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Front cover: more than one million tonnes of CO2 per year will be captured from Shell's Scotford Upgrader (pictured), located near Fort Saskatchewan, Alberta, Canada

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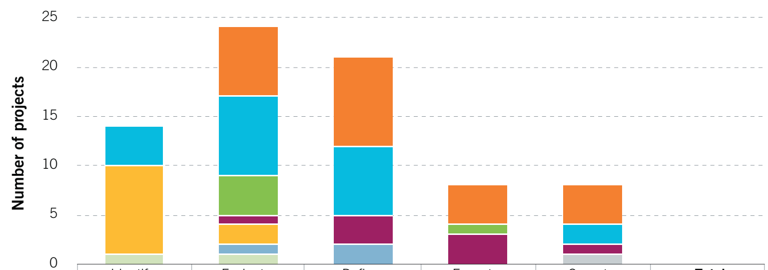
Global CCS Institute Status of CCS 2012

The Institute has released the fourth edition of its flagship state of CCS report, concluding that CCS is already making a contribution to climate mitigation but that progress has been too slow. It also makes recommendations to decision makers for the first time.



	Identify	Evaluate	Define	Execute	Operate	**Total**
United States	0	7	9	4	4	**24**
Europe	4	8	7	0	2	**21**
Australia and New Zealand	0	4	0	1	0	**5**
Canada	0	1	3	3	1	**8**
China	9	2	0	0	0	**11**
Middle East	0	1	2	0	0	**3**
Other Asia	1	1	0	0	0	**2**
Africa	0	0	0	0	1	**1**
Total	**14**	**24**	**21**	**8**	**8**	**75**

Figure 1 - Large Scale Integrated Projects (LSIPs) by asset lifecycle and region/country

Global CCS Institute CEO Brad Page launched the report in Calgary, highlighting the importance of keeping CCS on the international agenda.

The report concludes that actively supporting carbon capture and storage (CCS) as part of the suite of low-carbon technologies used to tackle climate change would save electricity customers around the world more than US$3 trillion.

The Global CCS Institute has estimated that carbon abatement from eight CCS projects already operating is greater than that achieved by all other energy-related climate efforts combined to date in Australia or the UK.

Brad Page highlighted four key issues needing to be addressed to accelerate CCS deployment:

- the need for a stronger commitment to CCS by governments, in the form of timely and stable policy support to deal with barriers to implementation, drive industry confidence, encourage innovation and, ultimately, reduce capital and operating costs

- that it is critical the technology is not disadvantaged; CCS is often not treated equivalently to other low-carbon technologies in government policy settings and support even though it is a cost-competitive technology

- a need to accelerate government and industry investment into demonstration projects to develop technology and bring down costs

- the importance of capturing and sharing lessons learnt from all CCS projects, particularly with non-OECD countries, where 70 per cent of CCS deployment will need to occur by 2050.

In the past year, the net number of large-scale integrated projects increased by one, to 75; eight previously identified projects were cancelled; and nine new projects were identified, most of which will investigate enhanced oil or gas recovery options.

"CCS projects are on track to achieve 70 per cent of the International Energy Agency's [IEA] target mitigation activities for CCS by 2015," Mr Page said, "but beyond that, it is clear that a very substantial increase in new projects will be required to meet the 2050 target."

"The number of operational projects would need to increase to about 130 by 2020, but this seems unlikely, with Institute projections indicating that only 51 of the remaining 59 projects identified in our annual survey may be operational by then."

Mr Page said that CCS was already making a contribution to meeting the target of global average temperature increases of no more than 2°C. He said it was the only technology currently available to decarbonise the production of industrial materials such as iron, steel and cement, and was pivotal to carbon reduction in other sectors.

"If, for example, CCS was excluded as a technology option in the electricity sector, the IEA estimates that investment costs in the sector would increase by 40 per cent—about US$3 trillion—to 2050, to draw on more expensive abatement options to provide electricity."

The Institute's analysis was informed by a quantitative and qualitative survey of global CCS projects. Significant progress in CCS during the past 12 months included:

- inclusion of CCS in the United Nations Framework Convention on Climate Change Clean Development Mechanism

- introduction of a comprehensive policy to drive deployment beyond demonstration projects and reform of electricity market arrangements in the UK

- inclusion of CCS in China's 12th Five-Year Plan for building on clean energy.

"Progress of CCS in China is particularly strong," Mr Page said. "Five of the nine newly-identified large-scale integrated projects are there, making a total of 11 CCS projects in development in China."

"Support for capacity building activities in developing countries is also progressing well, with 19 non-OECD countries engaged in CCS, mostly at the early stage. Sharing expertise with these countries to overcome complex and difficult challenges is particularly important," he said.

Other notable developments during the past year included:

- the opening of the US$1 billion Technology Centre Mongstad in Norway, an industrial-scale test centre for carbon capture

- in Canada, the announcement that Shell's Quest project would be built to capture and store more than one million tonnes a year of CO2 produced at the Athabasca Oil Sands Project

- Southern Company's post-combustion Plant Barry in the US became the world's largest integrated CCS project at a coal-fired power plant

- advances in oxyfuel combustion were realised through two pilot-scale projects, CIUDEN in Spain and Callide in Australia

- construction continued on two large-scale demonstration power generation projects scheduled to become operational in 2014—Kemper County in the US and Boundary Dam in Canada.

More highlights from the Report

Barriers must be overcome to realise the benefits of CCS

Like many emerging technologies, CCS faces barriers which discourage new projects from emerging and prevent existing projects moving to construction and operation.

Funding for CCS demonstration projects, while still considerable, is increasingly vulnerable and the level of funding support still available will service fewer projects than initially anticipated. The relatively higher-cost CCS projects (for example in the power, steel and cement sectors) require strong government support continuing into the operational phase. There are significant issues with debt availability to support CCS in the current challenging economic climate. CCS is also often not treated equivalently to other low-carbon technologies in policy settings and government support. In order to achieve emission reductions in the most efficient and effective way, governments should ensure that CCS is not disadvantaged.

Storage site selection and characterisation is a lengthy and costly process so this must begin at initial project stage. Indeed the majority of perceived risk in CCS projects is often associated with storage. Public understanding of CCS remains low. Early stakeholder engagement is therefore important and this must include addressing perceptions of storage.

Reducing the cost of technology through demonstration projects is vital

In Norway and Canada, two projects highlight the benefits of public and private sector support in advancing cost-effective technologies. The opening of the US$1 billion Technology Centre Mongstad (TCM) in Norway, an industrial-scale test centre for carbon capture, marks an important milestone in research, development and demonstration (RD&D) efforts and should demonstrate the potential for CCS costs to be significantly reduced over time.

In Canada, Shell's Quest project announced it will capture and store more than one million tonnes of CO2 per year produced at the Athabasca Oil Sands Project. The knowledge generated by both of these projects will drive innovation around the world.

Commercial-scale demonstration of capture requires application at increasing scales with integration into an industrial process or power station, and it is noteworthy that power generation has yet to be demonstrated at scale. Southern Company's post-combustion Plant Barry in the US recently became the world's largest integrated CCS project at a coal-fired power plant. Advances in oxyfuel combustion have also been realised through the commissioning of two pilot-scale oxyfuel combustion demonstration projects, CIUDEN in Spain and Callide in Australia.

Two large-scale demonstration power generation projects are currently in construction and scheduled to begin operation in 2014: Kemper County in the US and Boundary Dam in Canada. These early commercial-scale demonstration projects will identify any construction and operating problems through 'learning by doing'.

CCS in the iron and steel and cement manufacturing industries remains a challenge, and considerable work is still needed to encourage capture demonstrations and CCS technology developments.

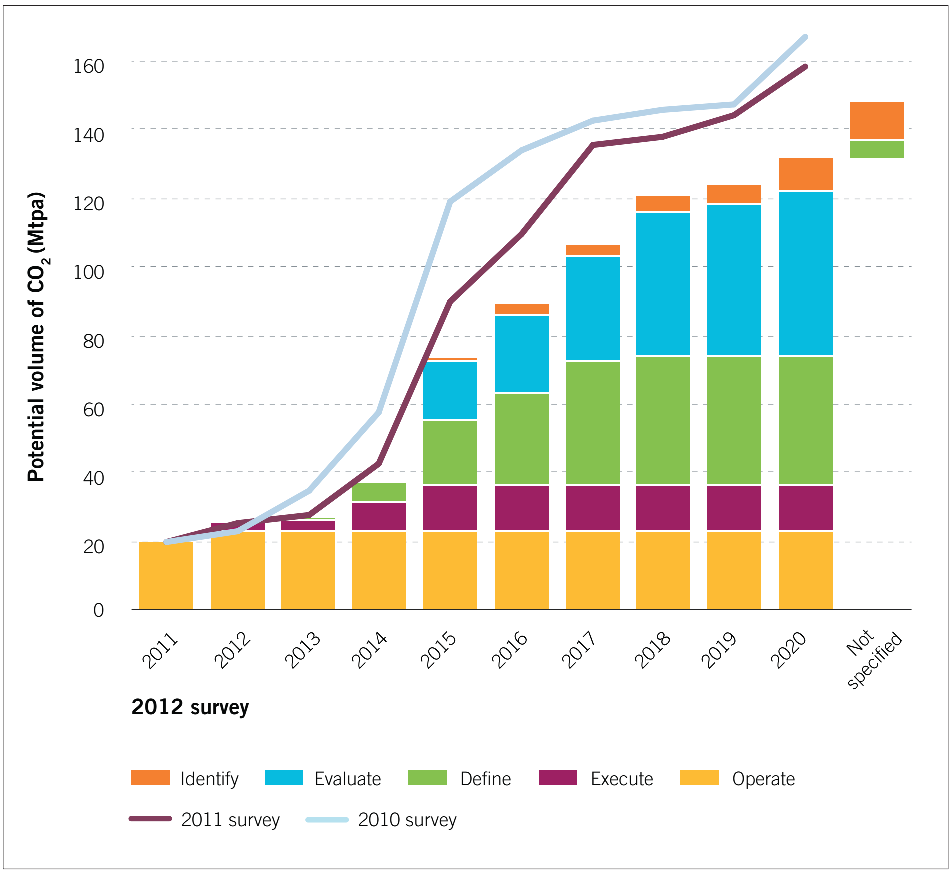


Figure 2 - Volume of CO2 potentially stored by LSIPs

Acceleration of CCS depends on collaboration and knowledge sharing

Sharing information and lessons learnt from CCS projects has great benefits, helping stakeholders address difficult and time-consuming challenges such as building the business case for CCS projects and improving understanding of the technology. For example, there is limited CO2 pipeline operation experience outside the US, Canada and Norway, and transfer of this knowledge to other countries would assist in accelerating the deployment of CCS.

Recommendations for policy makers

Climate change legislation must not be delayed. Timely and stable policy support is required to deal with the barriers to implementation of CCS. This will drive industry confidence, encouraging more innovation, and ultimately reducing capital and operating costs.

To achieve emission reductions in the most efficient and effective way governments should ensure that CCS is not disadvantaged. They must review their policies to ensure that CCS can play a full part in the portfolio of low-carbon technologies.

Funding for CCS demonstration projects by governments and industry should be accelerated to develop the technology and bring down costs through innovation.

Sharing expertise and learning from CCS projects around the world must be encouraged to ensure that progress is made as quickly as possible. Creating a business case and managing the technology is a complex and difficult process, so capturing and using lessons from other projects is vital. This knowledge must be shared with developing countries where 70 per cent of CCS deployment must occur.

More information

Download the full report at:
www.globalccsinstitute.com

Shell's Quest project going ahead

David Hone, Climate Change Advisor for Shell, discusses the significance of the project for Canada and the international climate mitigation effort.

Shell Canada, as operator of the Athabasca Oil Sands Project joint venture (with Chevron and Marathon), has announced plans to proceed with a carbon capture and storage project (Quest) within the current oils sands project. This is a project that has been under discussion in one form or another since almost day one of production from the facilities, but the lack of a workable economic justification for the project has been the major impediment to progress.

In recent years the story has changed though. The Government of Alberta has developed a carbon pricing system which provides a level of underlying support for the project. The World Bank "State and Trend of the Carbon Market 2012" report describes the Alberta system (on page 89) as follows:

Alberta is Canada's largest greenhouse gas (GHG) emitting province, accounting for 34% of the country's total GHG emissions in 2010. This represents 235 MtCO2e, a 41% increase from 1990 levels, driven primarily by increased production activity in its oil and gas sector. On July 1, 2007, Alberta launched a mandatory GHG emission intensity-based mechanism, enacting the first GHG emissions legislation in Canada. Approximately 100 entities with annual emissions exceeding 100,000 tCO2e (ktCO2e), are required by the legislation to reduce their emission intensity by 12% from average 2003-2005 levels. Entities that do not meet reduction requirements on a given year may choose to meet these obligations by:

- *Trading "Emissions Performance Credits" (EPC) that are awarded to covered entities that reduce emissions below their set target*
- *Paying CN$15 (US$15.2) into a technology fund; and/or*
- *Purchasing Alberta-based offsets issued by the Alberta Offsets Registry under an approved protocol*

N.B. The World Bank chart (Fig. 2) shows the number of offsets retired annually through the system with an estimate for 2011 (not announced at the time the report was published). The price has remained very close to the technology fund alternative.

As such, this system provides an underlying base level of support of some CAN$15 per tonne of CO2 for the CCS project. In addition, in 2011 the Alberta Government announced a further support mechanism for CCS though the system, which now grants a second bonus credit for CCS projects meeting certain criteria.

Figure 1 - Aerial view of the Shell Quest project site, where more than one million tonnes of CO2 per year will be captured from Shell's Scotford Upgrader, located near Fort Saskatchewan, Alberta, Canada

The Canadian based Pembina Institute published a diagram (Fig. 3), challenging the environmental integrity of the approach, but it also gives a simple explanation of how the mechanism works. In a completely closed system the environmental integrity argument would be correct, but in the open ended Alberta system with payment into a technology fund as a compliance option, the argument is hardly valid.

A further, but much less quantifiable, price signal is that coming from the California Low Carbon Fuel Standard (LCFS) and

Figure 2 - World Bank chart shows the number of offsets retired annually through the system with an estimate for 2011

to a much lesser extent the EU Fuel Quality Directive (FQD). These mechanisms place a carbon footprint target on the fuel in the transport sector with a starting baseline about equal to the carbon footprint of oil products processed through a conventional production and refining route and then declining by about 1% per annum.

When oil sands products arrive in these markets, their higher carbon footprint generates a penalty on the use of the component in the fuel pool which manifests itself as a price on carbon emissions associated with the production and use of the product. Of course the product may be targeted at other markets, but even a small location constraint on a product can lead to a trading discount in some market circumstances. This is also a carbon price of sorts. In any case, the prevalence of LCFS type approaches could well increase over the years ahead, which could penalize oil sands relative to some other production routes.

The combination of Provincial and Federal grants, a Province based carbon pricing system and its bonus credits and consideration of the role played by fuel standards in export markets in the future has allowed the project to get the green light. This should be seen as good news. CCS is the critical technology for real long term reductions in emissions – I have argued in the past that it may well be the only technology, so supporting it now and getting at least some early projects up and running should be an essential policy goal.

Support remains a dilemma for policy makers, particularly in challenging economic times. However, there is a valid role to play here in that almost every carbon roadmap to 2030 and beyond shows CCS being required, yet there is currently no carbon price signal strong enough in any jurisdiction to actually build one now and therefore begin the process of demonstration and commercialization.

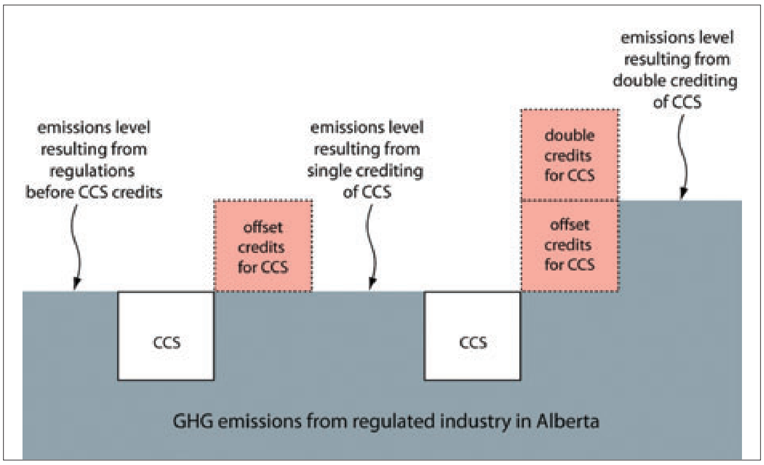


Figure 3 - The Canadian based Pembina Institute diagram challenging the environmental integrity of the approach

Project details

The project itself is medium in scale, storing about one million tonnes per annum of CO_2 coming from the Hydrogen Manufacturing Unit (HMU) linked to the oil sands bitumen upgrader. The HMU produces hydrogen by steam reforming of natural gas, with a nearly pure CO_2 stream as a byproduct. At high temperatures (700–1100 °C), steam (H_2O) reacts with methane (CH_4) to yield syngas.

$$CH_4 + H_2O \rightarrow CO + 3\,H_2$$

In a second stage, additional hydrogen is generated through the lower-temperature water gas shift reaction, performed at about 130 °C:

$$CO + H_2O \rightarrow CO_2 + H_2$$

Heat required to drive the process is supplied by burning some portion of the natural gas. A very simple overview of the process is shown (Fig. 4).

