriously promote CCS. Apart from encouraging energy efficiency and stimulating renewable energy production, they re-

gard CCS as a crucial part of their plans to reach EU goals on fighting climate change.

“Let us be realistic,” said minister Van der Hoeven recently at a conference on CCS in the Netherlands, “CCS is inevitable”. The state government in The Hague therefore finances 50% of CATO II, the national research programme for CCS that has a total budget of 100 million euros. The other half is paid for by energy companies active on the Dutch market. RWE is one of three leading industrial partners in CATO II.

Public support

Although the Dutch government is very supportive of CCS, it is still hard for companies like RWE to obtain all necessary permits for testing CCS. That may seriously slow down the process of creating a CCS chain, confirms professor Jepma. “That is a typical Dutch problem. There are many ways parties can protest against tests with CCS. However, I think that public protest in North Netherland could be less problematic than in other regions in the country. Here people are used to and sometimes proud of the activities of gas and energy companies.”

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Further information

See: www.rwe.nl/ccs for a short simulation movie on RWE’s CCS project.

The author can be contacted at:

www.momentum-media.nl

Energy Delta Institute

www.energydelta.nl

Groningen Seaports

www.groningen-seaports.com

HTC Pureenergy - focused on environment, economy and energy security

HTC Pureenergy sees itself as Canada's 'national champion' in CCS, and the 'go to' place for technology on the capture, sequestration and repurposing of carbon dioxide.

By HTC Pureenergy

"HTC's view is that Canada has a twofold obligation to KYOTO – its obligation to the global environment is not only to reduce emissions and set an example," says Lionel Kambeitz, Chairman and CEO of HTC PUREENERGY, "it's also to be a technology developer whereby other countries would adopt our leading edge technology. We can provide quite a contribution to other countries around the world in terms of technology adoption that's developed and commercialized here in Canada."

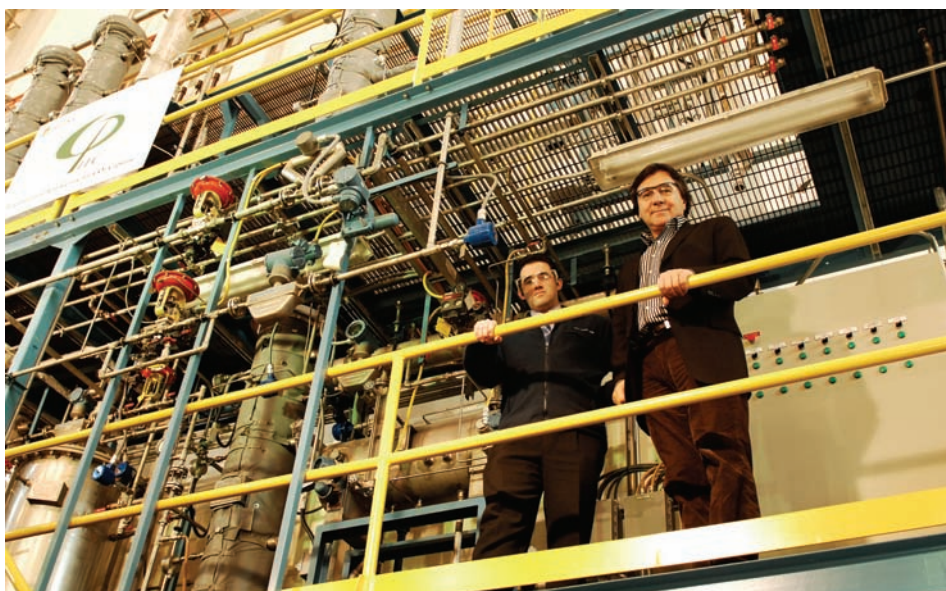
HTC had its beginning in 1997 and became involved in CO₂ in 2000 when it became clear that a new carbon economy was emerging in the world. "We're an energy technology company," says Kambeitz. "Our company licenses technology from the U of R, has acquired technologies, and has internally developed technologies to create a world leading carbon capture product offering for large industrial emitters; primarily coal fired or natural gas powered plants, oil upgraders and oil refiners."

HTC formed a collaborative licensing agreement with the University of Regina ("UofR") and the International Test Centre for CO₂ Capture ("ITC"), a leading research, demonstration and engineering facility whose mandate is to develop technologies to reduce the capital and operating costs associated with post-combustion CO₂ capture.

While the U of R has been researching CO₂ capture technologies since 1987, HTC has developed substantial CO₂ capture expertise under the monogram of "Team CO₂". Since its inception in 2000, "Team CO₂" has attracted over 40 members and includes some of the world's leading engineers and scientists working on post combustion CO₂ capture and CO₂ management.

Together, Team CO₂ has worked to develop innovative CCS product and in January 2008 HTC announced the launch of the world's first modular, pre-engineered CO₂ Capture System, called the "Pureenergy CCS Capture System™".

This stand-alone system captures CO₂ from the flue gas exhaust of power plants, oil and gas processing facilities, and large industrial emitters. The system is pre-engineered, pre-built and modularly construct-



Lionel Kambeitz (CEO – HTC Pureenergy), Scott Hume (Senior Process Engineer Doosan Babcock Energy) at the CO₂ Pilot Plant located in the International Test Center for CO₂ Capture, University of Regina

ed by strategic partners Pinnacle Industrial Services and NuVision Industries using technologies developed at the University of Regina. Because of its modular design, the system can be manufactured, shipped and erected at the emitter sight at a much lower cost than other systems that have to be custom built on site.

Dr. Raphael Idem, Associate Dean of Engineering at the U of R and lead solvent developer commented; "It is disappointing when we read that 'CO₂ capture is a long way off' and 'is too expensive to implement'. There are ways to bring down these costs. We are working very hard to build a commercial plant that will demonstrate to the world that CO₂ capture can be done cost effectively now, and not 10 to 15 years from now as indicated by others"

Asked to comment on the future of CO₂ capture, Dr. Idem continued, "We are currently developing a number of exciting new technologies including synthesized solvents, better internals (packing materials and configurations), extension of the solvent life, and further reduction of the energy penalty by using other sources of heat within the CO₂ Capture plant and from the emitter site. There are many opportunities that are yet to

be exploited to continue driving down the cost of CO₂ capture"

Most recently, Team CO₂ has introduced two new technologies; the patented Thermal Kinetics Optimization TKO™ process configuration, and the new RS™ solvent formulation. The TKO™ process significantly reduces the energy demand required for CO₂ capture by optimizing existing energy within the system. The TKO™ process has proven to reduce the largest single cost of CO₂ capture – the use of power plant steam - by up to 30%.

Source to Sink Provider

Although there are a handful of CCS systems available today, HTC Pureenergy is one of the few companies in existence that offers a full range of services in the area. Kambeitz describes the process as a CO₂ management value chain whereby HTC helps the customer to manage the CO₂ by either sequestration or in enhanced oil recovery (EOR).

Oil producers use CO₂ in enhanced oil recovery - a process whereby the injection of carbon dioxide into mature oil fields will allow significantly more oil to be recovered.

Stats collected in Canadian EOR fields suggest that injecting one ton of car-

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modular
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sequestering CO₂
from power plants
for enhanced oil
recovery (EOR)."***



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Providing Global Solutions for CO₂ Capture

bon dioxide could increase production by four to seven barrels of incremental oil while the US Department of Energy estimates the potential for CO₂ EOR in that country is 43 billion barrels. At \$50.00 (USD) per barrel oil that could be recovered in that country alone would be worth over 2 trillion dollars.

HTC can also manage the long term storage or sequestration of carbon in deep underground, geological formations such as the spaces left by depleted oil and natural gas wells, naturally occurring saline aquifers or unmineable coal beds.

“And then at the end of the value chain comes the monetization of this CO₂,” says Kambeitz. “We assist in the assessment and inventory and monetization of the carbon credit. A ton of carbon in the ground - it’s an intangible. We help our customer package it then monetize it as a tradable commodity. You either trade it or use it as an offset to the new carbon management regime that governments around the world are installing.”

“The value chain is - first capture the CO₂ from large industrial emitters. Secondly utilize the CO₂ for EOR, put it into formations where there are existing oil fields and they can produce more oil and then assist in the monetization of the carbon credit inventory and the carbon credit that’s in the ground afterwards.”

Goin’ Global

On September 3 2008, HTC signed a global licensing agreement for carbon capture and storage technology with one of the world’s leading power plant equipment supplier and power plant constructors – Doosan Babcock Energy of the UK and with Doosan Heavy Industries of Korea. As part of the agreement Doosan now owns fifteen percent of HTC and has appointed one person to sit on HTC’s Board of Directors.

In support of their newly developed partnership, Doosan has created a business group within their Power and Technology business stream, called Post Combustion Capture and Storage (PCCS). The new business group, led by Mark Bryant of Doosan Babcock Energy (UK) will be responsible to provide strategic focus on carbon capture and storage, and lead the development of Doosan’s global PCCS business plan.

In October 2008 a Technology Transfer Program was immediately initiated between HTC, Doosan, and the University of Regina. The training program being held at the University of Regina’s International Test Centre for CO₂ Capture in Regina, has already hosted as many as 18 resident engineers from the U.K and Korea. In addition to sharing tech-



The Terrace Building, Innovation Place – Home of HTC Purenergy

nical expertise, the program is designed to develop an understanding of the companies, their business, as well as their key competencies.

Looking Forward

On May 7, Saskatchewan and Montana announced their intention to “work together on the development of one of the largest international carbon capture and storage demonstration projects in the world.”

Under the announcement, a commercial scale CO₂ capture reference plant will be built on an existing coal fired plant in Saskatchewan to facilitate and validate the scale up of Post Combustion Carbon Capture (PCC) technologies. The CO₂ captured will be stored in a CO₂ storage facility in Eastern Montana. Proponents of CCS are pleased by the vision and commitment that the governments of Saskatchewan and Mon-

tana have shown as they move quickly towards demonstrating the value and validity of carbon capture and storage.

In response to the increasing global demand for CCS expertise, HTC will accelerate product development and continue to invest heavily and aggressively to continue to bring more technology through the pipeline, says Kambeitz. “We have a global competitive advantage today by virtue of the historic work done by the U of R and the global OEM and EPC capability that Doosan will provide.”

“We’re going to invest heavily to maintain that advantage. Beyond power production, we’re also going to commercialize our technology with an emphasis in oil and gas upgrading and processing which really are the oil upgrader, oil refinery and natural gas processing businesses.”

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L to R: Salim Kadiwala (Lead Process Engineer, HTC), Scott Hume (Senior Process Engineer Doosan Babcock Energy), Lionel Kambeitz (CEO – HTC Purenergy) at the CO₂ Pilot Plant located in the International Test Center for CO₂ Capture, University of Regina

Will the wheels of CCS be oiled?

Many supporters of carbon storage contend that an additional benefit will be enhanced oil recovery. Sam Gomersall says that's a dangerous assumption.

By Sam Gomersall, a director at CO2DeepStore

In 2005, BP announced groundbreaking plans to develop the world's first decarbonised fossil fuel power station in the North East of Scotland. The project planned to generate 350MW of useful electrical power using hydrogen manufactured from natural gas. It was claimed that CO₂ emissions would be reduced by around 90%, by transporting it offshore and injecting it into the depleted Miller oil field to drive a CO₂ enhanced oil recovery process and for long term geological storage.

BP said that the project would permanently store 1.3 million tonnes of CO₂ each year, the equivalent of removing 300,000 cars from the UK's roads. By injecting the CO₂ into the depleted Miller oil reservoir, BP also forecast additional production of about 40 million barrels of oil that were not otherwise recoverable. However, in early 2007, BP abandoned the project citing a lack of government subsidies to help it develop the scheme further.

That first project did have positives as it flagged a significant and growing shift in the attitude of the oil industry to climate change and did much to highlight carbon capture and storage technologies. But the question remains whether putting CO₂ into depleted oil fields to recover more oil has a role to play in fighting the worst effects of climate change or whether the claims being made about possibilities discussed are simply exaggerated?

How effective is CO₂-EOR?

All oil and gas fields rely on pressure to force petroleum towards the wells. As oil and gas fields start to become depleted so the pressure and the production rates fall. CO₂ injection can help to maintain reservoir pressure and mixed with the oil it can help flush out remaining reserves by changing the oil properties and making it flow more easily. At surface the CO₂ will fizz out of the solution before the oil is sent for refining.

The separated gas mixture contains both CO₂ and natural petroleum gas. The CO₂ may be stripped out and the petroleum gas sold or alternatively the full mixture can be compressed and recycled back into oil fields to drive more oil upwards. Otherwise the CO₂ will be vented to the atmosphere resulting in no emission savings whatsoever.

So how effective is CO₂ in enhancing oil recovery? Enhanced oil recovery using

CO₂ has been widely deployed onshore in North America since the early 1970s. Until recently the only source of CO₂ for these projects were a small number of large underground reservoirs filled with naturally occurring CO₂ of volcanic origin which were accidentally discovered in the search for oil and gas. The CO₂ has been transported through pipelines to large depleted oilfields where it drives enhanced oil recovery projects.

US operators are currently producing over 250,000 barrels of oil every day from CO₂ enhanced oil recovery projects. As much as 25% extra oil might be extracted from these fields as a result. In some fields offshore it is possible that an additional 10% could still be recovered.

With the right conditions, the CO₂ driven enhanced oil recovery is not in doubt. There are no major technical hurdles to overcome, simply commercial ones associated with retrofitting pipes and vessels resistant to the corrosive wet CO₂ environment and the requirement for very large gas handling and compression systems along with the associated modifications for health and safety. There is also the cost associated with getting the CO₂ offshore. If oil prices were to be stable at above \$100 / bbl such options are close to commercial viability and several companies are evaluating potential projects.

A win-win for CO₂-EOR?

