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Tore Amundsen
Managing Director,
CO2 Technology Centre Mongstad

Philip Lowe
Director General,
DG Energy, European Commission

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Front cover: Technology Centre Mongstad (TCM), which opened in April, was one of the success stories from 2012. The aim of TCM is to develop and test different technologies for extracting the carbon dioxide from the exhaust gas emanating from the combined heating and power plant and from the refinery's emission gases.

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Carbon Capture Journal review of 2012

Another mixed year as nine new projects are announced, including five in China, while eight are cancelled, put on hold or restructured. The U.S. and Canada lead the way on moving projects to the operational phase. Funding efforts in Europe and the UK were set back by low carbon prices and the failure to find qualifying projects to support.

January

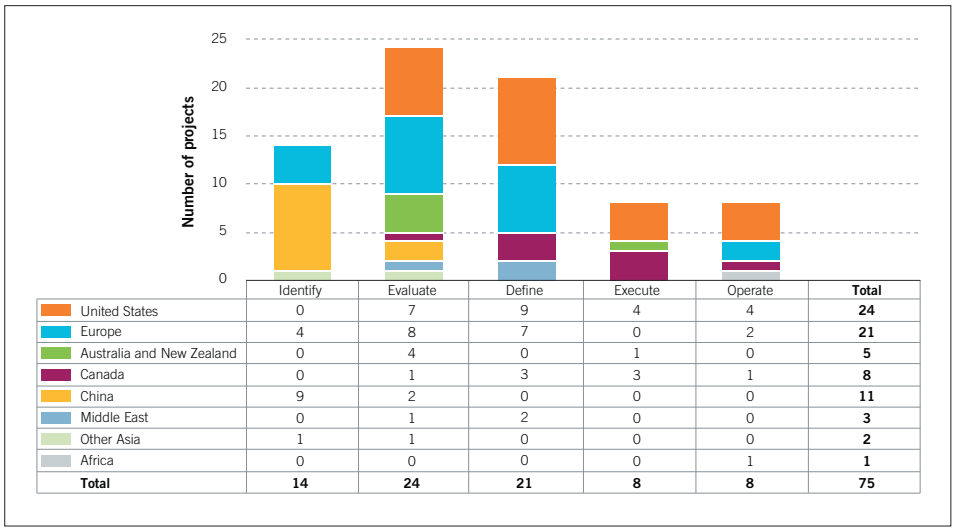
Emirates Steel Industries' project - Abu Dhabi National Oil Company and Masdar signed an agreement for the CCS project in the Gulf region.

Global CCS Institute grants over AU$2million to CCS research - funding was announced for leading Australian carbon capture and storage demonstration projects.

February

CarbonNet awarded AU$100 million - the Australian and Victorian Governments will provide the funds for the project to store CO2 emissions in the Latrobe valley.

Summit's IGCC project moves ahead - Summit Power Group's Texas Clean Energy Project signs engineering, procurement and construction contracts.



	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 (Source: Global Status of CCS Report ©Global CCS Institute)

March

Mitsubishi to build Qatar CO2 recovery plant - a large-scale CO2 recovery plant will be built for Qatar Fuel Additives.

UK launches £20 million CCS competition - the competition offers up to £20 million to fund the development of innovations in CCS technology.

Japan tests CO2 offshore storage - CO2 captured from power plants and factories could be stored in the seabed off Hokkaido.

SaskPower & Hitachi to build CCS test facility - the companies partner to construct a $60 million carbon capture test facility at SaskPower's Shand Power Station in south-eastern Saskatchewan.

April

TransAlta abandons Project Pioneer - the company said markets for CO2 sales and the price of emission reductions were not sufficient to allow the project to go ahead

IEA releases CCS Progress Report - the IEA and Global CCS Institute report concludes that, despite developments in some areas, significant further work is required.

CCS Research Centre launched in the UK - the government announced a £13 million investment to establish a UK CCS Research Centre at the University of Edinburgh.

May

Technology Centre Mongstad opens in Norway - the centre for testing and development of carbon capture technologies was opened.

North American Carbon Storage Atlas published - the United States, Canada and Mexico have collaborated on the first-ever atlas which maps the potential carbon dioxide storage capacity in North America.

Canada's Husky Energy launches CCS and EOR project - the CO2 capture and liquefaction project allows the company to recover more oil from existing fields while reducing emissions at its ethanol plant.

UNO MK3 capture plant at University of Melbourne - carbon capture mini-plant will be part of significant industrial trials of a new CO2 capture technology.

Coolimba Power Project in Australia cancelled - the company cited a reprioritisation of investments with no further money for the project.

June

North Sea CO2-EOR centre launched in Scotland - the Centre for North Sea Enhanced Oil Recovery with CO2 will develop understanding of enhanced oil recovery technology.

July

Can CCS cause seismic events? - scientists from the U.S. Clean Air Task Force and the Petroleum Technology Research Council rebutted the claims that CO2 storage can cause seismic activity.

Closing in on a solution for amine emissions - Statoil says it has made good progress in solving the challenges associated with amine emissions from carbon capture at Mongstad.

Shell and SSE receive first UK offshore carbon storage licence - carbon from the 385MW gas-fired power plant in Peterhead can be pumped to Shell's depleted Goldeneye gas field offshore Scotland.

August

DOE begins integrated CCUS project at Plant Barry - CO2 injection began at the world's first fully integrated coal power and geologic storage project at Alabama Power's Plant Barry.

Air Products begins construction of Texas plant - the hydrogen plant is expected to become operational by the end of 2012.

First CO2 storage in China - the first CCS project in China sequestered 40,000 tonnes of carbon dioxide in a Shenhua Group project.

September

Shell proceeds with Quest oil sands project - the project at the Athabasca oil sand proceeds with support from the Governments of Canada and Alberta.

Imperial College London CO2 storage

labs opened - exploring ways of storing CO2 deep underground in carbonate rock will be the focus of research carried out by scientists in four laboratories with £6 million funding.

DNV KEMA certification framework for CCS projects - a new certification framework to help Carbon Capture and Storage projects pass regulatory hurdles was released.

October

US policy shift to Carbon Capture, 'Utilization' and Storage - the Atlantic Council's Energy and Environment Program released an issue brief looking at driving CCS by enhanced oil recovery.

Petronas and Lanzatech to recycle CO2 into chemicals - waste CO2 from Petronas operations will be captured by LanzaTech's process to create acetic acid.

CIUDEN completes oxyfuel CFB carbon capture test - for the first time in the world CO2 was captured using oxycombustion in circulating fluidized bed (CFB) technology.

Australian national research centre in Perth - the National Geosequestration Laboratory was opened in Perth.

November

CCEMC funds 13 new clean technology projects - the Climate Change and Emissions Management Corporation in Canada funds 13 new clean technology projects led by small and medium sized businesses.

UK CCS competition shortlist - four bidders were short listed for the next phase of the UK's re-launched £1bn Carbon Capture and Storage competition.

Europe's leading carbon capture project to close - the UK's Don Valley project failed to win government support despite leading the competition for EU finding.

US-Canada standard for CO2 geological storage - CSA Group and the International Performance Assessment Centre for Geologic Storage of Carbon Dioxide announce the world's first bi-national standard for the geologic storage of carbon dioxide.

Global CCS market to be worth $7.78BN in 2013 - a Visiongain report predicts that the global carbon capture & storage market will reach a value of $7.78bn in 2013.

Illinois project completes first year of CO2 injection - Led by the Illinois State Geological Survey, the Illinois Basin-Decatur Project used CO2 from an industrial source and inject it into a saline reservoir.

ULTimateCO2 project launched - the new €4M European project seeks to improve understanding of the most effective ways to store CO2.

Plant Barry completes 100,000 tonnes of CO2 captured - the Southern Company plant near Mobile, Alabama uses Mitsubishi CO2 capture technology

December

EU NER300 funding programme fails to find project to back - the EU's funding programme was delayed after all the potential projects withdrew from the process.

Callide oxyfuel demo plant opens in Australia - the $208 million plant seeks to demonstrate carbon capture technology applies to an existing coal-fired plant.

Environmental NGOs join call for more action on CCS - at the COP18 climate change talks in Doha a group of NGOs calls on governments to act quickly to put a higher price on carbon emissions.

UK taskforce report: CCS cost-effective in 2020s - the Carbon Capture and Storage Cost Reduction Task Force interim report concludes that CCS could compete with other low-carbon forms of energy in the 2020s.

New home for CCS legal resources site - the UCL Carbon Capture Legal Programme will now be hosted by the Global CCS Institute.

Testing times for CCS in UK and Europe

There is still time to secure CCS projects in Europe, but a repeat of recent efforts won't be good enough, says Chris Littlecott, Senior Policy Adviser at E3G, and a Policy Research Associate with Scottish Carbon Capture and Storage.

It should all have been so different. Four years ago, collaborative advocacy from industry and NGOs helped the European Parliament and member state governments to secure an innovative funding mechanism for CCS. The 'NER300' scheme would sell allowances from the EU's Emissions Trading System (ETS) to create a funding mechanism to support a suite of CCS demonstration projects. Soon afterwards, the European Energy Programme for Recovery (EEPR) selected six projects to receive fast-track assistance. The future looked bright.

In late December 2012, the future at last arrived. European Commissioner for Climate Action Connie Hedegaard did her best to play Santa, but could only award €1.2bn to 23 innovative renewables projects across Europe. Not one CCS project was funded. This is hugely embarrassing for European efforts to address climate change. Originally intended as a CCS-specific instrument, the inclusion of renewables in NER300 was a late addition to secure agreement. But in this first funding round, renewables have eaten the CCS sector's lunch.

Rotterdam's ROAD project is the lead candidate for EU funding, but it is waiting for partners to emerge to share some of the funding gap

So what went wrong?

Let's start with a comparison. Projects are moving forward in the USA and Canada thanks to a combination of tax incentives, grants, and revenues from CO2 used for enhanced oil recovery. Governments on that side of the Atlantic have worked intensively to select workable projects and agree the deals necessary to bring them to the point of a positive Final Investment Decision. But industry has played its part there too, by actively developing business models that can function even in the absence of a policy commitment to reducing carbon emissions.

In Europe, however, the collapse of the carbon price under the ETS has undermined the business case for CCS demonstration projects over their 15 to 20 year lifetime as well as reducing the funds available for the NER300 pot. The economic crisis has similarly reduced demand for electricity and further damaged the balance sheets of the utilities set to be the early sponsors of CCS projects. As a consequence, neither of the European Commission's funding approaches has been able to cope with changed circumstances. But the blame must be shared beyond Brussels.

The EEPR funding provided by DG Energy has failed to secure a single project yet able to move forward, with technical delays by some and an absence of member state support in others combining to thwart progress. Rotterdam's ROAD project continues to sit in the starting blocks as the lead candidate, but it is waiting for partners to emerge to share some of the funding gap. Its utility sponsors are unwilling to absorb on their own a financial hit anticipated to be in the region of €100m. This is understandable from an individual company perspective, but mind-blowingly short-sighted from the energy sector as a whole. Other industrial players need to step up in support.

In respect to the NER300 funding process, it is primarily member states that failed to deliver on the agreed milestones. They were asked to confirm which projects they would support, together with the level of co-funding they would contribute.

The Italian economy is struggling and its project is behind schedule: no wonder its government couldn't commit funding now. The Romanian government had taken positive steps by introducing a feed in tariff for CCS, but was unable to commit funding given an impending election and a fight with the European Commission about EU budget spending. Poland meanwhile has been staying close to its broader obstructive approach to climate policy and holding out for more funding to defray the operational costs of CCS.

Only the French government confirmed co-funding, for the proposed steel mill CCS project at Florange, and €275m was assigned by the European Commission. Bizarrely, ArcelorMittal then withdraw at the last minute, citing technical problems. It is clear that the Florange plant had become a political football being kicked between company and government, but it was supposed to be the host CCS location for a wider consortium of European steel producers. ArcelorMittal's withdrawal has done a huge disservice to the rest of the steel sector and European process industries more widely. Early deployment of CCS offered the prospect of job retention and a value-added, low-carbon product. The unions are right to be furious.

The Dutch government came close, but was unfortunately too late with a revised offer to support its proposed Green Hydrogen project. A combined solution for both of its linked Rotterdam projects might yet be possible with the unspent NER300 monies. This must be a priority for 2013.

A promise unfulfilled

That leaves us with the UK: the EU member state best-placed to deliver CCS, and the driving force behind the original NER300 agreement. Furthermore, the UK had submitted 7 of the original 13 CCS projects, while as late as October 2012 the UK still had 4

projects out of the 8 vying for funding. The UK has plentiful offshore CO2 storage options, the technical and engineering skills required, an urgent need for investment in low-carbon power generation, and a commitment to decarbonisation. With so much promise, the failure to secure European co-funding has been a slow-motion car crash.

Let's rewind to the closing months of the last Labour government. The then Secretary of State Ed Miliband had recognised that there would be 'no new coal without CCS' and Energy Act 2010 was enacted with cross-party support, creating a dedicated levy for CCS. This was projected to raise around £11bn over 15 years to support a programme of 4 CCS demonstration projects.

When the coalition government took office in 2010, it promised not only to be the 'greenest government ever', but also that it would implement an Emissions Performance Standard and be 'First Choice for Investment in CCS'. All-too-quickly, however, these aims were undermined by decisions from Treasury and delays from the Department of Energy and Climate Change (DECC).

First, the CCS levy was pulled. Then the negotiation of the first CCS competition ended without award to the last-standing Longannet project. A year was lost before a new CCS commercialisation competition was launched. Industry momentum had been kept alive largely thanks to the EU's NER300 process, and at last it looked like the timelines for decisions under the UK and EU competitions would align. But to great disappointment and surprise, the only decision made by DECC in October 2012 was to kick out 2CO's Don Valley project, with neither a firm selections of projects or confirmation of funding made to the other bidders.