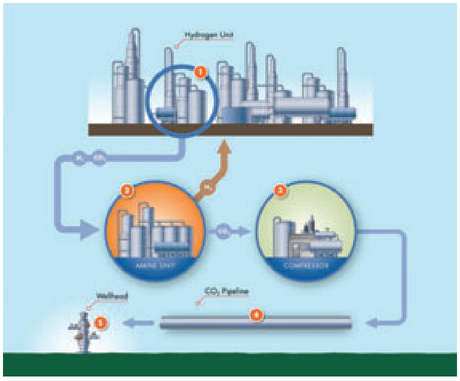


Figure 4 - a very simple overview of the process

The capture plant is located in Fort Saskatchewan, approx 50 km N.E. of Edmonton, Alberta. The CO_2 will be transported by 12 inch pipeline to storage, approximately 65 km north of the upgrader site. The CO_2 will be stored in a saline aquifer formation called Basal Cambrian Sands (BCS). At 2,300 metres below the surface it is some of the deepest sandstone in the region, with multiple caprock and salt seal layers and no significant faulting visible from wells or seismic activity. The BCS is well below hydrocarbon bearing formations and potable water zones in the region. Relatively few wells have been drilled into the BCS and none within 10 km of the proposed storage site.

It's been a long road from initial discussion, to early concept and finally the investment decision last week. But the end result is a real CCS project!

More information

David Hone

David combines work as a climate change adviser for Shell, with his responsibilities as Chairman of the International Emissions Trading Association (IETA). He also works closely with the World Business Council for Sustainable Development and has been a lead contributor to many of its recent energy and climate change publications. The most recent of these discusses the role of a carbon price in an economy.

blogs.shell.com
www.shell.ca
www.ieta.org

Making money from mineralisation of CO2

Mineral Carbonation is an emerging commercially-driven alternative to geological CCS. Michael Priestnall, CEO of Cambridge Carbon Capture Ltd and Industry Chair of CO2Chem's Mineralisation Cluster, explains what mineral carbonation is, how industry is beginning to make money out of it and why policy makers should pay attention.

In 1989, as I was finishing up four years as a British Gas research scholar in solid oxide fuel cells at the Wolfson Unit for Solid State Ionics at Imperial College, I accepted a job with Cookson Group in Oxford to lead their SOFC materials development programme.

The company was gearing up to supply the advanced electronic ceramic powders and components needed for Westinghouse's and Dornier's SOFC generator systems, but my first task alongside colleagues from Johnson Matthey, British Gas and Alstom, was to organise a conference celebrating the 150th Anniversary of the invention of the fuel cell by Sir William Grove. We were apparently just five years away from mass-market fuel cells delivering 70% electrical efficiency, high-grade waste heat, zero pollutants and (unremarked at the time) an exhaust output of pure CO2.

I mention this for several reasons (and fuel cells are relevant to the subject of this article, mineral carbonation) – cleantech innovation is a dangerous area for any business to engage; it seems especially risky if it is policy led and technology pushed. Fuel cell technology is a prime example where policy makers and funding agencies have pushed and led most technology developers down one R,D&D roadmap while a few business-minded companies have quietly got on with addressing what customers actually want and delivering it to them.

Today there is a global market for commercial fuel cell systems approaching $1bn/year and most do not use hydrogen. Although still tiny and niche, the fuel cell market is growing exponentially and, as units costs reduce by ~20-25% for every doubling of sales, applications will inevitably progress from niche to mainstream.

For reasons which I don't need to rehearse here, commercial implementation of the chosen technical solution to CCS – geological sequestration – faces hugely greater challenges than fuel cells. We all want to stop CO2 molecules going into the atmosphere in the cheapest and least economically and environmentally disruptive way; we want CO2 sequestration to be commercially driven and cost reduced and we know that policy makers shouldn't try to pick winners. So why in the UK are we wasting time and money and risking our climate by allowing the same divergence of policy and reality again?

"What would we prefer, a CCS infrastructure that uses a quarter of a power station's electricity to sequester its CO2 emissions under the North Sea or one that generates additional electricity and useful materials products?" - Michael Priestnall, Cambridge Carbon Capture Ltd

Mineral carbonation in a nutshell

- Mineral carbonation involves reactions of magnesium or calcium oxides (typically contained in mineral silicates and industrial wastes) with CO2 (dilute in the atmosphere or exhaust gases, or as captured pure CO2) to give inert carbonates. Due to the lower energy state of carbonates compared to CO2, these reactions release significant amounts of energy and, in nature, occur spontaneously (but slowly). Vast amounts of suitable and readily accessible mineral silicates exist – many times more than is needed to sequester all anthropogenic CO2 emissions.
- Slow speed of reactions of natural silicate rocks (requiring mechanical, chemical or biological treatments) and the large amounts of minerals or wastes that must be handled (2-3 tonnes rock per tonne of CO2) are the primary challenges for commercially viable industrial mineral carbonation applications. Processes that accelerate kinetics and maximise materials values with minimal additional costs and environmental impacts are the focus of R&D by Cambridge Carbon Capture and others around the world.
- Mineral Carbonation offers a commercial route to large-scale CCS starting with bottom-up, market-driven and highly profitable distributed niche applications where cost-reduction learning curves apply. Valuable and useful by-products such as silica, metals, chemicals, cements and construction materials, as well as remediation of waste feedstocks, enable a business case to be made. It is already being implemented across different industries and scales in profitable business operations and demonstration projects around the world.
- Mineral carbonation enables CO2 sequestration without capital and energy-intensive large-scale solvent capture and avoids the cost and public acceptability challenges of supercritical CO2 pipeline transport and storage infrastructure. It is primarily a disruptive, not an additive technology to conventional geo-CCS and UK policy makers risk missing a major opportunity by ignoring it.

Leading global chemicals companies like Solvay and SABIC don't see CO2 as a waste to be stored underground, but are making strategic investments in the processes to use it as future industrial feedstock that will inevitably replace syngas. As Parliamentary Office of Science & Technology Note 403 points out, there are unsubsidised market driven technology solutions & applications for CO2 sequestration that are out there and already being implemented commercially.

They may be small and niche today – e.g. the storage of stranded excess renewable electricity via conversion of CO2 and water into fuels; the use of CO2 to convert alka-

line dust wastes from paper burning into aggregates; and carbonation to stabilise aluminium industry wastes to avoid the risk of toxic red-mud spills – but with the right policy approaches, applications can be stimulated massively and the 20% cost-learning curve will do the rest.

Mineral carbonation – this is one of those rare technologies where the business models exist today to make CO2 sequestration commercially attractive in niche applications. Economic feasibility is underpinned not by the price of CO2 but by the release of substantial energy when gaseous CO2 reacts to form a lower energy state carbonate and by the value of the various by-products.

If we can understand all that makes these first commercial applications stack-up, and identify what scope there is for process improvements and changes (and dare I say policy measures) that can widen the commercially-driven applications, then we stand a chance of stimulating and accelerating a disruptive emergence of a market-led sequestration industry.

At the largest scales, carbonation of minerals can strip CO2 directly from the air – a geo-engineering approach featuring strongly in Virgin Earth Challenge's £25m competition – or reactions of exhaust gas or captured CO2 with minerals to form construction materials can be used to substitute for pipelines and underground storage infrastructure in conventional power station CCS applications. Making the business case and developing the appropriate carbonation technologies across these scales of implementation will be challenging, but with energetics, economics & scaleability going with it rather than against it, mineral carbonation would seem a more feasible solution than geo-sequestration.

These are some of the themes that around forty industrial and academic members of the Mineralisation Research Cluster of the UK's CO2 Chemistry Network will be discussing at its first workshop on November 28th (http://co2chem.co.uk/calendar).

Mineral carbonation explained

So what exactly is mineral carbonation? It encompasses a diverse range of processes and applications developed and researched globally over the last couple of decades, but most typically, mineral carbonation involves the use of exhaust gas CO2 to transform industrial wastes and minerals into valuable materials products, and because it consumes CO2 it can avoid any need to separate, transport and store CO2 gas.

Process variants can range in scale and complexity from simple sprinkling of suitable rock dusts onto large areas of land or sea to soak up atmospheric CO2 (e.g. www.smartstones.nl), to sophisticated multi-step chemical digestion, sequential precipitation and carbonation processes designed to produce high purity metal, silica, zero-carbon calcium & magnesium oxides and carbonate mineral powders (e.g. www.cacaca.co.uk).

Mineral carbonation brings opportunities particularly to the energy and materials intensive industries such as iron & steel, cement, glass, waste and minerals & mining, and also can provide low-cost CO2 capture materials as a scalable solution for the wider industrial and power generation CCS markets.

We are talking here about a fast and potentially profitable industrial version of the Earth's natural silicate-carbonate cycle that strips around a billion tons of CO2 out of the atmosphere every year. This natural CO2 capture and sequestration is driven by the energy released when magnesium and calcium-containing silicate rocks are slowly weathered by wind and rain and react chemically with CO2 and water to form carbonates and silica. Over millennia, this process has locked up the vast majority of the Earth's carbon into limestone rock.

The natural process is slow because, in rocks, ions of magnesium and calcium are protected from reaction with CO2 by the silicon dioxide structure that surrounds them. However, the carbonation reaction speeds up massively when mining companies dig up, crush and process these types of rocks to get at useful metals they contain or to provide aggregates and fillers for construction materials.

Crushing rock to powder is fairly energy intensive and the mixed product of a simple direct carbonation reaction may have little if any commercial value at large scales. An alternative approach is to chemically extract the magnesium or calcium ions from the rock or from appropriate industrial wastes before carbonation. In this approach, with the appropriate chemical processes, it may be possible to achieve faster, less energy intensive and more complete carbonation and also to enable metals, silica and carbonates to be recovered as separate and valuable products.

For example, Cambridge Carbon Cap-

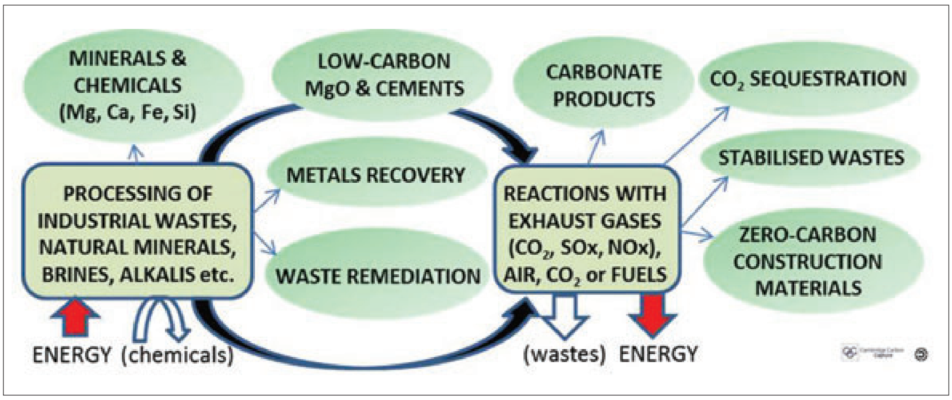


Figure 1 - Mineral Carbonation: how to make CO2 sequestration profitable

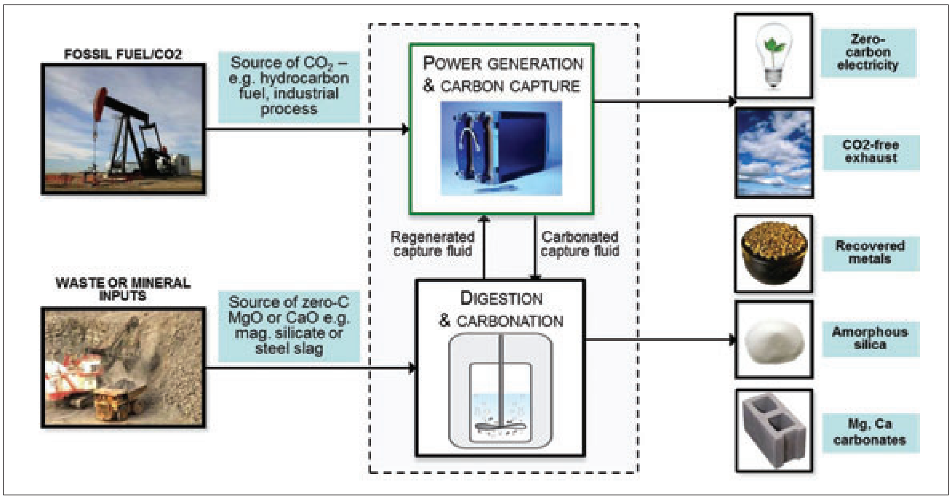


Figure 2 - Electrochemical mineral carbonation – captures the energy of carbonation as clean electricity

ture is developing a fast low-cost chemical digestion process to extract amorphous silica and magnesium and calcium as pure oxides from olivines and steel slags; these oxides can then be used as zero or at least lower-carbon substitutes for conventional CO2-intensive lime in industry and also used directly as a medium for CO2 capture from exhaust emissions (one of our customers, Polarcus, plans to use CCC's process for on-board sequestration in their fleet of marine survey vessels).

Product carbonates, if they have sufficient purity, may then find high value and volume application as white pigments or fillers for e.g. paper making. Silica powders, if they are produced with appropriate purity and particle size, are worth thousands of pounds per tonne as chemical inputs to the glass, electronics, construction and plastics industries.

It's not just rocks that can be used as sources of magnesium and calcium for mineral carbonation processes. Industrial processes such as metals refining and combustion generate huge volumes of silicate slags and ashes. In their initial state, many of these wastes are unstable and risk leaching heavy metals into the environment and therefore often have a financial penalty associated with their storage as hazardous wastes. Mineral carbonation processes can offer an economic route to remediate these problematic wastes while also sequestering CO2. As well as these opportunities, my company, Cambridge Carbon Capture Ltd, is also investigating the by-product recovery of valuable trace metals such as platinum, rare-earths, and stainless steel alloys from a variety of industrial slags and mining wastes.

Power from mineral carbonation

So back to fuel cells – which is also where Cambridge Carbon Capture started. Fuel cells convert chemical energy directly and extremely efficiently into electricity; chemical energy is available in the oxidation of carbon-based fuels and there is another 15% or so available from the further reaction of CO2 with mineral silicates to form carbonates.

In 2010, with a team from Cambridge University, we put the two of these together with an alkaline fuel cell to create a high-efficiency zero-carbon electrochemical fossil power generation system: fossil fuel and mineral silicates IN and zero-carbon electricity, carbonates and silica OUT. This breakthrough won us a 2011 Shell Springboard Award and the fact that our electrochemical mineral carbonation system stripped net CO2 out of the air at the same time took us through several rounds of the Virgin Earth Challenge.

Figure 3 - Polarcus & Cambridge Carbon Capture are developing a mineral carbonation based solution for on-vessel sequestration

So what would we prefer, a CCS infrastructure that uses a quarter of a power station's electricity to sequester its CO2 emissions under the North Sea or one that generates additional electricity and useful materials products?

More information

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co2chem.co.uk/calendar

CCJ conference - getting CCS moving

Carbon Capture Journal hosted a free half day conference in London on October 8, where delegates discussed whether the industry is developing at a satisfactory pace and looked at possible ways to accelerate growth. The conference was chaired by Stuart Haszeldine, professor of carbon capture and storage, School of Geosciences, University of Edinburgh

Stuart Haszeldine opened the event by outlining the cluster concept in the UK. The Yorkshire and Humber cluster offered economies of scale, he said, and had been very well thought out by CO2 Sense. There are also storage clusters that, although not ready yet because more work needs to be done to fully understand them, could also offer economies.

