carbon capture journal

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Front cover:
A Maersk gas tanker loads at a berth. CO2 tankers could provide a cost effective alternative to pipelines for smaller quantities, over long distances or for shorter periods of time

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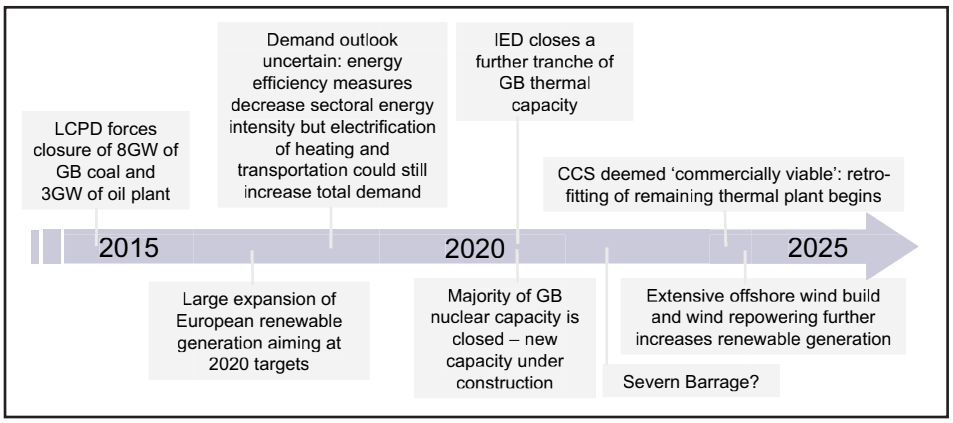
Pöyry - context for commercial CCS

In this series of articles we strain our eyes towards the horizon, to anticipate the form of the future power markets in which CCS will be competing, with a view to understanding the potential implications for the here and now, particularly in the areas of R&D, regulation and policy.

By Steve Esau, Pöyry Energy Consultants

The industry focus to date in Carbon Capture and Storage has been on the technical challenges, policy and regulatory issues and support mechanisms associated with commercializing the new technology. Little attention has been given to the market context in which CCS is likely to operate, and the business models and roles and investment perspectives of key actors in the value chain.

Equally reasonably, CCS has become synonymous with tackling the CO2 emissions associated with coal-fired power generation – less consideration has been given to the role of gas and CCS and its application to industrial processes.



The evolving power market

Context for commercial CCS – the power market in 2025

While much necessary and exciting work on CCS technology is underway, the market in which the majority of CCS plant will actually come to operate will be very different from that seen today. Optimistic timescales suggest that reasonable sized demonstration plant may be in operation from 2014 with the first commercial scale plant unlikely until the early 2020's.

The most important commercial years for these early plants will be their initial years of operation: 2025 to 2030, as developers seek to recoup their investment. A key question is what will the power markets of 2025 look like. Our focus here is on the UK but similar challenges are faced by other European markets.

- The LCPD (Large Combustion Plant Directive) and the Industrial Emission Directive will have forced the majority of the current coal fleet to close.
- 2020 renewables targets imply deployment of up to 33GW of mainly offshore wind capacity and the Severn Barrage could well be online.
- According to the most recent proposal contained in the National Policy Statements (driving planning consent decisions) the Government may be forcing all thermal plant to retrofit with CCS if it believes it to be technically and commercially viable.
- The existing nuclear fleet is planned to close but new nuclear is still in its infancy.
- The demand picture is uncertain – energy efficiency measures should push emissions form certain sectors down but this still leaves the option of a large increase in demand from widespread electrification of heating and transportation.