So is there really the promise of a win-win where climate changing CO₂ emissions can be successfully reduced by permanently storing them in oil reservoirs whilst producing additional oil? Or is this just spin and greenwash from an oil and gas industry who have accepted the evidence of climate change but are struggling to decide how to respond to

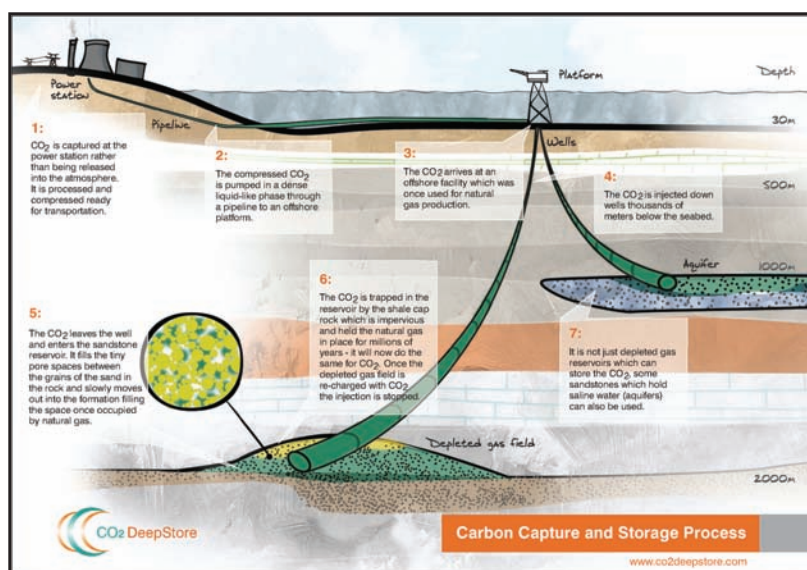


"It is my belief that any emissions trading benefits which arise from CO₂ sequestration as part of a CO₂ EOR project should be discounted according to a detailed analysis of the full cycle carbon balance by an independent verifier using the principal of additionality." - Sam Gomersall, a director at CO₂DeepStore

it?

Onshore operators need to pump between 4,000 and 8,000 cubic feet of CO₂ underground to recover one extra barrel of enhanced oil.

At first analysis the prospect of injecting one tonne of CO₂ so that 97% of it is permanently stored, gaining an additional three barrels of oil that could not otherwise



be recovered and creating only 30kg of further operational emissions from compression processes appears compelling. It looks good for both the oil industry and the fight against climate change.

Accounting for the emissions

The big question is how to account for the emissions arising from the upstream operations of extra oil production, downstream refining and finally combustion of the fuel.

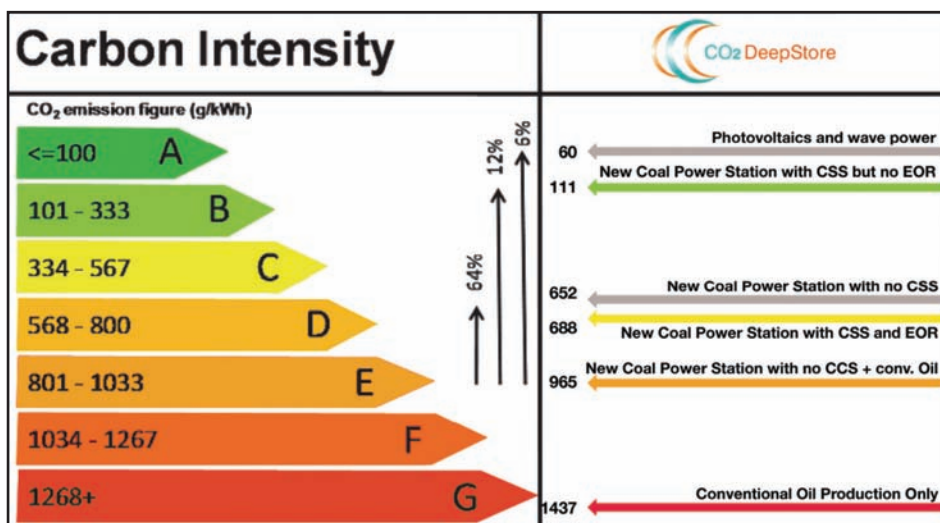
The common oil industry view is that the emissions resulting from its products are the responsibility of the customer and should not be counted. Furthermore, they say, if the EOR barrel was not being produced, refined and combusted here then it would be replaced by another barrel from somewhere else in the world.

The alternative view is that if the barrel had stayed in the ground without a CO₂ EOR process in place then it must be considered additional. Subsequent emissions associated with production, refining and combustion of the barrel must be accounted for in the carbon balance, a concept known as additionality.

In my view, the replacement concept put forward by the oil industry is only viable if the recovered EOR barrel is offset by permanently stranding a proven barrel of conventional oil reserve underground elsewhere in the world. Otherwise total CO₂ EOR emissions discharged into the atmosphere will be greater than CO₂ sequestered.

But with additionality comes additional useful energy. A more sensible analysis might therefore focus upon carbon intensity, energy delivered against CO₂ emitted. We are all becoming familiar with the emissions rating of our cars in gCO₂/km. We can use a similar measure here of gCO₂/kWh.

Emissions from oil production, most commonly used in transport applications are



A CCS system supplying CO₂ into a depleted gas field or aquifer without any EOR opportunities could deliver the same amount of useful energy, but with only 12% of the emissions of current practice

around 1250g/kWh (in equivalent terms). If CO₂ EOR is used to produce this oil, and the CO₂ is effectively stored, the emissions intensity may be reduced to about 750g/kWh. That looks good, however perhaps not so impressive when you see that a CCS system delivering CO₂ into a depleted gas field or aquifer without any associated EOR could deliver the same amount of useful energy from a coal fired power plant with only about 150g/kWh. This is getting very close to the intensity of renewables which is less than 100g/kWh. CCS can also be used with biomass power generation to create a carbon negative solution.

CO₂-EOR not an emissions reduction strategy

A carefully planned CO₂ EOR project designed to minimise full cycle emissions may have a role to play in producing more energy and perhaps assisting with energy security

in the UK and elsewhere. However CO₂ EOR is not effective as an emissions reduction measure.

Although it does offer some reductions to the carbon intensity of our energy production, we should bear in mind that Norway has delivered tremendous success in recent

years in decreasing carbon intensity whilst emissions themselves have continued to rise due to increases in energy demand.

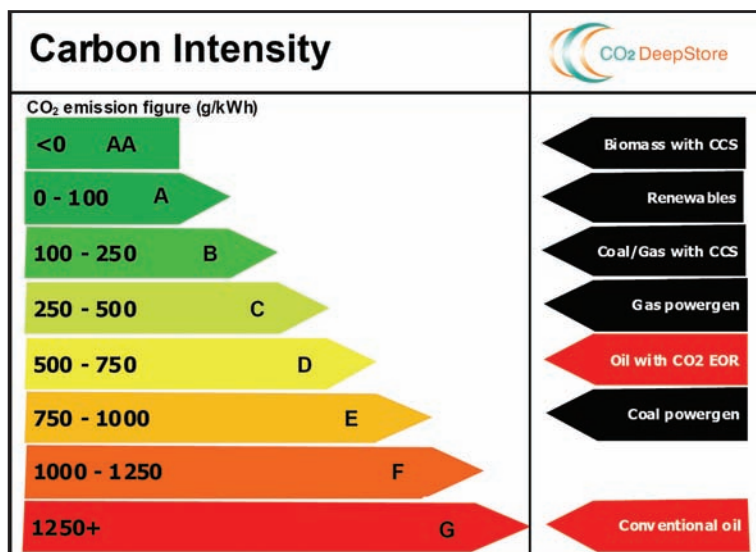
It is my belief that any emissions trading benefits which arise from CO₂ sequestration as part of a CO₂ EOR project should be discounted according to a detailed analysis of the full cycle carbon balance by an independent verifier using the principal of additionality.

Fledgling CO₂ EOR projects have done much to develop the technologies and promote the concept of carbon capture and storage across the world. Without such initiatives the technology would still be conceptual. However, EOR has only a limited role to play in the fight against dangerous climate change.

There has been much focus on CCS with EOR as a combination providing a unique win-win solution. It has been popular with the oil and gas industry due to the potential for increased production. It has been popular with power generators who have considered that the liability of emissions charges could be converted into a valuable revenue stream. However it is not a viable CO₂ abatement technology and will result in increased emissions. The UK focus should be placed firmly on CO₂ Storage without EOR.

About the company

CO₂DeepStore's business is focussed on commercialising the deep geological storage of CO₂ by being an active CO₂ Storage Operator in order to make a significant contribution to mitigating the worst effects of climate change. For more information visit: www.co2deepstore.com



CO₂ emissions for each kWh of useful energy produced

CCS – where is the money coming from?

As acceptance grows that clean coal is an essential component of the world's energy mix the industry's development must now be funded. Calum Hughes looks at the emerging sources of finance for CCS in the UK and further afield.

Calum Hughes, Trainee Solicitor, Martineau

CO₂ is a valueless waste product and there was, until recently, no statutory restriction on its release into the atmosphere at zero cost. Therefore, without regulatory intervention, a commercially viable carbon capture and storage industry, at anywhere approaching the scale required, could not develop.

Accordingly, at International and National level, policies and measures to create markets in greenhouse gas (GHG) abatement and, more recently, to fund CCS development directly are being conceived and implemented. As private sector confidence that these moves are backed up by long term political commitment increases, private investment in the industry is also being made.

Regulatory and fiscal measures

Carbon allowance trading schemes are currently the preferred method of state control over GHG emissions (including CO₂). These schemes are based upon a 'cap and trade' model in which the emission of a given amount of GHG requires the acquisition of a corresponding amount of licences to emit (dubbed "Allowances"). The amount of Allowances made available, and therefore GHGs emitted, is restricted in line with the relevant regulator's emissions targets.

As GHG emissions are generally related to profitable commercial activities, the right to emit the gases has a value to the businesses wishing to carry out those activities. Hence the state can sell Allowances in order to raise revenue. When this is done the schemes are, in effect, a method of taxation on GHG emissions.

Where cap and trade systems differ from other forms of taxation is that Allowances are transferable, and therefore the right to emit GHG can be traded.

This creates a market in the right to pollute and, in theory at least, the Allowance market price will converge upon a value at which just enough emitters will find it economically favourable to reduce their emission rather than purchase Allowances. These will be the emitters with the lowest abatement costs and hence the desired emission reductions should be achieved at the lowest overall cost.

These schemes have the potential to

skew the market in favour of carbon abated plants as well as generating revenues which could be used to subsidise CCS development.

By far the most advanced of these schemes is the European Union's Emission Trading Scheme (EU ETS), which is now into its fifth year of operation. It was instigated to help the EU to meet its GHG emission reduction obligations under the Kyoto protocol to the UN Framework Convention on Climate Change (UNFCCC).

Allowances under the scheme (EUA's) were initially given free of charge to emitters participating in the scheme but charging for EUAs at the point of issue, which raises revenue for the EU members, is now being phased in.

A policy of hypothecation of EUA auction revenues to fund climate change related projects has been much debated but currently remains un-adopted. However, when the EU ETS scheme rules were amended in December 2008, a fund of up to 300 million EUAs, with an estimated value of between €6 and 9 billion, was allocated to 'help stimulate the construction and operation of up to 12 [CCS] commercial demonstration projects'.

The EU ETS amending directive also specifically states that 'an obligation to surrender allowances shall not arise in respect of emissions verified as captured and transported for permanent storage'. This statement is arguably unnecessary because of the definition of 'emission' in the ETS Directive, but, in any event, its inclusion gives assurance to industry that facilities fitted with CCS will avoid having Allowance purchase as part of their operating expenditure.

In addition, as an apparent blanket exclusion to state aid rules, an EU Commission statement annexed to the same Directive allows up to 15% of the cost of a new 'CCS ready' energy power plant to be met from a member state's EUA auction revenues between 2013 and 2016.

In the US, the country's first mandatory GHG cap and trade scheme, the Regional Greenhouse Gas Initiative (RGGI) is now operational. Although the scheme currently only covers ten north-eastern states there are strong indications that it may shortly be subsumed into a federal emissions trading



"The key question currently is whether the necessary combination of public policy and private confidence can be achieved to yield sufficient funding, quickly enough, to enable CCS to meet its potential in combating climate change." - Calum Hughes, Martineau

scheme.

The next step could well be a trading link between the US and EU ETS with allowances issued under the two schemes being fungible.

Other ETS schemes are in various stages of development in Australia, New Zealand and Japan as well as, vitally, China. It is hoped that all schemes will eventually be connected to create a global ETS.

Closely linked to emission trading schemes are the Kyoto protocol's Flexibility Mechanisms. One of these, the Clean Development Mechanism (CDM) allows countries with emission reduction commitments under the protocol to 'offset' their commitment by purchasing emission reduction credits (called Carbon Emission Reductions (CERs)). CERs are earned by qualifying GHG emission reducing projects in developing countries. This provides funding for the project and the scheme has been particularly popular in India and China. CERs can be used to offset a proportion of an emitter's obligations under the EU ETS.

CCS projects are currently excluded from the CDM but there was a strong pro-

posal to amend this at the 2008 UNFCCC conference in Poznan. The proposal was eventually rejected but it is widely predicted that CCS projects will be eligible for inclusion in any replacement for the CDM agreed at the 2009 UNFCCC conference in Copenhagen.

The EU Commission has proposed that post-Copenhagen only Least Developed Countries (LDC's) should benefit from CDM support. This would reduce the potential benefit of the scheme for the CCS industry, but the Commission's proposal is also the subject of much opposition. It is too early at this stage to know which way the debate will go but it seems likely that any deal struck in Copenhagen will offer some support for CCS.

Governments are also beginning to introduce direct subsidies for research and development of CCS projects. In the UK and the US particularly, there have been major recent shifts in policy.

In the UK the Conservatives have said that, were they in power, they would introduce Emissions Performance Standards for power stations, a feed-in tariff for CCS abated electricity and fund three CCS demonstration projects from EUA auction revenues.

In response, the Government announced measures in the budget on April 22nd which instigated a levy to fund a CCS incentive mechanism. The details of the levy, who will pay it and the levels of revenue it will raise were not specified but the Government hopes to support up to three new demonstration projects including both pre and post-combustion technologies.

There will be a consultation on whether the incentive mechanism will take the form of a feed-in tariff for electricity generated or a fixed price subsidy for carbon abated but in any event the Government has said it will provide a 'reliable stream of finance' for CCS.