It is how you go from individual projects to developing a network that is currently unclear. “That plan is not very emergent yet,” he said, “because it is pretty clear that we have six or so bidders into the UK competition, there may be one or two or even three lucky winners, but what we do with the others to incentivise them to keep on being interested is not clear.”

Moving on to transport, the role of shipping is not often discussed, he said. We have a lot of port infrastructure in the UK and it is strange that we are not talking about shipping more. A CO2 ship would be a good way to transport CO2 to test a storage site before you build an expensive pipeline. It could also bring in CO2 from Europe and would be very flexible.

Talking about getting CCS going, most of the projects around the world that have got off the ground involved a value added proposition, he said. An example of this is Enhanced Oil Recovery, which CCS could enable, and the extra oil out of the ground could make a project cost effective.

Panel discussion

Stuart Haszeldine was joined by all the speakers: Vegar Stokset, head of communications, CO2 Technology Centre Mongstad, Dr Chris Satterley, Technical Consultant, EON Newbuild and Technology Ltd, Dr Ward Goldthorpe, Programme Manager, CCS & Gas Storage, Crown Estate, James Watt, technical manager, AMEC.

Sheila Baynes Senergy: I am a geologist, so I have to bring the storage part into this. So, the storage part- it's got the longest lead time, you're talking about certifying storage sites, that in itself is 2-3 years minimum, a big investment. How are you looking at that taking place? There are many-many studies out there. Are they of a level that we are allowed to certify a store– what levels of understanding are you expecting before you certify a store, because the subsurface is quite pesky, you can have carbon capture once it is efficient and safe, you can repeat it… storage is different every time. Is there a way that we can speed this up? Is there a way of getting investment companies

themselves or groups themselves investing in the future and to creating certified storage sites?

Dr. Ward Goldthorpe: If one stands back and looks at this as a system, and says what are the things that need to take place to take us to a certain point in time, let's say around the mid 20's, then that parallel pathway has to encourage this type of thing.

When I talk about that positive feedback coming back from storage and the things, it's about how does one encourage and how does one facilitate those sorts of different timeline, and different set of activities to what's happening in the capturing of the chain. So, if we need to certify storage sites within the few years what are the things we need to do?

We need to let's say provide some kind of tax incentives- if you are going to spend money on doing something that is totally a risk that there's no value in it or use for business, but there is value in doing it to the community then is it tax incentives, is it capital allowances, is it other sorts of joint industry projects, do we raise funding from different sources because banks won't give it to you to undertake such…well at the end of the day it's so high risk that there is no future for it, unless we create the future for it.

So, this is what I mean about market enabling business models – how do we from a regulatory point of view, how do we from a financing point of view, how do we from a policy point of view or in the government interventions will they be through the taxation mechanisms - all of those sorts of things have to be looked at, and have to be looked at independently and on separate pathways to the way we've been approaching CCS for the power industry.

James Watt: I don't agree with Ward frankly. Well we have been looking at how effective this is, there are certain things that I think from my personal perspective I would like to see may be the paradigm changing, maybe not relying so much on the developers, maybe someone taking control and saying, 'this is our resource.'

I think that's what it needs, there are too many people messing around us saying the same thing and not actually doing anything, I think there needs to be a consistent approach, not a driven approach otherwise it could just stop.

Stuart Haszeldine: Because Ward you talked about returning value by the carbon avoided, but how do you monetize that? How does that get transmitted to somebody. That's a communal benefits, but I didn't quite understand how that turns into dollars or pounds.

Goldthorpe: That part of the feedback is something that we would see in the future…but I think the first point is that I believe that it's been forgotten in the current framework that is being set up, so my agenda is to start thinking about it.

Now the second thing is can we actually ascribe a value that should flow in that direction, and one of the things we have done at the Crown of State is the framework that we have set up for the first of a kind of leasing arrangements to ensure that there is a linkage back to the price of carbon.

The afternoon panel discussion, from the left: Vegar Stokset, head of communications, CO2 Technology Centre Mongstad, Dr Chris Satterley, Technical Consultant, EON Newbuild and Technology Ltd, Dr Ward Goldthorpe, Programme Manager, CCS & Gas Storage, Crown Estate, James Watt, technical manager, AMEC

Why? This is not because we want to gouge a price out of the whole system, it is because on the one hand the non renewable resource ala the poreage space is being messed up, and what is the value of that poreage space? Ultimately the value of that poreage space is linked to avoided emissions. But secondly the first of a kind of projects – if they did not link to the cost of the carbon, then I believe that the model going forward would forget about that particular branch of the feedback.

So that's why we have deliberately structured our arrangements in the first of a kind projects, including the carbon price linkage. But the point is that as I said that if you had a carbon price large enough overnight £70 pounds, £100 per ton, people would come out of the woodwork because it's a reliable alternative. So, our task jointly I think is to commence the process of an understanding that there is a carbon value flow which is happening in places where you have utilization. There is a value on carbon flowing along the value chain. In this case if we have the only value flow coming from a feeding barrel then we will forget about creation of the value flow we need to create from carbon.

Haszeldine: So it's partly descaring the government.

Mike of Planetizen: Ward and James both made comments which would have come straight from the mouth of Greenpeace. Ward at the beginning of his presentation said really the time will change, and James saying the best thing to do is possible carbon chemically used up, not to burn it.

That really brings me to Ward's contention that we can still increase the value of CCS by employing Enhanced Oil Recovery (EOR), which strikes me as a contradiction in terms because we are taking carbon from big point sources, projecting it, pushing it straight underground, and pulling out oil which is only going to be used for motor transport and where it is of course completely irrecoverable what is burnt in millions of car engines.

Goldthorpe: I have a view that we need to look at all of what we do from a system level…So, from that starting point the globe has a carbon budget…we know that…and we know that if we exceed that budget we may be on a different track - certainly beyond the 2 degrees warming track…and the more we exceed the carbon budget the further beyond that we go.

So, when I do talk about these things, I don't talk about them in isolation, I talk about them in the context of the carbon budget. We have to also take a pragmatic and a practical view…we can talk about the theory of de-carbonization, or we can do it in a practical way. We clearly are not going to remove that dependency on liquid fuels for transport in a hurry. But we do have to do it.

And I would suggest that that is another feedback within the system. The feedback that I am talking about at the moment is within the context of removing the most damaging of emissions, at the same time as getting ourselves on a pathway where we can handle other emissions, because herein is the feedback that we need to deal with.

The feedback that we are consuming oil for transportation but we would really like to have let's say electrical transportation,

electrical cars….but to get electric cars, we have to produce more electricity. To produce more electricity we have to have the electrical generation system de-carbonized, because obviously we don't want that to be adding to emissions….so my view is we really do have to look at the entire system…we do have carbon budgets, we recognize that…. but liquid fuels as part of that system will have to be phased out…..but in phasing them out, we obviously phase in a feedback that requires more electricity. So, I think short answer to your question is well I truly understand where you are coming from, but in order to manage these various feedbacks, we have to start somewhere.

Satterley: Just from a power generator's point of view as well, and looking at this from our side and going back to Stuart's graph with what the large cost requirements would be (Fig. 1), we want to bring this technology online and move it forward…we have to as Ward says do it in a pragmatic way that EOR gives a potential in the relatively short term to add a lot of value to that carbon initially - to get those high cost first projects off the ground. So there's a benefit there longer term in looking at EOR. Even though again, I agree with you that as a longer term strategy in itself, it pays a lot to be consistent.

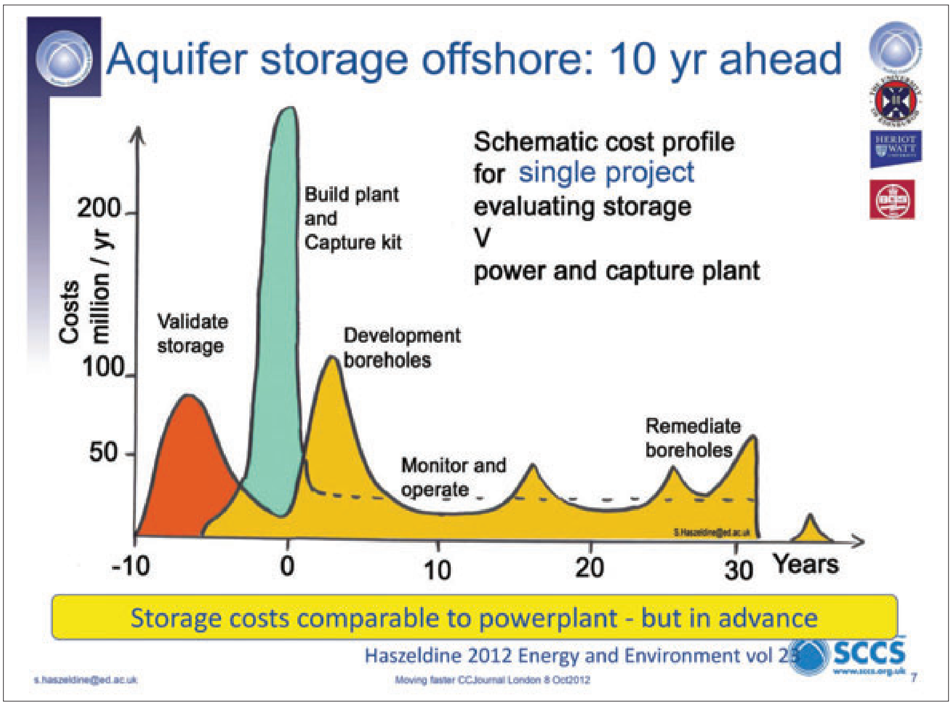

Figure 1 - costs of acquifer storage offshore ten years ahead of power plant

Crown Estate

Dr Ward Goldthorpe, Programme Manager, CCS & Gas Storage, Crown Estate, talked about how to make the best use of the Crown's offshore storage resources and how to overcome the barriers to commercialisation of CCS.

He began by saying that the current approach is setting up strains in the system and not creating a level playing field.

"We are not intervening in the economic theories in a way that it is going to deliver what it is that we all wish to deliver," he said. "In fact if anything, one of the concerns that I would like to suggest is that what we are doing is increasing the difficulty for ourselves of deploying CCS because we are actually setting up new market failures [...] and new externalities that will feed back to prevent us or constrain us from delivering CCS."

He continued by outlining the Crown's objectives moving forward. "First is that we are and have been for a while now working on the number of supporting functions to go into delivering the first of a kind CCS Project here in the UK. We have done a lot of work with DECC (Department for Climate Change), we have done a lot of work with potential storage operators who have I must say contributed a lot to thinking on how the UK licensing and permitting and in our case leasing regime should work."

"But also because it's where we want to go, it's not where we are, we have a clear objective, and this is where most of our effort now is being focused. Our clear objective for the future is we will or we believe we have the role to take on competitive storage leasing on the UK continental shelf."

"We are giving a lot of thought to the way that we could bring storage sites to the market place beyond the commercialization program. But also bearing in mind that the commercialization program itself is a rather long term affair for anyone who is going to be involved in contract negotiations with DECC and then the financing arrangements, and putting their projects together; it's not going to happen overnight."

He compared CO2 transport & storage (CTS) to the fledgling LNG industry, where a complex value chain had to be put together to make it commercial and no-one was willing to take on the risk. The transition between first-of-a-kind and commercial projects was all important, he said, and that is what the Crown of State is looking at.

He talked about how CCS deployment is currently being driven through electricity market reforms, but pointed out that transport and storage operates in a different sector with different economics and lead times.

"We had a bad experience with trying to drive CCS in Queensland in Australia through the Zero-Gen project. Fine to do the power station, fine to do the capture, but it turned out that the storage proposition didn't work- too risky. So we actually have a real life learning from this type of model."

Looking at the CTS side first, we can optimise the resource and develop clusters to benefit from collobration, he said.

"So, get to the crux of the issue here. How do we make CCS move faster? I believe we have to create what I call a positive feedback. At the moment, we are driving the development of CO2 transport and storage from one end of the chain. We need to drive from the other end of the chain, at the transport storage end of things to deliver the benefits upstream at the source and these twin conjunction will provide much more of a system approach to CCS and to de-carbonization than a linear one dimensional approach."

AMEC

James Watt, technical manager, AMEC, talked about the challenges of deploying a common infrastructure network for CCS, given that first-of-a-kind projects inevitably only require small scale point to point CO2 transport.

"The only way we are going to make this industry go faster is to tell people what we have learnt, and we have learnt an awful lot," he said. "The key learning I will point out over six years infrastructure studies [...] is that it's not actually about the emitter, the more we do the more we realize it's more about the store."

"And the store…in the last study we did the metrics around the storage cluster and how you store the stuff actually drives

the shape of the network more than the emitter and that's easy forgotten at the start. It's been a long hard process to learn but we are getting there."

"So, what are the deployment challenges that are facing us? The first projects are not here yet, we are talking about predominantly source to storage projects from A to B, so there's one emitter maybe two emitters that are close together, next door to each other, one pipeline, one store. That's not going to answer your infrastructure challenges, that's not going to make infrastructure roll in itself into clusters quicker, it's going to slow it down to a certain extent."

Funding is of course an issue, he said, and emitters and stores need to get talking so storage sites can be proved well ahead of time, "emitters can build quicker than you can assess and properly evaluate a store and then build that store."

He said there were some pretty major unknowns that could hold up the deployment of pipelines, but the issues were being looked into, "there's no evidence from that body of knowledge that comes out from the States that CO2 pipelines are any more inherently dangerous than natural gas pipelines or oil pipelines."

"Clustering, we need a better understanding of behaviors. Now what I mean by behaviors is not just the technical behaviors, it's how all those emitters and all those different companies interact on a cluster basis, how you are going to transport all that carbon dioxide, how are you going to trace the carbon dioxide, how is the emitter gonna be responsible for its carbon dioxide if it goes out of specification for example. There needs to be a commercial and technical understanding of those clusters."

Flexibility is a major issue that is coming up, he said. "Power stations don't generally just come on and stay on: there are power stations that that will come on at a certain time of the day. How that affects the pipeline, and more importantly how does that affect the storage site? The crux of the last study we did was that the storage site impacts the flexibility requirements of the pipeline. How the pipeline can react to both emitters and stores is not very well understood."

"We need to understand compression; the forgotten child of transportation is dehydration and conditioning. The different stores have different requirements for water and oxygen, and that has the possibility of raising costs, and that's not very well understood. So we need to understand that to move forward."

There were a few learning points about moving things faster gained from experience

Delegates discussed how to get the CCS industry moving faster at the Carbon Capture Journal event at the Geological Society in London

over the years, he said..

"Competency, it sounds silly, there's not that much experience in CO2 whether it's capture, whether it's pipelines, or it's offshore. It's the research, the normal engineers, the engineering companies like mine, making sure that they are up to standard, it's a new fluid that's not been handled very much. It's not a new fluid, but it's an old fluid being handled in a different way."

"These things need to be built on. We have a new course within AMEC to be run out - no one is allowed to do anything on a CCS project until I have certified they are okay to do it."

"The forgotten thing on where we need to go make the industry go a little faster in this regard is Experience, Engagement, Education. We need to train our engineers, we need to train our people, to be able to deliver these projects, we need to raise our knowledge levels up from there, and that will come from the demo programs, second generation deployments, developments, and research, and transferring that research in usable form to industry."

"Regardless of whether it's a cluster or a single source, the key things to make this industry go faster is we need a project, we need a project to move on, to close that learning loop between academic and industry experiences," he concluded. "The industry is not going to move any faster until someone starts mainstream at the ground."

In the Q&A session, Belinda Perriman from Shell said, "You finished your talk saying putting steel in the ground; I would love to hear your opinion on putting a lot more plastic. Either pipelines in wells, in capture plants, that was mentioned by Chris earlier as well. So how much potential is there you think in changing what we are thinking about."

"I kind of have to stick my hand up and say back in 2006, when we were looking at the Mersey & Dee Basin, we were looking at plastic pipelines were probably the way to go, but that's only low pressure," replied Mr. Watt.

"They can only stand so much. And if you can enable small emitters and medium sized emitters into that kind of gas network, polyethelene, one of the big plastic pipeline systems, then that's great. But you have to look at the whole mechanical aspect of CO2 and then the failure issues."

"I don't think we quite understand the failure behavior of CO2 and pipelines to say we want to go plastic pipelines. And we need to understand that a bit more, but I would like to think once we have go past the point where steel pipeline is good and it works, then the industry particularly the universities will start looking at what's next, what kind of hybrid materials you can use, what kind of polymers you can use, and all the different aspects which come with it. And that goes the same for the absorbers, and the same for downhole."