So when it comes to delivering on the agreed rules of the EU's NER300 programme it is the UK government who has most visibly failed to deliver. Yes, CCS projects are different than renewables, and yes, the co-funding requirements are an order of magnitude larger. But funding was there for the taking, and the UK failed to grab it.

New year, new approach?

At EU level, there needs to be a pause for breath rather than a headlong rush into the second round of NER300 funding. As part of the review of the first funding round the Commission should reconsider the criteria for project assessment. The original approach favoured CCS projects on coal and lignite, reflecting an assumption that the ETS would incentivise CCS on these carbon-intensive fuels first. But CCS on gas and industrial emitters offers the prospect of greater added value to the economy and is an area of existing European technological leadership. It would also be cheaper in respect to capital costs and could help make CCS more palatable in the eyes of sceptical stakeholders.

Adjusting the NER300 criteria might take a few months, but the wait could be worth it. With the EU looking to strengthen the ETS in the meantime, not only would the business case for CCS be improved, but additional funds might be secured for the NER300 pot. Member states, too, need to sort out their own co-funding contributions, and many will struggle with a rapid 2013 timetable.

In the UK too, a positive approach in the new year can make all the difference. After throwing away the strong hand of cards it held just two years ago, DECC needs to craft a can-do strategy that strengthens its chances of success. At present the department appears to be stuck deep in the administrative bunker, grappling with delivering the commercialisation programme and overwhelmed by the recent efforts to secure some (limited) funds for CCS out of the levy control framework settlement with Treasury. The good news is that operational support necessary for two UK projects appears at last to be available, but there is a worrying lack of clarity on how further projects will be supported to stimulate a UK CCS sector.

With political tensions within the coalition government seeding uncertainty as to the future of UK climate policy, it is even more important for DECC to lift its eyes to the bigger picture and communicate a vision of how CCS can play a catalytic role in a low-carbon economy. It must make policy decisions that shape the political context and generate momentum. It can start by liberating the CCS sector from the blanket of silence it imposed as part of its competition rules.

Key decisions will be taken in early 2013. DECC should seize this opportunity to advance a proactive approach by:

Funding all 4 of the remaining UK projects to undertake detailed engineering studies, as a means of enabling cost reduction via investment in CO2 infrastructures and accelerated deployment on industrial emitters;

Selecting one project to bid for the last remaining UK slot in the NER300 second round, not wasting projects' time by re-submitting multiple bidders;

Confirming how many projects it expects to take forward in the '£1bn' competition, and the timescales at which this funding will be made available;

Creating a supportive package of measures to assist follow on projects seeking to bid for Contracts for Difference, including assistance from the Green Investment Bank, tax incentives and infrastructure guarantees; and

Amending the proposed Emissions Performance Standard to shorten the free pass offered to new unabated gas plant from 2045 to at latest 2030, and improving the review process so that it can be revised downwards in the subsequent five-yearly delivery plans to require CCS on both coal and gas.

An approach along these lines that combines efforts to address the long-term business case while securing support for a core set of initial projects would inject new energy back into the UK and EU CCS sector.

Industry leadership needed

Industry players must help too. Technology companies, project developers and infrastructure providers have all suffered from the seemingly deliberate slowness of some of the major fossil fuel players over recent years. At long last European utilities are supporting efforts to strengthen the ETS. This needs to receive full support from across the CCS sector.

More generally, a proactive and positive approach to CCS would win new friends. With the economic crisis continuing, it is imperative that the CCS industry offers a value proposition not simply a cost imposition. It must communicate how it can help retain jobs through early deployment of CCS on clusters of industrial emitters. It must concentrate on approaches that allow flexible CCS power plant in support of electricity generation from renewables. And it must resolutely show that it is serious about addressing climate risk, addressing its potential to enable carbon negative emissions.

We can still secure CCS projects in Europe, but we are running out of chances. The second round of the NER300 needs to succeed, but a repeat of recent efforts won't be good enough. 2013 needs to see improved collaborative efforts to secure timely political support and ensure projects can deliver. Let's do it.

More information

Chris Littlecott is Senior Policy Adviser at E3G, and a Policy Research Associate with Scottish Carbon Capture and Storage. He is a member of the Advisory Council of ZEP.

www.e3g.org

www.sccs.co.uk

ENGO perspective on CCS

Governments have a pivotal role in ensuring carbon capture and storage is used as part of a suite of tools to combat global warming, says a report written by the ENGO Network on CCS for UN climate talks in Qatar. By Camilla Svendsen Skriung, Political adviser CCS globally, ZERO - Zero Emission Resource Organisation.

The network's study, Perspectives on Carbon Capture and Storage, urges swift action by governments to not only set a price on carbon but also place a significant market value on the avoidance of CO2 emissions. Without supportive policies worldwide, the report says, there is no economic driver for CCS and little incentive for operators of power plants or industrial facilities to capture and store CO2.

The report was presented to the COP18 gathering in Doha this week by members of the ENGO Network on CCS. It has been welcomed by climate experts, such as Lord Nicholas Stern and former executive director of the International Energy Agency (IEA), Claude Mandil, who both attended the report launch in support of its findings.

We hope the report can contribute to broaden the discussion of CCS as a complement to the key strategies of energy efficiency and renewable resources in combating climate change. The need now to embrace all climate solutions is paramount. This is not a time for discrediting technologies that has proven its potential for mitigating CO2 emissions. We need to use all solutions, be it small or large ones, to reach our needed climate targets.

As would be expected, our organisations have approached CCS with caution. The prospect of injecting millions of tons of compressed carbon dioxide in the subsurface has to be taken seriously. After long and careful study of the available science, we have concluded that CCS can be carried out safely and effectively, provided it is adequately regulated. Our conclusions are based on, and are backed by, an overwhelming consensus of the scientific c literature and prominent research institutions.

The Network believes that CCS has a valuable role to play in the climate mitigation portfolio, alongside other solutions. First generation CCS technology is commercially available today, enabling the deployment of the technology to begin worldwide immediately.. Regulatory frameworks for carbon dioxide injection are being finalised in various countries around the world, and it is important that these contain adequate safeguards for public health and the environment, and that all countries abide by minimum standards.

Now we need political will and action to ensure that CCS can take the needed part of reducing the global emissions of greenhouse gases.

These are our main findings and recommendations:

Limits and a price on carbonGovernments have the most important role to play in advancing CCS. Since the technology is ready to begin deployment but is being held back by market and regulatory conditions, concerted policy intervention holds the key to its future prospects. The biggest policy imperative for CCS, or indeed other large-scale clean energy technologies, is for limits on carbon emissions and an associated price on carbon. Without limits and a price – be it direct or indirect – there is no real need for markets to gravitate toward a technology that is specifically targeted toward reducing carbon emissions.

Overcome the initial high-cost hurdle for first moversCCS comes at a price premium today, but significant cost reductions are expected to be achieved once the initial 'hump' is overcome. Governments have a long track record in assisting technologies through these initial stages until technological improvements and a sufficient body of experience and know-how enable costs to come down. A correctly structured subsidy or assistance program would act as a catalyst to enable broader and faster deployment at lower cost. But such programs cannot by themselves provide a viable pathway toward deployment, since operating costs also need to be covered on an ongoing basis. For that reason, a price on carbon is a necessary prerequisite for subsidies or assistance programs. Finally, alongside such programs, sustained basic research and development (R&D) would ensure that a new generation of technologies is ready to replace existing ones.

More effective regulations and mechanismsWe also believe that regulations mandating or providing a pathway for CCS deployment are necessary, and complementary to limits and a price on carbon emissions. Performance standards for particular types of facilities, for example, can safeguard against market failures and provide a clear pathway for CCS deployment that provides the needed certainty for the large capital investments needed. Although some have argued that the market should deliver the optimal solutions, there is ample evidence that markets do not operate as intended and that failures due to bad design, application or unforeseen circumstances can cause significant distortions and delays.

Our groups are supportive of an international mechanism that will facilitate the development of CCS in developing countries with assistance (technical or financial) from industrialised countries. We believe that a CCS-specific mechanism is needed in order to ensure meaningful deployment in developing countries, its safety and effectiveness, as well as broad acceptance.

A global framework for safe CCSA sound regulatory framework for the safe injection and proper monitoring and accounting of captured, transported and sequestered carbon dioxide is paramount. This framework should cover enhanced hydrocarbon recovery projects as well as deep saline injection. Rigorous regulation is necessary to ensure that projects are sited and operated responsibly by capable entities, that shortcuts are not taken that could endanger public health or the environment, and to establish public trust in the application of the technology.

Demonstration projects proving CCSFinally, a carbon price alone, even combined with incentives, will not be enough to ensure the wide uptake of the CCS technology. Demonstrations are an essential next step in the innovation cycle for CCS, but even if they are successful, they will not magically result in technology uptake. For that uptake to become reality, limits on carbon emissions and regulations against business-as-usual will be necessary.

As well as being a call to action on CCS, the report also reflects the current status of CCS in various geographic regions. Members of the ENGO Network on CCS who contributed to the report are the Clean Air Task Force, E3G, Natural Resources Defense Council, The Climate Institute, The Pembina Institute, World Resources Institute and ZERO.

More information

The ENGO Network on CCS, of which ZERO is a founding member, was launched one year ago to promote knowledge about CCS and work towards its safe and effective use as a climate change mitigation tool.

www.engonetwork.org

EURELECTRIC recommendations for CCS

EURELECTRIC is of the view that Europe needs to show a sense of urgency in demonstrating CCS if it is to live up to its potential as a climate technology.

Further discussion on the pros and cons of the technology at this stage would be unhelpful, says a report by EURELECTRIC, the industry association representing the interests of the electricity sector at European level.

If we cannot demonstrate the technology now, Europe could become locked into a considerably higher-cost trajectory to decarbonisation. Diversity of the energy mix could also be threatened.

Europe could be at a serious competitive disadvantage if other regions of the world go ahead with CCS while Europe gets stuck in the demonstration phase. What has happened with the development of renewables, especially solar photovoltaic (PV), proves that Europe has everything to lose in surrendering its technological leadership. Given the rapid development of shale gas in the US and the continuing increase in coal use particularly in Asia, it is all the more important that Europe is able to advance CCS as a decarbonisation technology.

Therefore, EURELECTRIC has made the following four recommendations to launch the CCS demonstration programme as soon as possible:

The European Commission should without delay table proposals to amend Regulation 663/2009 to allow the unspent CCS funds resulting from the official cancellation of projects to be directed towards other CCS demonstrators.

Assuming this process takes 6 to 8 months, it will still be compatible with final investment decisions being taken that comply with the EEPR and NER300 timing.

It is absolutely necessary to maximise the effectiveness of the EU funds already committed to CCS and taking account of the European Parliament's 'Motion for a Resolution on a Roadmap for moving to a competitive low carbon economy in 2050'1 (document A70033/2012, dated 2 February 2012).

It is of the utmost importance that the unspent money stemming from the cancellation of the Jänschwalde or any other project should be directed towards other CCS projects which have a higher likelihood of succeeding and contributing to the demonstration of the CCS technologies.

The European Parliament called, inter alia, on the Commission "to propose that unspent funds for CCS projects within the European Economic Recovery Programme be reallocated towards alternative CCS demonstration projects."

Member states must transpose and implement the provisions of the EU CCS Directive without further delay in such a way as to facilitate the development of CCS; otherwise they risk jeopardising the uptake of the CCS demo programme.

CCS can only flourish in a supportive political and regulatory environment at all levels: European but also national, regional and local. EURELECTRIC sees the need for such a framework to be put in place as soon as possible.

The EU treaties require member states to transpose and implement in a timely fashion the directives adopted by the Council and the European Parliament. Member states must therefore transpose the CCS Directive even should they not want CCS projects to be implemented on their territory – which is indeed legitimate according to the CCS Directive. We urge member states to take such steps as a matter of urgency: developers need clarity to go ahead with their plans!

Those member states currently developing CCS demo projects, or with a prospect to develop CCS projects shortly, should put in place mechanisms for supporting the uptake of CCS by using part of the revenues generated from the auctioning of allowances under the Emission Trading Scheme (ETS).

Article 10.3 of the ETS Directive (Di-

State of play of the EU CCS demonstration programme

On 21 September 2012 the European Commission organised a high-level stakeholder roundtable that took stock of the (lack of) progress in establishing the EU CCS demonstration programme, following the call by the European Council, in March 2007 and June 2008, for up to 12 CCS demonstration plants to be put into operation by 2015, a commitment also contained in the EU CCS Directive (Directive 2009/31/EC).

This commitment is now clearly out of reach. However, the consensus remains that CCS is a fundamental low-carbon technology needed to combat climate change and secure Europe's electricity supply, along with other low-carbon technologies and increased energy efficiency.

Two main EU funding programmes provide support for CCS at the moment:

-The European Energy Programme for Recovery (EEPR), that awarded €180 million each to five CCS demonstrators located in Poland, the Netherlands, UK, Germany and Spain and €100 million to a project located in Italy

-The New Entrant Reserve under the EU ETS (NER300), that will identify CCS (and innovative RES) projects to be funded under two successive calls for proposals and whose first results are expected by the end of 2012.

The EU CCS demonstration programme is at a tipping point, as also demonstrated by the European Commission's recent decision to push back the adoption of the list of projects to receive funding under the first NER300 call for proposals. This is to allow for further negotiations with the concerned governments.

The difficulties encountered by some of the projects include regulatory hurdles (e.g. failure to implement the CCS Directive or gaps in regulation across the CCS value chain), public opposition to the pre-selected storage site(s), economic uncertainties (e.g. low emission allowance prices) and lack of political support at national level.