In addition, the existing demonstration competition may still go ahead and, in any event, the companies short-listed will receive £90 million to help them complete their front end design studies.

Along with these carrots comes a stick. Firstly, as a pre-condition of obtaining planning permission consent for any new coal fired power station in England and Wales, there will be a requirement to install, from day one, a CCS demonstration plant capturing a proportion of the plant's CO₂ output equating to 300 MW of net capacity.

Secondly, again as a condition of planning permission, all new coal fired power plants would be required to fit CCS to 100% of the plant's capacity by 2025 or, if



Vattenfall's Jämschwalde coal plant will receive funding through the EU economic recovery plan for a CO₂ capture demonstration

later, whenever the technology is considered by the Environment Agency to be 'proven'.

There is also a proposal to require all combustion power stations over 300 MW, regardless of fuel type, to be carbon capture ready. These proposals will now be consulted upon and converted into legislation.

The US Federal Government has also given the CCS industry a fillip this year. The American Recovery and Reinvestment Act introduces funding of \$4.6 billion for fossil energy research and development: \$2 billion to the NZEP project, \$1 billion to the Clean Coal Power Initiative and \$1.52 billion to fund CCS demonstration projects. The US Department of Energy has already issued Funding Opportunity Announcements for much of this money.

At EU level, the European Parliament has backed a Commission proposal to provide CCS projects with grants of €1,050 million in 2009 and 2010 as part of the European Energy Programme for Recovery Regulations. Only 13 specified projects in seven EU states are eligible to apply for the funding and only one project per member state will actually be funded. Funding will be for up to 80% of 'eligible investment' costs.

In other parts of the world including Australia, Canada, Norway and South Africa, public funding is also currently being made available to fund CCS research institutes and project developments.

Private investment

The various regulatory and fiscal measures considered above will only be applied to the degree necessary to achieve Governments' aims in attracting sufficient private investment into the industry. The point at which investment is considered commercially attractive will vary from one business model to another but interest, and investment, is increasingly forthcoming from industry participants.

Privately funded research and development is already ongoing in several key areas, including: improved solvents and processes for post combustion scrubbing; large scale air separation units for oxyfuel combustion; and multi-fuel gas turbines suitable for IGCC plants. Reservoir leak monitoring systems and industry service provision businesses are also being privately financed.

Oil and gas industry organisations have already played a large part in financing CCS related technologies as a result of their use of CO₂ injection as a method of reservoir pressure maintenance and enhanced hydrocarbon recovery (EHR).

This knowledge coupled with their wealth of offshore experience and the regulatory changes allowing combined EHR/CCS permitting in Europe is likely to see continued investment from these organisations.

The electricity generation companies

are also at the forefront. In Europe, Vattenfall is the obvious example and E.ON and Scottish Power seem to be taking a particular interest in policy developments and also have specific plans to invest.

In response to the UK's recent CCS consultation, all of the contributing electricity generators stated that they would leave sufficient space for CCS retrofit on any new power stations, whether mandated to do so or not. This would seem to suggest that all these companies have an expectation that CCS will become economically desirable at some stage.

Enhanced coal-bed methane recovery could also help the economic viability of some CCS projects.

The days of CO₂ as a waste product that can be freely released to the atmosphere are increasingly behind us and there now seems little doubt that CCS is becoming a major industry.

The key question currently is whether the necessary combination of public policy and private confidence can be achieved to yield sufficient funding, quickly enough, to enable CCS to meet its potential in combating climate change.

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The EU's economic recovery plan

The EU's economic recovery plan will invest €5 billion in energy projects, broadband internet infrastructure and rural development.

MEPs gave the green light to investing €3.98 billion of the funds in gas and electricity infrastructure, offshore wind parks and carbon capture and storage projects. Parliament also backs allocating €1.02 billion to rural development measures.

MEPs backed a political agreement reached with the Council ahead of Parliament's first-reading vote on a co-decision report drafted by Eugenijus MALDEIKIS (UEN, LT) on the energy projects of the recovery plan.

The European Energy Programme for Recovery will provide €3.98 billion to energy projects in the following fields (article 3):

- gas and electricity infrastructure (€2,365 million);
- offshore wind energy (€565 million);
- carbon capture and storage (€1,050 million).

The recovery plan will bear up to half of

the costs of gas and electricity infrastructure and offshore wind energy projects. Carbon capture and storage (CCS) installations can be co-financed by up to 80% of the costs.

€200 million for Nabucco gas pipeline

The programme reserves €200 million for supporting the construction of the Nabucco pipeline which will bring natural gas from the Caspian Sea to the EU.

Moreover, the recovery plan lists 13 CCS projects in seven Member States which can apply for funding installations to store CO₂ permanently and safely underground.

The list of potential projects also includes offshore wind energy parks in the North Sea and projects to integrate future offshore wind installations in the North and Baltic Seas into the onshore grid.

About the author

Calum Hughes has 19 years experience in engineering and the project management of upstream oil and gas and gas storage projects. He is currently completing his training as a Solicitor.



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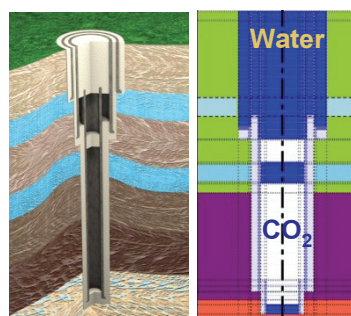
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UK - no new coal without CCS

The UK government has set out proposals that would require new coal plants to include a CCS element from day one, with full scale retrofit required when CCS becomes technically viable.

The UK government has made a clear statement on its support for CCS in coal-fired electricity generation. Any new plant would be required to have around 25% CCS from the outset.

Full scale retrofit of CCS within five years of the technology being independently judged as technically and commercially proven would also be required under the proposals.

Alongside the Government's ongoing competition to build a post-combustion demonstrator, up to three further projects including pre-combustion technology, would be funded by a new levy mechanism.

The Government will also seek views on whether it is possible to implement these conditions through an emissions performance standard.

These proposals form part of a consultation that will be released in the summer, alongside an environmental report.

"CCS is the only technology with the potential to reduce emissions from fossil fuels by up to 90%. But there must be a global effort to develop this technology and the UK is in a strong position to lead this charge," said Ed Miliband, UK

"This signals the era of unabated coal is coming to an end, and a new low carbon future for coal with CCS can begin."

"There is no alternative to CCS if we are serious about fighting climate change and retaining a diverse mix of energy sources for our economy."

Financing the demonstration projects

The new demonstrations will be funded by an incentive mechanism as announced in the Budget, but it is not yet clear how this would work. "Proposals for how the incentive will work are being developed," said Miliband.

It will likely be a levy on the power system, which may add a small increment on energy bills.

According to David Kennedy, Chief Executive, Committee on Climate Change, this "may be bad from a fuel poverty perspective, but actually when you look at the numbers, there will be a negligible impact of this levy on electricity bills, so I don't think the fuel poverty consequences are significant in this case."

There is also £90 million to fund detailed preparatory studies.

These studies would reduce technologi-



The proposed 1600MW coal plant at Tilbury would be 'capture ready', with an element of CO₂ capture by 2014. It is one of the projects receiving funding through the EU economic recovery plan

cal risk for CCS projects and give greater clarity on costs. They would also ensure that preparations for construction start at the earliest possible date.

"It would be a requirement of funding that information from the studies is made available to promote global understanding of CCS," stated the Budget Report.

Proven by 2020?

Some uncertainty exists over what would happen if the technology is not ready by 2020, which is the date the government is using in its forecasts.

Miliband has stated that he would "seek views on whether we need a safety net in the eventuality that it [CCS] does not become proven as quickly as we expect".

The energy companies are lobbying for a get out clause that would enable new coal-fired plants to continue operating if the 2025 deadline is too ambitious.

This worries the environmental groups, who see the proposals as a way to make coal plants more palatable in the short term, with no way to shut them down if CCS does not materialise.

"The Minister's proposals are equivalent to giving the green light to four new coal-fired power stations, only one of which would have full CCS and the others to remain entirely unabated until about 2025," said Dr David Golding, Development Coordinator, North East Make Poverty History.

"The Government accepts that CCS

technologies 'have still to be demonstrated as a chain and at scale'. So will it close down the new stations if CCS proves to be unworkable, or (more likely) uneconomic? This simply beggars belief, given the billions which will be invested in them and the hole in the energy budget which would be created as a result."

Capture readiness

The Government also published its response to last year's consultation 'Towards Carbon Capture and Storage', which set out its approach to carbon capture readiness. This will apply to all new gas, oil, biomass, waste-to-energy and also coal power station applications on or above 300MW.

The Government will only consider applications if they:

- Confirm sufficient space available to retrofit CCS
- Identify a suitable potential offshore area to store carbon dioxide
- Map a feasible potential transport route from the power station to the storage area and
- Do not have foreseeable barriers to retrofitting CCS.

Together, these criteria will prove a power station is 'carbon capture ready'.

Comments on the proposals and budget

"We welcome further clarity from the Government on developing CCS. The Government must ensure that any funding mecha-

nism is sustainable for the long-term development of this urgently important technology- to create green jobs and invest in a low-carbon economy,” said **Dr Jeff Chapman, Chief Executive of the Carbon Capture and Storage Association.**

“The Government’s renewed commitment to see the UK lead the world in bringing forward CCS is welcome, but we must ensure that further consultations do not create unnecessary delay.”

“The CCS community looks forward to working with the Government on how to urgently deploy commercial scale CCS plants to meet our ambitious climate change targets.”

Lord Turner, Chair of the Committee on Climate Change (CCC), said, “We welcome the Government’s proposals, which are consistent with the recommendations in our December report.”

“In particular, we welcome the commitment that any new coal plants should demonstrate CCS, and should be fully retrofitted with CCS once the technology has been demonstrated. These proposals are a very positive contribution to required decarbonisation of UK power generation in the period to 2030.”

“We were clear in our report that there can be no role for conventional coal genera-

tion in the UK beyond the early 2020s. This should be reflected by a very tight emissions limit being placed on any non-retrofitted plant beyond the early 2020s. We will work with the Government to ensure that the detailed proposal to be set out later in the year includes a tight emissions limit.”

Building a low-carbon economy, the CCC’s first report, sets out the analysis underpinning the recommendation that the UK should reduce emissions of all greenhouse gases by at least 80% by 2050. It also proposes the level of the first three carbon budgets covering the periods 2008-12, 2013-17 and 2018-22.

In September, the CCC will publish its first progress report which will set out a roadmap for building a low-carbon economy in the UK. This will look in more detail at the specific policies that are required to produce clean electricity, improve the energy efficiency of homes and promote more sustainable forms of transport.

Stephen Hale, Green Alliance director, said, “This is only a small step for mankind, but it is a big leap for HM Treasury. This Budget contained much more than an abysmal Pre-Budget report.”

“But there’s a very long way to go. There are a daunting backlog of issues that need resolution now in order to sustain the govern-

ment’s claim that it is finally delivering on their rhetorical commitment to the low-carbon economy. Other countries, notably the US, have done more in recent months.”

“Green Alliance is delighted that the Chancellor announced a new financing mechanism for carbon capture and storage. We have pushed hard for support for this vital technology in the war against climate change. We also welcome the additional support for renewables and energy efficiency, and the private investment this should trigger.”

“But we will need a further gear change in the next twelve months and beyond to deliver action at the necessary scale and speed. All parties wanting to be credible at the next election will need to demonstrate they have a plan to finance the transition to a low-carbon economy.”

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Further information

The government consultation and reports and Ed Miliband’s speeches are available at www.decc.gov.uk

Carbon Capture and Storage Association

www.ccsassociation.org.uk

Committee on Climate Change

www.theccc.org.uk

Green Alliance

www.green-alliance.org.uk

A transatlantic dynamic for CCS policy

US experts visited London and Brussels to share experience in CCS policy development: smart packages of finance and regulation will be key to unlocking action.

By Chris Littlecott, senior policy adviser, Green Alliance

The engineering challenge of delivering CCS is well known and often stated. But the policy challenge is just as tough. How can we best assemble a package of financing and regulation that can foster technology deployment and guarantee emissions reductions, and all at acceptable public cost? The combination of economic recession and growing climate concerns make this a tricky challenge for national decision-makers.

It was with this policy challenge in mind that Green Alliance convened a delegation of US policy experts from the areas of regulation, business, and NGOs (see box for details). The delegates visited London and Brussels in March 2009 to share their experience at pushing forward a credible US climate policy.

They met with Ed Miliband, UK Secretary of State for Energy and Climate Change, and with the shadow ministers from the Conservative and Liberal Democrat parties; shared insights with senior officials in

the European Commission; and spoke at public events on the themes of the emerging US climate policy, the opportunities for energy efficiency, and CCS deployment.

Key messages were quick to emerge:

On regulation

Richard Cowart delivered two foundational insights for the emerging US approach. Firstly, cap-and-trade alone is not enough, with additional regulatory measures now recognised as required. Secondly, for CCS in particular, there are a number of promising regulatory options in different US states. But as of now, none of these have been assembled into a coherent package alongside sufficient funding to bring CCS projects onto the market.

On the California approach

Hope was given on this point by Michael Peevey, President of the California Public Utilities Commission, who expressed his be-

lief that California would be the first US state to have a functioning CCS project. His Commission has issued decisions supportive of a joint CCS project between Hydrogen Energy International and Southern California Edison. This project hopes to rapidly proceed if it can secure federal funding from the Obama administration recovery package.



Michael Peevey, President of the California Public Utilities Commission

Projects and Policy

Key to the development of this project was seen to be the role of the Emissions Performance Standard (EPS) introduced in California in 2007. Meg Gottstein oversaw that process, and explained how it had been pursued to protect ratepayers from future carbon liabilities. Contrary to many expectations, she reported that the setting of the EPS parameters had been an uncontroversial decision following stakeholder engagement on the policy options. While the EPS ruled out unabated coal investments, it deliberately left the door open for CCS projects, and these were now coming forward.

Joining the delegates at the London CCS conference organised by Green Alliance and the Carbon Capture and Storage Association, Lewis Gillies of Hydrogen Energy endorsed this perspective, explaining that the California regulations had provided a market signal that the state was now a 'taker' of CCS projects.