More information

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CCS for gas - results of Element Energy study

How much CCS can be practically deployed in the gas power sector and when? Recent modelling by Element Energy shows that the current trajectory of CCS activity in Europe will not deliver 10s of GW of gas CCS capacity. The study quantifies the most efficient policies by EU Member States and industry across the CCS chain required to deliver higher levels of gas CCS readiness.

By Harsh Pershad, Element Energy

The question of how much CCS can be deployed in the gas sector is becoming increasingly relevant in Europe, where scenario modelling points to an economic demand for tens of GW gas power with CCS in the 2030s delivering 100s of TWh of low carbon electricity. with demand ramping up steeply in the 2030s.

However the "practical" potential for gas CCS could be constrained by lack of CCS readiness across the fleet. Meaningful CCS readiness demands the availability by 2030 of suitable sites for capture and "bankable" options for CO2 transport and storage. It is clear that choices made today will have significant impacts on the CCS opportunities for the 2030s.

The European Commission recently published an Energy Roadmap to achieve deep CO2 cuts by 2050. The roadmap identifies a substantial ramp up in the capacity for gas CCS by the 2030s. However there are multiple hurdles to CCS deployment. An inability for a gas power station to deploy CCS where this is economically viable creates two important risks:

- "carbon lock-in", where the plant continues to operate, which makes overall decarbonisation of the economy more difficult and more expensive to achieve; and
- "stranded assets", where operating unabated plant is uneconomic, so that run hours are highly curtailed and society as a whole suffers from inefficient investment choices.

In December 2011, the European Climate Foundation commissioned Element Energy and Green Alliance to analyse the "practical" potential for CCS in European gas power sector in 2030, exploring at high level policies that could improve the take-up of gas CCS in the EU. For the purpose of the study, the practical potential is defined as the capacity (in GW) of the CCGT fleet that combine capture readiness with high feasibility of CO2 transport to one or more storage locations with sufficient available capacity.

The demand for gas power capacity is predicted to be 180-310 GW in 2030, with higher levels associated with decarbonisation scenarios involving high renewable electricity generation. This must be met through a combination of new build plant and, assuming typical plant lifetimes of 20 years, repowering of the existing fleet.

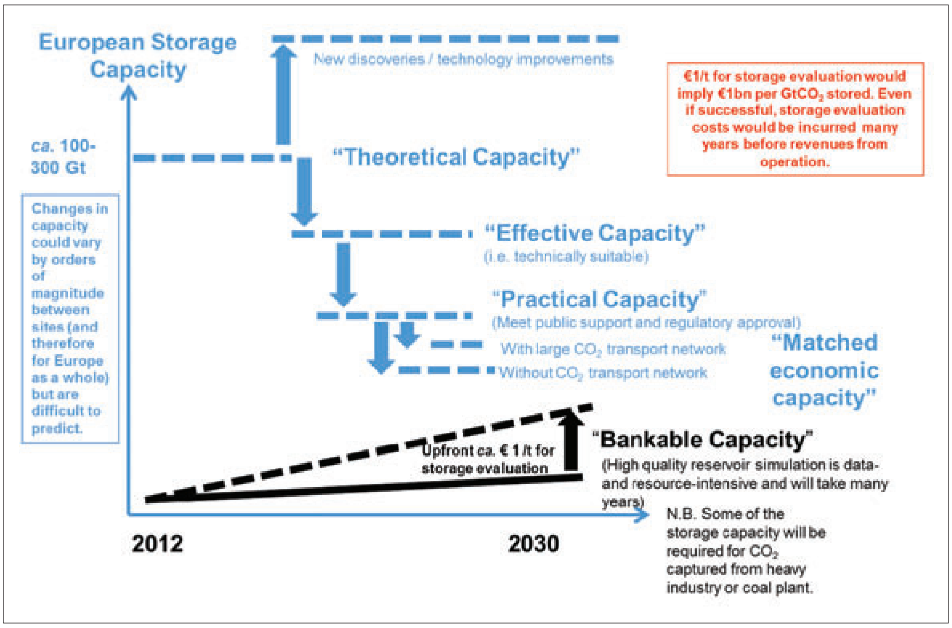

Figure 1 - estimates of European storage capacity

The CCS Directive requires, as part of consenting, that all new CCGT above 300 MW plant assess the feasibility of capture, transport and storage. Repowering provides an additional opportunity to make plants capture ready, but there is currently no legal requirement for this. There is a large gulf between the conditions that define minimal and meaningful CCS readiness. Sites which are meaningfully "CCS ready" must be able to implement CO2 capture, CO2 transport and CO2 storage. This implies that:

- Site selection is consistent with FEED-quality level information on the design requirements for capture, transport and storage facilities.
- Rights-of-way, Environmental, Safety and other approvals have been obtained (and are consistent with the required capture technology and any temporary storage requirements).
- Sufficient capacity for permanent CO2 storage exists, recognizing the potential competition for capacity from other sources and the inherent uncertainties associated with the subsurface.
- There is sufficient political and public support for CCS implementation.

The challenges of capture, storage and transport

Experience with flue gas desulfurization (FGD) requirements on coal power stations has shown the challenges of retrofitting clean-up technologies to plants that were not designed with this in mind. The experience suggests a plausible scenario where capture readiness is not meaningfully implemented early in the 2010s, and it becomes correspondingly more difficult to retrofit capture equipment on these plants when economics or regulations support deployment.

Current implementation of the requirements of the Directive by Member States appears very weak. During the 2010s, the timing and extent of implementation will likely remain vulnerable to the prevailing political

pressure towards (or against) CCS deployment by industry and individual Member States.

Estimates for the theoretical CO2 storage capacity in Europe span a wide range (e.g. 100-300 Gt), but the "Bankable" capacity likely to be available in 2030 is likely to be orders-of-magnitude lower. Storage capacity is distributed unevenly across Europe in thousands of sites. Each of these will require data, time, and resource-intensive analysis to understand their capacity, containment, injectivity, cost, degree of appraisal work required, ease of monitoring, and conflict with other land users (Fig.1)

A significant (but currently unknown) fraction of the sites are unlikely to prove viable upon close analysis. The EU and/its Member States will need to be more pro-active in establishing condition that ensure high levels of confidence in CO2 storage site performance in time to underpin CCS investments.

Recent studies have emphasized the potential need for large CO2 transport networks in 2030 to meet high CCS demand scenarios. Indeed some scenarios envisage CO2 transport tonnages greater than the existing natural gas and oil transport capacity in Europe, which took several decades to build up and which benefitted from high confidence in reservoir properties, infrastructure standards, political support, robust demand, and compelling economics.

But even with strong market drivers, extensive or cross-border pipeline infrastructure can take more than a decade from concept to commissioning, implying that the foundations for widespread use of the infrastructure in 2030 must be in place before 2020. In addition, CO2 transport onshore may be heavily limited by the availability of corridors for pipelines and conflicts of land use.

To quantify the practical potential for CCS on gas power plant under a wide range of scenarios, Element Energy developed a model which considered:

1) The overall CCGT fleet capacity and country distribution between now and 2030
2) Member State social and political enthusiasm for CCS, and the subsequent timetable for regulators to enforce a meaningful set of equirements for CCS readiness.
3) Levels of bankable storage capacity, onshore and offshore, including competition for capacity including reserved storage for coal or industrial CCS, and levels of storage redundancy.
4) The ability to connect CCGT fleet with storage locations, either directly or by sharing CO2 transport infrastructure with coal or industrial CCS projects.

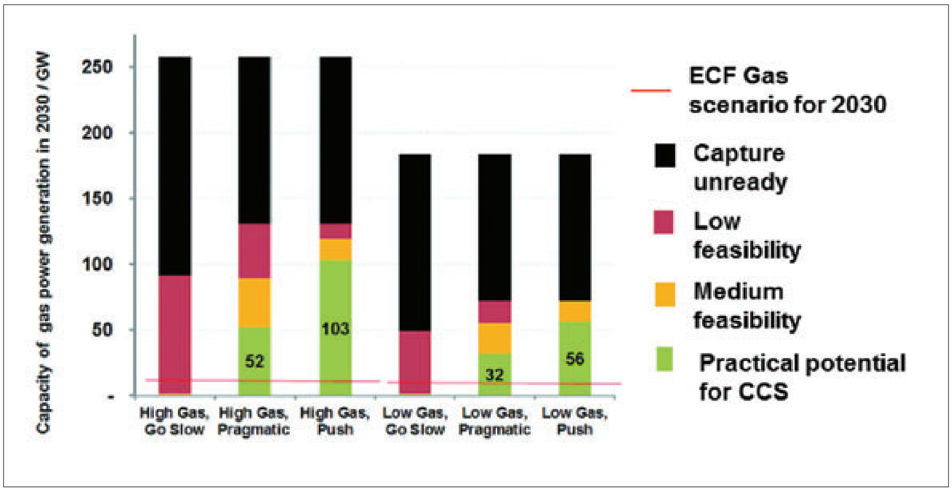

Figure 2 - Scenarios for potential gas CCS readiness. The black segments correspond to plant which is unlikely to be capture ready. The remaining segments illustrate the potential for transport and storage for plants that could be capture ready.

The results of modelling individual CCGT sites in Europe across six scenarios covering high and low levels of gas power demand with "CCS Push", "CCS Pragmatic" and "CCS Go Slow" levels of policy intervention are shown in Figure 2.

The green bars indicate the how much (in GW) of the European gas power fleet has a high level of CCS readiness in 2030, i.e. capture, transport and storage all appear plausible. The range of practical potential spans <1 GW to >100 GW. It is clear that even in the "CCS Push" scenario, much of the fleet existing in 2030 is unlikely to be CCS ready.

How to increase the CCS readiness of the gas fleet?

Figure 3 illustrates how policy interventions could serve to increase the practical potential for gas CCS.

Importantly considerable efficiencies can be obtained by treating capture, transport and storage as a whole – as policies to target these individually may be inefficient as impacts are not simply additive. A one-size-fits-all approach to encouraging gas CCS in Europe may be politically challenging to implement, especially in advance of successful CCS demonstration.

The analysis shows that an efficient alternative could be policy development focused on a few lead countries with the most significant CCGT capacities and/or storage capacities. The table below illustrates the rel-

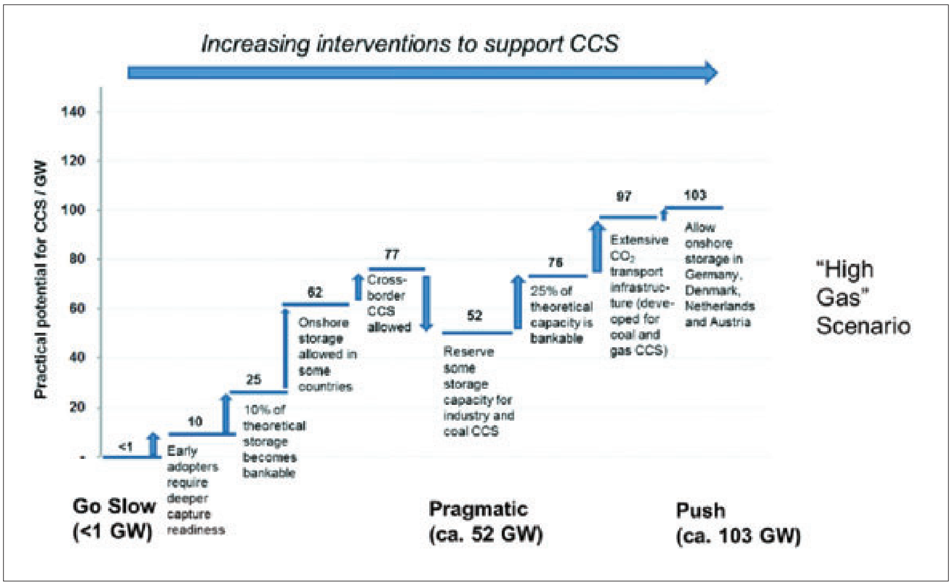

Figure 3 - how policy interventions could serve to increase the practical potential for gas CCS

ative importance of selected issues for the countries with the largest predicted CCGT capacities in Europe, namely UK, Spain, Germany, Italy and France.

Country	Impact of CCGT demand	Value of early capture readiness on ready stock in 2030	Impact of bankability of domestic theoretical storage	Value of onshore storage	Impact of reserving storage for coal and industry CCS	Value of cross-border CCS	Value of integrated CO_2 transport networks with coal and industrial sources	Most useful policy to increase gas CCS ready capacity
Spain	++	+	+++	+++	+	+ (only if onshore restricted)	+	Increase bankable storage & acceptance of onshore storage
Italy	++	+	+++	++	+++	++	++	Increase bankable storage, acceptance of onshore storage (& cross-border if storage reserved for coal/industry)
UK	++	+++	++	No onshore	+	Not required	+	Early capture readiness
Germany	++	+	++	++	+++	+++	++	Facilitate cross-border storage e.g. with Norway if storage reserved for coal/industry
France	++	+	++	+++	+++	++ (esp. if coal and industry capacity reserved or onshore restricted)	+	Increase bankable storage & acceptance of onshore storage (& cross-border if storage reserved for coal/industry)

Table 1 - the relative importance of selected issues for the countries with the largest predicted CCGT capacities in Europe. UK, Spain, Germany, Italy and France

Conclusions

The modelling shows that the deployment of CCS on gas cannot be assumed to be straightforward. Scenarios indicate it would be practical for gas CCS to play an important and growing role in the supply of low carbon electricity in 2030 and beyond, particularly in Spain, the UK, Germany, France and Italy – the countries with the largest predicted CCGT capacity. These positive outcomes are however dependent on policy action to avoid the following barriers to CCS deployment:

- late or weak application of capture readiness requirements,
- low levels of “bankable” storage capacity,
- restrictions on onshore storage,
- the absence of CO2 integrated transport networks with coal or industrial sources, and
- the absence of strong cross-border agreements.

Stakeholders who wish to ensure widespread practical potential for gas CCS in the period to 2030 and beyond must therefore consider the following interventions as a matter of urgency:

- early enforcement of capture readiness (possibly informed through a real CCS demonstration project)
- extensive storage characterization
- engaging with public concerns over the potential safety of onshore CO2 storage
- developing integrated CO2 transport networks, and facilitating cross-border CCS

Policies specifically aimed at encouraging the development of increased levels of practical potential for gas CCS could be initially targeted at a limited number of countries for maximum efficiency, but must be holistic, i.e. covering capture, transport and storage readiness, rather than treating these independently which appears to be the case at present. As the technology and CCS capacity requirements for the gas power sector become better understood, policymakers, investors and regulators could demand wider geographic coverage and increasingly meaningful levels of readiness in capture, transport and storage to avoid the threats of lock-in or stranded assets in the 2030s and 2040s.

More information

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Capturing attention - building an EU & UK CCS industry

Judith Shapiro, of the UK Carbon Capture & Storage Association (CCSA), shares her views on why the EU and UK must seize the opportunity to kick start the CCS industry.

The UK and Europe are now deep into competition mode to see the first CCS projects built, which will finally enable inclusion amongst the global 'club' of countries that have already started down the CCS path.

In the UK, the Government launched the 'CCS Commercialisation Programme' in April this year – its revamped CCS Competition, after the first competition (launched in 2007) culminated in the cancellation of the sole remaining project at Longannet power station last year. Whilst the Commercialisation Programme does not commit to a total number of projects to be supported the Government has committed to supporting four commercial-scale CCS projects in its coalition agreement.

This competition presents the industry with a much more flexible package including both coal and gas, consideration of all capture technologies and inclusion of industrial emitters where part of a cluster project. A change in the name of the competition indicates that the Government is now focussed on the long-term commercialisation of CCS, with the high-level aim of enabling CCS to compete cost-effectively with other low-carbon technologies in the 2020s. Crucially, the Programme now states clearly the need for projects to demonstrate their contribution to the development of early transport and storage infrastructure which will support CCS projects into the future, an issue which has long been at the forefront of industry discussions.

Alongside the Commercialisation Programme, the Government also published the long-awaited CCS Roadmap – setting out the Government's goal of seeing commercial CCS deployment in the next decade, and the actions that will be taken to achieve this goal. Crucially, the Roadmap recognises the industry ambition of at least 20-30 GW of installed capacity of fossil fuel power plant fitted with CCS by 2030 – as set out in the CCSA report "A Strategy for CCS in the UK and Beyond", published in September 2011.