Amid the difficulties described above, the six EEPR demo projects are at different development stages. One project – Vattenfall's Jänschwalde – has been officially cancelled and withdrawn from the NER300 competition and the EU-sponsored CCS Project Network. Among the EEPR demos, only the ROAD project ("Rotterdam Capture and Storage Demonstration project") sponsored by a joint-venture between E.On Benelux and GDF Suez Energie Nederland did not lodge an application for the NER300 1st call. However, this project was already set to receive about €150 million of funding from the Dutch government.

rective 2003/87/EC, as amended by Directive 2009/29/EC) stipulates that, even though member states shall determine the use of ETS revenues they raise, "at least 50 % of the revenues generated from the auctioning of allowances […] should be used for one or more of the following: […] e) the environmentally safe capture and geological storage of CO2".2

It needs to be recalled here that the first CCS demos will not create value for their project sponsors in the short term; on the contrary, they will probably destroy value, as the CCS demos are likely to create stranded assets, even though they are fundamental to proving the technology at integrated scale and helping it move along the development phase to demonstration and finally commercialisation. Furthermore, given the current economic environment and outlook we believe that re-investing (part of) the revenues generated from the auctioning of the ETS allowances in CCS will not only help Europe to decarbonise, but also allow for the creation of technology centres as well as a CCS industry in Europe, stimulating economic growth and helping Europe's economic recovery.

Other measures include reduction of greenhouse gas emissions (10.3.a), support to renewables (10.3.b), afforestation (10.3.c), support to energy efficiency in the sectors covered by the directive (10.3.g), etc.

Several mechanisms could be envisaged for supporting CCS demonstration, including inter alia premium feed-in tariffs, power purchase agreements for CCS-electricity, tax breaks/rebates, loan guarantees, etc. EURELECTRIC takes the view that wherever those mechanisms are introduced they should be well-designed, i.e. transparent, proportionate and transitional. This will give investors the needed confidence to invest in capital intensive CCS projects while ensuring the right value for money to consumers and tax-payers.

Support should also:

i. Have no (or negligible) impact on other policies/instruments (i.e. the ETS);

ii. Not distort the functioning of wholesale electricity markets;

iii. Evolve from technology-specific to technology-neutral.

In the medium to long term, all low-carbon technologies should freely compete on a market basis and their development should be driven by the ETS CO2 price.

The industry and the European Commission should explore possibilities to Europeanise – or at least regionalise – the projects being funded by the EU.

This could take different forms including (but not limited to) pooling of resources into projects with the highest chances of succeeding in demonstrating the technology.

The current difficulties encountered by some demonstration projects call for a renewed approach to the development of the EU demonstration programme that puts co-operation among operators at its heart.

The recent developments with the discussion on the Regulation on trans-European energy infrastructure have shown that consensus exists among political parties in the European Parliament and member states to allow CO2 infrastructure projects to benefit from the status of projects of common interest (PCI). This is indeed a first step in setting up a truly EU programme where projects can be linked together across borders by a common CO2 infrastructure (both transport and storage) which would allow significant economies of scale. While these developments only apply to transport and storage, greater consideration should be given to the possibility of Europeanising the capture part of the CCS chain at demonstrator level.

More information

The Union of the Electricity Industry–EURELECTRIC is the sector association representing the common interests of the electricity industry at pan-European level, plus its affiliates and associates on several other continents.

In line with its mission, EURELECTRIC seeks to contribute to the competitiveness of the electricity industry, to provide effective representation for the industry in public affairs, and to promote the role of electricity both in the advancement of society and in helping provide solutions to the challenges of sustainable development.

www.eurelectric.org

CCS – EU/RSA partnerships conference

A free conference in South Africa on 13-15 Feb 2013 sponsored by the EU under the OCTAVIUS project will focus on CO2 capture and opportunities for EU/RSA collaboration.

While Europe is on the verge of making its investment decisions regarding the first real CCS demonstration projects, CCS is in its early stages in South Africa. Several options for storage, to which industrial sources of CO2 may connect, are still under assessment. From an EU/RSA relationship point of view, the opportunity is obvious, says EcoMetrix Africa, which is co-ordinating the event

How can South African stakeholders collaborate with European partners with experience in Carbon Capture and Storage, learning from the successes, mistakes and insights gained? Likewise it is important for European CCS experts and managers to understand the specific local context of South Africa as it is diverse from the EU.

Having this aim in mind, the OCTAVIUS CCS project has chosen "EU/RSA Partnerships in CCS" as the theme for this conference with "A focus on Capture". Preceding South African CCS events have already covered storage extensively. However, as with Storage, Capture and Transport are also prerequisites to applying CCS.

In case of electricity generation, contributing to around half of South Africa's greenhouse gas emissions, the CCS cost per tonne of CO2 is dominated by the cost of Capture. Therefore, it is apparent that in assessing the economic viability of CCS for South African power generation cases, capture is of great importance. This is why the OCTAVIUS project specifically looks at the demonstration of technologies that can reduce capture cost.

Main topic's covered:

- CCS in the EU and South Africa
- Making CCS a Reality
- Cost and Financing of CCS
- Commercial Capture Technologies
- Next Generation Capture
- OCTAVIUS Project Results

More information

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www.octavius-co2.eu

The potential for reducing CCS costs in the UK

The UK CCS Task Force has published its interim report into policies and technologies that could reduce costs across the CCS value chain.

The Carbon Capture and Storage Cost Reduction Task Force has published an interim report confirming that fossil fuel power generation with CCS has the potential to compete cost-effectively with other low-carbon forms of energy in the 2020s.

The interim report, undertaken as a collaboration between Department of Energy and Climate Change (DECC), The Crown Estate and industry, demonstrates that UK gas and coal power stations equipped with carbon capture, transport and storage can be cost competitive with other forms of low-carbon electricity generation such as nuclear and renewables. Critically, the sector will be able to generate electricity at a levelised cost approaching £100 per megawatt hour by the early 2020s, and at a cost significantly below £100 per megawatt hour soon after.

The task force believes that reductions in the cost of CCS electricity can be achieved in the early 2020s through:

- Investment in large offshore CO2 storage clusters, supplying multiple onshore CO2 emitters and with investment in large, shared pipelines, with high usage.
- Investment in large power stations with progressive improvements in CO2 capture technology capacity, which should be available in the early 2020s following the first couple of projects.
- A reduction in the cost of project capital through a set of measures to reduce risk and improve investor confidence in the sector.
- Exploiting potential synergies with CO2 based enhanced oil recovery in some Central North Sea oil fields.

The task force, chaired by Dr Jeff Chapman, Chief Executive of the Carbon Capture & Storage Association, was set up to advise Government and industry on ways of reducing the cost of CCS for the next wave of projects, which will be constructed after the current DECC CCS Commercialisation Programme. The aim is to help CCS to become commercially operational by the early 2020s, which requires the initial projects to begin operation this decade.

Rob Hastings, Director of Energy and Infrastructure at The Crown Estate said: "With many of the UK's fossil fuel plants set to be decommissioned soon and with challenging EU targets for carbon reductions, it's welcome news that CCS looks set to compete as a major player in the nation's low carbon future. This report provides important evidence that CCS-equipped power generation could be cost competitive with other low carbon forms electricity by the early 2020s."

Dr Jeff Chapman commented, "This report presages an enormous and exciting opportunity for the UK to reduce its emissions cost-effectively whilst establishing a massive export opportunity. In anticipation of this the industry has already embarked on an extensive programme of investment in engineering and R&D to ensure UK cost-competitiveness in CCS."

More information

www.thecrownestate.co.uk
www.ccsassociation.org.uk
www.decc.gov.uk

Join the Team that Will Drive the Future of Clean, Affordable, Coal-Fired Power

Our mission is to accelerate the development and commercialization of POXC™ "pressurized oxy-combustion" as the preferred clean-combustion platform for repowering existing coal-fired power plants and building new power plants around the world with near zero air emissions. With technology from Enel, ITEA, and ThermoEnergy Corp., and two pilot plants already in operation, we are well on the way.

We are seeking alliances with engineering companies, utilities, independent power producers, air separators, service companies, CO_2 pipeline companies, transportation companies, and other key industry stakeholders who believe near zero emissions fossil fuel power production is a desirable and achievable near-term goal that will provide maximum benefit to the global environment and economy.

Learn how your company or organization can join our team and help drive the future of clean, affordable, coal-fired electric power. Email info@unitypoweralliance.com, or visit our website www.unitypoweralliance.com.

Unity Power Alliance

One Goal – Zero Emissions

ETI ECOFIN report on UK CCS financing

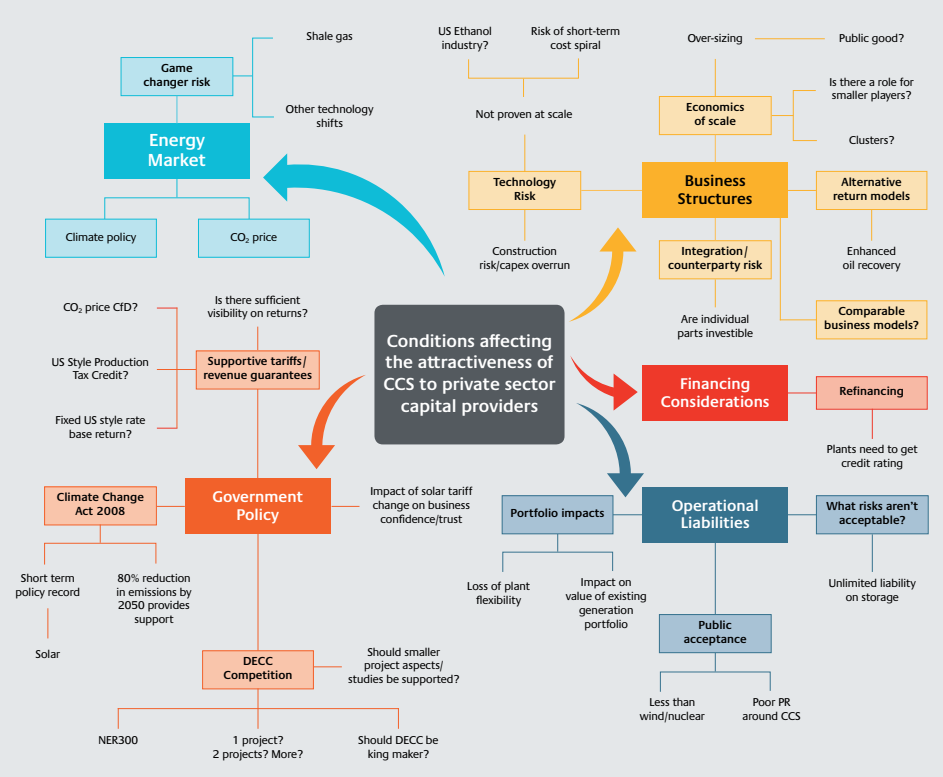
A report from the UK Energy Technologies Institute looking at private sector financing for CCS projects, concluded that deployment of CCS in the UK would cut the cost of meeting carbon targets by 1% of GDP.

A new report from the Energy Technologies Institute (ETI) and the Ecofin Research Foundation into attracting private sector finance to support the development of CCS in the UK, concludes that successful deployment of the technology could be a huge economic prize for the UK in its low carbon transition – cutting the annual cost of meeting the country's carbon targets by up to 1% of GDP by 2050.

The report entitled "Carbon Capture and Storage – Mobilising private sector finance for CCS in the UK" explores the challenges that both the public and private sector needs to overcome to help build CCS into a viable low carbon industry that is economically competitive.

Making early CCS projects investable is a key priority in allowing CCS to develop as an industry and fulfil its potential in the UK's transition to a low carbon economy. Both ETI and Ecofin believe that creating a vision for CCS financing requires willingness on the part of the key public and private sector players to engage and to explore the issues and options open-mindedly.

George Day, Strategy Manager, Economics at the ETI, co-author of the report said: "As well as being a technological opportunity for the UK, CCS is an economic opportunity. However nobody is immune to the fact that the investment case to support development has to be made clearly. CCS is very policy dependent so investors are sensitive but the exploration of public-private partnerships and co-ordination mechanisms can provide a financial solution."



Key challenges

Investability challenges

– The scale, policy risk and long term nature of financing needs for CCS projects are uniquely challenging.

– CCS will have to compete in challenging market conditions to gain access to finance

– Bank finance is tight due to markets and tougher regulatory requirements

– Major energy or utility companies have strategic interest in CCS, but have constrained balance sheet capacity and appetite for exposure to early CCS projects

Potential solutions

– Develop a compelling vision of how CCS can progressively solve for risks and access lower cost sources of finance

– Ways to reduce, manage and share risks are needed for the key early projects

– Consider a role for the Green Investment Bank in facilitating access to capital

– Create absolute visibility of returns based on clear revenue support over sufficient time periods

Confidence in long term policy

– CCS is policy dependent, so investors are highly sensitive to mixed signals around policy commitment, either to CCS itself or to broader carbon emission targets

Potential solutions

– Build on promising early steps (e.g. the commercialisation programme) to create a clear sense of direction for CCS

– Explore public-private partnerships and coordination mechanisms

Energy marketplace challenges

– Emerging reforms and market changes create significant uncertainty for investors, and EMR reward structures remain to be fully clarified

Potential solutions

– Attractive pricing for contracts for CCS projects with appropriate risk sharing

– Create rewards for broader CCS applications beyond the power sector

Business structures

– CCS projects involve a complex new value chain with novel business structures and counterparty arrangements

Potential solutions

– Actively explore the future regulatory and market framework, and industry collaboration on collective business structure challenges

Operational and technology risks

– There is appetite in the private sector to bear technology and integration risks

– Storage is a key area of risk, with major concerns about the uncapped nature of storage liabilities

Potential solutions

– Consider new ways to address concerns around storage liability risks, including a potential public sector role in derisking North Sea storage

More information

www.eti.co.uk

www.ecofinfoundation.org

Schlumberger CCS factbook

The Schlumberger Business School has produced a comprehensive overview of CCS technologies and economics, using some excellent graphics, and gives the Institute's recommendations for the future deployment of CCS.