On political realities

David Hawkins and Steve Corneli made clear that there was no prospect of a viable US federal climate policy without specific attention to the interests of 'coal states'. For this reason, the consensus approach set out in January 2009 by the United States Climate Action Partnership (USCAP) coalition of NGOs and Corporations was so important. The USCAP proposals on CCS have now been incorporated into the Waxman-Markey bill, proposing a sliding scale financial mechanism to reward early movers and fuller capture levels, combined with an EPS to drive CCS deployment and retrofit. Corneli underlined that NRG Energy supported this approach as a vital market creation foundation that would bring down equipment costs and reduce commercial investment risks.

Creating a policy dynamic

Delegates all agreed that CCS would not be delivered without a package of finance and regulation. But the political and policy risks are real and significant, so decision-makers need to act in concert to have confidence that their policies will deliver at scale. Further actions in the UK and EU should therefore look to build a mutually reinforcing momentum for CCS delivery that reduces risks and maximises market creation.

This is a challenge not just policy makers, but one for all stakeholders to find consensus around a stable policy framework. Green Alliance pursues this goal alongside its industry partners and NGO colleagues, and will be undertaking further work to address investment risks and support CCS commercialisation during 2009.

About the Author

Chris Littlecott is a senior policy adviser at Green Alliance, an independent environmental organisation based in London, UK. He leads work on CCS and European policy engagement.

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US delegation members

Californian Perspectives

Terry Tamminen (leading climate strategist and author, former cabinet secretary to Governor Schwarzenegger)

Michael Peevey (President, California Public Utilities Commission)

Nancy Ryan (Deputy Executive Director for Policy and External Relations, California Public Utilities Commission)

Gene Rodrigues (Director of Energy Efficiency, Southern California Edison Inc)



Steve Corneli, Senior Vice President, Market and Climate Policy, NRG Energy (left) and David Hawkins, Climate Centre Director, Natural Resources Defense Council (right)

Meg Gottstein (Principal, Regulatory Assistance Project; formerly Administrative Law Judge, California Public Utilities Commission)

Federal Perspectives

David Hawkins (Climate Centre Director, Natural Resources Defense Council; member of US Climate Action Partnership)

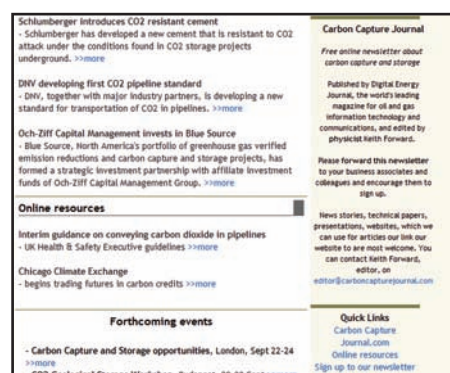
Steve Corneli (Senior Vice President, Market and Climate Policy, NRG Energy Inc; member of US Climate Action Partnership)

Richard Cowart (Director, Regulatory Assistance Project; formerly energy regulator in Vermont and Chair of the National Council on Competition and the Electric Industry)

Delegate biographies and London CCS conference presentations are available on the Green Alliance website

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US Budget boosts CCS funding

President Obama's FY 2010 budget seeks \$881.6 million for the Office of Fossil Energy (FE) to support improved energy security and rapid development of climate-oriented technology.

www.fossil.energy.gov

The request includes \$617.6 million for Fossil Energy Research and Development, \$229.0 million for the Strategic Petroleum Reserve, \$11.3 million for the Northeast Heating Oil Reserve and \$23.6 million for the Naval Petroleum Reserves.

Additionally, the FE R&D program will be complemented by \$3.4 billion from the American Recovery and Reinvestment Act of 2009. These funds will be used to advance research, development and deployment of carbon capture and storage technologies.

The FY 2010 budget request for FE's Fuels and Power Systems program is \$403.9 million. Initiatives will focus on research, development and deployment of technologies to use coal more cleanly and efficiently.

The core research and development efforts of the Fuels and Power Systems program focus on:

- the creation of a portfolio of technologies that can capture and permanently store carbon dioxide (CO₂) from power plants and industrial processes;
- carbon capture for existing coal-fired power plants;
- improved gasification technologies;
- coal-to-hydrogen conversion;
- development of fuel cells;
- improved turbines for future coal-based combined cycle plants.

Carbon Capture

The Department of Energy is requesting \$179.9 million for FE's Carbon Sequestration program. CCS is the primary pathway that DOE is pursuing to enable the sustainable use of coal as part of the nation's clean, secure energy portfolio in a carbon-constrained future.

FY 2010 funding will support CCS site selection and characterization, regulatory permits, community outreach, and completion of site operations plans for large-scale, geologic carbon storage tests.

It will also fund large-scale injections and infrastructure development. The funding will also pursue research on low-cost/low energy penalty carbon capture technologies for power plants.

Essential to these objectives are the Regional Carbon Sequestration Partnerships, which unite public and private enti-



Great River Energy's 1,100 MW Coal Creek power plant in North Dakota is the host of a Clean Coal Power Initiative project to test a prototype coal dryer that uses waste heat to remove moisture from coal, reducing emissions

ties in an effort to complete and evaluate small- and large-scale CO₂ injection tests across the nation with the aim of developing best practices and supporting the regulatory development process.

Additionally, U.S. engagement and collaboration with the global community will continue through FE's participation in the Carbon Sequestration Leadership Forum and other international initiatives.

FE will support the Department of Energy's Energy Innovation Hub for Carbon Capture and Storage. In FY 2010, the Energy Innovation Hub for Carbon Capture and Storage will focus on enabling fundamental advances and discovery of novel and revolutionary capture/separation approaches leading to transformational capture technologies to dramatically reduce the energy penalty and costs associated with CO₂ capture.

Innovations for Existing Plants (IEP)

The FY 2010 budget request for the IEP program is \$41.0 million. The IEP program is focused on developing post-combustion CO₂ retrofit capture technology. Post-combustion CO₂ capture technology can be used in pulverized coal power plants, which is the industry standard for coal-fueled electricity generation.

Advanced Integrated Gasification Combined Cycle (IGCC)

DOE is requesting \$55.0 million in FY 2010 for the IGCC program. The IGCC program is developing advanced gasification-based technologies to: reduce the cost and energy penalty of near-zero emissions (including CO₂) coal-based IGCC plants; improve thermal efficiency; and achieve near-zero atmospheric emissions of all pollutants, including CO₂, sulfur dioxide, nitrogen oxides, and mercury.

In FY 2010, the program will continue to develop technologies for gas stream purification to: achieve near-zero atmospheric emission goals and meet synthesis gas quality requirements for use with fuel cells and conversion processes; enhance process efficiency and availability; reduce costs for producing oxygen; and system reliability.

Advanced Turbines

In FY 2010, the Advanced Turbines program will continue projects to develop efficient, clean and cost-effective hydrogen fueled turbines for coal-based integrated gasification combined cycle power systems that capture and sequester carbon dioxide. DOE is requesting \$31.0 million for this activity in FY 2010.

E3G report: Delivering a Sustainable Low Carbon Future

The G20 must make green investment top priority in economic reboot says leading think-tank E3G. In a report 'Delivering a Sustainable Low Carbon Recovery' aimed at the 2009 G20 summit, Nick Mabey, co-founder E3G says that at least half of the multi-billion dollar financial stimulus plans already announced or on the drawing board must be ring-fenced for true green projects against the current average of around 20 percent.

Leaders of the industrialised nations must put low carbon investments at the heart of their global economic recovery plans to try to find a way out of the twin crises of the world recession and the climate crisis, the leading sustainable development think-tank says.

Not only that, there must be no delays. The bulk of the green investment requirement, calculated as being worth between \$911 billion and \$1.2 trillion, must be injected over the next 24 months.

"Unless investment in a low carbon economy is committed immediately, there will be little room for doing this in the future," Mabey writes, adding that aggressive growth in low carbon markets could account for as much as three percentage points of sustained global growth between 2011 and 2015.

Only that way can the crucial transition from the present high carbon to the necessary low carbon global economy be achieved in the little time that scientists say is available before the target of limiting global warming to 2°C becomes little more than a dream, and three or four degrees a near certainty instead.

Mabey notes that so far only the United States, France and Germany of the rich, developed world have committed more than 10 percent of their stimulus packages to low carbon investments while Europe as a whole, which leads in so many other areas of the climate change battle, has earmarked only five percent and Japan just 2.6 percent.

South Korea on the other hand has dedicated 80 percent of its stimulus package to green investments and China 37 percent.

Renewables like wind and solar, smart energy grids, energy efficiency, low carbon vehicles and public transport must all be targeted as part of the green economic revolution. Not only would this produce the much needed cuts in carbon emissions, it would also reduce dependence on oil, hence exposure to the renewed price shocks that are expected in coming years.

Setting out a three-stage switchover, Mabey says governments must take the lead initially because of the turmoil in private finances as well as setting out a clear and stable medium- to long-term strategy that will grad-

ually give private money the courage to come forward again.

As part of this confidence building process Mabey proposes that governments create a low carbon investment vehicle that he dubs "Green Bonds" to attract private savings and bypass the commercial banks which are heavily preoccupied in rebuilding their balance sheets and likely to be for some time to come.

The money raised would go directly into financing green projects and the bonds would have the added attraction of directly engaging the general public in the global economic transformation.

As the agenda develops into the medium-term and private finance re-emerges, government regulations and incentives giving clear guidance and assurances will take the place of emergency pump priming and job creation to move the building of the low carbon economy up a gear or two.

"Such is the scope of the economic and climate crises that the task of grappling with them must be taken out of the sole hands of finance ministries to involve a far broader range of policymakers and economic players," Mabey says.

In all of these areas the G20 "with the rich G8 taking the lead" can start to set the stage next week of motivating and coordinating actions as well as ensuring that the imperative of the economic meltdown does not overshadow or divert that of climate change.

One key area for the G20 is to make sure that the current economic climate does not lead to a resurgence of protectionism which would dilute or prevent the flow of technology and information vital to the climate change fight and risk locking in high carbon industries for decades to come, Mabey says.

With an eye firmly on the longer term, the crucial UN climate meeting in Copenhagen in December must agree a new, all encompassing treaty for the period beyond 2012, he continues.

Here too, the G20 has a major role to play, including as it does, the major players from the rich developed and major developing nations who all too frequently fail to see



"Unless investment in a low carbon economy is committed immediately, there will be little room for doing this in the future," - Nick Mabey, co-founder E3G

eye-to-eye on key details of a new pact "especially, who leads and who pays."

Mabey calls for the G20 to set up a cross-disciplinary task force to produce practical proposals on the necessary quantity, sources, mechanisms and control of the low carbon finance that is essential to fuel the green transformation.

This task force, he says, should produce its proposals by October "an extremely tight deadline given the usual bureaucratic sloth involved in such bodies" in order for them to feed into the Copenhagen process, the first full negotiating meeting of which will be taking place at the UNFCCC headquarters in Bonn over the next two weeks as the G20 meets in London.

"It is clear that without a substantial financial package there will be no Copenhagen agreement, which will result in longer term costs an order of magnitude higher in the next decades from uncontrolled climate change," Mabey warns.

The full report, or an executive summary in English or German, can be downloaded from the E3G website

www.e3g.org

Policy, company and regulation news

Australian budget - \$4.5B for clean energy initiative

The Australian Government will invest \$4.5 billion to support the growth of clean energy generation and new technologies, and to reduce carbon emissions and stimulate economic activity.

The Clean Energy Initiative will support clean technologies and industries and assist Australia's transition to a lower emissions path.

The Government will invest:

- \$2.4 billion in low emissions coal technologies, including new funding of \$2 billion in industrial-scale CCS projects under the Carbon Capture and Storage Flagships program;

- \$1.6 billion in solar technologies, including new funding of \$1.365 billion in a Solar Flagships program - helping position Australia as a world leader in this vital energy technology for the future; and

- \$465 million to establish Renewables Australia to support leading-edge technology research and bring it to market, including new funding of \$100 million. The new body will advise governments and the community on the implementation of renewable energy technologies, and support growth in skills and capacity for domestic and international markets.

This represents an investment of \$3.5 billion in new money by the Rudd Government in clean energy in this Budget.

The \$2 billion CCS funding is new money and will be spent over nine years on industrial scale demonstration projects.

The CCS Flagships program complements the recently founded Global CCS Institute, the government says, and may include a carbon dioxide storage hub.

The two strategic technology priorities of CCS and solar will be underpinned by supporting specialised research, development and demonstration programs.

Australian carbon pollution reduction scheme postponed

www.climatechange.gov.au

The Carbon Pollution Reduction Scheme will be delayed by one year and a new, ambitious 25 per cent by 2020 target has been introduced.

The Carbon Pollution Reduction Scheme (CPRS), a cap and trade system, will now be phased in from 1 July 2011, delayed by one year 'to manage the impacts of the global recession.'

A one year fixed price period will be introduced, with permits costing \$10 per tonne of carbon in 2011-12, with the transition to full market trading from 1 July 2012.



Fortum aims at starting a CCS demonstration project jointly with Teollisuuden Voima (TVO) at the Finnish Meri-Pori power plant (pictured Image ©Fortum)

Australia has also committed to reduce carbon pollution by 25 per cent of 2000 levels by 2020 if the world agrees to an ambitious global deal to stabilise levels of CO₂ equivalent in the atmosphere at 450 parts per million or less by 2050.

This would be met by 'substantial investment in clean, renewable energy and energy efficiency and strategic investment in carbon capture and storage.'

Up to five percentage points of the 25 per cent target could be achieved through Government purchase of international credits, such as avoided deforestation credits, using CPRS revenue no earlier than 2015.

Centrica pulls out of UK CCS competition

www.centrica.com

Centrica has sold its 50% stake in the Eston Grange IGCC project on Teeside back to developers Progressive Energy.

The company said the technology was too uncertain, and will concentrate on wind and nuclear projects.

"Given the large investment we are making in other low carbon technologies and the current uncertainties surrounding CCS we decided to end our involvement in the Eston Grange CCS project," said Centrica.