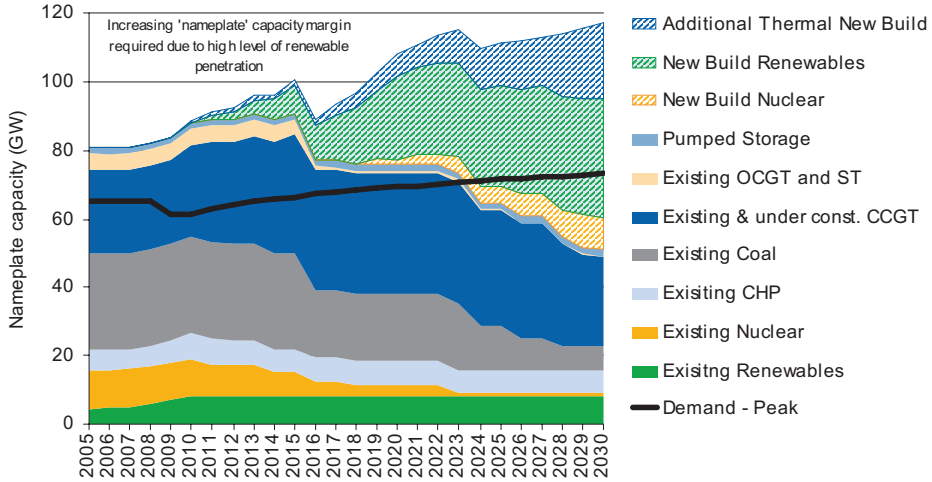
This all adds up to a world where generation has high capital cost and low flexibility. There will also be a large proportion of generation with low marginal costs. It begs the question as to where CCS with its high capex and relatively high operating costs fits in to the picture.

Conventional financial models for project valuation look at half yearly revenues and costs, often taking average prices and assuming baseload running as a good approximation for revenues. However in a world where wind could potentially move from generating more than 40GW of wind power to zero in just a few hours, capturing price spikes will be a key component for revenue generation. Commercial and technical decisions will need to consider not only the cost of the energy produced but also the value of flexibility.

Decision making – investing in CCS in 2025

Over the next few issues of the Carbon Capture Journal, Pöyry Energy Consulting will be writing a series of articles covering the evolving energy markets, the potential role for CCS in these markets, the investment decision and business models for the new value chain. Specifically, we will examine the following issues.

Pöyry: UK power generation capacity scenario to 2030



1. The implications of increased levels of renewable power generation on CCS

Our recent intermittency study[1] examined scenarios for significant increases in wind generation in the UK and Irish markets.

The analysis included the potential impact on load factors for various technologies and the extent to which wind and nuclear might displace coal and gas-fired generation (with and without CCS). It raises questions about where CCS plant will fit in the future merit order and how the economics of CCS coal compare with CCS gas.

2. Valuing flexibility

The intermittent nature of wind is likely to increase the volatility of wholesale electricity prices and increase the importance of flexible and peaking generation. Our modelling suggested that in 2030 CCS units could be starting 60 to 70 times per year, implying that they will predominately operate during the week and switch off for weekends.

There may also be concerns over the extent to which installed CCS facilities will be used. For example, when capacity is tight, the wholesale power price will rise, which incentivises operators to switch off their CO2 scrubbers, sell the energy otherwise used in the capture process, i.e. avoid the efficiency penalty, and pay for the vented CO2.

These possibilities have profound technical, regulatory and financial implications for CCS. From a technical perspective this raises concerns over whether CCS units can be made more flexible without adversely affecting capital and operating costs or overall performance, and when CCS can be considered commercially viable.

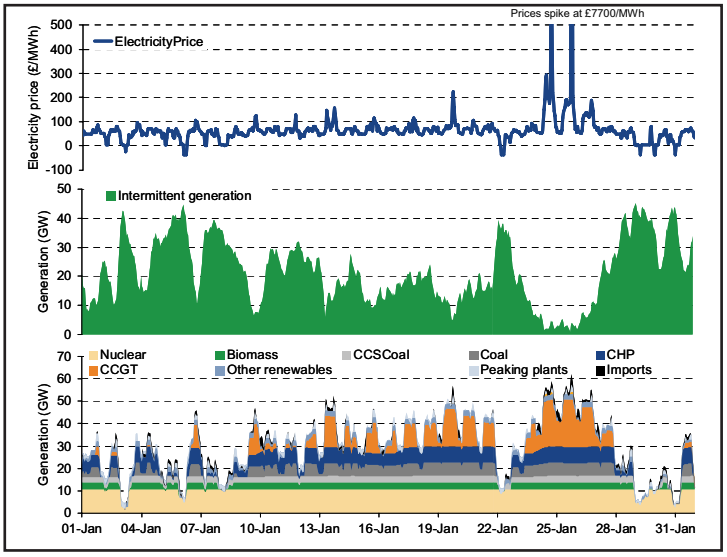
3. Changes to energy market design

There is currently considerable debate about whether competitive markets will deliver the required investments in new low carbon generation capacity or whether a more interventionist approach is required.