CCS is a useful and viable technology

CO2 emissions reached a record high in 2010. The International Energy Agency (IEA) recently said average global temperatures are on track to rise by more than 3.5°C by 2100, and the margin for maneuver to mitigate global warming is becoming dangerously slim.

CCS, widely considered an essential technology to mitigate climate change, is technically viable. Several large-scale projects are currently capturing 15MtCO2 per year from natural gas processing or coal gasification plants and storing it in deep saline aquifers or in oil reservoirs as part of enhanced oil recovery (EOR) operations. This is equivalent to avoiding emissions of 2.5GW of coal-based electricity. Industry players are adamant that CCS component technologies have been proven technically feasible and are ready to be demonstrated on a large scale in power generation, cement and steel production, chemicals plants and refineries.

R&D investments in CCS are significant (~$1.5 billion in 2011, compared with $1.2 billion for wind). Public laboratories and corporate players – chemicals companies, utilities and oil and gas firms – are developing efficient capture processes.

Key recommendations

Public authorities

- Leverage EOR projects to enable CCS to take off:
  - −Reward for emissions avoided by storing CO2 along with EOR
  - −Promote collaboration in R&D and demonstration among major oil-producing countries
- Focus public support and investment incentives on overcoming hurdles to CCS:
  - −Project type: large integrated demonstration
  - −Sectors: power, steel and cement
  - −R&D: capture processes
- Secure, stable regulation regarding long-term investment

Private sector

- Educate governments and the public on the potential of CCS technology in terms of decarbonisation
- Overcome knowledge-sharing issues by establishing consortia or industry alliances
- Explore new business models to ease partnerships in integrated projects (clusters)

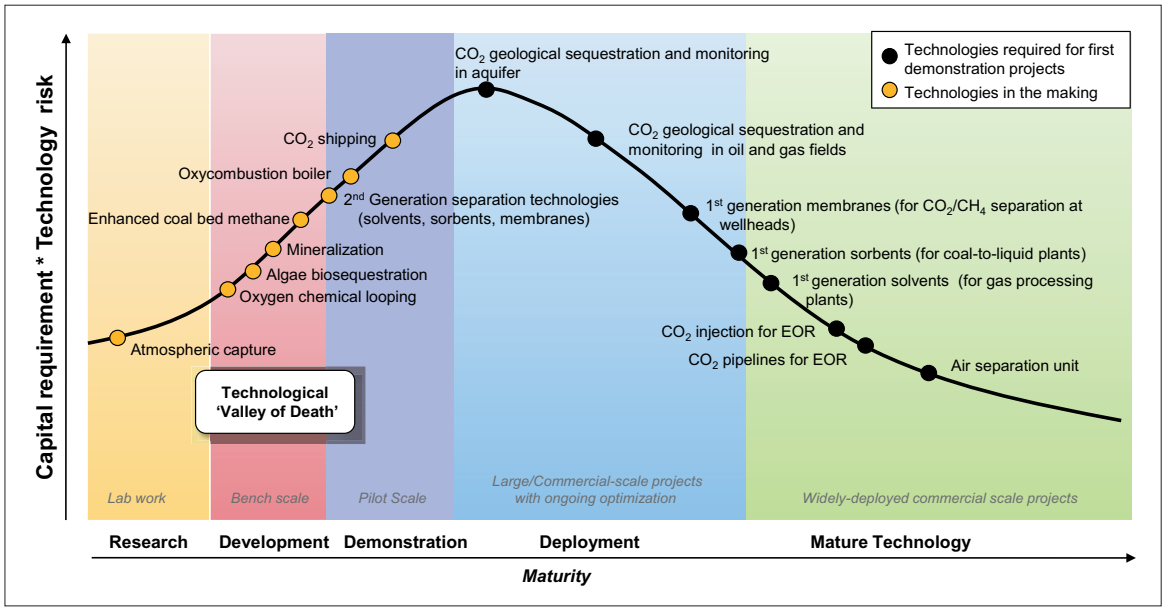
The demonstration phase is not moving fast enough

The demonstration of large-scale CCS projects has progressed far more slowly than is required to mitigate climate change. Financing for large demonstration projects (below $3 billion a year, with no sign of an increase) remains considerably below that of renewable energy sources such as wind and solar ($131 billion and $75 billion in 2011, respectively). With growth of only 6% per year over the last five years and a forecast 50MtCO2/year in operation by 2017, the IEA's recommended pathway towards decarbonization appears out of reach (37% annual growth required and 255MtCO2/year stored by 2020 in the "2DS Scenario")

Most existing projects are associated with oil and gas production, wherein the CO2 is either captured from natural gas processing plants or is sold for use in EOR. This trend is likely to continue for the next decade, as passive CO2 storage adds complexity and bears regulatory risks, public-acceptance issues and reservoir discovery costs that EOR can avoid. To date, no CCS power plant has reached a final investment decision without both EOR revenues and strong government financial support. By 2017, 45% of operating CCS capacity is expected to be in power generation, and 75% is expected to be targeting EOR operations.

CCS demands strong political will towards decarbonization

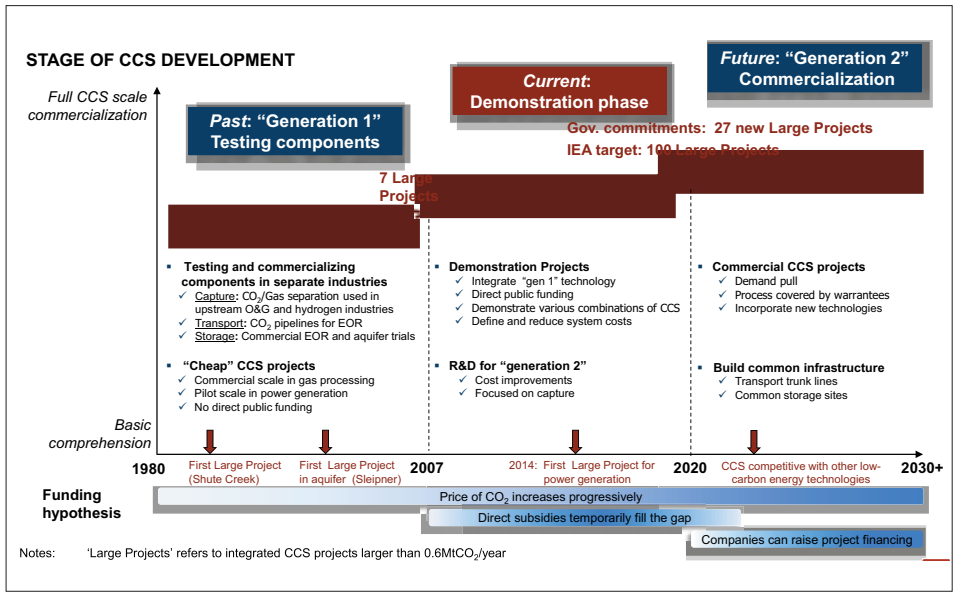
Abatement costs for coal-fired electricity with CCS range from $54/tCO2 to $92/CO2. Nevertheless, CCS is a competitive way to abate CO2 emissions in power generation, as abatement using CCS is significantly less expensive than replacing coal power plants with solar plants ($105-$239/tCO2) or offshore wind farms ($90-$176/tCO2). Besides,



Investment risk curve of individual CCS technologies (©SBC Energy Institute)

few alternatives to CCS exist for cutting emissions from industrial applications such as steel and cement production, chemicals plants and gas-processing units.

CCS is seen as a costly technology because of its high up-front costs and uncertain long-term benefits. Each commercial-scale CCS project can cost up to a billion dollars in capture costs alone, although they are capable of abating over a million tonnes of CO2 per year for several decades (the equivalent of taking over 200,000 cars off the roads). The financial support required for each project is so large that governments rarely have the political will to subsidize CCS to the extent required. OECD governments have committed $22-25 billion to help CCS demonstration projects, but grants allocated so far have represented an average of just $15/tCO2 avoided over the lifetime of each project. In addition, no carbon-price mechanism has yet enabled the recovery of CCS costs: globally, the market price of CO2 averaged $15/tCO2 in 2011, and most carbon taxes are set below $25/tCO2.



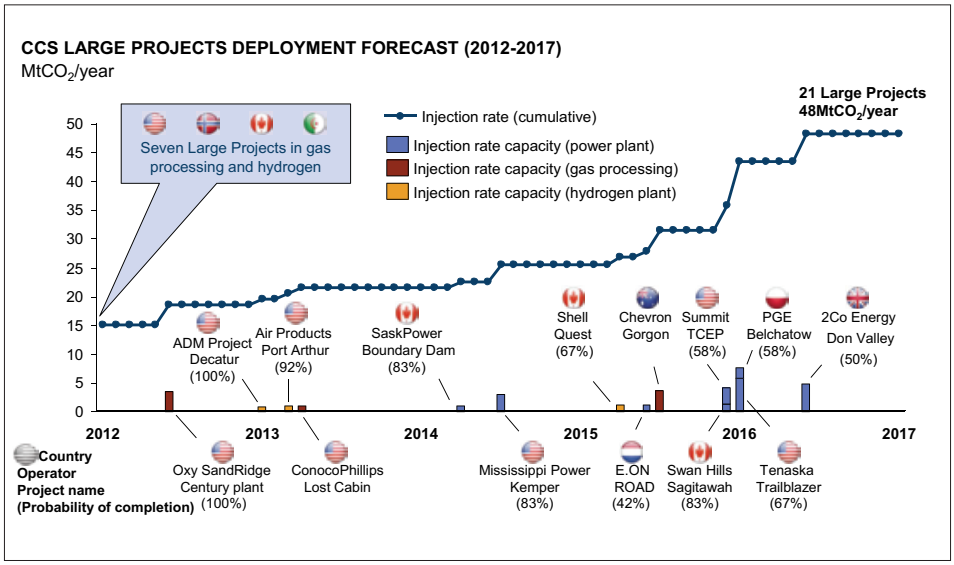
Stage of CCS development (Source ©SBC Energy Institute)

There are grounds for optimism that CCS deployment may accelerate after 2020

Growing demand for the beneficial reuse of CO2 for EOR should drive CCS forwards during this decade and help to demonstrate the technology, in conjunction with large government grants. Oil prices above $100/bbl have tended to boost CO2 contract prices above $30/tCO2, greatly improving CCS-EOR economics.

China is also rapidly driving down the cost of capture, having openly expressed the ambition to build capture-only coal power plants for its own needs and to export low-cost capture technologies. The levelized cost of electricity from coal-fired power plants with CCS – using either post- or pre-combustion technology – could decrease by 14%-21% after the first 100 GW are installed.

Looking beyond 2020, more stringent carbon policies will be required to develop CCS beyond upstream oil and gas and at the scale needed to tackle climate change. CCS may become a must-have for climate mitigation, as CO2 emissions are being locked-in by existing plants. In addition to public funding and a more robust carbon-pricing system, public and private sector actions could contribute to CCS' wider adoption by: leveraging CCS-EOR projects; implementing stable regulation governing long-term investments; exploring new business models to assist the formation of partnerships in integrated CCS projects, etc…



CCS large projects deploymeny forecast (2012-2017) (Source: ©SBC Energy Institute analysis, based on Bloomberg New Energy Finance database (March 2012))

Conclusions

Meeting international CO2 emissions-reduction targets will be extremely difficult to achieve without CCS

- CCS is now a viable technology, although integrated, large-scale projects need further demonstration
- R&D's priority is reducing the cost of CO2 capture, and technological breakthroughs are expected
- Projects are now commercial in the EOR sector, which is the main driver in the CCS industry today and will remain so during the current decade
- Projects remain at a standstill for power generation and heavy industry when associated with passive CO2 storage
- Stakeholders of demonstration projects need to secure public support for storage and develop overall awareness of the benefits of CCS

More information

The factbook is based on the SBC Energy Institute report, "Bringing Carbon Capture and Storage to Market", published in June 2012. It summarizes the status of existing technologies and the main R&D priorities, analyzes the economics of the main large-scale demonstration projects, and gives the Institute's view of the future of CCS technologies and projects.

The SBC Energy Institute, a non-profit organization founded in 2011 at the initiative of Schlumberger Business Consulting (SBC), is a center of excellence for scientific and technological research into issues pertaining to the energy industry in the 21st century.

www.sbc.slb.com

Policy, projects and regulation news

CCEMC to fund 13 new clean technology projects

www.ccemc.ca

The Climate Change and Emissions Management (CCEMC) Corporation plans to fund 13 new clean technology projects led by small and medium sized businesses.

The projects will advance carbon capture and storage efforts, enhance energy efficiency and reduce emissions from fossil fuels. Combined, the projects are valued at more than $34 million.

The CCEMC is investing more than $6 million in these projects that will each receive up to $500,000 to advance their technology.

Three carbon capture projects are receiving funding:

Carbon Engineering Ltd., for Direct Air Capture – Pilot Plant Demonstration

CO2 Solutions Inc., for Optimization of Enzymatic System for CO2 Capture from Oil Sands Production

Sustainable Energy Solutions, for Cryogenic Carbon Capture with Energy Storage

New Zealand invests $700k in CCS

www.msi.govt.nz

The Ministry of Business, Innovation and Employment will invest about $700,000 in research to better understand the opportunities and risks of adopting CCS technologies in New Zealand.

Three research proposals have secured funding from the Ministry's Energy and Minerals Research Fund after a contestable investment process.

The investment in this area supports the development of innovative technologies — such as how to store carbon in a safe and sustainable manner — that have the potential to be exported and generate economic returns for New Zealand.

The priorities for Government investment in this area have been set in conjunction with the New Zealand Carbon Capture Storage Partnership that brings together government and end users of the research such as Solid Energy and the Coal Association of New Zealand. The investments reflect the interests and areas of focus of the Partnership.