"While we are not looking to develop any further projects, we believe in time CCS technology will be commercially viable and we may be involved in this technology in the future."

Fortum and Polish PGE cooperate on CCS technology

www.fortum.com

Finnish Fortum Corporation and PGE Belchatow Power Plant, a subsidiary of Poland's biggest energy company PGE, have signed an agreement to start cooperation in CCS solutions.

The contract was signed at the European Economic Congress in Katowice.

Both Fortum and PGE have their own development projects on-going, which are aiming for the CCS demonstration programme of the European Commission.

The PGE Belchatow power plant in Central Poland is Europe's largest and the world's second largest fossil fuel fired power plant with total installed power capacity of 4,440 megawatts.

Fortum aims at starting a CCS demonstration project jointly with Teollisuuden Voima (TVO) at the Finnish Meri-Pori power plant. The Meri-Pori plant is one of the cleanest and most effective coal-fired power plants in Europe. The power plant was completed in 1993 and its power generation capacity is 565 MW. It is jointly owned by Fortum and TVO.

EPA greenhouse gas ruling paves way for emission controls

www.epa.gov

After a thorough scientific review ordered in 2007 by the U.S. Supreme Court, the Environmental Protection Agency issued

a proposed finding that greenhouse gases contribute to air pollution that may endanger public health or welfare.

The proposed endangerment finding, which now moves to a public comment period, identified six greenhouse gases that pose a potential threat.

It states, "In both magnitude and probability, climate change is an enormous problem. The greenhouse gases that are responsible for it endanger public health and welfare within the meaning of the Clean Air Act."

If the ruling is upheld, it would open the way to emissions controls on CO₂ from large industrial sources.

EPA's proposed endangerment finding is based on rigorous, peer-reviewed scientific analysis of six gases – carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulfur hexafluoride – that have been the subject of intensive analysis by scientists around the world.

The science clearly shows that concentrations of these gases are at unprecedented levels as a result of human emissions, and these high levels are very likely the cause of the increase in average temperatures and other changes in our climate, the finding says.

The scientific analysis also confirms that climate change impacts human health in several ways. Findings from a recent EPA study titled "Assessment of the Impacts of Global Change on Regional U.S. Air Quality: A Synthesis of Climate Change Impacts on Ground-Level Ozone," for example, suggest that climate change may lead to higher concentrations of ground-level ozone, a harmful pollutant.

Air Products joins Schwarze Pumpe pilot

www.airproducts.com

Air Products will install its proprietary CO₂ capture, purification and compression system at Vattenfall's research and development facility in Schwarze Pumpe, Germany.

The two companies also executed a joint research and development agreement related to the project. Air Products' pilot plant is to be operational at Schwarze Pumpe in December 2010.

Air Products will take flue gas directly off Vattenfall's 30 megawatt (MW) wall-fired boiler at the oxyfuel pilot plant. It will purify and compress the carbon dioxide, a portion of which will ultimately be transported for sequestration.

Air Products' proprietary sour compression technology uses a staged compression process to optimize pressure, hold-up, and residence time to allow removal of impurities during the compression process.



Air Products' CO₂ capture pilot will be located at Vattenfall's Schwarze Pumpe 30MWth oxyfuel pilot plant. Photo courtesy of Vattenfall

This allows cost savings in the oxyfuel combustion process and minimizes the concentration of acidic components, important in preventing corrosion during the CO₂ sequestering process, the company says.

The pilot will demonstrate the efficient purification of CO₂, and remove inert gases, in particular oxygen. In addition, it will incorporate novel membrane technology, targeting carbon capture rates as high as 98 percent.

Air Products is currently working on several carbon capture and storage demonstration projects around the world. In early March the company announced work with the U.S. Department of Energy (DOE) to design and construct a CO₂ purification system in support of an oxyfuel technology development project at a boiler simulation facility in Windsor, Connecticut.

Funding for UK CCS research

www.eon-uk.com

www.geos.ed.ac.uk/sccs

E.ON UK and the Engineering and Physical Sciences Research Council (EPSRC) have awarded GBP6.9m (\$10m) of research funding to four university-led projects investigating CCS technologies.

Project teams led by the universities of Nottingham, Newcastle, Edinburgh and Leeds will investigate combustion and CO₂ capture and transport technologies.

The three projects funded under the E.ON/EPSRC Partnership are:

- The University of Nottingham will lead a consortium of four universities looking at how the surfaces of materials can be chemically altered to enhance CO₂ absorp-

tion or 'soak up' rates. This may be an alternative to chemical absorption using amines in post-combustion capture systems. The other participants are the University of Birmingham, the University of Liverpool and University College London.

- Newcastle University is leading a project to address some of the technical and material challenges of large-scale transportation of CO₂ through pipelines. This will help the development of a storage pipeline network. The other members of the group are University College London, the University of Nottingham, Cranfield University, and Imperial College London as well as range of industry partners

- Leeds University, Imperial College London, Cranfield University, the University of Kent, the University of Nottingham and the University of Cambridge are working on the oxyfuel combustion process in which coal is burned in a mix of pure oxygen and power station flue gases, creating a stream of CO₂ that can be captured for storage.

- EPSRC is funding a fourth consortium, led by the University of Edinburgh, on improving the economics of large-scale carbon capture and storage and how to separate CO₂ formed by emissions from fossil fuel power stations.

Fluor selected for SaskPower CO₂ capture project

www.fluor.com

Fluor Corporation has been awarded the contract for front-end engineering for CO₂ capture for the SaskPower Boundary Dam Integrated Carbon Capture and Sequestration Demonstration project in

Estevan, Saskatchewan, Canada.

If the project proceeds as planned, it would be the first commercial-scale carbon capture system used on a coal-fired power plant in North America.

The project involves updating and refurbishing an existing unit at Boundary Dam. Fluor will add its carbon capture process using its Econamine FG Plus solvent. The project will determine the technical, economic and environmental performance of the CCS technology.

The front-end engineering involves the preparation of a detailed process design, cost estimate and a design verification analysis using Fluor's CO2 technology.

Fluor is one of three companies selected to proceed to the next stage for further evaluation of the carbon capture technologies. SaskPower is expected to make a final selection by the end of 2009.

Saskatchewan and Montana develop joint CCS project

www.gov.sk.ca

Saskatchewan Premier Brad Wall has signed a Memorandum of Understanding with Montana Governor Brian Schweitzer to work together on the development of a cross border CCS project.

The project involves the construction of a technology-neutral CO2 capture plant (reference plant) at an existing coal-fired electrical generating station in Saskatchewan that would have the flexibility to test a range of post-combustion carbon capture technologies.

A CO2 storage facility in eastern Montana will be built including injection infrastructure that allows the possibility to withdraw the CO2 for enhanced oil recovery at a

later date.

New pipeline infrastructure for the transportation of CO2 from the reference plant in Saskatchewan to the storage facility in Montana, a distance of around 60 miles, would be required.

The project will also develop a North American training facility to meet the needs of a growing CCS industry and regulators, based primarily at the University of Regina and Montana State University.

The total cost of the project in Canadian dollars is estimated to be \$270 million. On the Canadian side, it is approximately \$150 million to design and build the CO2 reference plant, related CO2 pipeline infrastructure and a North American training facility for CCS technicians.

The Government of Saskatchewan will provide up to \$50 million through Crown Investments Corporation and has requested funding of \$100 million from the federal government through its Clean Energy Fund.

The State of Montana has requested \$100 million (US) from the Government of the United States through the Department of Energy to support construction of a CO2 pipeline on the U.S. side of the border and development of the underground CO2 storage and research in the infrastructure in Montana.

"Both of our countries rely on coal as a low cost fuel for the majority of our power generation, but burning coal comes at a significant cost to our environment," Wall said. "This project will help us to meet our needs for power while developing new clean energy technologies to address the challenge of climate change."

Governor Schweitzer and Premier Wall agreed that the international carbon capture

and storage demonstration project will also help address national policy priorities in both countries including the development of near zero, sustainable energy technologies; continental energy security and economic stimulus to support the North American economy.

A steering committee including Crown Investments Corporation President Ron Styles, SaskPower President Pat Youzwa and University of Regina President Vianne Timmons has been formed to oversee the Canadian component of the project. The committee will complete work on the development phase by August 31, 2009, including a full project plan, engineering design, business plan, detailed budget and construction timeline.

With the financial support of the Governments of Canada and the United States, construction of the plant could begin as early as September 2009 and the plant could be operational as early as the summer of 2011. The goal for the reference plant is to test a range of technologies in the capture of up to one million tonnes of CO2 over a four-year period.

MGA launches CCS inventory and toolkit

www.midwesterngovernors.org

The Midwestern Governors Association (MGA) has released a CCS inventory and toolkit designed to aid the development of a platform for coal power generation with CCS.

The Midwest has extensive geological reservoirs for storing carbon dioxide, and has been home to pioneering work in the area of enhanced oil and gas recovery.

To build on the region's existing strengths, Midwestern governors agreed in

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November 2007 to establish a carbon management infrastructure partnership through its Energy Security and Climate Stewardship Platform (Platform). In order to implement the many goals of the Platform, an advisory group was charged with the development of an inventory and toolkit for CCS.

The toolkit provides background information on a range of issues, along with a menu of actions and potential options for states and the region to consider.

The inventory provides a state-by-state analysis of statutes and regulations that could be applied toward a regional approach to the regulation of CCS.

These documents will assist Midwestern states and stakeholders in addressing issues that will support the Platform's goals of regional development of advanced coal with CCS, says the MGA.

"Michigan boasts one of only three currently active carbon storage sites in North America, and we are eager to advance this industry," said Michigan Gov. Jennifer Granholm, MGA chair. "While advancing environmental stewardship, this industry has the potential to create thousands of jobs throughout the Midwest."

The MGA is a nonprofit, nonpartisan organization that brings together the Midwestern governors of states to work cooperatively on public policy issues of significance to the region.

UK Conservatives promote EU-ETS money for CCS in Green budget

www.conservatives.com

The Government should announce that it will use part of its receipts from the EU Emissions trading Scheme to fund the installation of CCS equipment and pipeline networks for at least 5GW of new coal-fired power plant, said the Conservative Party.

The Conservative Party has set out measures that the Government could introduce at the 2009 Budget that would unleash at least £30 billion of private sector investment, and lay the foundations for a stable, competitive and low carbon recovery, the Party says.

This includes using EU-ETS money to fund CCS and introducing feed-in tariffs for renewable electricity.

"Gordon Brown has failed to grasp the CCS opportunity, by only running one slow and narrowly defined pilot project and passing up any real chance of industry leadership by green-lighting more unabated coal power to be merely 'CCS ready'," the Party said.

"The Government should also bring forward the introduction of feed in tariffs for both renewable electricity and heat, as pro-

posed by Conservatives and as already legislated for in the Energy Act," it said.

"The revenue stream from these tariffs will help people lower their energy bills and give the long term market certainty that homes and businesses need to secure finance."

The Government should also make it easier for companies to borrow money to invest in green technologies by providing government guarantees for bank loans to environmental technology companies, as part of our proposed National Loans Guarantee Scheme. "This would help overcome one of the main current obstacles to investment in new renewable energy technologies."

The Government should also work with the London Stock Exchange to launch the world's first Green Environmental Market (GEM) to provide the next generation of British environmental companies with the investment they need to expand and succeed in the global market.

Nuon starts construction of CO2 capture test at Buggenum

www.nuon.com

All the permits have been issued for Nuon's CCS trial at the Buggenum power plant in Holland. Construction will start before the summer of 2009 and the installation will be in operation in the second half of 2010.

The purpose of the installation is to make the method suitable for use in the electricity sector, says the company. It will probably take two years and cost around 40 million euro.

To restrict the building activities at the site, the test installation is to be constructed in five big parts. The components will be transported mainly by water. The individual parts will be joined together in Buggenum.

Nuon plans to use the knowledge and experienced gained to install a large scale CO2 capture plant at the planned Nuon Magnum power plant in Eemshaven, near Groningen.

"The power plant in Buggenum offers excellent opportunities for testing CO2 capture because fuels are gasified there already," says Øystein Løseth, CEO of Nuon. "This makes it possible to capture CO2 before the combustion process. Nuon is the first company in northern Europe to use this technique. The main advantage is that it's a cleaner alternative than post-combustion capture. In addition, it's more efficient, somewhat cheaper and the installation takes up less room."

A substantial research programme is linked to the project, involving ECN, TNO, Delft University of Technology and KEMA.



"The power plant in Buggenum offers excellent opportunities for testing CO2 capture because fuels are gasified there already" - Øystein Løseth, CEO of Nuon

Nuon has received a subsidy of 10 million euro for this purpose via the Unieke Kansen Regeling (UKR – Unique Opportunities Scheme) of the Ministry of Economic Affairs.

UK Energy Research Centre 'Energy 2050' report

www.ukerc.ac.uk

The UK Energy Research Centre (UK-ERC) has released a new report addressing two of the Government's toughest energy policy goals – delivering reliable energy to consumers while meeting its legal commitment to reduce CO2 emissions by 80% by 2050.

The report concludes that the UK electricity sector must be decarbonised by 2050, by which time oil use will be virtually eliminated.

Tougher energy efficiency measures could reduce exposure to volatile energy markets, buying time before full decarbonisation of the electricity system takes place.

New and improved low-carbon technologies need a reliable carbon price; a market signal of around £200/tonne CO2 by 2050, 15 times the current EU carbon price, is needed to hit the long-term target. This rises to £300-350/tonne CO2 if action is delayed or more stringent targets are set.

The report finds that decarbonising the electricity system with nuclear, renewables and coal plant fitted with carbon capture and storage (CCS) would unlock new potential, allowing electricity to be increasingly used in transport and buildings. A low-carbon energy system could be a high-electricity system.

Recent development on solid sorbents for CO₂ capture

Maoqi Feng, from the Southwest Research Institute in San Antonio, Texas looks at some of the solid sorbents under development to replace MEA in CO₂ scrubbing applications in flue gas streams.