Although much detail still remains to be seen, the Roadmap is beginning to send much-needed positive signals to the CCS industry regarding the Government's commitment to a long-term CCS industry, enabling developers to make the investment decisions into the first CCS projects, as well as the ensuing roll-out of the industry.

In Europe, CCS policy has virtually come to a standstill whilst the Commission assesses the bids into its NER300 Competition (for CCS and innovative renewables) – an announcement on which is expected in the Autumn of this year. Whilst some CCS projects across Europe have faced difficulties recently, the UK remains in a very strong position, contributing half of the total 10 CCS projects that have been put forward by Member States. A recent Commission review of the NER300 process ranked a UK project as top of the list for potential funding – further cementing the UK's opportunity to become one of the leading CCS countries in Europe.

However, this is no time for complacency, as the NER300 will only fund up to 50% of a project costs and the Commission requires that Member States set out clearly how they intend to provide sufficient co-funding to make up the difference. Details of this co-funding must be provided to the Commission by the time of final project selection, and the UK must therefore make sure that the Commercialisation Programme concludes on time, allowing the UK and EU processes to be fully synchronised.

A key factor that will influence the success of CCS will be the ability of the technology to reduce costs to a level that is competitive with other low-carbon technologies. Current estimates suggest that CCS is already cost-competitive with some low-carbon forms of electricity generation; however as with any emerging technology, CCS must go through a process of cost-reduction to reach commercial maturity.

The sooner we get some momentum behind building the first CCS plants, the faster the process of technology optimisation and cost reduction can take place. To this end, the Government has set up a CCS Cost Reduction Task Force, which will look at key areas that will be instrumental in achieving cost reduction in CCS in the immediate future. The interim findings of this Task Force will be published later this year and the conclusions will play a key role in securing vital Government support for early CCS projects beyond the Commercialisation Programme.

In the UK, the commercial case for early and long-term CCS projects will be determined to a large extent by the UK's Electricity Market Reform (EMR) – introduced in 2011 to create an overarching framework by which all low-carbon electricity generating technologies can compete for a level of support. Key to EMR is the Feed-in-Tariff Contract-for-Differences (FiT CfD) mechanism, which will provide a level of top-up to the wholesale electricity price to support nuclear, CCS and renewables on a similar and comparable basis.

Whilst discussions are ongoing regarding the appropriate design of the FiT CfD for CCS, EMR must provide a sufficiently clear and strong signal to both those projects selected under the current Commercialisation Programme as well as projects not selected and those that will come on stream after. Policymakers need to ensure that developers have the confidence to make long-term investments, creating a CCS industry into the future.

We must not forget that CCS is becoming an increasingly necessary option for industrial sectors such as steel, cement, chemicals and oil refining – which will soon be faced with tough decisions regarding their continued operation in a carbon constrained world. For many of these sectors, there is no realistic means of decarbonisation other than CCS, because the CO2 is process as well as fuel generated.

The importance of CCS for both power and industry should not be underestimated. The power sector will experience increased amounts of intermittent and inflexible electricity sources coming on stream, and fossil fuels will have to play a vital role in providing the flexibility needed to balance the system. Only with CCS, can we ensure that fossil fuels can fulfill this role, whilst enabling climate change targets to be met alongside the decarbonisation of the power sector in the next few decades.

The time is ripe for CCS in the UK and EU and we must seize the opportunity to kick-start this vital industry, which will create a market measured in $ trillions by 2050, with the associated jobs and growth that this will bring.

More information

www.ccsassociation.org.uk

IEA report - hybrid carbon capture systems

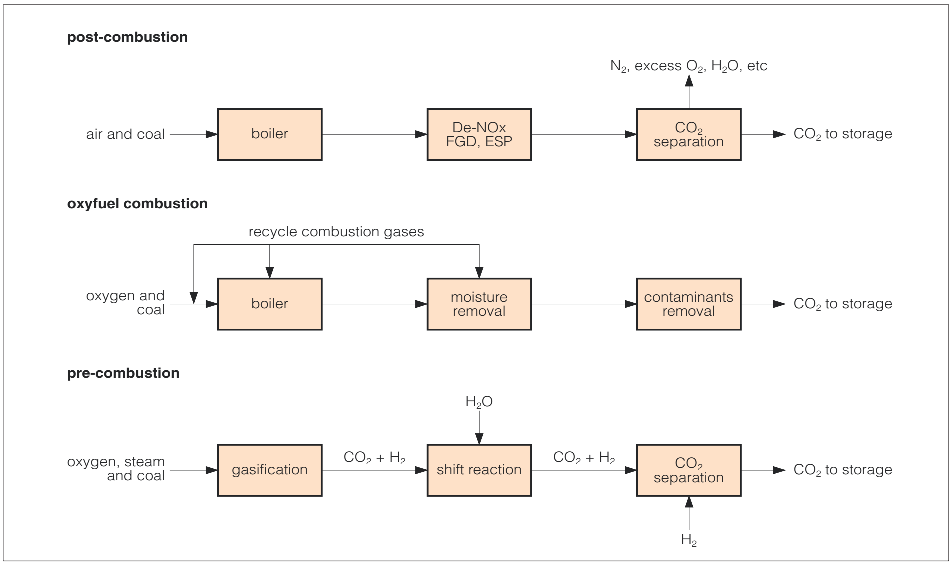
A report from the IEA Clean Coal Centre looks at the potential for combining conventional carbon capture technologes such as post-combustion and oxyfuel to achieve a more efficient process.

Post-combustion and oxyfuel have often been treated as distinct or even competing technologies for CO2 capture, but recently, there have been signs that this is no longer the case, says a new report by Robert Davidson.

Some researchers have realised that it may be possible to pick and choose among the elements of the main CO2 capture systems and develop hybrid systems which are possibly cheaper and more energy efficient.

Most hybrid systems are at a very early stage of development compared with the conventional methods with much of the research aimed at evaluation or modelling. The report provides a brief survey of these proposed systems comprising:

- postcombustion capture with oxygen enriched combustion;
- regenerable sorbents (calcium looping) with oxyfuel combustion;
- postcombustion capture in IGCC plants;
- gasification with oxyfuel;
- gasification with chemical looping.



Conventional CO2 capture systems

The consideration of hybrid capture systems is evidence that the capture of CO2 need not necessarily be limited to the three 'conventional' strategies. However, the hybrid capture systems are mainly concepts that have not been physically studied or tested. An exception is the use of oxyfuel combustion for the calcination step in carbonate looping capture. This, though, is probably the least hybrid system of those considered.

As conceptual systems, they can offer thermodynamic advantages but there can be added complexity. So, for example, in combining postcombustion capture with oxygen enriched combustion, the reduced energy requirements for CO2 capture is offset by the release of more reaction heat and a lower quantity of gas to exchange heat with.

As noted above, regenerable sorbents (carbonate looping) is the system that has made most headway, especially with the establishment of the 1.7 MWth La Pereda pilot plant. Again, although the thermodynamics of the system appear favourable, the plant complexity is higher than in competitive technologies such as full oxyfuel combustion or aminebased postcombustion capture.

The situation is similar when combining postcombustion capture with IGCC plant. The need for high levels of integration might lead to reduced flexibility and reduced availability of the plant. If chemical solvent capture is used then the heat needed for solvent regeneration may lead to lower efficiencies than precombustion capture with physical solvents.

Some of the concepts studied involve processes and components that are still under development, for example, syngas chemical looping may encounter engineering challenges. It has also been reported that, due to high capital investments and operating costs, the CO2 avoidance costs for CLC systems have been found to be exceptionally high. But again, it has also been concluded that the energy penalties are lower compared with more conventional capture technologies.

Based on the limited number of what are largely conceptual studies a general conclusion is that, to be successful, hybrid systems must not only be thermodynamically superior but they need to avoid introducing both higher cost and increased engineering complexity. However, the existence of hybrid capture concepts means that capture systems may not have to be limited to the trinity of postcombustion, oxyfuel combustion, and precombustion.

More information

'Hybrid carbon capture systems' was written by Robert Davidson for the IEA Clean Coal Centre. Buy the full report:
www.iea-coal.org

Lessons from Vattenfall's Jänschwalde project

Although the Jänschwalde project has been postponed indefinitely, lessons from the project can be put to good use by other demonstration projects. Vattenfall has released the FEED documents for public view and the European CCS Demonstration Project Network has summarised the findings in English.

Jänschwalde was one of the most advanced CCS projects in the world, says the summary report from the European CCS Demonstration Project Network, "Lessons learned from the Jänschwalde project."

It would have been a 250MW oxyfuel plant operating at a net efficiency of 36% and capable of flexible operations between 50-103% and a 50MW retrofitted post combustion capture plant. Transport would have been by steel pipeline.

Had the project gone ahead the 1,700,000 tonnes per year of CO2 emissions could have been safely and permanently stored over 1000m underground in either the Birkholz-Beeskow or the Neutrebbin structure. The ongoing impasse in passing the German CCS law, as stipulated by the European Union's CCS Directive, has led to Vattenfall cancelling the project.

Public acceptance has also been a challenge throughout the project, despite Vattenfall's good public engagement activities which included a local information centre, road shows and newsletters. A lack of political support on national level and ultimately the impasse in the German CCS law forced Vattenfall to cancel the project.

Vattenfall has consistently emphasised its commitments to CCS, and has invested extensively in the development programme. This was undertaken with the expectation that CCS will be a cornerstone of the future energy mix, and will be vital particularly by 2020-30. Vattenfall has consistently monitored and often contributed to R&D efforts in all three carbon capture technologies, (oxy fired, pre and post combustion), with close links to pilot plants across Europe.

Vattenfall will continue to monitor and actively support developments concerning the CCS technology with the expectation that full-sized commercial CCS plants will be an essential part of the generation fleet of Europe during the 2020s onwards – complementing renewable generation – as the most realistic route to a future where average global warming is limited to 2°C.

This is articulated within Vattenfall's strategic ambition to reduce its specific CO2 emissions by 50% by 2030 and to produce heat and electricity in a manner that is neutral to the climate by 2050, even if fossil fuels are still required for security of supply.

Project background

Jänschwalde is a lignite fired plant owned by Vattenfall and located in Germany in the state of Brandenburg, approximately 120 km southeast of Berlin. The project was planning to store around 1.7 million tonnes of CO2 per year. This CO2 was to be captured from two units -a new build 250MWe (gross) oxyfuel capture unit operating at a net efficiency of 36%, and capable of flexible operations between 50-103% and a 50MWe (gross) post combustion capture unit retrofitted to an existing 500 MW lignite block.

The CO2 would have been transported via a steel pipeline. It was intended that the captured CO2 would have been safely and permanently stored in the Birkholz-Beeskow or in the Neutrebbin structure at a depth of approximately 1300m depth, with 2 caprocks.

A lack of political support on a national level and ultimately the impasse in the German CCS law forced Vattenfall to cancel the project.

Key project management lessons

In terms of overall project management the capture elements were much like any generation infrastructure project. The oxyfired plant at Schwarze Pumpe had a development cycle that went much better than expected, and it was fully anticipated that there would be no operating penalty of capturing the CO2 on this new unit compared to an older operating unit.

In terms of operating expectations, it quickly became evident that load following was an important design element for any new CCS capture plant, as given the anticipated future generation mix - baseload operations cannot be necessarily assumed. This created some challenging design considerations for both the transport and injection elements in particular.

It was the transport and storage elements that proved to be significantly more challenging than originally anticipated. While only representing a relatively small fraction of the overall investment costs – these elements were the most attention consuming, and it would have been beneficial to consider them more fully earlier in the project development life-cycle.

The project had to create a new joint venture company for the Transport and Storage of CO2. Vattenfall's Head of R&D commented that it was initially assumed that a number of independent organisations would be keen to pick up the storage operations, seeing it as a business opportunity.

It turned out that was not the case, and as a consequence they had to start developing in-house competence. As a 'lesson learnt' it was felt that in any case having internal expertise regarding CO2 storage was of great use.

Cost

In terms of capital costs, the Jänschwalde project was going to be a €1.5bn investment. €1.250 bn of that was dedicated to the capture component of the project. The procurement contract for the ASU alone took around 14 months, but was below the budgeted €150M. While only €250m of capex was required for the transport and storage, the required time and effort were much higher than originally assumed.

The operating costs for the capture of CO2 would have resulted in an 8% point drop in performance, the equivalent of an 18% efficiently loss. Nevertheless, with the much higher operating efficiencies that can be achieved with a new unit using oxyfuel technology – the net operating efficiency would have been the same as a conventional unit refurbished in the mid-1990s (including compression), illustrating that if the high capital costs can be accounted for CCS is a very viable technology.

More information

The European CCS Demonstration Project Network was established in 2009 by the European Commission to accelerate the deployment of safe, large-scale and commercially viable CCS projects.

The detailed front end engineering and design (FEED) studies and summary report in English are available from the EU CCS Network's website:
www.ccsnetwork.eu

IEA CCS legal and regulatory review

The CCS Review gathers contributions by national, regional, state and provincial governments, at all stages of CCS regulatory development. Each edition focusses on a particular theme, which for this third edition is stakeholder engagement in the development of CO2 storage projects.

For the third edition of the Review, published in July 2012, contributions were received from 29 governments and 8 international CCS organisations.

Country specific overview

The period since publication of the second edition has seen muted efforts among governments to advance the broader policy and financial drivers required to promote deployment, the report says. By contrast, international advances towards legal and regulatory frameworks to enable deployment are tracking relatively well.

A number of key developments are being driven at the regional level. In Canada, for example, provinces continue to make significant headway. Alberta expects to complete its Regulatory Framework Assessment process by the end of 2012, in which the government is trying to pin down regulatory detail on complex issues such as pore space open access, methodology for determining rates to be paid into its post-closure stewardship fund, etc.

At the federal level, the government of Canada is one of a small number of jurisdictions to date to have advanced broader emissions reductions initiatives that could provide incentives for CCS installations in the future.

In the United States, Texas – one of six states reported by the United States Department of Energy in edition 2 to have elements of frameworks in place – has built on its existing framework, issuing new rules for both pure-play CO2 injection and storage, and injection and storage in association with enhanced oil recovery (EOR).

Given increasing international emphasis on the potential role of CO2-EOR as an early driver for CCS learning and infrastructure, the IEA will continue efforts to involve governments looking at the intersection between CO2-EOR and CO2 storage in the CCS Review moving forward.

Illinois is another US state that has made moves to regulate geological storage. At the federal level, the Environmental Protection Agency (EPA) reports that it has built on its Safe Drinking Water Act geological storage rule, proposing to conditionally exclude CO2 streams injected into Class VI wells – the new well class established by the 2010 rule for wells used to inject CO2 for geological storage – from federal hazardous waste regulations.

The 25 June 2011 deadline for transposition of the EU CO2 Storage Directive has galvanised action across the European Union, despite this progress not being immediately apparent in the official infringement proceedings figures. The European Commission reports that it launched proceedings against 26 out of 27 member states for incomplete (11 member states) or non-communication of transposition measures (15 member states) following last year's deadline, with Spain being the exception.

Germany is a high-profile example of the difficulties surrounding the transposition process in some EU countries, following public opposition to CCS.

In practice, however, infringement proceedings are not uncommon, and as at June 2012, nine cases had been closed following communication of full transposition legislation. Almost all member states with planned CCS demonstration projects have completed transposition.

Work is generally ongoing in areas where the EU CO2 Storage Directive affords discretion to member states.11 The United Kingdom announced a comprehensive electricity market reform process in July 2011; the proposed reforms are significant as they represent the first more comprehensive approach globally to set CCS policy beyond the first demonstration facilities.

At the Australian state-level, Victoria – one of three states with legislation in place to regulate onshore geological storage, together with South Australia and Queensland – reports that its legislative framework for offshore CO2 storage is now also in force.

This makes Victoria the first Australian state to have finalised its regulatory framework for CO2 storage across both onshore and relevant offshore areas. A fourth state – Western Australia – has been working to develop its onshore framework since 2010; its bill has reached the initial consultation phase and will be introduced into parliament shortly.

The federal government has finalised secondary legislation to underpin its offshore geological CO2 storage legislation, and now has all elements of its CO2 injection and storage framework in place. The regulations, which entered into force in June 2011, set out detailed provisions dealing with, amongst other things: the interaction of GHG storage and petroleum activities; storage site selection and characterisation; and site plan requirements.