The results of the research will help the government and industry make informed decisions about the feasibility of carbon capture and storage technologies in New Zealand.

The three successful research proposals are:

- $245,000 for research into what the pipeline infrastructure needed for successful carbon capture and storage would look like (research provider: Transfield Worley Limited)

- $245,000 for research to provide a comprehensive framework for the development of law and policy to govern carbon capture and storage in New Zealand (research provider: University of Waikato)

- $215,000 for research to develop a carbon capture technology suitable for medium scale biomass and coal gasification projects for the production of hydrogen, chemicals and biofuels (research providers: CRL Energy, University of Canterbury's Wood Technology Research Centre and Industrial Research Limited).

UK projects to reduce CCS costs receive funding

www.decc.gov.uk

The winners of an £20m competition for innovative projects to reduce the cost of CCS development have been announced by the UK Government.

13 projects have been awarded the money from the UK's CCS £125m research and development fund. Projects include NET Power which is working with Stoke based Goodwins and Toshiba to develop high pressure turbines, and Millennium Generation, which is building a 3MWe carbon capture pilot plant in Stainforth, Doncaster.

Grants worth £18.3million have been agreed so far, which will leverage an additional £18m from project participants. The UK CCS Research Centre has also announced a further £1.8m government funding for 13 projects, involving 14 different universities, to fund research needs set out in the DECC CCS Roadmap.

The 13 successful projects under the DECC £20m CCS Innovation competition are listed on the DECC website:

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.

Invensys to develop operator training system for DOE CCS simulation

fossil.energy.gov

A new U.S. Department of Energy (DOE) cooperative research and development agreement to develop, test, and deploy a dynamic simulator and operator training system (OTS) could eventually help commercialize carbon capture technologies.

The high-fidelity, real-time OTS for a generic supercritical once-through (SCOT) pulverized-coal power plant will be installed at the National Energy Technology Laboratory's (NETL's) Advanced Virtual Energy Simulation Training and Research (AVESTAR) Center in Morgantown, W.Va. It will be used for collaborative research, industry workforce training, and engineering education on SCOT plant operations and control under the agreement signed with Invensys Operations Management.

The SCOT dynamic model will be designed to include all process- and heat-integration connections to post-combustion CO2-capture, -compression, and -utilization processes, allowing it to serve as the baseline power plant model for DOE's Carbon Capture Simulation Initiative (CCSI). The NETL-led CCSI is a partnership among national laboratories, industry, and academic institutions geared toward developing and deploying state-of-the-art computational modeling and simulation tools to accelerate the commercialization and widespread use of carbon-capture technologies at the nation's power plants. Working in collabora-

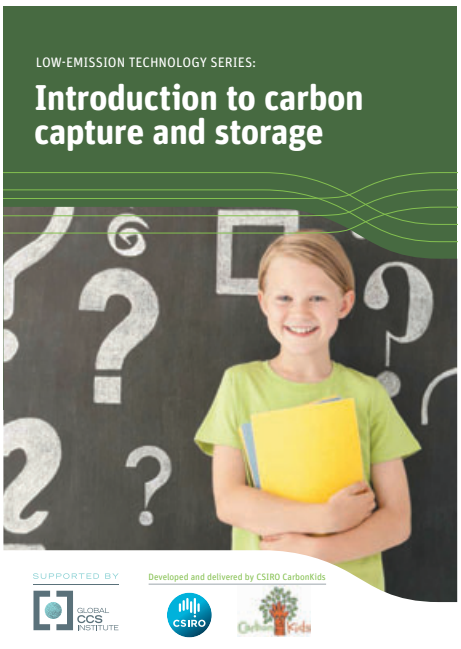
tion with NETL, Invensys will develop the SCOT dynamic simulator/OTS using Invensys' SimSci-Esscor® DYNSIM® dynamic simulation software and Wonderware® InTouch® operator training interface software . NETL and Invensys previously collaborated on the high-fidelity, full-scope, real-time dynamic simulator/OTS for an integrated gasification combined cycle (IGCC) power plant with CO2 capture that is currently deployed at the AVESTAR Center. The IGCC dynamic simulator also utilizes Invensys Operations Management's software, ensuring that both simulators will efficiently coexist on the AVESTAR computer hardware.

The SCOT dynamic simulator developed under this agreement will enable the AVESTAR Center to provide a virtual test bed for optimizing the operation and control of post-combustion CO2-capture technologies. Ultimately, the collaborative research conducted through this partnership will be used to accelerate progress toward achieving operational excellence for SCOT pulverized-coal power plants with carbon capture.

CarbonKids demo makes learning about CCS fun

www.csiro.au

Delegates at the National CCS Conference in Perth were given a demonstration by students from St Anne's Primary School of CCS experiments developed by the CSIRO as part of its CarbonKids program.



The CCS demonstration was arranged to coincide with National CCS Week, along with a creative challenge in which 160 primary and high school students from eight Western Australian schools took part to find new ways to showcase their learning about CCS.

The CarbonKids CCS resources were developed using the best available science following a global review of what was already available for schools and teachers, says CSIRO. The CCS module, which forms part of the low-emission technology series, was reviewed by science and education experts and trialed in classrooms across Australia and internationally.

The CCS education resources are free and available online.

North West Redwater Partnership goes ahead with phase 1 of the Sturgeon Refinery

www.nwrpartnership.com

North West Redwater Partnership (NWR), a partnership between North West Upgrading Inc. (NWU) and Canadian Natural Upgrading Limited (CNUL) has approved Phase 1 of the project.

NWR will build and operate the Sturgeon bitumen refinery in Alberta. The first 50,000 barrels per day phase of the project has a cost estimate of $5.7 billion and is expected to take approximately three years to build, with above ground construction starting in spring 2013.

The project represents the first of potentially three phases of 50,000 barrels per day accumulating to a 150,000 barrel per day plan to convert bitumen to high value products, primarily ultra-low sulphur diesel for local and export markets.

"This project will demonstrate that Alberta has the lowest carbon footprint solutions for converting bitumen into diesel fuel," said Ian MacGregor, Founder and Chairman of NWU. "This is the first refinery in the world that incorporates CO2 capture into the initial design. The facility will capture 1.2 million tonnes of CO2 per year per phase, which will be sold for use in enhanced oil recovery before being sequestered."

UK National Grid announces results of Yorkshire & Humber study

www.ccshumber.co.uk

National Grid has identified the proposed locations of the above ground installations required for the safe operation of its pipeline and selected a proposed landfall point at the coast.

The announcement comes after National Grid held seven public exhibitions in the summer. Local communities were able to view the proposals and give their feedback on the proposed above ground installations required for the safe operation of the pipeline. More than 400 people attended the events and local people and organisations gave written responses about the project to National Grid.

"We were delighted that so many people took the time to visit our exhibitions and comment on our proposals," said Jim Ward, Head of CCS for National Grid, said. "This is an important project for National Grid and we are looking forward to entering the next phase of our proposals which will include another round of community consultation in 2013."

National Grid says it has considered all of the responses received as part of its consultation, together with detailed environmental and technical studies, to determine proposed locations for the required above ground installations to support the pipeline. This includes a compressor station to compress a carbon dioxide before transportation, three block valve sites for maintenance and safe operation of the pipeline, and a pumping station near to the coast, to re-pressurise the carbon dioxide before it goes offshore. A landfall point at the coast has also been selected. Local people also chose their preferred style for the design of the compressor station and pumping station.

The proposed locations chosen for the above ground installations and the reports detailing the rationale behind their choice can be viewed on the project website as well as a report of the recent consultation events and further information on National Grid's CCS project.

National Grid will now carry out further environmental and technical studies along the preferred route corridor before opening the next stage of consultation.

New home for CCS legal resources site

www.globalccsinstitute.com

UCL Carbon Capture Legal Programme to be hosted by Global CCS Institute.

For the last five years, the UCL Carbon Capture Legal Programme has developed and hosted a highly successful legal resources site, designed to provide accessible and objective information on developments in CCS law and policy around the world.

From December 1st 2012 the Global Carbon Capture Storage Institute will be managing the Resources site, initially using material from UCL.

Professor Richard Macrory, director of the UCL CCLP commented, "We know that many lawyers and non-lawyers within the carbon capture cummunity have found the UCL Legal Resources site an invaluable source of accessible and impartial analysis over the past few years. I am absolutely delighted that this initiative of the GCCSI means the Resource will now continue to be available and develop during a critical period in the development of CCS law and policy."

Capture and utilisation news

New material uses trapdoors to capture carbon dioxide

www.co2crc.com.au

A team of Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC) researchers based at the University of Melbourne have developed a new material with exceptional properties for separating carbon dioxide from other gases.

The chabazite zeolite synthesised by Professor Paul Webley and his team, including PhD student Jin Shang and research Fellow Gang Li from the Melbourne School of Engineering, uses a molecular 'trapdoor' to separate molecules based on their properties rather than their size.

"Zeolite granules are highly porous, with one gram often containing as much surface area as a football field," said Professor Webley.

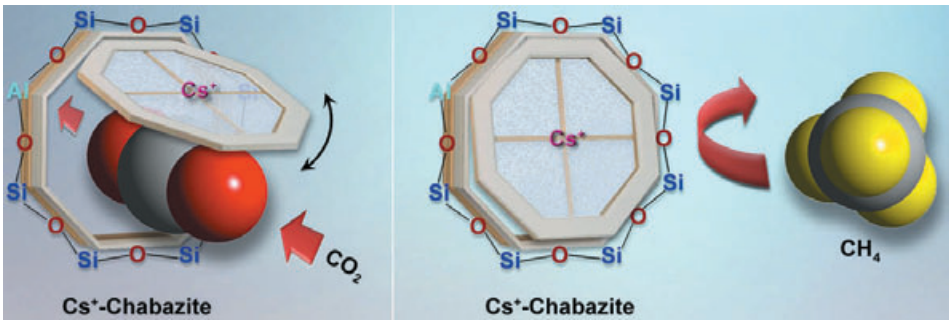
"Zeolites have previously been considered to be molecular 'sieves' – separating gas molecules based on size. The trapdoor mechanism that allows the chabazite zeolite to trap CO2 so efficiently is a new discovery."

In the case of the new material, a 'doorkeeping' molecule prevents access but allows CO2 to pass into the structure before the 'door' slams shut again. The material can separate CO2 from gas streams at a wide range of temperatures and pressures and has excellent potential for separating CO2 from power station flue gases and natural gas production.

"The major costs of carbon capture and storage are on the capture side of the equation," said Professor Webley.

"The high selectivity and lower energy requirement of the material mean that there is considerable potential to reduce the cost of gas separation, and therefore the overall cost of carbon capture and storage."

The team took a collaborative approach to the research with input from CSIRO, the Department of Materials Engineering and Mechanical Engineering at Monash University and the Australian Synchrotron.



The molecular trapdoor mechanism captures CO2

Alstom awarded concept study for Mongstad

www.alstom.com

The Norwegian state owned enterprise for Carbon Capture and Storage, Gassnova, has awarded Alstom a concept study for a full-scale CO2 capture plant to be located at Mongstad near Bergen, Norway.

The commissioned study includes a cost estimate for the erection and operation of a full-scale CO2 capture plant based on Alstom's proprietary chilled ammonia process (CAP). Mongstad is the location of the Technology Centre Mongstad (TCM), which is the world's largest facility for testing and improving CO2 capture technology.

This study is the third phase of the "Technology Qualification Program" being undertaken for the CO2 Capture Mongstad (CCM) project. During the first phase Alstom successfully executed a feasibility study for the project.

During the second phase of the program, which is currently on-going, Alstom continues to demonstrate with its own plant the application of the company's CAP technology for flue-gases coming from a gas-fired power plant. This second phase establishes the basis for the study now awarded.

The knowledge gained will prepare the ground for widespread CO2 capture deployment to combat climate change. Alstom's CAP process is a chemical absorption process, in which flue gas is contacted with an ammonia based solution which then reacts with the CO2. Raising the temperatures reverses the reaction – releasing the CO2 and allowing the solvent to be recycled.

Ohio State develops CO2 capture membranes in DOE-funded project

fossil.energy.gov

Researchers at The Ohio State University have developed a new hybrid membrane that combines the separation performance of inorganic membranes with the cost-effectiveness of polymer membranes.

Membranes consist of thin layers of either polymer (organic, plastic) or inorganic (metal, ceramic) materials that are permeable to the molecules they are meant to capture, such as water, CO2, or oxygen. The layers are generally deposited on a membrane support structure. Polymer membranes are mass produced and very cost effective, while inorganic membranes are expensive to produce but exhibit much better performance.

To illustrate how membranes are more energy efficient than other separation methods, scientists sometimes use a familiar substance: seawater. Pure water can be obtained by boiling the seawater and condensing the salt-free vapor, but boiling requires heat, which means using energy. Alternatively, membrane processes for separating salt from water don't require heat, making them more cost effective and environmentally friendly. Separating CO2 from flue gas is similar. Energy is still required for pre- and post-separation processes, such as compressing the gas, but for the key process of separating the CO2, new membrane technologies pioneered by FE's National Energy Technology Laboratory (NETL) and its research partners are designed to eliminate most of the energy costs.

Ohio State's new hybrid membrane consists of a thin, inorganic "zeolite Y" layer sandwiched between an inorganic intermediate and a polymer cover. These three layers sit atop a polymer support, which in turn rests on a woven backing. According to NETL project manager José Figueroa, "Combining inorganic and organic membrane materials in a hybrid configuration is a breakthrough that could potentially lower costs associated with clean coal technologies."

Ohio State researchers realized a first prototype by combining new nanotechnology characterization and fabrication methods with state-of-the-art manufacturing techniques. In the laboratory, they were able to slash the zeolite Y growth rate from 8 hours to less than 15 minutes and reduce ceramic processing time from 43 hours to 20 minutes, resulting in inorganic/organic membrane development within one hour. They have also achieved adhesion of the inorganic intermediate layer onto a polymer support.