The conventional method to scrub CO₂ from flue gas streams is to use monoethanolamine (MEA) and its analogues, but this is not cost-effective for power plant flue gas because of the high volume, low pressure, and the CO₂ content of only 12 – 15%. Also, the solvent's performance is degraded by other pollutants, such as sulfur dioxide, oxides of nitrogen (NO_x), and oxygen. It also causes corrosion problems.

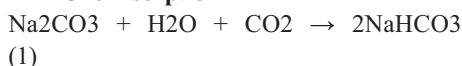
One of the technologies under development for CO₂ capture includes the use of improved solid sorbents to replace MEA and its analogues. Gas-solid adsorption systems that are applicable to removal of CO₂ from mixed-gas streams employ solid adsorbent beds, in which processes are a hybrid of adsorption and absorption. This paper gives a brief review on recent developments on solid sorbents for CO₂ capture.

Na₂CO₃

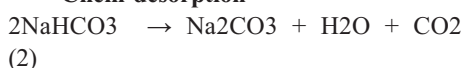
Since the traditional monoethanolamine (MEA) solvent has some drawbacks for scrubbing CO₂ from flue gas, more effective solid adsorbents are being developed.

Sodium carbonate has been used as sorbent in a process for CO₂ capture from flue gas [1]. Environmental friendly sodium carbonate would be an interesting chemical for CO₂ capture. Sodium carbonate absorbs CO₂ forming sodium bicarbonate (NaHCO₃), see Reaction 1. The process flow diagram is shown in Figure 1. After the flue gas is desulfurized in a wet scrubber, it is passed through a fluidized bed loaded with Na₂CO₃ particles; the Na₂CO₃ particles adsorb CO₂ to form bicarbonate at 50–80°C. When the particles are loaded they are heated with steam or CO₂ to about 120°C to drive off a 99%-pure CO₂ stream and regenerate Na₂CO₃ (see Reaction 2). The process uses much less energy than the amine process. Research Triangle Institute (RTI) is building a 10 metric tons/day pilot plant.

Chemisorption



Chem-desorption



A CO₂ capture system based on Na₂CO₃–NaHCO₃ slurry and its integration

with a power plant was studied in literature [2]. The results were compared to MEA-based capture systems. Since the low solubility of NaHCO₃ is a disadvantage for the sodium carbonate based liquid systems since this limits the total concentration of carbonate, the formation of solid bicarbonate was allowed, thus forming slurry, which could increase the capacity of the solvent.

Feasibility study for combined heat and power plant for CO₂ capture was studied by simulation. The energy requirement for stripping of captured CO₂ from the slurry was ~3.22 MJ/kg [2], which was significantly lower than the MEA-based systems which typically have energy consumption about 3.8 MJ/kg.

This system seems to be attractive for combined heat and power plants because of the high total energy efficiency of the plants. For a condensing power plant, the CO₂ capture will directly reduce the electricity production; whereas for a combined heat and power plant, part of the loss can be gained from heat production, thus the energy efficiency will be better.

Carbonate Minerals

Carbonate minerals can also be used as solid sorbent for CO₂ capture by reacting with CO₂ to make stable solid products, like carbonate minerals that can be returned to the environment. Weathering of alkaline rocks, e.g., calcium and magnesium silicates are a natural method of CO₂ sequestration.

Olivine sand and wollastonite can be pulverized, dissolved, and reacted with CO₂ from power plant flue gas to form magnesium and calcium carbonates. Energy needs for the pulverization generate CO₂ that is from 1 to 15% of the CO₂ sequestered [3]. While the process seems feasible, large amounts of rock must be transported and handled, which is several times the weight of the CO₂ sequestered.

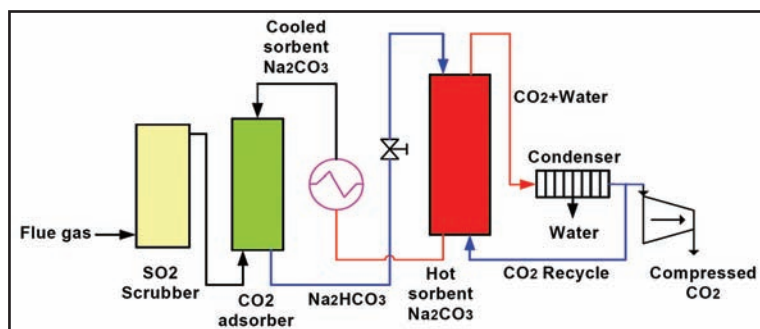


Figure 1. Process flow Diagram for CO₂ Capture from Fluegas with Na₂CO₃ Solid Sorbent

CaO Sorbent

Alkali doped CaO (Cs/CaO) sorbents have been used to capture CO₂ from fluegas in a wide temperature range [3]. The reactions of carbonation and desorption are listed in Equations 3–6.

Chemisorption



Desorption



Thermo-gravimetric analysis (TGA) study of the sorbents with loadings of CaO doped with 20 wt% cesium (cesium hydroxide) demonstrated high CO₂ sorption uptakes (up to 66 wt% CO₂/sorbent), as listed in Table 1. High selectivity for CO₂ adsorption was achieved since zero adsorption affinity for N₂, O₂, H₂O and NO was observed at temperatures as high as 600 °C.

For water vapor and NO, a positive effect was observed for CO₂ adsorption. In the presence of steam, the CO₂ adsorption increased to the highest adsorption capacity of 77 wt% CO₂/sorbent. In the presence of NO, the final CO₂ uptake was the same, but the rate of adsorption was 10% higher at the initial stages than the case that no NO was fed.

The CO₂ sorption increased in the following order: Li < Na < K < Rb < Cs. The advantage of cesium hydroxide doped CaO sorbent is due to the fact that cesium oxide leads to higher surface basicity, which favors the chemisorption of a weak acid such as CO₂.

Temperature, °C	50	225	300	375	450	525
CO ₂ captured/gram sorbent	1.5	3.1	4.5	10.4	34.0	45.5

Table 1. CO₂ captured at different temperature after 300 minutes of adsorption

The optimum adsorption temperature for CO₂ was 600°C and the thermal stability of the formed Cs₂CO₃ is limited for the bulk face to ~610°C.

Besides high selectivity for CO₂ and very low affinity for water (CO₂/H₂O ratios >100), cesium doped CaO sorbents have other advantages, such as high CO₂ sorption capacities at high temperatures, rapid sorption characteristics, CO₂ sorption at a very wide temperature range (50 - 650°C), durability, and low synthesis cost. The sorbent basicity (optimum number of basic sites of the appropriate strength) can be controlled, which allows for the selective chemisorption of CO₂ at a wide range of temperatures.

This family of sorbents is promising for development of advanced industrial sorbents for the effective CO₂ removal from coal-fired power plants as well as other types of applications such as fuel cells, inorganic membranes, water gas shift reaction (WGS), and syngas applications.

Activated Carbon

Activated carbon has been used to remove CO₂ from a flue gas stream. In general, activated carbon has lower selectivity and lower working capacity than other sorbents such as zeolites. However, activated carbon is useful for flue gas applications because the surface interaction between the activated carbon and carbon dioxide are much weaker than that for zeolites, implying a much lower desorption energy requirement. Activated carbon is also much less affected by water than other adsorbent materials and does not require stringent upstream moisture removal.

A carbon adsorbent is being tested at SRI International that adsorbs ~20% of its weight in CO₂ [1]. During the operation, desulfurized flue gas is passed through a fixed bed of porous carbon pellets under ambient conditions. The adsorbent is regenerated with steam at about 100°C. The process is expected to have only about 25% energy cost of MEA. The process is still at bench scale.

Zeolites

Zeolites are crystalline aluminosilicates of alkali or alkali earth elements with large surface areas onto which CO₂ can adsorb. The BET surface area for zeolites is in the range between 500 and 800 m²/g. Zeolite cages can occlude large amounts of gas molecules. CO₂ is preferentially adsorbed on the surface of zeolites over the competing nitrogen and oxygen.

Water vapor, if available, will also be ad-

sorbed; therefore, it is necessary to remove water vapor from the flue gas stream prior to passing the gas through a zeolite adsorption bed. Desorption of CO₂ is achieved by heating the zeolite bed under vacuum; however, compared to activated carbon, zeolite regeneration requires more energy because of the strong attraction of CO₂ to the zeolite substrate.

Adsorption Research, Inc. is developing a kind of zeolite adsorbent beads for CO₂ capture [1]. In the process, the adsorbent beads are delivered to the top of an adsorber column by a bucket elevator and fall down through an adsorption section, with counter, upflowing of cooled flue gas. A series of perforated trays are used to slow down the beads flow to provide a residence time of 30-60 seconds for CO₂ adsorption. Then, the beads drop through a heat-exchanger section where they are heated indirectly to 200 - 300°C by upflowing flue gas. The CO₂ is released by the heat and is withdrawn through a perforated pipe.

In laboratory tests, the process has achieved 89% CO₂ recovery with 99% purity. Compared with MEA adsorption, the process requires less parasitic heat or cooling energy and the adsorbent is not degraded by SO₂, NO_x or O₂. It was estimated that a commercial unit could process 15,000 tons/d of CO₂ from a 500-MW power plant for under \$20/ton [1], while it was about \$40/ton for MEA.

Immobilized amine sorbents (IAS)

Solid IAS formulated by impregnation of liquid amines within highly porous substrates is reactive towards CO₂ and may offer an alternative means for cyclic capture of CO₂. This eliminates, to some degree, the inadequacies related to chemical absorption by aqueous alkanolamine solutions.

In literature, tetraethylenepentamine (TEPA), acrylonitrile-modified tetraethylenepentamine (TEPAN), and a single formulation consisting of both TEPAN and N, N'-bis(2-hydroxyethyl)ethylenediamine (BED) supported on poly (methyl methacrylate) (PMMA) substrate were reported [4]. Under a dry mixture of 10% CO₂ in nitrogen at 25°C and 1 atm, TEPA supported on PMMA (TEPA/PMMA) over the initial 60 minutes of exposure adsorbed ~3.2 mmol/g of sorbent whereas TEPAN supported on PMMA (TEPAN/PMMA) along with TEPAN and BED supported on PMMA (TEPAN-BED/PMMA) adsorbed ~1.7 mmol/g of sorbent and ~2.3 mmol/g of sorbent respectively.

Cyclic experiments with an IAS formu-

lation of a 1:1 weight ratio of TEPAN and BED supported on poly (methyl methacrylate) beads and a gas mixture simulating a fluegas environment (9% CO₂, 3.5% O₂, nitrogen balance with water vapor) with trace contaminants were studied. CO₂ sorption capacity of the IAS material was ~ 3 mmols CO₂/g of sorbent at 40°C and 1 atm for a humidified 9% CO₂/N₂ gas mixture. A high SO₂ concentration (750 ppmv) resulted in incremental loss in IAS performance. Upstream removal of SO₂ prior to CO₂ capture is needed for the IAS sorbents.

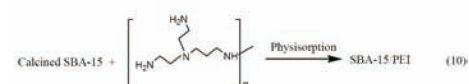
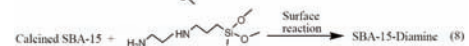
Hyperbranched aminosilica (HAS)

Many types of amine-modified silica materials have also been reported, e.g., amine-tethered silica materials, amines impregnated into porous silica, etc. as possible solid adsorbents for CO₂ capture from flue gas streams.

Amine-modified silica generally suffer from low CO₂ capacities or lack stability over many cycles, especially when amines are physisorbed onto the support. Therefore, it is advantageous to synthesize an organic/inorganic hybrid amine-tethered silica material with high amine loadings (> 6 mmol/g) capable of reversibly binding CO₂ rather than employing physisorbed, impregnated adsorbents that may be unstable after several cycles. The syntheses of the HAS materials are shown in Equations 7-10.

The covalently tethered HAS materials are capable of binding CO₂ reversibly from simulated flue gas, and their CO₂ capacity is compared with those of other reported solid amine adsorbents as listed in Table 2 [5]. The HAS materials are practical CO₂ adsorbents due to their simple synthesis, covalent inorganic-organic linkage, and low cost. The HAS material has the highest fully regenerable CO₂ capacity for a covalently supported adsorbent under simulated flue gas conditions.

The robust HAS materials are easy to synthesize, and are capable of adsorbing CO₂ reversibly with very high capacities of 3.1 mmol CO₂/g material at 25°C. The materials



can be recycled by thermally desorbing the CO₂ from the surface with essentially no changes in capacity. Furthermore, the organic groups on the surface are stable in the temperature range between 25 and 130°C due to

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www.infocastinc.com/carbon09

Material	Temperature, °C	mmol CO ₂ /g sorbent
SBA-15 - HA	25	3.11
SBA-15 - HA	75	2.11
SBA-15/PEI	25	1.99
SBA-15/PEI	75	2.14
SBA-15-diamine	25	0.72
SBA-15-NH ₂	25	0.40

Table 2. Comparison of Amine Adsorbents as Solid CO₂ Traps

Note: Adapted from Reference [5]. The molecular weight for SBA-15/PEI is 750,000.

the covalent attachment between the support and the organic groups. Based on the high amine loading, the ability to recycle the materials, and the high CO₂ affinity, these materials are very promising new materials for acid gas capture from flue gas streams.

Metal-organic frameworks (MOFs)

MOFs represent a new class of porous materials that offer the following advantages for CO₂ capture and storage: ordered structures, high thermal stability, adjustable chemical functionality, extra-high porosity, and the availability. MOFs consist of large molecules with engineered macromolecular cavities that can adsorb CO₂. A high storage density is possible, and low heat is required for CO₂ recovery.

In literature [6], nine compounds were selected in order to examine a range of structural and porous attributes. The list represents a cross-section of framework characteristics such as square channels (MOF-2), pores decorated with open metal sites (MOF-505 and Cu₃(BTC)₂), hexagonally packed cylindrical channels (MOF-74), interpenetration (IRMOF-11), amino- and alkyl-functionalized pores (IRMOFs-3 and IRMOFs-6), and the extra-high porosity frameworks IRMOF-1 and MOF-177.