However, it is important to recognise that governments are seeking to balance three key policy objectives of which the environment is only one. Historically, the focus of UK and EU regulators has been on security of supply i.e. ensuring generation adequacy and fuel diversity, and promoting competition. The result is a relatively unstable policy framework in which the different objectives often pull in opposing directions.

In the UK a number of proposals to revise market arrangements are currently being discussed. Ofgem's recent Project Discovery posits a number of options ranging from targeted reforms, focused on a minimum carbon price and strengthening price signals, to the creation of a Central Energy Buyer for both energy and capacity.

Reforms being considered by DECC include a return to capacity payments in which power generators would be paid for the electricity they generate and also for capacity made available. The purpose of such payments would be to give greater certainty to investors in renewable and nuclear energy.



UK market 2030: January power generation simulation

It will be a major challenge to successfully revise market arrangements to achieve these objectives at a time when significant investment is required to replace retiring generation capacity. It is key for the nascent industry to understand the potential implications of changes to electricity trading arrangements for the commercial deployment of CCS.

4. Business models: Where's the risk and how to manage it?

Business models for CCS will need to find an acceptable way in which the market, technical and operational risks can be mitigated across the various parties involved in the value chain.

The key challenge is to find a business model which shares risks and rewards in a way that adequate returns are earned by each individual party as well as for the project as a whole. In addition to actions at company level, the CCS industry as a whole can work at reducing these risks notably through technology testing and information sharing.

Government has an important role to play in mitigating risks, both in introducing a policy framework favourable to CCS and in the early stages of commercialisation, establishing the appropriate funding mechanism for CCS to allow the industry to overcome the penalties it faces with regards to its short-run marginal costs. Government may have a further role to play, in preparing the foundations for a vibrant CCS industry, by:

• increasing confidence in the available storage capacity;

• removing any barriers and incentivising the deployment of a CO2 transport network; and

• identifying and resolving constraints in the CCS supply chain, such as engineering, manufacturing, operational expertise, and available finance.

At Pöyry we believe that the challenges are significant but can and will be overcome. This will require careful and intelligent marshalling of resources by industry and government and supportive regulatory and policy frameworks. The key is for industry to understand the role of CCS in the broader energy market context, how it is likely to operate, the likely project risks and how they can best be mitigated.

More information

Pöyry Energy Consulting is Europe's leading energy consultancy providing strategic, commercial, regulatory, and policy advice to Europe's energy markets. Our team of 250 energy specialists, based in fifteen offices in twelve European countries, offers unparalleled expertise in the rapidly changing energy sector.

Our Carbon Capture and Storage practice is recognised as one of the leading consultancies in CCS. Recent projects include policy advice to Governments, economic assessment of several potential CCS projects and strategic advice to many leading industry participants.

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What's in the pipeline?

It is becoming increasingly certain that the UK's first steps into full scale CCS will be subsidised by the electricity consumer via a new legislative scheme. It is less clear whether the projects which become the recipients of this public funding will create a foundation of infrastructure designed to promote subsequent growth in the UK's CCS industry.

Calum Hughes of Yellow Wood Energy considers this issue and the policy considerations that surround it

The UK Government has now accepted that, if it is to meet its CO2 emissions reduction targets whilst maintaining an acceptable level of security of energy supply, the installation of CCS on fossil fuel fired power plant is essential.

It also recognises that, given the uncertainty of the signals coming from the carbon markets, if this is to be done within the timescales recommended by the Government's advisors, then the early development of the CCS industry must be subsidised.

Accordingly, provisions of the Energy Bill, currently going through Parliament, include powers to raise and distribute funds in order to provide financial assistance to CCS demonstration projects. Those funds will be raised through the charging of a levy on electricity supplies which, DECC has estimated, will increase electricity bills by between 2 and 3 percent and will generate between £7.2bn and £9.5bn.

In the wording of the Bill (at the time of going to press), the application of these monies will be to projects which, "demonstrate and assess carbon capture and storage technology through its use in commercial electricity generation".

Benefiting future CCS development

There are currently a number of consortia working on development proposals for CCS projects which would vie for a slice of this funding. The individual projects are, generally, at the front end engineering stage and specifics of the design schemes are not known.

However, unless constrained to do otherwise, it seems likely that the developers of these projects will pursue a design specification based upon a CCS chain which operates in isolation of any other CCS project or potential project and will seek to optimise the economics of their project on that basis.