The report also highlights progress beyond these regions in the context of the Clean Energy Ministerial (CEM) Carbon Capture, Use and Storage Action Group (CCUS AG), in which jurisdictions that have not traditionally had the lead in this area participate, such as China, Japan, Mexico, South Africa and the United Arab Emirates (UAE).

CO2 storage stakeholder engagement

Stakeholder engagement in development of CO2 storage projects is firmly on the international CCS agenda as a critical element in ensuring successful CCS deployment, says the report. This follows high-profile examples, such as the delay and then cancellation of the Barendrecht project (Netherlands, 2010) and challenges experienced by the German government in passing laws to regulate CCS, that illustrate the impact that stakeholder opposition and resistance can have on development of both individual projects and government deployment policy.

The role of project developers in stakeholder engagement has been a key area of focus to date. In contrast, the potential role of government and CCS regulation has received less attention. The report therefore aims to consider the relationship between stakeholder engagement processes and CCS regulation, to assess how government might play a more effective role in contributing to social acceptance of CCS (i.e. as a key aspect of CCS deployment).

The section also assesses current regulatory approaches to engagement and how these match up with the "best-practice" principles and lessons learnt from various case studies. It acknowledges that, depending on existing processes and practices on engagement generally, regulation may be more or less relevant in this area depending on the country in question.

More information

The full report is available for free from the IEA website:
www.iea.org

Policy, projects and regulation news

Carbon capture using oxycombustion in a circulating fluidised bed boiler is achieved for the first time at CIUDEN's pilot facility in Spain

CIUDEN completes oxyfuel CFB carbon capture test

www.ciuden.es

For the first time in the world CO_2 has been captured using oxycombustion in circulating fluidized bed (CFB) technology, said CIUDEN.

The Fundación Ciudad de la Energía (CIUDEN) has successfully completed the full CO_2 capture process using oxycombustion in a circulating fluidized bed (CFB) boiler provided by Foster Wheeler at its es.CO2 pilot facility in Spain.

The milestone was achieved after the commissioning of a CO_2 Compression and Purification Unit (CPU) by Isolux Corsán with technology provided by Air Liquide.

es.CO2 has a 30 MWth CFB boiler which can be operated both in air-fired (as in current power plants) and oxygen-fired modes. This boiler has been designed, supplied and manufactured by Foster Wheeler SL in Spain and is financed by the European Economic Recovery Program of the EU. This is one of the five European projects selected to develop CCS technology.

CIUDEN, jointly with Endesa and Foster Wheeler Oy, are cooperating on this project, funded with EUR 180 million from the European Commission, whose objective is the validation of CFB technology and the subsequent development, in a second phase, of a 300MWe industrial power plant.

Oxycombustion offers several advantages, such as near zero emissions and the flexibility to use different fuels, with the peculiarity of using a mixture of pure oxygen and recirculated flue gases instead of air that produces a concentrated CO_2 flow, ideal to be applied in CO_2 capture projects.

es.CO2 has now become one the world's most outstanding references on CCS, said CIUDEN, and this now opens up a promising line of application of these technologies on a commercial scale, strengthening R&D in areas of industrial interest and generating knowledge.

DOE reaches milestones in Illinois integrated CCS project

fossil.energy.gov

The U.S. Energy Department has marked two important milestones in the Illinois Industrial Carbon Capture and Storage (ICCS) project in Decatur, Illinois.

The Archer Daniels Midland Company (ADM) marked the progress made on construction on the project's storage facility, as well as the public opening of the National Sequestration Education Center.

The Center was funded in partnership with the Richland Community College and will contain classrooms, training, and laboratory facilities, offering students associate degrees in sequestration technology.

Once fully operational in 2013, the Illinois project will be able to store 1 million tons of carbon dioxide (CO_2) per year and will help demonstrate the feasibility and reduce the cost of clean coal and carbon capture, utilization and storage (CCUS) technologies.

Led by ADM, a member of DOE's Midwest Geological Sequestration Consortium, the Illinois ICCS project is designed to sequester approximately 2,500 metric tons of CO_2 per day in the saline Mount Simon Sandstone formation at depths of approximately 7,000 feet. Researchers estimate that the sandstone formation can potentially store billions of tons of CO_2 and has the overall potential to sequester all of the more than 250 million tons of CO_2 produced each year by industry in the Illinois Basin region.

In October 2009, DOE selected the ADM team—which now includes Schlumberger Carbon Services, the Illinois State Geological Survey, and Richland Community College—to conduct one of 12 projects in Phase 1 of its ICCS program, aimed at testing large-scale industrial CCUS technologies. DOE then selected the project in June 2010 as one of three projects to receive continued (Phase 2) funding.

The Office of Fossil Energy's National Energy Technology Laboratory manages the Illinois ICCS project, which received $141 million in funding under the American Recovery and Reinvestment Act and leveraged another $66.5 million in private sector investments. The federal investment is enabling ADM and its partners to gather crucial scientific and engineering data to help continue to reduce technology costs and demonstrate the feasibility of industrial CCUS.

The Illinois-ICCS project includes the design, construction, and demonstration of a CO_2 compression and dehydration facility that will enable the high pressure stream of CO_2 available to the pipeline and injection well. The operations phase of the project — capture and storage of the CO_2 — is expected to begin in late summer 2013.

Australian national research centre in Perth

www.innovation.gov.au

A new national research and development facility was launched in Perth by Minister for Science and Research, Senator Chris Evans.

The centre will play a critical role in reducing Australia's greenhouse gas emissions by answering the key questions surrounding

the storage of commercial-scale carbon dioxide, said Mr. Evans.

The National Geosequestration Laboratory (NGL), based at the Australian Resources Research Centre, is a collaboration between CSIRO, the University of Western Australia and Curtin University.

It will conduct research to support the design and implementation of commercial-scale CO2 storage programs, such as Western Australia's South West Hub Carbon Capture and Storage (CCS) Flagship project.

Launching the project Mr. Evans said the NGL will be one of the most significant international centres for research, training and technology development for the global resources sector.

"Effective carbon capture and storage technologies are key to securing Australia's clean energy future and reducing global warming," Senator Evans said.

"The commercial use of carbon capture and storage technologies is expected to drive significant emissions reductions in Australia's electricity generation sector.

"The NGL will provide critical research to develop innovative solutions to minimise any risk associated with the long term storage of CO2."

Lead agency CSIRO received $48.4 million from the Federal Government's Education Investment Fund for the project.

The NGL provides opportunities for large scale collaboration on a local, national and international scale between government, industry and the community, and will be a significant drawcard for attracting international research talent and cooperation.

"By strengthening partnerships between industry, government and the global research community we will secure genuine sustainability and the best results," Senator Evans said.

The NGL will support projects under the $1.68 billion CCS Flagships program, a key component of the Gillard Government's Clean Energy Future package.

DNV KEMA certification framework for CCS projects

www.dnv.com/ccs

DNV KEMA has launched a new certification framework to help Carbon Capture and Storage projects pass hurdles related to permitting, stakeholder support and internal decision gate requirements.

How can project developers, regulators and the public be assured that underground storage of CO2 is safe, predictable and commercially viable over the long term?

DNV KEMA believes the answer to this question lies in a new certification framework for CO2 storage sites that is designed to mitigate these uncertainties through a site-specific and risk-based approach to site selection, monitoring and verification

The new framework builds on preceding DNV KEMA guidelines for CO2 storage and is organised as two distinct documents for clarity. The first document is Recommended Practice (RP) J203 for the selection, qualification and management of geological storage sites. The second document is DNV Service Specification (DSS) 402, which defines the following statements and certificates that may be issued in accordance with the RP at successive stages of project development:

- Statement of Feasibility
- Statement of Endorsement
- Certificate of Fitness for Storage
- Certificate of Fitness for Closure

“The new framework builds on five years of development work with industry and regulators that took the form of Joint Industry Projects and resulted in publication of the CO2QUALSTORE and CO2WELLS guidelines,” explains Michael Carpenter, Acting Head of DNV KEMA’s CCS Unit in Oslo, Norway. “The content of both guidelines has been streamlined and collated into RP-J203, which will be actively maintained by DNV KEMA to take account of industry developments.”

According to Carpenter the new framework fills a gap by providing a common international method for CO2 storage site selection, risk assessment, monitoring and verification. This is important because the safe, reliable and long-term storage of captured CO2 in geological reservoirs is a prerequisite for CCS, but remains a key uncertainty affecting wide-spread deployment of the technology.

“Confirmation of site suitability by an independent and trusted partner may therefore be helpful to create an extra level of reassurance. However, to provide reassurance to regulators and stakeholders the basis for such confirmation must be transparent, available to the public, and based on industry best practice,” emphasises Carpenter and adds, “the importance of such an internationally recognised process has become more critical with the recent inclusion of CCS under the CDM mechanism of the Kyoto protocol.”

Fluor to build Shell’s Quest Carbon Capture facility in Canada

www.fluor.com

Fluor Corporation has been selected as Shell's engineering, procurement and construction (EPC) contractor for the Quest project at the Athabasca Oil Sands in Alberta, Canada.

The Quest project is being built on behalf of the Athabasca Oil Sands Project joint venture owners (including Shell, Chevron and Marathon Oil) with support from the Canadian and Alberta governments. Fluor booked the undisclosed contract value in the third quarter.

“Shell’s confidence in choosing Fluor as its EPC contractor for this first-of-its-kind CCS project is a testament to our long-term, successful business relationships established by building Shell projects in Canada and throughout the world,” said Peter Oosterveer, president of Fluor’s Energy & Chemicals Group.

“Fluor has more than two decades of experience with carbon capture technologies and the Canadian oil sands industry, so this unique opportunity will demonstrate our project execution abilities to bring clean energy to the marketplace. The use of CCS technology will allow our customers to address their carbon footprint and sustainability needs.”

The Athabasca Oil Sands Project produces bitumen, which is piped to Shell’s Scotford Upgrader. Fluor will provide full EPC services using its patented and innovative 3rd Gen Modular Execution approach for a 1.1 million tonne-per-year carbon capture facility at the Scotford Upgrader near Edmonton, Alberta.

Captured carbon dioxide will be sent about 80 kilometers from the facility via underground pipeline to an underground storage site. Fluor has been providing preliminary services and front-end engineering and design for Quest since 2009.

UK Committee on Climate Change expresses concern on UK policy

www.theccc.org.uk

The Committee on Climate Change (CCC) has written an open letter to Minister Ed Davey expressing concern over recent Government statements on unabated gas-fired generation, and recommending that a carbon intensity target should be set for the power sector.

"We are writing to express the great concern of the Committee on Climate Change about the recent Government statement “that it sees gas as continuing to play an important role in the energy mix well into and beyond 2030...[not] restricted to providing back up to renewables”,"says the letter.

"Extensive use of unabated gas-fired capacity (i.e. without carbon capture and storage technology (CCS)) in 2030 and beyond would be incompatible with meeting legislated carbon budgets."

Next Gen coal projects backed by DOE

Robert Marrs, Managing Director, Unity Power Alliance, outlines the projects awarded funding by the U.S. Department of Energy and argues that pressurized oxy-combustion is the more promising technology.

The United States Department of Energy's National Energy Technology laboratory (DOE/NETL) recently announced multiple funding awards focused on advanced oxy-combustion as a means to increase the efficiency of future coal-fired power generation with carbon capture.

Atmospheric pressure oxy-combustion has been under development in the EU, UK, USA, Australia and Asia for a number of years. In fact, the DOE has allocated $1 Billion for the world's largest proposed atmospheric oxy-combustion project, FutureGen 2.0, planned to produce 200MWe from coal and sequester the CO2 in an approved site.

While the DOE feels that atmospheric oxy-combustion in slightly superior to the current state of amine based capture systems, analysis indicates that it still will not meet the DOE's long term cost and performance targets, and as such, the DOE recently awarded multiple contracts for the next generation of advanced oxy-combustion. The goal of the advanced oxy-combustion awards is to evaluate and develop technologies that can achieve greater than 90% CO2 capture at a cost less than $25/ton applicable to both retrofit and new coal fired power plants.

Two major technical routes were funded as part of the overall award: Chemical Looping Combustion (CLC) and Pressurized Oxy-Combustion. Alstom, Babcock and Wilcox and the University of Kentucky Research foundation were selected for CLC programs. The main object of CLC is to reduce the inherent cost of oxygen by using a solid "carrier" which can be oxidized in air, thereby avoiding the cost of producing oxygen by typical air separation technologies, and using coal or another hydrocarbon to reduce the solid "carrier" back to a state where it can be looped back to the oxidation reactor.

One key difference between CLC and conventional power production is that the heat is produced by oxidation of the carrier, not the hydrocarbon. Lower exhaust gas temperatures, solids handling, and coal ash residuals/carrier poisoning are issues which will likely be addressed.

Selections in the Pressurized Oxy-Combustion category were given to Unity Power Alliance, Pratt and Whitney Rocketdyne, the Gas Technology Institute, the Southwest Research Institute, and Washington University. Advantages of operating in a pressurized regime include higher combustion efficiency and heat transfer rates, reduced equipment sizing (CAPEX and footprint implications), as well as higher CO2 concentrations by eliminating air in-leakages.

As opposed to CLC, the pressurized oxy-combustion solutions will almost assuredly take advantage of improvements in the well-proven Air Separation Unit (ASU) technologies roadmap, including the potential incorporation of ion transport technologies, the use of low-purity oxygen solutions like VPSA, and will certainly include energy integration, thereby lowering the "risk" profile and improving time to market.

Figure 1 - 5MWth Pilot in Italy – Operated by ITEA since 2004

Chemical analysis of the effluents	Isotherm PWR®
CO	< 1 mg/m^3
NOx	< 100 mg/m^3
SOx	< 30 mg/m^3
TOC	< 0.05 mg/m^3
HCl	< 0.1 mg/m^3
PAH	< 0.00001 mg/m^3
Dust (total)	< 1 mg/m^3
PM 2.5	< 10 $\mu g/m^3$
Dioxin, Furans	< 0.0001 ng/m^3
Heavy metals	< 0.1 mg/m^3
SOOT	Zero
CO2 v (in flue gas)	> 93%

Unity Power Alliance technology

The Unity Power Alliance (UPA) award team includes ThermoEnergy of Massachusetts, ITEA SPA of Italy, MIT, and Georgia Tech, (UPA is a joint venture between ThermoEnergy and ITEA). The program is fundamentally geared around optimizing, not proving, Pressurized Oxy-Combustion.

The core of the technology being optimized involves a "flameless" combustion system that was developed by ENEL of Italy and ITEA. The "flameless" system is already successfully operating at a 5MWth scale at four atmospheres pressure.

Key advantages of the "flameless" combustor system already proven include:

- Dramatic reduction in the scope of the CO2 Purification Unit, or "CPU"
- Elimination of fly ash by creating an inert, non-leachable, vitrified slag
- Operational Robustness including the ability to successfully handle low rank coals

The ability to substantially reduce the size and complexity of the CPU is a major step in itself as the CPU has shown itself to be both complex and capital intensive in atmospheric oxy-combustion systems. Actual data from operations without any CPU are provided in the Table.

UPA project

The first key part of UPA's program is a techno-economic modeling optimization to be conducted by MIT, as previous studies have indicated, the optimum pressure may in fact be higher than 4 atmospheres. One important technical advantage of raising the pressure of the system is the ability to capture the latent heat of vaporization of the water, increasing the system's overall efficiency and dramatically reducing the overall plants water footprint.

The new Carbon Neutral Energy Solutions (CNES) laboratory at Georgia Tech will host the second major part of the project: testing the "flameless" reactor over a wide range of pressures. While proven at 4 Bar, flue, slag, and water analysis will be gathered over a series of pressures which will then be analyzed in conjunction with the techno-economic modeling conducted by MIT.

After completion of the first phase of the DOE awards, it is anticipated that a much larger Phase II will occur for both the "most promising" CLC and Pressurized Oxy-Combustion technology. The goal of the Phase II program would be to advance the selected technologies to a pilot stage at a suitable host site. The fact that the "flameless" technology has been successfully operating at a 5 and 15 MWth scale and ENEL and ITEA have already done considerable engineering on both the scale-up to a 50MWth Pilot and a 320MWe system, lowers the risk profile and accelerates commercialization.

All of the next generation technologies under consideration will advance the interests of utilities, the communities and jobs they support, and job creation in the engineering sector, not to mention the environment.