Silica- and carbon-based physisorptive materials such as zeolites and activated carbons are often referenced as benchmark materials. The highest reported gravimetric CO₂ capacity for these materials at ambient temperature is 7.4 mmol/g (at 32 bar) for zeolite 13X. MOF-177 has a very high surface area of 4508 m²/g, and it was tested to have a 33.5 mmol/g of CO₂ adsorption capacity at ambient temperature, which is more than 10 times of the capacity of zeolites.

Zeolitic Imidazolate Frameworks (ZIFs)

A new kind of adsorbents, zeolitic imidazolate frameworks (ZIFs), is developed recently and has potential for CO₂ capture [7]. ZIFs are porous crystalline material with tetrahedral networks that resemble those of aluminosilicate zeolites. Transition metals (Zn, Co) are used to replace tetrahedrally coordinated atoms (for example, Si), and imidazolate links replace oxygen bridges.

ZIFs are also called super-sized molecular sponge that trap and store CO₂. ZIFs are

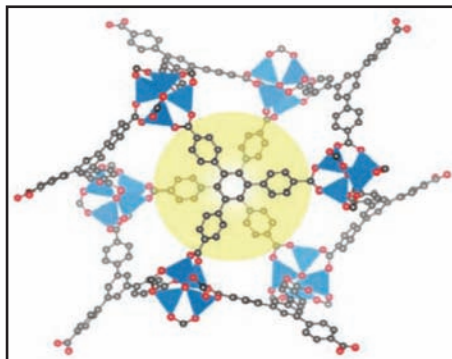


Figure 2. Molecular Structure of MOF-177 [6]

synthesized by a solvothermal reaction of Zn(NO₃)₂·4H₂O or Co(NO₃)₂·6H₂O and an excess amount of purine in N,N-dimethylformamide (DMF) at 65°C or 85°C, respectively [8], to give crystalline Zn(Pur)₂·(DMF)_{0.75}(H₂O)_{1.5} (ZIF-20, Pur = purinate) and its Co(II) analogue [ZIF-21, Co(Pur)₂·(DMF)(H₂O)].

The properties of ZIFs are determined by link-link interactions, rather than by the structure directing agents used in zeolite synthesis [7]. ZIFs are chemically and thermally stable, yet have the long-sought-after design flexibility offered by functionalized organic links and a high density of transition metal ions. Porous ZIFs, such as ZIF-95 and ZIF-100, have complex cages that contain up to 264 vertices, and are constructed from as many as 7,524 atoms.

ZIFs selectively capture CO₂ from several different gas mixtures at room temperature, with ZIF-100 capable of storing 28 liter/liter sorbent at standard temperature and pressure. These characteristics, combined with their high thermal and chemical stability and ease of fabrication, make ZIFs promising candidate materials for strategies aimed at ameliorating increasing atmospheric CO₂ levels.

ZIFs have very good selectivity due to the functional groups on the organic linker which act like 'revolving doors' to allow CO₂ molecules to enter but keeping out other gases. ZIFs can be regenerated for reuse by ex-

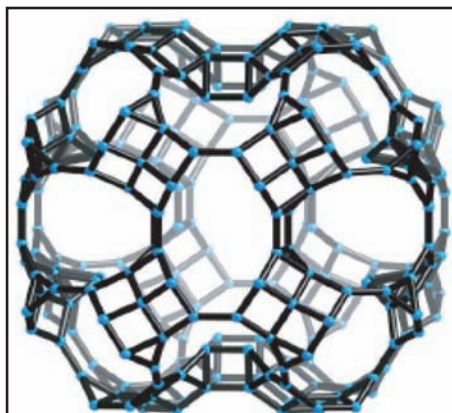


Figure 3. Cage Structure in ZIF-100 [7]

posing to lower pressures in which CO₂ is sucked out of the lattice.

Other Solid Sorbents

ADA-ES Inc. is using solid sorbents (undisclosed) in field tests in a temperature swing adsorption (TSA) process for CO₂ capture from power plant flue gas. The pilot scale field unit is designed to recover 1 ton/d of CO₂. An ADA-ES team member, Adsorption Research, Inc, will study and optimize the process.

We need to mention that there is no commercial plant using solid sorbents for CO₂ capture. All the solid sorbents summarized above are either at lab scale or pilot plant scale test. Some of the sorbents are very promising for the future.

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Maoqi Feng: mfeng at swri.org

Capture news

Siemens develops CO₂ capture technology for combined cycle power plants

www.powergeneration.siemens.com

Siemens Energy is to adapt its proprietary process for carbon dioxide capture to the special conditions prevalent in, and mode of operation of, combined-cycle power plants for the Norwegian utility Statkraft.

The project started in January 2009 and is scheduled to be completed within two years. The technology will then be generally available for industrial-scale applications.

Combined cycle plants impose stringent requirements on the process used for CO₂ capture. Their flue gas has a lower CO₂ concentration than that in coal-fired plants while simultaneously exhibiting a high oxygen content, conditions which have a very negative impact on known solvents.

The project includes investigations into the behavior of Siemens' solvent under these special flue-gas conditions.

"We will also be matching the CO₂ capture process to the dynamic load profile of combined cycle power plants, which is characterized by frequent load cycling. We will optimize the entire process to enable easy backfitting of a CO₂ capture system in future combined cycle power plants," said Tobias Jockenhoevel, head of Post-Combustion Technology in the Fossil Power Generation Division, Siemens.

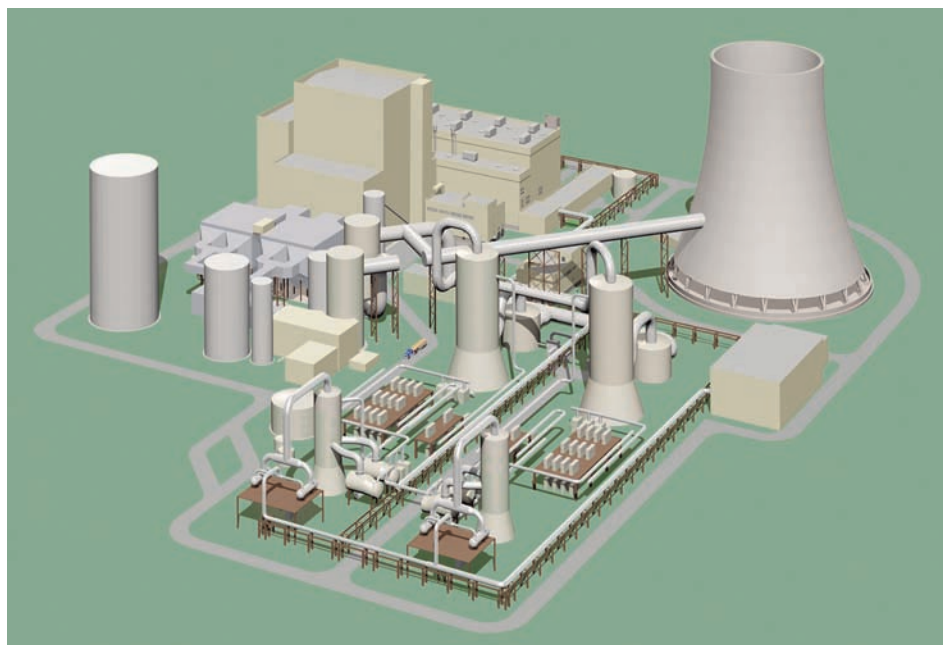
In 2008, revenue from the products and solutions of Siemens environmental portfolio was nearly EUR 19 billion, which is equivalent to around a quarter of Siemens total revenue.

Singapore scientists discover low energy CO₂ to methanol process

www.ibn.a-star.edu.sg

Scientists at the Institute of Bioengineering and Nanotechnology (IBN) in Singapore have found a catalyst that can enable a CO₂ to methanol reaction at room temperature.

The process uses N-heterocyclic carbenes



The conceptual unit of Siemens' power plant where its proprietary process for carbon dioxide capture will be tuned for the mode of operation of a combined cycle plant

(NHCs), an organocatalyst, to react CO₂ with Hydrosilane, a combination of silica and hydrogen. The product of this reaction is transformed into methanol by adding water through hydrolysis.

In contrast to heavy metal catalysts that can contain toxic and unstable components, NHCs are stable, even in the presence of oxygen. Hence, the reaction with NHCs and carbon dioxide can take place under mild conditions in dry air.

IBN's says its research shows that only a small amount of NHC is required to induce carbon dioxide activity in a reaction.

Previous attempts to reduce CO₂ to more useful products have required more energy input and a much longer reaction time,

say the scientists. They also require transition metal catalysts, which are both unstable in oxygen and expensive.

Ongoing research at IBN aims to find cheap alternatives for the hydrosilane reagent so that the production of methanol can be more cost-effective for mass industrial production.

The paper was published in international chemistry journal *Angewandte Chemie*.

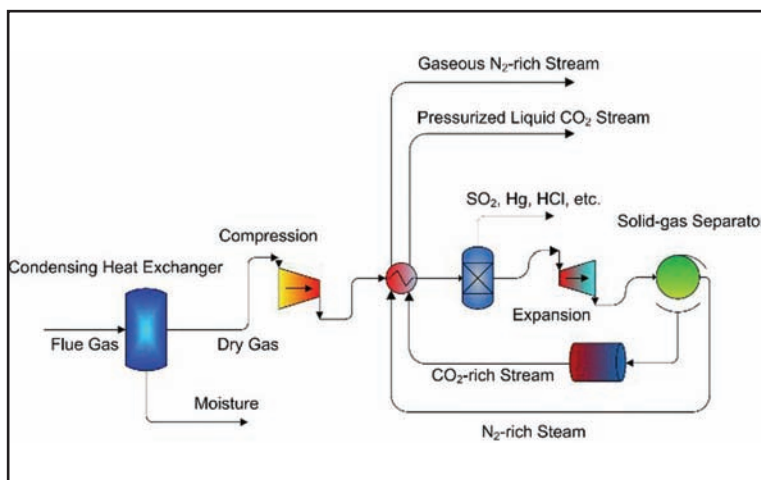
Dr. Geert Versteeg joins CO₂ Solution's scientific advisory board

www.co2solution.com

CO₂ Solution has announced that Dr. Geert Versteeg has joined its Scientific Advisory Board (SAB). The company develops a proprietary bio-technological platform for the capture of CO₂ from power plants.

Dr. Versteeg brings over 25 years of professional experience in applied scientific research, including significant expertise in CO₂ capture processes which will be a valuable asset to the Company in its efforts to scale up and optimize its enzymatic carbon capture technology for commercial application.

Dr. Versteeg is Director and Co-founder of Procede Group BV ("Procede"), a leading developer of custom processes requiring advanced chemical-engineering knowledge, based in The Netherlands. Procede, a spin-off of Twente University of Technology ("Twente"), employs a research, develop-



The low energy CO₂ to methanol process pioneered at the Institute of Bioengineering and Nanotechnology (IBN) in Singapore

Separation and Capture

ment and design staff of 30 engineers and other scientific personnel and has performed work for numerous organizations in the oil and gas industry including Shell, Exxon-Mobil and The Dow Chemical Company.

Dr. Versteeg is also Professor and chairholder of Multiphase Reactions at the State University, Groningen in The Netherlands and was previously Professor and chairholder of Process Development and Design at Twente. Over the course of his career, he has co-authored over 200 publications on the subject of CO₂ capture and acid gas treating.

Sustainable Energy Solutions wins award

www.sustainablees.com

SES was selected the winner in the Clean Technology and Energy Category for a process that separates CO₂ from flue (exhaust) gases more cost effectively and uses significantly less energy than alternatives.

The technology is being commercialized by SES and is licensed from the Fulton College of Engineering and Technology at Brigham Young University.

It is called Cryogenic Carbon Capture Technology and is a patent pending process



Kent Udell of Seasonal Energy, Larry Baxter of Sustainable Energy Solutions, and Fred Jaeger of Innovative Wastewater Solutions, wait to hear the winner of the Clean Technology and Energy category on stage at the 2009 Utah Innovation Awards luncheon at the Little America in Salt Lake City on April 30, 2009

developed by Dr. Larry Baxter at Brigham Young University. It is designed to separate a nearly pure stream of CO₂ from power plant gases.

"Many scientists believe CO₂ emission is among the world's most significant technical challenges. The SES technology represents a direct response to this challenge," said Brent Webb, associate academic vice

president for research and graduate studies at BYU.

"This innovative technology solution has the potential to greatly reduce the energy and economic impacts of addressing CO₂ emissions from all combustion systems compared to alternative systems. We are pleased to have it recognized by the Utah Innovation Award sponsor and technical professionals."

The University of Edinburgh Masters Programme in Carbon Capture and Storage



This new multi-disciplinary programme within the world-renowned School of GeoSciences at the University of Edinburgh will provide high-level training in all aspects of carbon capture and storage, as well as an overview of global carbon management.

The programme is designed for geosciences and engineering graduates wanting an advanced academic qualification as a launch pad for careers within the energy industry. Specialisation is possible through choice of optional courses.

The Masters consists of full-time (12 months) or part-time (24 months) study, with assessment by course assignments and written examination. It boasts expert lecturers of international standing, excellent links to business, and the opportunity to conduct research projects in a wide range of CCS projects.

www.geos.ed.ac.uk/masters

www.ed.ac.uk

Study quantifies CCS storage potential in Scotland

A Scottish Government backed study, 'Opportunities for CO₂ Storage Around Scotland', has identified the UK's largest carbon dioxide storage sites beneath the North Sea.

The major one-year collaborative study, involving the Scottish Centre for Carbon Storage (SCCS), The Scottish Government and a number of industry partners has revealed that a range of 4,600 to 46,000 million tonnes of CO₂ emissions could be stored beneath the Scottish area of the Northern and Central North Sea.

The upper range of 46,000 Mt is more than enough for 100 years worth of the UK's total industrial CO₂, with several sites having the possibility of storing the next 200 years of Scotland's total CO₂ output alone.

The results from the study indicate that Scotland, and the UK as a whole, has a storage resource capacity much larger than its planned annual volume of industrial CO₂ output.

'Opportunities for CO₂ Storage Around Scotland' is the first fully integrated source-to-store research into CO₂ transportation and storage ever performed in the UK.

The detailed study proves that Scotland's offshore carbon dioxide storage capacity is comparable with Norway and greater than Netherlands, Denmark and Germany combined.