The Ohio State team, which has emphasized the membrane's broader separation ap-

plications in their reports, received funding for the project beginning October 1, 2011, and presented their first results at the NETL Carbon Capture and Storage meeting July 9–12, 2012. The promising results follow previous success the team has had in making continuous, intact inorganic layers on polymer supports and developing new membrane-production techniques.

Pulverized rocks used to strip CO2 emissions

www.cmc-nce.ca

Researchers in Quebec are developing a process that would see steel, coal and cement plants as well as oil and gas facilities remove most of the carbon dioxide from their emissions through chemical reactions with various types of crushed rocks in the stacks.

The project is adapting and improving the process by which CO2 reacts with different minerals to form carbonates, a benign but valuable by-product that can then be sold to other commercial operations.

Lead investigator Dr. Guy Mercier, of the Institut national de la recherche scientifique (INRS), says he and his team are developing an economically attractive process that could easily be integrated into existing facilities and use simple and abundant rocks, waste concrete or tailings from mines in Quebec. Carbon Management Canada (CMC), a federal Network of Centres of Excellence that supports research to reduce CO2 emissions in the fossil energy industry and other large stationary emitters, is providing Mercier and his team $300,000 over two years.

"You take the waste material, the rock, concrete or mine tailings, and crush it to make a powder and then you send that powder up the chimney with the gas," says Mercier. "The resulting chemical reaction removes 80 per cent of the CO2."

It also forms carbonate byproducts that can be sold to a variety of different industries for use as a refractory material or as an alcaline agent in wastewater treatment. "This will allow companies to profit while sequestering CO2, says Mercier. "They can create new jobs instead of creating pollution."

"It's a lower cost, low pressure, low temperature technology that doesn't require capturing purified CO2," Mercier says. "There are a lot of engineering challenges in this but we are well on our way to achieving success."

Mercier is working with an international team of researchers from INRS, the University of Calgary and the University of Melbourne. The project is also being undertaken with industrial partners Holcim Canada, a building materials and construction company, and SIGMA DEVTECH, a consulting company for startups. The research team will be reacting various magnesium and calcium rocks available in mine tailings mines with the gaseous emissions (containing CO2) of a Holcim cement plant with the participation of the cement plant staff in a chemical reactor (a plant in itself).

Carbon Clean Solutions to receive £3.35M for CO2 solvent research

www.carboncleansolutions.co.in

Carbon Clean Solutions (CCS Ltd.) is receiving a grant from the UK Department of Energy and Climate Change (DECC) to develop a low energy solvent for CO2 capture.

The Company emerged as one of the winners amongst numerous applicants under the DECC's competition for the development of CCS innovation technologies and will receive £3.35 million for developing and demonstrating its technology.

The proposed project named CAPSULE (CO2 Capture Solvents for Ultra Low Energy system), involves capturing carbon dioxide using regenerable advanced solvent patented by Carbon Clean Solutions combined with improved energy integration in the CO2 capture process.

Aniruddha Sharma, co-founder and CEO of Carbon Clean Solutions commented: "We believe the UK is one of the most progressive markets for carbon capture technology and our technology is suitably poised to deliver a step-change in performance for our customers. DECC funding will provide us with both credibility and required capital to support and demonstrate our technology at a pilot scale".

The solvent and process configuration increases the efficiency and reduces the amount of energy required for 90% carbon capture, thus making CCS technology cost effective. A special feature of the new solvent is that it can be swapped directly with the amine-based solvents used in existing CO2 capture and recovery plants. No process modification or new equipment change is required in existing CO2 recovery units. CO2 thus captured is ready for sequestration or reuse and can be transported to suitable storage/utilisation locations using pipelines.

CCS Ltd. is working with Imperial College London, the UK CCS Research Centre and PSE (Process Systems Enterprise) as research partners on the project. Advanced solvent degradation and corrosion testing will be conducted at Imperial College, while the UK CCS Research Centre's Carbon Capture "PACT" (Pilot-scale Advanced Capture Technology) facility at the University of Leeds will be operated to pilot test the performance. PSE will be engaged as the modelling expert to simulate and extrapolate scale-up performance using industry accepted "g-prom" software. CCS Ltd. will pilot test its technology at PACT facility at Beighton, Sheffield before being subsequently scaled up by 10 and then 20 times. The project will also include detailed investigation into the solvent's degradation, corrosion and real time dynamic modelling of the plant operations upon scale-up.

To help boost the project proposal and prove benefits both technologically and commercially, the project consortium with feedback from DECC, is looking to increase business participation in the project by seeking local power and/or industry partners to join the project.

The "PACT" (Pilot-scale Advanced Capture Technology) facility at the University of Leeds

Energy Pipelines Cooperative Research Centre work on CO2 pipelines

The Energy Pipelines CRC is looking at the principal knowledge gaps that must be addressed in developing efficient designs for CO2 pipelines. By Valerie Linton, CEO, Energy Pipelines CRC.

The Energy Pipelines Cooperative Research Centre (EPCRC) is a collaboration between the Australian Commonwealth Government, the fifty member companies of the Australian Pipeline Industry Association and the Universities of Adelaide, Deakin, Wollongong and the Australian National University.

The main focus of the Energy Pipelines CRC is the extensive network of high pressure gas transmission pipelines around Australia. These pipelines are responsible for the safe and continuous supply of natural gas from production sources to the range of industry, retail and domestic customers.

The Energy Pipelines CRC is conducting research into a wide range of topics covering materials and welding, corrosion and its control, design and construction and into human factors in relation to pipeline safety. Although this work is mainly focused on methane carrying pipelines, much of the work is also directly applicable to CO2 pipelines and for specific areas the research is extended from methane pipelines to both CO2 pipelines and pipelines carrying other energy fluids.

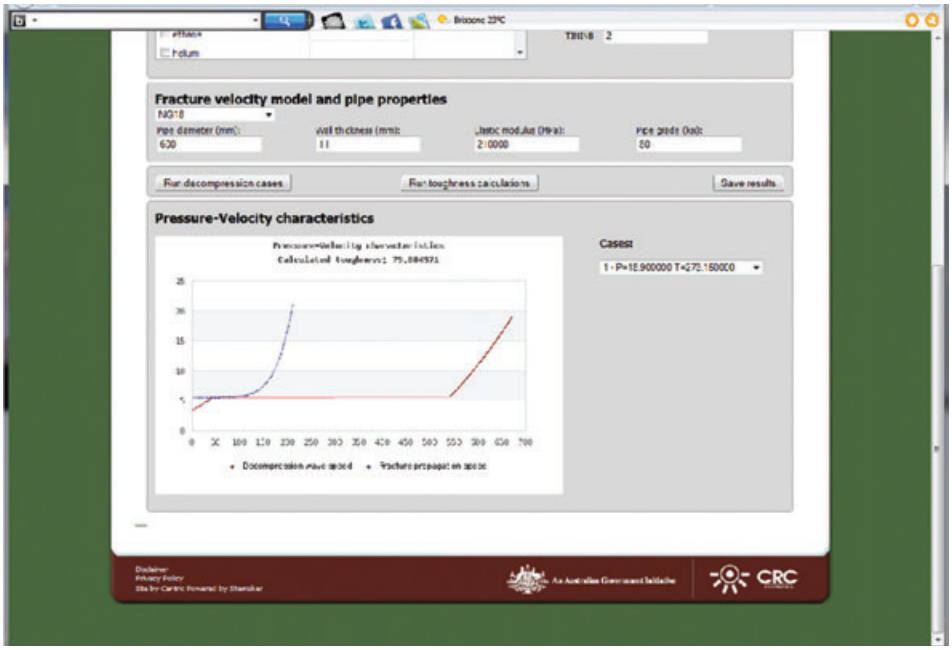


Figure 1: A screen shot from the Energy Pipelines CRC fracture control software showing the calculated decompression speed curve, fracture propagation speed curve and minimum arrest toughness.

Pipeline standards for CO2

In Australia, high pressure pipelines for transportation of gas and liquid petroleum are designed, operated and maintained in accordance with the requirements of AS 2885 – Pipelines gas and liquid petroleum (the Standard). This Standard is referenced in legislation in each State (jurisdiction) as providing the technical basis for regulating these pipelines.

The Standard is intended to provide a single and sufficient basis for design, construction operation and regulation of these pipelines, so obviating the need for any jurisdiction to develop standards of its own, which if implemented, would result in different requirements for pipelines constructed in different jurisdictions, and in particular, pipelines crossing jurisdictions.

While the Standard was developed for gas and liquid petroleum pipelines operating at pressures greater than 1050 kPa, the Standard recognises that its requirements for design and safety apply equally to pipelines transporting other substances, and permits its use for high pressure pipelines transporting CO2 (AS 2885.0 Clause 1.2.1 Amendment 1 (2012) and other substances (AS 2885.0 Clause 1.2.2(c)).

It should be noted that AS 2885 applies to petroleum fluids that are transported as a supercritical fluid, for example ethane. CO2 exhibits similar physical and thermodynamic properties to those of supercritical ethane. The principal difference is that CO2 is not flammable, but is an asphyxiant, while ethane is flammable. Consequently the same principles for safe design and operation of a pipeline apply to both fluids, with key differences existing in the assessment of consequential risk.

In 2010 the Energy Pipelines CRC commenced a program of research designed to help users of AS2885 to address requirements for the safety, design, construction and operation of CO2 pipelines. Initial work focussed on writing a draft appendix at AS2885 that would enable competent people to design a pipeline to transport CO2. The appendix outlined the requirements while identifying areas where more work needed to be done.

The 2012 revision of AS 2885.1 incorporates this document as Appendix BB (Guidelines for Pipelines for the Transport of CO2). As the work currently underway is completed, a future revision of the Standard will incorporate specific rules for design, construction, operation and maintenance of CO2 pipelines.

The research undertaken to develop the AS 2885.1 CO2 Appendix identified four principal knowledge gaps that must be addressed in developing efficient pipeline designs for CO2 pipelines. These are:

1. Development of suitable equations of state that address the interaction of low concentration components with the CO2 in anthropogenic CO2 mixtures to facilitate hydraulic and other process modelling associated with pipeline design.

2. Pipeline design to resist fracture of a pipeline transporting CO2, and in particular, control of fast tearing fracture.

3. The limiting concentrations of water and other contaminants needed for the fluid to be essentially non-corrosive to pipeline steels.

4. Safety requirements to reduce the

risk from intentional and unintentional releases of CO2 to tolerable levels.

Research into these areas is being undertaken by the Energy Pipelines CRC with primary funding being provided by the Commonwealth Government's Department of Resources, Energy and Tourism. The results of this work are currently confidential, but it is envisioned that they will be at least partially made available over time and the key findings will be incorporated into AS2885 in subsequent revisions.

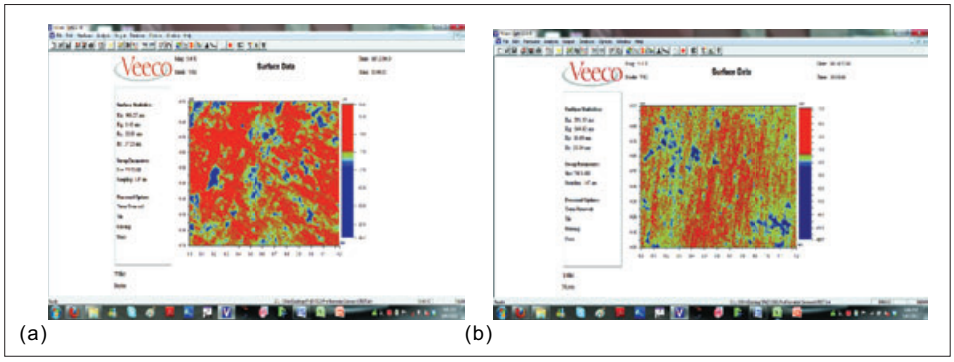


Figure 2: Optical profilometry image of steel samples immersed in aqueous electrolytes using various combinations of acids and impurities to simulate the conditions of the aqueous phase in supercritical CO2. Specifically (a) pH 2 H2SO4 at 25°C, (b) pH 4.5 H2SO4 at 25°C

Overview of EPCRC research

The sections below provide a broad overview of the work currently underway.

1. Development and testing of suitable equations of state for CO2 mixture compositions anticipated for known processes for carbon capture.

Carbon dioxide capture and storage (CCS) will require the transportation of the CO2 from "capture" locations to "storage" locations. Pipelines of this type, to be efficient, will transport the fluid as supercritical or dense phase CO2. In order to determine the behaviour of CCS CO2 mixtures during normal and fault conditions in pipelines it is necessary to have accurate means of predicting the thermodynamic properties of such mixtures through appropriate equations of state. Without such thermodynamic models it is not possible to predict important potential pipeline failure situations such as: i) rapid decompression in the pipeline following a pipeline fracture, and ii) release characteristics of the CO2 mixture in the immediate vicinity of the pipeline which, in turn, will determine how the CO2 cloud will disperse and potentially impact nearby human settlements and activities.

These thermodynamic models are described in equations of state (EOS) which provides a mathematical relationship between two or more properties of a substance, such as temperature, pressure, volume, or internal energy.

The most simple equation of state is the ideal gas equation. This ideal gas EOS is roughly accurate for gases at low pressures and moderate temperatures. However, this equation becomes increasingly inaccurate at higher pressures and lower temperatures, and fails to predict condensation from a gas to a liquid. Therefore, a number of much more accurate equations of state have been developed for gases and liquids. The work reviewed two major groups of EOS, cubic equations of state and virial equations of state, giving special attention to comparisons of accuracy of different EOSs for pure CO2 and CO2 mixtures. Each EOS was also tested against actual test data to determine its accuracy.

The work identified the best EOS for anthropogenic CO2 mixtures along with areas where the EOS could be improved to cover the full range of possible mixture compositions.