More information

Unity Power Alliance is a joint venture between ThermoEnergy Corporation and ITEA. The Mission of the Unity Power Alliance is to the develop and commercialize POXC™ "pressurized oxy-combustion" as a new, preferred clean combustion platform for repowering existing coal-fired power plants in the USA and building new power plants around the world with near zero air emissions.

www.unitypoweralliance.com

Capture and utilisation news

Petronas and Lanzatech to recycle CO2 into chemicals

www.lanzatech.com

Waste CO2 from Petronas operations will be captured by LanzaTech's process to create acetic acid.

LanzaTech, a producer of low-carbon fuels and chemicals from waste gases, and PETRONAS, the national oil company of Malaysia, will work together to accelerate the development and commercialization of technologies to produce sustainable chemicals from carbon dioxide and natural gas.

The agreement blends Petronas' experience and assets in the petroleum industry with LanzaTech's gas fermentation technology to create an economical and sustainable source of high value chemicals.

LanzaTech's proprietary fermentation process converts carbon monoxide (CO) in industrial waste gases, reformed natural gas and gas derived from any biomass source, into low carbon fuels and chemicals. LanzaTech and PETRONAS will work together to extend this technology to include carbon dioxide (CO2) containing gases from a variety of sources including refinery offgases and natural gas wells to produce acetic acid, a high value chemical with applications in the polymers and plastics markets.

The joint development agreement (JDA) builds on the relationship between the two companies established earlier this year when PETRONAS Technology Ventures SdnBhd (PTVSB), the venture arm of PETRONAS, invested in LanzaTech as part of the company's Series C round.

"We invested in LanzaTech because we saw an opportunity for PETRONAS to benefit from the integration of LanzaTech's technology in multiple areas of our business," said Haida Shenny Hazri, CEO of PTVSB. "This is a natural extension of LanzaTech's core gas fermentation technology and it is a natural fit with Petronas' commitment to achieving a sustainable future for all."

UK announces new £20 million CCS for gas project

www.eti.co.uk

The Secretary of State for Energy and Climate Change, Ed Davey, has announced a new £20 million ETI project to develop and demonstrate advanced carbon capture technology for gas-fired power stations.

The ETI has commissioned and funded a consortium to deliver the project which will see a 5MW carbon capture demonstration plant capable of capturing up to 95% of carbon dioxide emissions designed, built and tested by 2016.

The technology will be designed to be used on new-build Combined Cycle Gas Turbine (CCGT) power stations or to retrofit Carbon Capture Storage (CCS) onto CCGT power stations.

The project launch was marked by a visit to consortium member Howden's Global head office and UK factory in Renfrew, near Glasgow, by the Secretary of State. Howden's currently employs 378 at its premises in Renfrew.

The technology that will be employed by the consortium is based around post combustion capture using a structured carbon adsorbent, housed within a rotating bed. An initial assessment by the ETI suggests that the technology could reduce the typical cost of electricity by 13 per cent when compared to current CCS technology, based on the Levelised Cost of Electricity.

The first phase of the project will see the ETI invest £1.6 million in a small scale demonstrator prototype, laboratory work and techno-economic assessment to confirm the projected benefits. This will then be followed by a conceptual design for the larger-scale demonstrator plant.

Once this initial stage completes, the ETI then expects to invest up to £20 million over three years in the detailed design, assembly and testing of a UK demonstrator plant. The technology is expected to be capable of large-scale deployment by 2020, at a cost and performance level which could make investment more attractive to project developers.

"With a large and relatively young CCGT fleet in operation, and the prospect of new builds continuing into the future, we are likely to enter 2020 with 30GW of CCGT capacity, much of which will require retrofit with CCS by 2030 if we are to meet UK CO2 reduction targets," explained Dr David Clarke, Chief Executive, ETI.

"Newly developed technology which reduces costs and accelerates deployment for new builds and retrofits by 2030 is critical. Major developments such as this project will support job creation and growth in the energy sector."

"The UK government's initiative in creating the ETI to accelerate the development of low carbon technologies has in this case helped bring together an innovative gas separation technology developer with two world leading UK-based engineering companies; both of whom are well established within the global power generation industry," added Ian Brander, CEO of Howden Group.

The consortium will be led by Inventys in collaboration with Howden, Doosan Power Systems and MAST. Howden will manufacture the large rotating devices in which the carbon adsorbents will be housed; Inventys will design the carbon dioxide capture process and system known as VeloxoTherm™; Doosan Power Systems will provide expertise in the area of engineering design, system integration and assessing the commercial value of developing such technology; MAST will provide the expertise in manufacturing the carbon adsorbent material; and ETI member Rolls-Royce, will provide specialist engineering support for the project.

This project adds to the ETI's existing £33 million investment in its CCS technology programme, which aims to build CCS infrastructure capability for the UK.

3H Company receives $3.48 million for pilot carbon capture study

www.uky.edu

3H Company's CCS technology has been selected by LG&E and KU Energy for a 50-megawatt-scale demonstration project.

LG&E, KU Energy and EPRI (Electric Power Research Institute) provided matching funds to 3H for a pilot-scale study to collect data for future large-scale CCS development.

The CO2 capture technology being developed in the laboratory of 3H Company is radically different from the conventional absorption processes used today, the company said. 3H uses a specially designed chemical agent matched with a solvent that, when absorbing CO2, rapidly forms two distinct liquid phases: a CO2 rich liquid phase and a lean phase. Only the CO2 rich phase, a significantly smaller liquid volume compared to the conventional process, will then be collected and undergo regeneration to remove the CO2, and to recycle the solvent.

"The solvent we use in the CO2 capture process is much more efficient than any currently available CO2 capture technologies," said Dr. Liang Hu, founder and CEO of 3H Company. "Energy consumption using 3H's technology reduces by 80 percent when compared to the industrial benchmark Monoethanolamine (MEA) aqueous solution used today."

"Following a successful pilot-scale study, our vision is to have a 50 megawatt demonstration at Central Kentucky's E.W. Brown Power Plant in 2016," said Hu. "At this magnitude, 50 tons of CO2 will be captured per hour."

HDS International granted CCS patent

www.hdsicorp.com

HDS International, a green technology company, has been granted a U.S. Patent for a "Method for Eliminating Carbon Dioxide from Waste Gases."

Purification of process gas streams by the removal of acid gases, such as carbon dioxide, is required in many major industrial processes such as hydrogen manufacture for refinery hydrotreating, synthesis gas manufacture from coal, purification of natural gas, and ammonia manufacture, among other applications. Bulk removal of acid gases from such streams is usually accomplished by use of a scrubbing solution composed of a solvent.

The invention preserves the advantages of prior methods for eliminating carbon dioxide from waste gases while providing new advantages not found in currently available methods and overcomes many disadvantages of such currently available methods, says HDS.

The patent covers the elimination of carbon dioxide from waste gases. Additionally, the invention can transfer carbon dioxide in increased concentrations for growth of algae; consists of a photobioreactor system used in the method for increased production of algae; and provides a method for operating an open-pond system using carbon dioxide from waste gases.

FuelCell Energy coal power CO2 capture project advances

www.fuelcellenergy.com

FuelCell Energy will continue research that evaluates the use of Direct FuelCells (DFC) to cost effectively separate carbon dioxide from the emissions of coal fired power plants.

The company will enter Phase II of the project under the previously announced award from the U.S. Department of Energy Office of Fossil Energy's Carbon Capture Program (DOE) implemented by the National Energy Technology Laboratory.

The three and half year research project that began in late 2011 involves system design, cost analysis, and long-term testing of a Direct FuelCell® stack, with funding occurring in stages upon reaching certain progress milestones. Approximately $0.8 million from the total DOE award of $3 million was authorized to continue the development of the carbon capture system development based on DFC technology. This funding authorization follows favorable results achieved from the technology and economic analysis conducted in the initial stage of research.

"The potential for efficient and cost effective carbon capture from our Direct FuelCell power plants illustrates the versatility of our technology," said Chip Bottone, President and Chief Executive Officer, FuelCell Energy, Inc. "This award enables us to further advance and refine our research as we pursue this opportunity that has the potential to favorably impact public health while providing FuelCell Energy with the possibility of a new and potentially large market opportunity."

FuelCell Energy's DFC technology separates and concentrates CO2 as a side reaction during the power generation process. In this application of the technology, the exhaust of a coal fired plant is directed to the air intake of a DFC power plant, which separates and concentrates the CO2 in the exhaust for commercial use or sequestration.

Another side reaction that occurs when the fuel cell is used in this application is the destruction of some of the nitrogen oxide (NOx) emissions in coal plant streams as the exhaust passes through the fuel cell. This reduces the cost of NOx removal equipment for coal-fired power plant operators.

Since DFC power plants produce power efficiently and with virtually zero emissions, the net result is a very attractive solution to prevent the release of green-house gases by coal-fired power plants while simultaneously increasing the net efficiency and power output of the plant.

Additional benefits include reduction of the operating cost related to removal of NOx and reduction in water usage as existing carbon capture technologies are water intensive.

Conventional technologies used for the capture of CO2 from the emissions of coal fired power plants are energy-intensive with high operating costs. Most of the existing carbon capture technologies penalize the power plant output by as much as 30 percent. For these reasons, the DOE's Carbon Capture Program seeks advanced technologies that reduce the cost and energy requirements for the capture of CO2 from coal fired power plants.

DFC power plants potentially represent an efficient and cost effective approach to separating CO2 while generating ultra-clean power rather than consuming power.

Partners in the project include Pacific Northwest National Laboratory (PNNL), Richland, Washington and URS Corporation, Austin, Texas.

US policy shift to Carbon Capture, 'Utilization' and Storage

www.acus.org

The Atlantic Council's Energy and Environment Program has released an issue brief entitled: "US Policy Shift to Carbon Capture, Utilization, and Storage Driven by Carbon Dioxide Enhanced Oil Recovery."

The issue brief is one in a series the Atlantic Council is publishing analyzing carbon capture, utilization, and storage (CCUS). Contributors to this brief include Pamela Tomski, Senior Fellow, Energy and Environment Program; Vello Kuuskraa, President, Advanced Resources International; and Michael Moore, Executive Director of the North American Carbon Capture and Storage Association and Vice President of Business Development with Blue Strategies. Each is an internationally recognized experts on CO2 enhanced oil recovery (EOR) and carbon markets.

In the absence of US legislative action on climate policy, there has been a shift in US policy emphasis from carbon capture and storage (CCS) technology to CCUS with the "U" for "utilization" for EOR. Although there are many uses for carbon dioxide, the primary utilization opportunity in the United States is enhanced oil recovery.

Currently, CO2-EOR offers the only significant price signal for carbon, and it provides the nation's most viable commercial CCUS pathway, increasing domestic oil production and helping to revitalize the US economy. The report states that the extent to which CO2-EOR will be leveraged for wide-scale CCUS deployment depends largely on how the CO2-EOR market develops and on what type of policy actions are taken to incentivize CO2 capture.

Transport and storage news

Report looks at Central North Sea C02 storage hub

www.scottish-enterprise.com

A Scottish Enterprise report highlights the potential role of a Central North Sea C02 storage hub in enabling the development of CCS in the UK.

The report sets out a number of possible scenarios for the future of CCS in the Central North Sea and the potential to develop infrastructure and networks to capture, transport and store CO2 from across Scotland, the UK and continental Europe.

It highlights the potential for a Central North Sea Storage Hub to receive and store as much as 100 million tonnes of C02 a year by 2030 and 500 million tonnes a year by 2050 – equivalent to 25 per cent of total EU emissions in 2007 – if all opportunities are effectively exploited.

“The offshore geography of the Central North Sea gives us an unique advantage in developing CCS capabilities which has huge potential for the Scottish economy," said David Rennie, Scottish Enterprise oil and gas, thermal generation and CCS director.

“This new report highlights the scale of the opportunity of CCS and a Central North Sea hub, and the steps needed to exploit this. Much of the infrastructure and skills to develop CCS is already in place in Scotland thanks to our globally renowned oil & gas sector – and the recently launched Oil & Gas Strategy for Scotland has already highlighted CCS as an area of real significance for our existing supply chain."

“The challenge now is to make sure we fully exploit these advantages to develop a reputation for Scotland as a world-leader in this area.”

The study examines the added value of the Central North Sea as a location for CCS – particularly through its affordability, diverse geography and deliverable existing knowledge and capabilities.

This includes the re-use of significant lengths of existing subsea pipelines, offshore platforms for injection to depleted gas fields and the building of new pipelines to link clusters of capture plants in both the power and industrial sectors to the storage assets.

The publication also highlights the potential for Peterhead Port as a key location for the shipment of captured CO2 from other parts of the UK and Europe, and onward transportation to the vast storage sites of the Central North Sea. It contains new figures which estimate that the development of such an import facility could receive 4 million tonnes of CO2 per year and lead to the creation of over 500 jobs.

“It’s important to look at what we get for our public support of CCS funding," commented Professor Stuart Haszeldine University of Edinburgh, Scottish Carbon Capture and Storage. "Ideally we want low cost projects now, which help us to keep jobs, and we want projects which can extend rapidly whilst reducing difficulties. The Central North Sea offers all of that security, in well-understood and well-supported industries.”

DNV releases experimental data on CCS safety

www.dnv.com/ccs

The DNV led CO2PIPETRANS joint industry project (JIP) is making freely available experimental data which will further support global CCS implementation.

“The data released today by the CO2PIPETRANS JIP complements previously released data and will greatly assist dense phase CO2 computer model development and validation,” said Hamish Holt at DNV KEMA Energy & Sustainability.

The material released by the CO2PIPETRANS JIP in May was gathered by BP in 2006 as part of their Peterhead/Miller CO2 capture and Enhanced Oil Recovery (EOR) project. Its release was the first step by the JIP to fill an identified gap in available data suitable for dense phase CO2 model development and validation.

Hamish Holt, who is DNV’s CO2PIPETRANS JIP work package manager for release modelling data collection and sharing, stressed the importance of this complementary second batch of data.

“The BP data we released previously gave modellers material that they could use to improve and assess the accuracy of their dense phase CO2 models. The data being released today, collected by Shell in 2010, provides complementary datasets covering different initial conditions and with greater number of measurements. The combined material now released by the JIP provides a very valuable reference source for all those involved in large scale CO2 handling be it within CCS, CO2 EOR or CO2-rich hydrocarbon extraction,” said Mr. Holt.

The material covers a significant number of experiments undertaken to investigate the behaviour of releasing dense phase CO2 up to 150 bar (2175 psi) and 150°C (300°F) through orifices up to 25mm (1 inch) diameter at constant or decaying inventory pressure. The data has all been critically reviewed prior to being made available and the review reports are also being provided with the datasets to help data interpretation.

The participants in CO2PIPETRANS are Arcelor Mittal, BP, DNV, Endesa, ENI, E.ON Ruhrgas, Gassco, Gassnova, Health and Safety Executive (HSE) UK, Maersk Oil, Petrobras, Petroleum Safety Authority (PSA) Norway, Shell, V&M Deutschland, and Vattenfall.

The project concludes in mid-2013 and the recommended practice ‘DNV-RP-J202 Design and Operation of CO2 Pipelines’ will be updated to reflect the new knowledge to help ensure the highest standards of safety are delivered in transporting CO2.

All the data can be downloaded for free on the DNV website.

LEWA and Burckhardt Compression join for CCS-EOR

www.burckhardtcompression.com

LEWA and Burckhardt Compression have joined forces to develop solutions for CO2 compression for CCS-EOR applications.

The agreement unites two leading comapnies from the fields of pumps and compressors: Lewa is the leading manufacturer of process diaphragm pumps and metering and mixing packages for process engineering, while Burckhardt Compression is one of the world’s largest manufacturers of reciprocating compressors.

With their combined know-how the companies have developed a process that allows for a highly energy efficient compression. Unlike ordinary compression processes, this so-called hybrid approach makes use of an intermediate step: gas liquefaction.

First, the semi isothermal compression is conducted in multiple stages by the reciprocating compressors from Burckhardt. After that, cooling and liquefaction follow. Eventually a LEWA triplex diaphragm pump boosts the liquid up to the required pressure (up to over 400 bar).

The overall power saving due to liquefaction can be up to 15% because the power consumption for the compression of liquids is lower than for gases, say the companies.

"The limit for piston compressors and diaphragm pumps lies at approximately 150 t/h of acid gas. In terms of carbon capture & storage, the CO2 emissions of many carbon dioxide generating processes and fossil fuelled power plants of 200 - 300 MW can be handled with one set of machines. Power plants of 200 - 400 MW would need two or three sets of machines.

The range above (up to 1200 MW) would be the field of multistage turbo compressors."