Scottish First Minister, Alex Salmond said that Scotland's ambition is to become a world leader in reducing harmful emissions and producing clean, green energy. He believes Scotland and the UK could be a destination for European CO₂ emissions storage.

"This report, a unique collaboration between a range of partners from business, universities and research facilities, signals a milestone in Scotland's energy policy. It is evident from our wealth of natural resources that we have a competitive and comparative advantage both in terms of renewable energy and carbon capture," he said.

Now, more work will be done to evaluate the most promising of Scotland's offshore storage sites, with the study recommending a phased and integrated approach to CCS.

This will mean commencing as quickly as possible a more detailed mapping and evaluation of specific saline aquifers, akin to that undertaken by the oil industry assessing hydrocarbon prospects prior to exploratory drilling.

The major findings

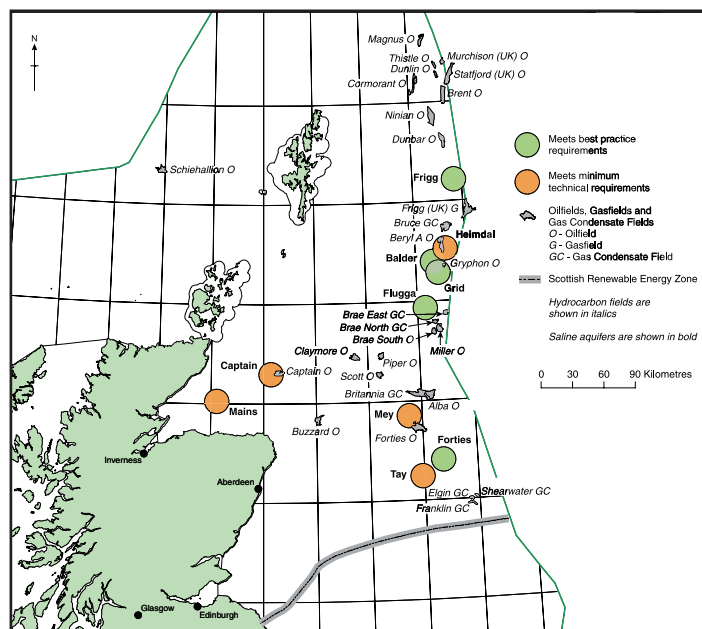
Initial costs of assessing potential saline aquifer stores are likely to be considerably higher than for oil and gas fields which have previously been fully evaluated during many years of both exploration and production operations.

Only detailed appraisal studies that include drilling of boreholes are likely to provide sufficient confidence to initiate a commercial-scale CCS project. Thus, pilot CO₂ capture projects will be an essential element of developing any new CO₂ storage site.

From a resource of more than 200 hydrocarbon fields, 29 have been identified as clearly having potential for CO₂ storage. Four gas condensate fields and one gas field offer significant potential for CO₂ storage. However, most of the oil fields can only be used as CO₂ stores in conjunction with CO₂-EOR technology.

CO₂-EOR may act as a stimulus for CCS especially if developers come to expect that the price of oil will remain over US\$100 per barrel for the period of their investment. Development of a CCS infrastructure in Scotland could lead to application of CO₂-EOR (and, therefore, additional oil production and revenue) in certain fields.

Storage hubs are proposed to give multiple storage options within a geographical area to reduce costs and risks to CCS infrastructure. A pipeline network would be used to transport 20 million tonnes/ year of CO₂ from sources to distribution hubs offshore. Capital costs are £0.7 to £1.67 billion, depending on hub location. The hubs are proposed to give multiple storage options within a geographical area to minimise costs and risks to CCS infrastructure. The preferred route is through an onshore pipeline from the



The location of all 29 hydrocarbon fields and 10 saline aquifers identified as potential CO₂ storage sites within the Scottish offshore.

Firth of Forth to St Fergus, then onwards to an offshore storage hub, while an offshore pipeline route from the Firth of Forth should also be considered. Transport of additional CO₂ from NE England is best served by a pipeline direct to an offshore storage hub. Ship transport is possible as an interim solution, ideally discharged at the offshore hub.

A phased approach is appropriate to support the development of CCS technology. Direct Government funding will be required in the short term for R&D and pilot projects. In the medium term, CCS demonstration projects required under the UK Government and EU programmes, will need income support. Other low-carbon technologies, such as renewable power generation, currently receive incentives which are envisaged to continue for the medium term. In the long term, low-carbon generation projects are capable of being supported by the price of carbon alone. However, the volatility of the carbon market will place an additional financial risk on such projects.

The long term carbon abatement cost of CCS coal and CCS gas appear comparable with other available low-carbon power generation technologies and CCS has the potential to materially contribute to carbon abatement in Scotland.

Transport and storage news

Australia releases offshore storage areas

www.ret.gov.au

The Australian government has released ten offshore areas for the exploration of greenhouse gas storage.

The Offshore Petroleum and Greenhouse Gas Storage Act 2006, which came into force on 21 November 2008, provides for a system of access and property rights for the geological storage of greenhouse gas in offshore waters under Commonwealth jurisdiction.

As the first step in the process of providing these access and property rights, the Minister for Resources and Energy, the Hon Martin Ferguson AM MP, has released 10 offshore areas.

These are located in the following basins:

- Gippsland Basin
- Torquay Sub-basin
- Otway Basin
- Vlaming Sub-basin
- Petrel Sub-basin

However, the Government has still to finalise a complicated regulatory regime before permits can be issued. The process could mean it will take up to a year before leases are finally agreed.

Victoria reveals CO₂ storage potential study

www.premier.vic.gov.au

The Victorian Government has conducted a preliminary study which reveals several large areas in the Gippsland Basin have excellent potential to store CO₂.

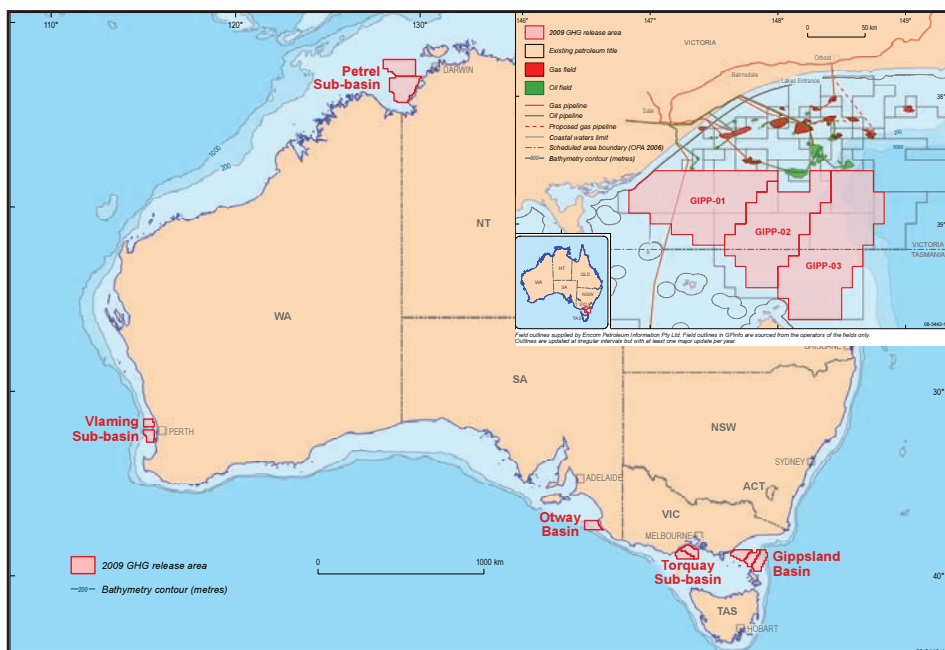
"The study, completed during the past 12 months, has been undertaken as part of the Brumby Government's four-year \$5.2 million Victorian Geological Carbon Storage initiative (VicGCS)," said Energy and Resources Minister Peter Batchelor.

"The study involved geologists analysing rock formations using 3D modelling and identifying areas at depths of between 1000 metres and 3000 metres that mimic formations where gas and oil are stored.

"The best areas identified for potential storage are offshore from Yarram to Lakes Entrance in Bass Strait.

"The results of this initial study confirm that further exploration and testing is warranted."

In late March, the Federal Government released offshore areas in the Gippsland Basin which are now open for tender to ex-



The Australian Government has released ten areas for CO₂ storage exploration in five areas (insert shows Gippsland Basin area)

plore.

"For companies considering bidding for these permit areas this report confirms there is real potential in Victoria for CCS. The study will also help companies searching in these areas to better target exploration," Mr Batchelor said.

The Brumby Government is also a foundation member of the Global Carbon Capture and Storage Institute.

It has also provided \$2.5 million for the Latrobe Valley Post Combustion Capture project, which last year was the first project to capture CO₂ from coal-fired electricity generation in Australia.

It was also the first state to pass stand-alone legislation enabling onshore injection and storage of carbon dioxide.

DOE report on monitoring CO₂ storage

www.netl.doe.gov

The Office of Fossil Energy's National Energy Technology Laboratory (NETL) has created a comprehensive new document that examines existing and emerging techniques to monitor, verify, and account for carbon dioxide (CO₂) stored in geologic formations.

The report, "Monitoring, Verification, and Accounting of CO₂ Stored in Deep Geologic Formations" was prepared with input from the seven Regional Carbon Sequestration Partnerships.

Its main goals are to:

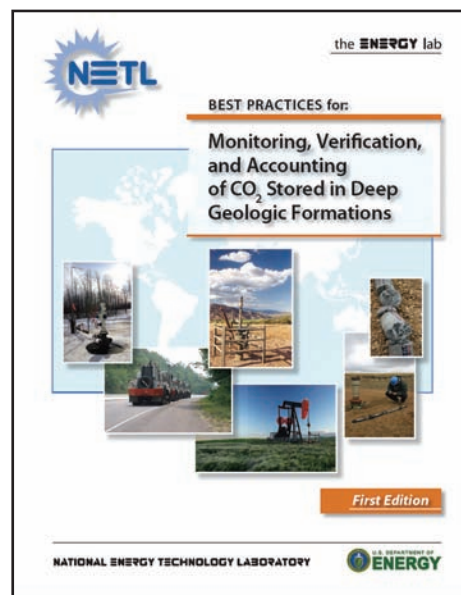
- Provide an overview of monitoring,

verification, and accounting (MVA) techniques that are currently in use or are being developed.

- Summarize the Energy Department's MVA research and development program.

- Present information that can be used by regulatory organizations, project developers, and national and state policymakers to ensure the safety and efficacy of carbon storage projects.

"Reliable and cost-effective MVA techniques are critical to making geologic storage a safe, effective, and acceptable method for reducing greenhouse gas emissions," said NETL.



Scottish Centre for Carbon Storage

One Day Short Courses

Thursday 27th August & Friday 28th August 2009



CO₂ Storage - Geological Storage for Engineers (ref:K1660)

Thursday 27th August

This short course is designed for Engineers and Managers with limited or no previous geological knowledge. The aim is to provide an up-to-date introduction of the geological and geophysical aspects of CO₂ Storage.

CO₂ Injection and Enhanced Oil Recovery (EOR) (ref:K1661)

Friday 28th August

This short course is designed for geologists, researchers, industry executives and managers with limited technical knowledge and anyone who wants to know more about CO₂ injection, flow and storage in underground geological reservoirs.

Location: **Raeburn Room, Old College, Edinburgh**

Map: <http://tinyurl.com/Raeburn-Room>

For further information visit: www.erp.ac.uk/sccs/



www.erp.ac.uk/sccs

GCCSI

Global Carbon Capture and Storage Institute

Career Opportunities

Senior Executive and Specialist Roles

Global Climate Change: accelerating CCS technology solutions

The global adoption of Carbon Capture and Storage (CCS) technology is a critical component of the technology solution to successfully address the climate change challenge facing our planet. The newly created Global Carbon Capture and Storage Institute (GCCSI) will accelerate the global deployment of safe, and commercially and environmentally sustainable CCS technology across a range of CO₂ emitters along the capture, transport and storage chain.

The GCCSI will directly support the G8 goal of achieving at least 20 fully integrated, industrial-scale CCS projects by 2020. Project facilitation and information sharing will be a major focus of the GCCSI's work. The newly created GCCSI has received strong support from the international community with 85 Foundation Members comprising major governments, companies, and other organisations.

The GCCSI is an initiative of the Australian Government. It will operate as a not-for-profit Australian company headquartered in Canberra, Australia, and commence on 1 July 2009. Satellite offices will be created in key global locations to deliver the GCCSI's work and this presents future employment opportunities for suitable individuals.

The GCCSI is seeking appropriately skilled and committed professionals to form the core team to build and drive this vital new enterprise.

Senior Executives

The GCCSI requires several well credentialed senior executives to strategically focus and deliver work across:

- **Strategic Projects**
- **Project Frameworks**
- **Partnerships and Alliances**
- **Communications**
- **Corporate Services**

Specialist Roles

The GCCSI also requires specialist staff including:

- **Technical Analysts/Advisors/Engineers**
- **Program and Project Managers**
- **Government regulation experts**

These roles require a strong understanding of the role that CCS technology will play to address the global climate challenge.

Applicants will require:

- A strong track record in relevant industry sectors - Power, Minerals and Energy, Industrial Processing, Environmental Science.
- Experience in management of multiple stakeholders with a diverse range of interests.

Further information is available from the GCCSI website www.globalccsinstitute.com

For further information or to apply, please forward your full details including area of interest to ewkmelbourne@ewki.com by **28 May, 2009**.

EWK International

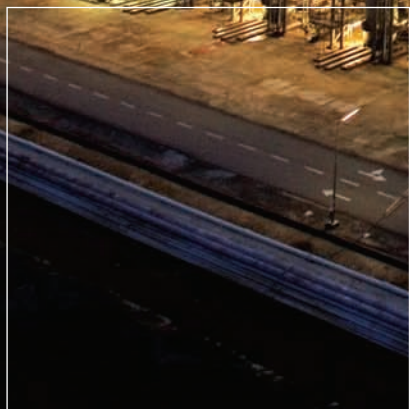
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RPS are global specialists in managing major, complex, multi-disciplinary projects.