These EOS are required to ensure that research on pipeline decompression and CO2 dispersion is accurate and therefore ultimately useful.

2. Shock tube testing of hydrocarbon gas mixtures and CO2 mixture compositions anticipated for known processes for carbon capture to establish decompression characteristics.

This is for:

i. Development of fracture control models and;

ii. Data against which the equation of state(s) can be tested.

Supercritical CO2 is a challenging fluid when dealing with fracture arrest. Its thermodynamics characteristics during decompression mean that a very high driving force of fracture can be sustained for a long time. The problem is not new and most current CO2 pipelines are provisioned against long fracture propagation via regularly spaced crack arrestors. CO2 for CCS can carry a variety of impurities that change the conditions of arrest due to the altered decompression characteristics of the fluid. The properties of these impurity carrying mixtures are poorly understood, making determining the required toughness of the pipeline tricky.

Impurities are only one factor of the decompression characteristics. The temperature drop of the pipe during decompression, accompanied by condensation of the fluid during the phase change, friction interactions between the fluid and the pipe wall and the physics of the fluid during transient flow are interrelated and will affect the decompression speed.

A better understanding of the decompression behaviour due to these factors has both safety and economic benefits. This can be achieved through substantial test programmes such as full-scale bursts test, shock tube tests and numerical modelling. The analysis and comparisons of the results from these three approaches have been instrumental in the past to advance pipeline techniques and safety. They are valuable and necessary for the development of CCS pipelines.

To help with this understanding, a series of shock tube tests was undertaken to provide data on the decompression of pressurised gas in a pipeline. Both the test gas composition and temperature was controlled. The test rig was instrumented to measure the speed of the decompression wave, together with a range of associated data. Decompression data was generated for pure CO2 and a range of binary and more complex mixtures over a range of pressures and temperatures.

Computational fluid dynamic modelling of the shock tube testing was undertaken to analyse the capability of this technique to accurately predict the decompression characteristics of CO2 mixture compositions in large pipe diameters and for pressure and temperature conditions other than those used in the shock tube tests.

This research has shown that computational fluid dynamics can be used to simulate the highly unsteady state decompression process in a shock tube experiment.

This knowledge has been integrated with the most accurate equation of state predicts the decompression characteristics of the CO2 gas mixtures examined in the shock tube test program with significantly improved accuracy over existing software.

In the next step, the Energy Pipelines CRC generated software links the decompression characteristic prediction with the arrest toughness characteristics of pipeline steels, enabling the prediction of fracture toughness required for pipe steel (where toughness is the design approach used for fracture arrest).

This software is currently undergoing user evaluation and once complete, the software is expected to be suitable for use with CO2 mixtures – with the proviso that there is very limited data on full scale burst testing of pipelines transporting CO2 mixtures. It is possible that the decompression / fracture arrest characteristics of supercritical CO2 mixtures may differ from those measured for hydrocarbon gas mixtures that are the basis for existing fracture control technology.

Work to assess whether this is a real concern is in progress at the Energy Pipelines CRC, as well as at other research institutions.

3. The limiting concentrations of water and other contaminants needed for the fluid to be essentially non-corrosive to pipeline steels.

This work dealt with the quantification of the damage that occurs in terms of corrosion as a result of the contact between steel and CO2 in its liquid and/or supercritical phase in the presence of impurities including water or other species which arise from the capture source. Water content between 100 and 50,000 ppm was studied. In addition, the role of additional impurities (in addition to water) was also studied by a number of limited supercritical CO2 exposure tests.

This work quantified the relationship between the test environment and the corrosion damage, including the depth of any pits on the surface of the steel sample. Further work in this project will assess this corrosion damage in terms of the likely durability of the pipeline in service conditions.

Safety requirements to reduce the risk from intentional and unintentional releases of CO2 to tolerable levels.

One of the significant issues for CO2 pipelines is what happens to the CO2 from a release. Understanding, and ultimately being able to predict, the dispersion of the CO2 is a critical element in managing the safety of CO2 pipelines.

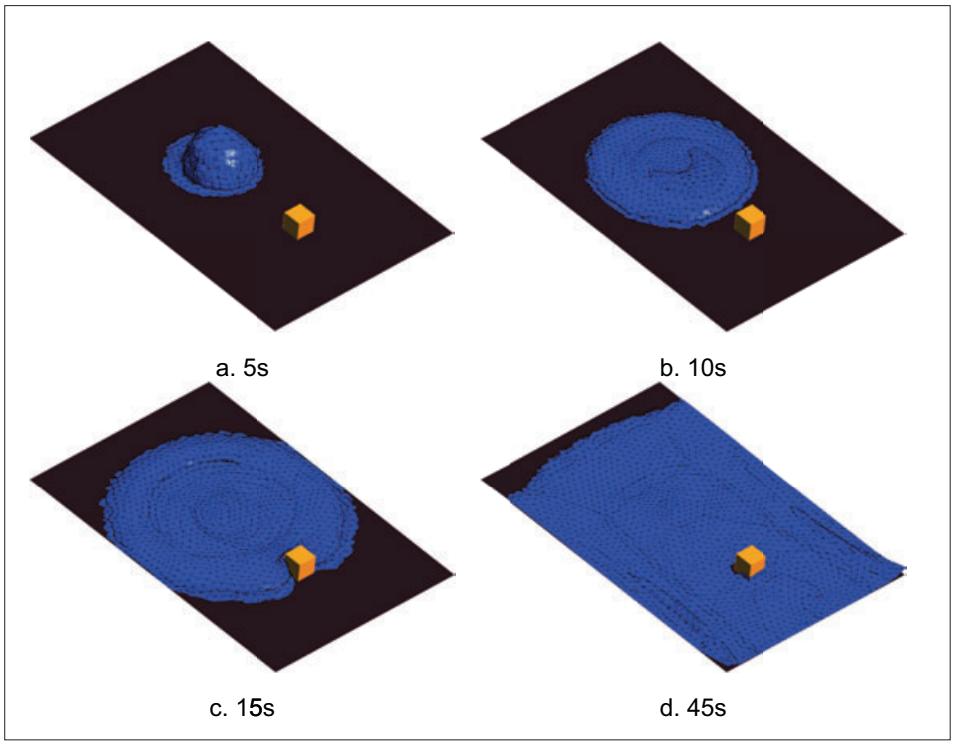


Figure 3: CFD model of heavy gas dispersion after dispersion at different times (ISO surface with 1% concentration).

In the area, a few researchers have used general-purpose CFD packages for atmospheric dispersion modelling, while others have relied on using CFD software packages (such as fluidyn-PANACHE) designed specifically for atmospheric dispersion modelling. Until recently, CFD simulations could not be considered as appropriate alternatives to Gaussian-type modelling, mainly due to the long run times involved. This situation has changed somewhat, and is likely to change even further in the future so that the application of computational fluid dynamics (CFD) to dispersion modelling in all its complexity (terrain topography, presence of obstacles, etc) will become a useful tool.

Preliminary CFD models have been produced and compared with data from actual release tests. The remainder of this project will focus on ever more complex scenarios in an attempt to determine whether these models are capable of predicting the dispersion of CO2 from a pipeline release.

More information

www.epcrc.com.au

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DOE releases new U.S. Carbon Storage Atlas

The DOE's latest Carbon Utilization and Storage Atlas estimates at least 2,400 Billion metric tons of U.S. CO2 storage resource.

www.natcarb.gov

The United States has at least 2,400 billion metric tons of possible carbon dioxide (CO2) storage resource in saline formations, oil and gas reservoirs, and unmineable coal seams, according to a new U.S. Department of Energy (DOE) publication.

This resource could potentially store hundreds of years' worth of industrial greenhouse gas emissions, permanently preventing their release into the atmosphere, says the 2012 edition of the Carbon Utilization and Storage Atlas (Atlas IV). Capturing CO2 emissions from large power and industrial plants and putting it to beneficial use or storing it in deep geologic formations is a key element in national efforts to mitigate climate change.

Of particular importance is that over 225 billion metric tons of storage capacity has been identified in depleted oil and gas fields which could accommodate storage of several decades of emission from stationary sources while simultaneously improving the energy security of the United States by enhancing oil and gas recovery.

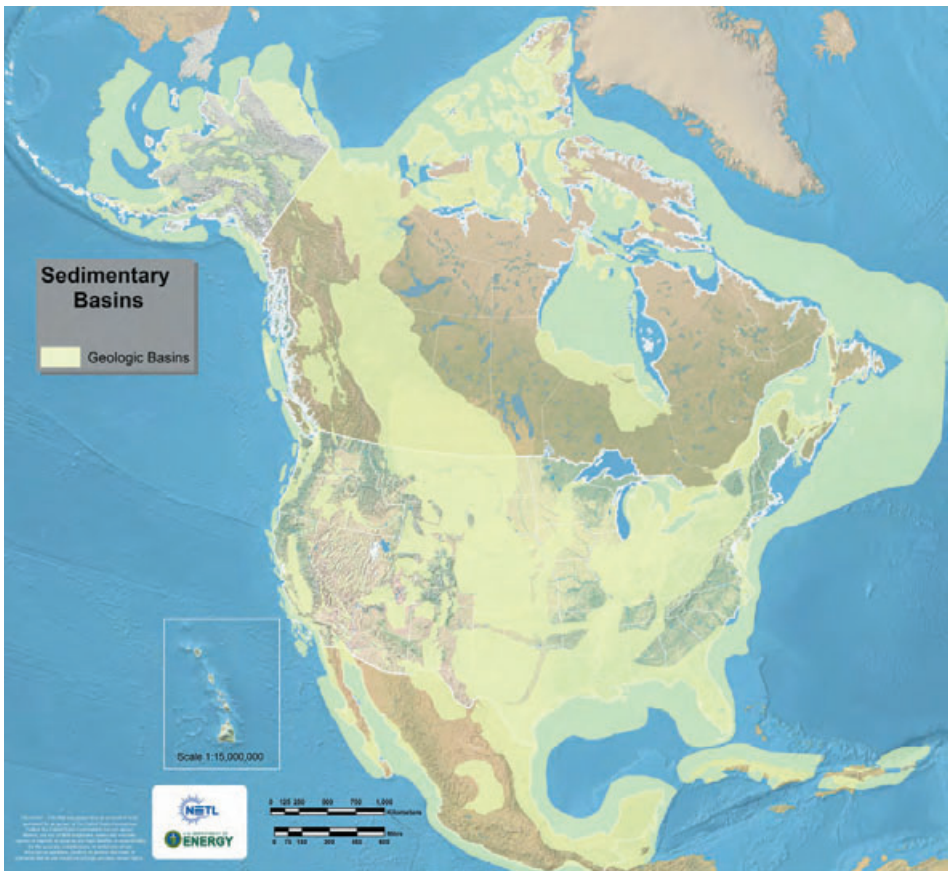
Atlas IV was created by the Office of Fossil Energy's National Energy Technology Laboratory (NETL) with input from DOE's seven Regional Carbon Sequestration Partnerships and ten Site Characterization projects. Comprising more than 400 organizations in 43 states and four Canadian provinces, the regional partnerships are testing CO2 storage potential and investigating best practices for CO2 storage in a variety of geologic formations.

The Site Characterization projects, funded by the American Recovery and Reinvestment Act of 2009, are furthering DOE efforts to assess the nation's CO2 storage resource by developing additional characterization data for possible storage reservoirs.

The primary purpose of Atlas IV is to provide an update on the CO2 storage potential in the United States and to showcase updated information about the partnerships' field activities and new information from the site characterization projects. Atlas IV outlines DOE's Carbon Storage Program and its carbon capture, utilization, and storage (CCUS) collaborations, along with worldwide CCUS projects and CCUS regulatory issues.

The atlas also presents updated information on the location of CO2 stationary source emissions and the locations and storage potential of various geologic storage sites, and it provides information about the commercialization opportunities for CCUS technologies from the regional partnerships.

The data used to create the resource estimates in Atlas IV is available in interactive form on the National Carbon Sequestration Database and Geographic Information System (NATCARB) website.



Sedimentary basins in North America

carbon capture journal

Free London CCS event

Developments in carbon capture technology

London Geological Society, Mar 26 2013

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Transport and storage news

ULTimateCO2 project helps understanding of long-term storage

www.ultimateco2.eu

A new €4M European project to improve understanding of the most effective ways to store CO2 has been launched.

ULTimateCO2, a four-year project involving researchers and industry experts from across Europe, will significantly advance understanding of the long-term fate of CO2 when captured and stored in geological formations as part of the CCS process.

It will cover detailed lab, field and modelling studies of the main physical and chemical processes involved and their impacts in the long-term including: trapping mechanisms of CO2 in geological formations; fluid-rock interactions and effects on the integrity of caprocks that seal CO2 stores; and leakage due to lack of integrity of operating or abandoned wells.

Proponents of CCS believe that it is an essential technology that will be required to be deployed over the next few decades if the world is to meet its greenhouse gas reduction and energy supply aims cost effectively. However, critics claim that the long-term assurance of geologically stored CO2 with a very high degree of certainty is still unproven.

ULTimateCO2 will develop recommendations for operators and regulators of CO2 storage sites to provide a higher degree of certainty over the long-term performance of storage sites. The outcomes of the project will be disseminated widely to a broad audience including policy makers and regulators, storage developers, investors, the scientific community and representatives of civil society. This will improve public understanding of CO2 storage and CCS.

US-Canada standard for CO2 geological storage

www.csagroup.org

CSA Group and the International Performance Assessment Centre for Geologic Storage of Carbon Dioxide (IPAC-CO2) have announced the world's first bi-national standard for the geologic storage of carbon dioxide.

The CSA Z741 Geological storage of cabron dioxide standard is a bi-national Canada-USA consensus standard, developed with a technical committee of more than 30 professionals representing industry, regulators, researchers and NGOs from both sides of the border. The genesis of the standard was a seed document developed by IPAC-CO2 based on their research. It is intended that the new standard will also be used as a basis for the international CCS standards through the International Organization for Standardization (ISO).