"Such extreme requirements pose a big challenge to the sealing systems of a package. In order to meet this challenge, typical Lewa qualities like hermetic tightness of diaphragm pumps and the broad experience of Burckhardt Compression in the field of CO2 compression, especially within the supercritical area, are crucial."

Operators also benefit in other ways: corrosion problems that in the case of carbon dioxide occur in compressors at relatively low pressures can be avoided in the liquid phase. Furthermore, variable flow rates and gas compositions can be handled by the use of speed control, thus enabling a constant high efficiency.

Also changes in the reservoir pressure are not disruptive because the system boosts the liquid to the final pressure in one single step.

DOE releases risk profiles for CO2 storage sites

fossil.energy.gov

A collaboration of five U.S. Department of Energy (DOE) national laboratories has completed the first risk profiles that can help to predict the probability of complications that could arise from specific CO2 storage sites.

The first-generation profiles were produced by the National Risk Assessment Partnership (NRAP), led by the Office of Fossil Energy's National Energy Technology Laboratory (NETL) and the NETL-Regional University Alliance (Carnegie Mellon University, Penn State, University of Pittsburgh, Virginia Tech, and West Virginia University).

The five national laboratories that form the Partnership and the expertise contributed include:

- Lawrence Berkeley National Lab — monitoring for risk assessment
- Los Alamos National Lab — modeling for risk assessment
- Pacific Northwest National Lab — risks to groundwater systems
- Lawrence Livermore National lab — natural seal integrity
- NETL — wellbore integrity

The effectiveness of carbon storage depends greatly on the ability of a specific site to store CO2 permanently. However, variable field conditions, such as geology, wellbores, and fractures, can complicate researchers' abilities to predict potential risks.

Following injection for underground storage, the site is monitored to ensure the CO2 remains permanently contained. However, a technical challenge for all storage sites is how to predict the long-term effectiveness of the storage site and what potential risks might develop.

NRAP's risk profiles offer a more concrete and detailed profile, meaning scientists will be able to design site-specific monitoring and mitigation strategies to minimize potential liabilities.

Additionally, NRAP's risk profiles define the quantitative probability of when key indicators could cross specific thresholds over time. For example, current profiles can predict the probability that more than 0.01 percent of the quantity of CO2 injected will be released back to the atmosphere for certain well configurations. Using these indicators, scientists will be able to assess potential consequences to human health, environmental health, and damage to property.

The risk profiles are part of NRAP's Phase I. During this phase, three different generations of risk profiles will be developed, each generation improving the technical complexity and reducing uncertainty compared to the previous generation.

In Phase II, NRAP researchers will focus on identifying and developing risk management approaches that include strategic monitoring to verify system performance and to lower uncertainty. The Partnership may also include a third phase, which would involve gaining additional data from field tests.

Aquistore drills deepest well in Saskatchewan

www.ptrc.ca

At a total depth of 3396 metres the deepest well in Saskatchewan has officially been drilled and is now home to the Petroleum Technology Research Centre's Aquistore project.

Located outside of Estevan, the Aquistore project is a deep-saline storage project partnered with SaskPower's Boundary Dam Carbon Capture demonstration.

While south-eastern Saskatchewan is well known for its oil and gas resources, most are shallow wells. Due to the lack of deep wells in the area, the Aquistore well is set to become a primary data point for the Deadwood formation. The Deadwood formation is the deepest sedimentary unit in the Williston Basin.

"As the PTRC's first well drilled, Aquistore is already the first project in the world to integrate commercial-scale CO2 capture, transportation, and injection from a coal-fired electrical generating station into a deep geological formation," commented PTRC CEO Dr. Malcolm Wilson. "We knew our targeted injection zone, the Deadwood, was obviously quite deep. Now that we know the depth, it's excellent."

The comprehensive suite of well logs and core samples are attracting interest. Project Manager Kyle Worth explained, "To have quality cores from such a depth is a rarity and our Science and Engineering Research Committee is eager to start analyzing the samples." The complete set of logs and other data that accompany this well are useful not only for CO2 storage, but also for oil companies in the area who have interests in hydrocarbon bearing formations.

Information following from the well will provide valuable knowledge for the robust monitoring, measurement and verification (MMV) program undertaken by the project.

To further track the CO2, a second 'observation' well will be drilled, with drilling anticipated in October, 2012. It is expected that this observation well will be of a comparable depth. These two fully instrumented wells can provide valuable information and data to the project and other interested parties.

National Grid and ETI to drill offshore CCS site off Yorkshire coast

www.eti.co.uk

National Grid and the Energy Technologies Institute (ETI) intend to conduct the UK's first drilling assessment of a saline formation site for the storage of carbon dioxide, at a site 70km off Flamborough Head in Yorkshire.

The ETI has invested £2 million in the project. National Grid will lead the drilling programme at the identified saline formation, a layer of porous sandstone rock over 1km below the seabed.

The operation, using standard oil and gas drilling activities, will involve drilling up to two wells in the seabed to gather data to confirm that carbon dioxide can be safely and permanently stored at the site, while also confirming the scale and economics of the store.

"We believe we are the first in the UK to physically assess a saline site for the storage of carbon dioxide," said Jim Ward, Head of CCS at National Grid. "This drilling operation is a major step forward in the development of long term, large scale CCS clusters of transportation networks and storage facilities in the UK, and we're excited to be working with the ETI on this project."

"We have engaged experts who have confirmed that our chosen site is the best potential store in the UK southern North Sea and the ideal foundation to develop a CCS network from."

Status of CCS projects

The status of large-scale integrated projects data courtesy of the Global CCS Institute

For the full list, with the latest data as it becomes available, please download a spreadsheet at:
www.globalccsinstitute.com/data/status-ccs-project-database

Asset Lifecycle Stage	Project Name	Description
Operate	**Century Plant**	Occidental Petroleum, in partnership with Sandridge Energy, is operating a gas processing plant in West Texas that at present can capture 5 Mtpa of carbon dioxide for use in enhanced oil recovery. Capture capacity will be increased to 8.5 Mtpa in 2012.
Operate	**Enid Fertilizer CO2-EOR Project**	Since 1982, the Enid Fertilizer plant has sent around 680,000 tonnes per annum of carbon dioxide to be used in enhanced oil recovery operations in Oklahoma.
Operate	**Great Plains Synfuel Plant and Weyburn-Midale Project**	About 3 Mtpa of carbon dioxide is captured from the Great Plains Synfuel plant in North Dakota. Since 2000 the carbon dioxide has been transported by pipeline into Canada for enhanced oil recovery in the Weyburn Field, and since 2005 in Midale Field.
Operate	**In Salah CO2 Storage**	In Salah is a fully operational CCS project in Algeria. Since 2004, around 1 million tonnes per annum of carbon dioxide are separated from produced gas, transported by pipeline and injected for storage in a deep saline formation.
Operate	**Shute Creek Gas Processing Facility**	Around 7 million tonnes per annum of carbon dioxide are recovered from ExxonMobil's Shute Creek gas processing plant in Wyoming, and transported by pipeline to various oil fields for enhanced oil recovery. This project has been operational since 1986.
Operate	**Sleipner CO2 Injection**	Sleipner is the second largest gas development in the North Sea. Carbon dioxide is separated from produced gas at Sleipner T and reinjected into a deep saline formation above the hydrocarbon reservoir zone. This project has been in operation since 1996.
Operate	**Snøhvit CO2 Injection**	The Snøhvit offshore gas field and related CCS activities have been in operation since 2007. Carbon dioxide separated from the gas produced at an onshore liquid natural gas plant is reinjected into a deep saline formation below the reservoir zones.
Operate	**Val Verde Natural Gas Plants**	This operating enhanced oil recovery project uses carbon dioxide sourced from the Mitchell, Gray Ranch, Puckett, Pikes Peak and Terrell gas processing plants and transported via the Val Verde and CRC pipelines.
Execute	**Air Products Steam Methane Reformer EOR Project**	This project in construction will capture more than 1 million tonnes per year of carbon dioxide from two steam methane reformers to be transported via Denbury's Midwest pipeline to the Hastings and Oyster Bayou oil fields for enhanced oil recovery.
Execute	**Alberta Carbon Trunk Line ("ACTL") with Agrium CO2 Stream**	Agrium's fertiliser plant in Alberta is currently being retrofitted with a carbon dioxide capture unit. Around 585,000 tonnes per annum of carbon dioxide will be captured and transported via the Alberta Carbon Trunk Line (ACTL) for enhanced oil recovery.
Execute	**Boundary Dam Integrated Carbon Capture and Sequestration Demonstration Project**	SaskPower is currently retrofitting a coal-based power generator with carbon capture technology near Estevan, Saskatchewan. When fully operational in 2014, this project will capture around 1 million tonnes per annum of carbon dioxide.
Execute	**Gorgon Carbon Dioxide Injection Project**	This component of a larger gas production and LNG processing project will inject 3.4 to 4.1 million tonnes of carbon dioxide per annum into a deep geologic formation. Construction is under way after a final investment decision was made in September 2009.
Execute	**Illinois Industrial Carbon Capture and Storage Project**	The project will capture around 1 million tonnes per annum of carbon dioxide from ethanol production. Carbon dioxide will be stored approximately 2.1 km underground in the Mount Simon Sandstone, a deep saline formation.
Execute	**Kemper County IGCC Project**	Mississippi Power (Southern Company) is constructing an air-blown 582 Mwe IGCC plant using a coal-based transport gasifier. Up to 3.5 million tonnes per annum of carbon dioxide will be captured at the plant and used for enhanced oil recovery.
Execute	**Lost Cabin Gas Plant**	This project will retrofit the Lost Cabin natural gas processing plant in Wyoming with CCS facilities, capturing around 1 million tonnes per annum of carbon dioxide to be used for enhanced oil recovery.
Define	**Alberta Carbon Trunk Line ("ACTL") with North West Sturgeon Refinery CO2 Stream**	Up to 1.2 million tonnes per annum of carbon dioxide will be captured at this new heavy oil upgrader in Alberta. In partnership with Enhance Energy, the carbon dioxide will be transported via the Alberta Carbon Trunk Line (ACTL) for enhanced oil recovery.
Define	**Belchatów CCS**	PGE EBSA intends to integrate a carbon capture plant into a new built 858 MW unit at the Bełchatów Power Plant, capturing around 1.8 million tonnes per annum of carbon dioxide.
Define	**Coffeyville Gasification Plant**	CVR Energy is developing a new compression facility at its fertiliser plant in Kansas. The plant currently produces approximately 850,000 tonnes of carbon dioxide which will be transported to the mid-continental region for use in enhanced oil recovery.
Define	**Don Valley Power Project**	Early in 2011, 2Co Energy acquired the Don Valley Power Project, a 650 MW IGCC facility in South Yorkshire. The project intends to capture around 4.8 million tonnes of carbon dioxide per annum for enhanced oil recovery or geological storage.

State / District	Country	Volume CO_2	Operation Date	Facility Details	Capture Type	Transport Length	Transport Type	Storage Type	Project URL
Texas	UNITED STATES	8.5 Mtpa (5 Mtpa in operation + 3.5 Mtpa in construction)	2010	Natural Gas Processing	Pre-Combustion (incl. Gas Processing)	256 km	Onshore to onshore pipeline	Enhanced Oil Recovery	www.oxy.com/
Oklahoma	UNITED STATES	0.68 Mtpa	1982	Fertiliser Production	Pre-Combustion (incl. Gas Processing)	225 km	Onshore to onshore pipeline	Enhanced Oil Recovery	www.kochfertilizer.com/
Saskatchewan	CANADA	3 Mtpa	2000	Synthetic Natural Gas	Pre-Combustion (incl. Gas Processing)	315 km	Onshore to onshore pipeline	Enhanced Oil Recovery	www.cenovus.com/
Wilaya de Ouargla	ALGERIA	1 Mtpa	2004	Natural Gas Processing	Pre-Combustion (incl. Gas Processing)	14 km	Onshore to onshore pipeline	Onshore Deep Saline Formations	www.insalahco2.com/
Wyoming	UNITED STATES	7 Mtpa	1986	Natural Gas Processing	Pre-Combustion (incl. Gas Processing)	190 km	Onshore to onshore pipeline	Enhanced Oil Recovery	www.exxonmobil.com
North Sea	NORWAY	1 Mtpa	1996	Natural Gas Processing	Pre-Combustion (incl. Gas Processing)	0 km	Direct injection	Offshore Deep Saline Formations	www.statoil.com/en/
Barents Sea	NORWAY	0.7 Mtpa	2008	Natural Gas Processing	Pre-Combustion (incl. Gas Processing)	152 km	Onshore to offshore pipeline	Offshore Deep Saline Formations	www.statoil.com/en/
Texas	UNITED STATES	1.3 Mtpa	1972	Natural Gas Processing	Pre-Combustion (incl. Gas Processing)	132 km	Onshore to onshore pipeline	Enhanced Oil Recovery	www.exxonmobil.com/
Texas	UNITED STATES	1 Mtpa	2012	Hydrogen Production	Post-Combustion	101 – 150 km	Onshore to onshore pipeline	Enhanced Oil Recovery	www.airproducts.com/
Alberta	CANADA	Up to 0.59 Mtpa (initially 0.29 Mtpa)	2014	Fertiliser Production	Pre-Combustion (incl. Gas Processing)	240 km	Onshore to onshore pipeline	Enhanced Oil Recovery	www.agrium.com/
Saskatchewan	CANADA	1 Mtpa	2014	Power Generation	Post-Combustion	100 km	Onshore to onshore pipeline	Enhanced Oil Recovery	www.saskpower.com/
Western Australia	AUSTRALIA	3.4 - 4.1Mtpa	2015	Natural Gas Processing	Pre-Combustion (incl. Gas Processing)	7 km	Onshore to onshore pipeline	Onshore Deep Saline Formations	www.chevronaustralia.com/
Illinois	UNITED STATES	1 Mtpa	2013	Chemical Production	Industrial Separation	1.6 km	Onshore to onshore pipeline	Onshore Deep Saline Formations	www.adm.com/
Mississippi	UNITED STATES	3.5 Mtpa	2014	Power Generation	Pre-Combustion (incl. Gas Processing)	75 km	Onshore to onshore pipeline	Enhanced Oil Recovery	www.mississippipower.com/
Wyoming	UNITED STATES	1 Mtpa	2012	Natural Gas Processing	Pre-Combustion (incl. Gas Processing)	Not specified	Onshore to onshore pipeline	Enhanced Oil Recovery	www.conocophillips.com
Alberta	CANADA	1.2 Mtpa	2015	Oil Refining	Pre-Combustion (incl. Gas Processing)	240 km	Onshore to onshore pipeline	Enhanced Oil Recovery	www.northwestupgrading.com
Łódź	POLAND	1.6 - 1.8 Mtpa	2017	Power Generation	Post-Combustion	101 – 150 km	Onshore to onshore pipeline	Onshore Deep Saline Formations	www.bot.pl/
Kansas	UNITED STATES	0.85 Mtpa	2013	Fertiliser Production	Pre-Combustion (incl. Gas Processing)	112 km	Onshore to onshore pipeline	Enhanced Oil Recovery	www.cvrenergy.com/
South Yorkshire	UNITED KINGDOM	4.75 Mtpa	2016	Power Generation	Pre-Combustion (incl. Gas Processing)	425 km for EOR, 175km to saline site	Onshore to offshore pipeline	Enhanced Oil Recovery	www.2coenergy.com/

Safe CO_2 Geologic Storage ...anywhere in the world

- *Applied risk mitigation and performance assessment -- protocols*
- *Knowledgeable regulatory frameworks – world geologic standards*
- *Public Trust – community engagement and education*
- *Asset evaluation -- storage capacity evaluation and design*

Independent, Reliable Risk Assessment and Mitigation

The Incident Response Protocol developed by IPAC-CO2 is an example of applied performance and risk assessment using our network of excellence. The protocol was deployed on the Kerr farm near the Weyburn project by IPAC-CO2 which concluded CO_2 was not leaking from depth. Performance audits and research are our next focus of attention.

Regulatory Frameworks and Compliance

Since 2009, researchers at IPAC-CO2 have been working with CSA Standards to develop the world's first standard for geologic storage of carbon dioxide. Our current focus is to assist companies with developing compliance measures.

Public Trust

IPAC-CO2 develops community engagement tools in order to raise awareness and understanding of carbon capture and storage as a Clean Development Mechanism.

Research and Information

IPAC-CO2 researchers identified potential sinks for geological storage of CO_2 in Saskatchewan with their storage capacities. IPAC-CO2 now is researching Enhanced Oil Recovery (EOR) capacity for CO_2 storage at depth.

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