The standard is primarily applicable to saline aquifers and depleted hydrocarbon reservoirs and does not preclude its application to storage associated with tertiary hydrocarbon recovery. It includes, but is not limited to, recommendations with respect to the safer design, construction, operation, maintenance, and closure of storage sites. It also provides recommendations for the development of management documents, community engagement, risk assessment, and risk communication.

The project life cycle covers all aspects, periods, and stages of the storage project, beginning with those necessary to initiate the project (including site screening, selection, characterization, assessment, engineering, permitting, and construction), that lead to the start of injection and proceeding through subsequent operations until cessation of injection; and culminating in the post-injection period, which can include a closure period and a post-closure period. The standard does not specify post-closure period requirements.

CSA Z741 Geological storage of carbon dioxide standard provides essential guidelines for regulators, industry and others around the world involved with scientific and commercial CCS projects.

It establishes requirements and recommendations for the geological storage of carbon dioxide to help promote environmentally safe and long term containment of carbon dioxide in a way that minimizes risks to the environment and human health.

Illinois project completes first year of CO2 injection

fossil.energy.gov

Led by the Illinois State Geological Survey, the Illinois Basin–Decatur Project is the first demonstration-scale project in the United States to use CO2 from an industrial source and inject it into a saline reservoir.

The CO2 is being captured from an ethanol production facility operated by the Archer Daniels Midland Company in Decatur, Ill., and is being injected in a compressed "supercritical" state into the Mount Simon Sandstone reservoir some 7,000 feet below the surface. Injection operations were initiated November 17, 2011, with an average injection rate of 1,000 metric tons (1,100 short tons) daily.

Analysis of data collected during the characterization phase of the project indicated the lower Mount Simon formation has the necessary geological characteristics to be a good injection target, a conclusion supported thus far by data accumulated from continuous monitoring of the site. The results from various monitoring activities – including tracking the underground CO2 plume; sensing subsurface disturbances; and continuous scrutiny of groundwater, shallow subsurface, land surface, and atmosphere around the injection site – show the Mount Simon Sandstone reservoir is performing as expected, with very good injectivity, excellent storage capacity, and no significant adverse environmental issues.

Nearing the 1-year mark, 317,000 metric tons of CO2 have been injected, about one third of the planned 1 million metric ton injection volume. The demonstration-scale project provides the opportunity to test how a real-world injection operation will perform where brief interruptions—such as planned maintenance of the compression equipment and conducting of various well tests, as required by regulations—will occur.

UK online CO2 storage database to be launched

www.eti.co.uk

The Energy Technologies Institute has announced that it has agreed a licence with The Crown Estate and the British Geological Survey to host and further develop its £3.8m UK CO2 Storage Appraisal project into an online database of mapped UK offshore CO2 storage capacity.

The web-enabled database – the first of its type anywhere in the world - contains geological data, storage estimates, risk assessments and economics of nearly 600 potential CO2 storage units of depleted oil and gas reservoirs, and saline aquifers around the UK.

The UK is potentially well served with offshore CO2 storage and although various estimates have been made of the total amount available, these figures vary widely. This new database will enable interested stakeholders to access information about the storage resource and to make more informed decisions related to the roll out of Carbon Capture and Storage (CCS) in the UK.

With data collection complete and this licence agreement in place, the database will go live in early 2013. As part of the licence agreement, The Crown Estate and the British Geological Survey (BGS) have together committed £1 million to further develop the content of the database and to provide users with a dedicated hosting service.

Australian CCS research showcased in Japan

www.ga.gov.au

Australian researchers are presenting the latest findings of research into CCS at the Greenhouse Gas Control Technologies conference being held in Japan.

Geoscience Australia researchers are presenting on a number of topics including:

- the development of CO2 monitoring techniques;

- the acquisition of CO2 baseline atmospheric data;

- pre-competitive data acquisition and geological characterisation of offshore sedimentary basins, including development of methodology for estimating CO2 storage capacity.

Geological storage of greenhouse gases is one approach the Australian Government is pursuing to assist Australia, and the world, to reduce greenhouse gas emissions into the atmosphere. Understanding the geology of Australia's sedimentary basins and their potential for greenhouse gas storage is an important component of Geoscience Australia's work in supporting emission reductions.

"One key component of our CCS research program is focussed on predicting processes and conditions of CO2 storage in geological formations," explained geochemist Dr Ralf Haese.

"We are working in partnership with the CO2CRC and a range of other partners to undertake experimental and modelling studies assessing fluid-rock interactions and rock mechanical behaviour under different CO2 storage conditions. This includes research investigating residual CO2 trapping, whereby CO2 is trapped by capillary forces within the pore spaces," Dr Haese said.

"This particular study was conducted at the CO2CRC Otway demonstration site in 2011, and is helping us to develop techniques to estimate CO2 trapping capacity, which is particularly important in basins lacking proven structural closure."

Geoscience Australia's CCS program is also working to develop techniques to verify the integrity of the geological storage of CO2. Recent work has been undertaken to trial CO2 emission monitoring and modelling techniques to quantify CO2 emission rates from a controlled CO2 release experiment; as well as development of techniques to establish baseline atmospheric levels of greenhouse gases.

In addition, preliminary assessments on geological potential for CO2 storage are currently being undertaken in the Vlaming Sub-basin (offshore Western Australia), the Bonaparte Basin (offshore Northern Territory) and the Gippsland Basin (offshore Victoria). This work is specifically designed to provide data to encourage exploration of offshore sites for the geological storage of CO2.

Project to use cosmic rays detectors to map out carbon storage volumes

www.sheffield.ac.uk

Researchers from the University of Sheffield will be at the centre of a bid by a group of scientists to develop a novel technique using cosmic rays for monitoring storage sites for carbon dioxide.

Geoscientists, particle physicists and engineers will work together to examine the potential of using sub-atomic particles from cosmic rays – known as muons – which cascade from the upper atmosphere and go on to penetrate rock several kilometres underground.

The detection of cosmic ray muons can be used to map the density profile of the material above the detectors and hence measure on-going levels of CO2 in any potential carbon store.

Carbon storage could play a major part of UK and global environmental policies to tackle global warming but still allow us to generate clean, affordable energy.

Dr Lee Thompson, Reader in Particle Physics at the University of Sheffield, said: "Applying Particle Physics know-how to the issue of monitoring the storage of captured carbon is a novel and innovative idea. This grant will enable us to refine our experimental techniques for this particular application and perform trial deployments of cosmic ray detectors."

The current monitoring methodology is expensive and typically involves the collection of seismic data which enables snapshots of carbon storage levels to be taken over time. Muon tomography offers the chance to develop a continuous and passive monitoring system for deep sub-surface storage sites.

Project leader Professor Jon Gluyas, of the Department of Earth Sciences at Durham University, said: "This technology crosses between traditional scientific disciplines and could radically reduce the cost of monitoring CO2 storage sites, saving perhaps hundreds of millions of pounds per annum.

The team comprises of the Universities of Sheffield, Durham, Bath and Newcastle, the STFC Rutherford Appleton Laboratory and NASA Jet Propulsion Laboratory, Caltech supported by Premier Oil & Gas and Cleveland Potash Limited.

The Department of Energy and Climate Change is providing £647,000 for the monitoring project alongside matched funding from industry. The devices developed will be tested deep underground at Boulby mine on the edge of the North Yorkshire moors.

Low temperature, power CO2 sensors developed in Canada

www.cmc-nce.ca

A technology to allow for long-term automated monitoring of greenhouse gases has been developed by Professor David Risk, of St. Francis Xavier University's (StFX) Department of Earth Sciences.

The patented sensor-housings function throughout cold winters and without using much power - two significant benefits that competing technologies do not provide, says Carbon Management Canada, that is funding the research.

Since 2006, Risk and his research group have been monitoring greenhouse gases at surface locations as far south as Antarctica and as far north as Alaska. Their specialized sensor-housings, called forced diffusion chambers, have also been in place at Saskatchewan's Weyburn-Midale CO2 storage site—the largest in the world. Risk and his research group at StFX originally developed the technology to measure gas fluxes in natural environments, including permafrost, where warming could release untold amounts of trapped carbon.

While carbon injection and storage technologies are relatively mature, for CCS to fulfill its role in climate change mitigation, good CO2 detection must also come of age. "Having direct sensing of CO2 would allow us to roll out the whole (CCS) technology in a much better way and with better confidence of containment," says Risk.

His next step is to marry the forced diffusion chambers with fibre-optic CO2 sensors. A Carbon Management Canada (CMC) funded research collaboration among investigators at five Canadian universities is supporting development of this novel direct-sensing technology.

Prof. Peter Wild of the University of Victoria is the Lead Principal Investigator on the CMC-funded project, and is lending his expertise in fibre-optic sensing to the collaboration.CMC is a national network that funds research to reduce carbon emissions in the fossil energy industry and other large-scale emitters.

Current methods of direct-detection include periodically halting CO2-injection to take samples, or using a secondary well to monitor CO2 in the primary well where injection is taking place. In contrast, explains Risk, fibre-optic sensors would be much more practical and cost-effective.

Using Risk's membrane-based housings with fibre optic sensors offers the ability to estimate rates of CO2 migration and

possibly also to act as selective filters, allowing CO2 to touch the sensors, but filtering out unwanted gases. His team will design the membrane-based housings in close collaboration with the fibre optics team.

Research tests geo-electric techniques to monitor CO2 injection

Carbon Management Canada is funding research into using the electric properties of CO2 for monitoring.

The current mainstream monitoring techniques measure seismic waves that travel underground because these waves are affected by the injection of CO2 and these changes are used to track where the CO2 is going says the project's lead investigator, Dr. Bernard Giroux, of Institut national de la recherché scientifique (INRS).

Carbon Management Canada (CMC), a federal Network of Centres of Excellence that supports research to reduce CO2 emissions in the fossil energy industry as well as from other large stationary emitters, is providing Giroux and his team $450,000 over three years.

In its 2012 round of funding, CMC is awarding $3.75 million to Canadian researchers working on eight different projects. The awards were made after a rigorous, international, peer-reviewed process.

"The rock contains water or oil or gas and we are replacing that with CO2, which has different physical properties. The injection process also changes the pressure and that can have a strong influence on the overall properties of the rock. Thus, seismic properties are both affected by changes in fluid and pressure," says Giroux.

"So, when we're injecting CO2 we're changing both fluid and pressure, and there's an ambiguity here. We're monitoring something, but we're not exactly sure in which proportion we should attribute measurements to changes in pressure or changes in fluid."

Giroux is leading an international team of researchers from the University of Alberta, the Geological Survey of Canada, the Technische Universität Bergakadmie Freiberg and the GFZ Centre for CO2 Storage, Potsdam. Also contributing to the project are Natural Resources Canada, the Petroleum Technology Resource Centre, and Junex.

There are three components to the research that will improve monitoring of injecting CO2.

In the lab, the researchers will fill in gaps of knowledge about the electrical properties of CO2 as well as cross relationships between seismic and electric properties. "We want to understand the relationship between fluid nature, pressure changes and temperature changes to improve our fundamental understanding of how CO2 affects the electrical properties of the rocks," says Giroux.

Using a saline aquifer in Saskatchewan and a reservoir in Quebec, the researchers will test different methods of measuring electrical properties underground. More specifically, the team will test how measuring the magnetic field instead of the electric field (as done usually) can be used to infer the electric conductivity of the rock.

The project will also develop numerical models that will help assess all the data gathered.

"We want, as much as physically possible, to give guarantees that we know where every drop of CO2 is going," says Giroux, "and we want to increase the safety and public acceptance of these sequestering operations."

Storage of CO2 should be top priority for CCS

www.australiancoal.com.au

The Australian Coal Association has called for top priority to be given to the development of storage sites for CO2 as part of a national collaborative approach to lowering greenhouse gas emissions in the fossil fuel sector.

The Deputy CEO of the ACA, Mr Greg Sullivan, said the task for developing carbon capture and storage technology, or CCS, was now becoming urgent if Australia was to deliver its greenhouse gas emissions targets in the coming decades.

"CCS is not only a coal technology. It is a carbon technology that will be as important for future gas use as it is for coal use, and for use in industrial processes such as steel and cement manufacture," Mr Sullivan told the National CCS Conference in Perth.

"Today coal and gas account for 90 per cent of Australia's total electricity generation for public consumption. Reducing the greenhouse emissions from power generation will require CCS technology.

"Treasury modelling indicates the importance of CCS to Australia's electricity supply and emissions abatement. It suggests that CCS will be applied to electricity generated from coal and gas for up to a third of Australia's electricity by 2050.

"However if CCS is not deployed, electricity will be fuelled by gas that has no carbon abatement. The result is Australia's electricity sector emissions would be around 40 per cent higher in 2050.

"Given the lead times for developing CCS storage sites and power stations with capacity for carbon capture, a sense of urgency is needed if CCS is to be ready and available for commercial deployment from 2030."

Mr Sullivan said the National CCS Council had been instrumental in bringing together stakeholders in the sector, but more collaboration and higher priority was needed, particularly on the development of storage sites.

"Fortunately, we have a strong foundation for CCS development and deployment in Australia, and the Australian coal industry is contributing to several demonstration projects through our COAL21 Fund," he said.

"Today the number one policy opportunity for the near term is to prioritise and accelerate the appraisal of large-scale CO2 sites.

"Placing priority on storage is not only consistent with our experience developing demonstration projects, but offers the opportunity to provide a foundation for adopting CCS across a range of emissions-intensive industries in the future.

"Australia needs to deliver a collaborative approach to identifying and funding CCS projects which are highly prospective and nationally significant."

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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.

To work with IPAC-CO2, contact peter.wyant@ipac-co2.com.

IPAC CO2

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