Therefore, they are unlikely to want their project to be saddled with the constraints (which are likely to be onerous) associated with ensuring that it should form the basis of future national, or regional, CCS infrastructure.

This is a problem if there is a desire that public subsidies from the new levy should be applied in order to yield the greatest benefits for the industry, and society, as a whole. Recent studies have concluded that an integrated network based upon 'backbone' pipelines is likely to be the most efficient long-term option and offer the fewest barriers to entry, whilst point-to-point pipelines offer lower costs for first movers and do not have the same capacity utilisation risks as 'backbone' pipelines.

It is likely, then, that, without incentives for the development of optimized networks, project developers will build pipelines without factoring in the flexibility required to accommodate new entrants.

This is unfortunate, as there are many reasons why the UK's demonstration projects should incorporate such flexibility: if the UK's Climate Change Act commitments are to be met, then virtually all CO2 emitting power generation in GB will be required to have CCS by 2030; if UK ETS participants are to avoid the risk of being at a disadvantage to their competitors in mainland Europe as EUA prices rise, then they will need access to CO2 transportation and storage infrastructure comparable with that in Europe generally; and an emerging UK CCS products and services industry, with the jobs and revenues it would bring, would benefit from a considered framework for the development of its home market.

All of these issues would be addressed with the construction of CO2 pipeline systems that have spare capacity and are suitable for efficient integration.

Open access to pipelines

There are also concerns as to what extent an inability of prospective new entrants to gain access to established CO2 transportation infrastructure might adversely impact on the EU's priority objective of developing a genuinely competitive internal energy market. The provisions of the Carbon Capture and Storage Directive address this specific issue and to some extent, the issue of access in general.

The Directive requires Member States to ensure that potential users of CO2 transport networks and storage sites are provided with access to them in a transparent and non-discriminatory manner. However, the method of conforming with this requirement

"Unless constrained to do otherwise, it seems likely that the developers of these projects will pursue a design specification based upon a CCS chain which operates in isolation of any other CCS project" - Calum Hughes, Yellow Wood Energy

is to be determined by each Member State, and how this is transposed into UK law has yet to be seen; 'access' need not, necessarily, equate to a requirement that project infrastructure should be capable of efficient integration with that of other projects or that there be sufficient spare capacity to be worth accessing.

Shifting sands

However, delivering demonstration project infrastructure which is suitable for future integration is not easy. Some of the obstacles are particularly evident if one considers government CCS policy over the past 12 months.

This time last year, ministerial talk was of eight coal-fired power stations with CCS being the preferred number for GB's energy mix. Then, in April, under apparent Treasury pressure, this number was reduced to 'up to four', which, it became clear, was to include the original demonstration competition.

The importance of coal to energy security policy was reiterated when, in a recent debate, the Government owned that, as part

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of its energy fuel mix policy, it considered it necessary that GB should have at least four coal-fired power stations and that, in order to achieve this, the Energy Bill, as introduced, mandated that CCS Incentive monies should only be applied to subsidise projects based upon coal-fired plant.

Currently, however, most generators remain more interested in building gas-fired than coal-fired plant in the UK, even if the installation of CCS on the coal-fired plant is subsidised by the State. This has made it difficult for Government to attract the desired number of developers to show interest in the demonstration projects, let alone dictate unwelcome terms regarding the projects' specification.

It seems that these difficulties, doubtless coupled with lobbying from large gas producers, have contributed to the amendment to the Energy Bill removing the restriction on the incentive monies going to coal-fired power generation projects and thereby widening the ambit to simply 'commercial electricity generation' based projects.

Whilst there is no suggestion that this legislative change has altered the basic Government policy with respect to coal-fired plant in the energy mix, it is to be hoped that it will strengthen Government's position by widening interest in the demonstration project process.

Planning ahead

Another obstacle that is often cited as a reason why the demonstration projects could not be designed for integration with a future industry model is that the form which the future industry may take is not known and, because there are so many potential permutations, predicting it with useful accuracy is very difficult. This argument has merit if it is posited as a guard against expending excessive resource on trying to discern the future in great detail, but is wrongly interpreted if it leads to a conclusion that all work to predict the shape of the industry's future development is pointless.

Some forward looking studies have been commissioned, but when the Government's stance on CCS is compared with, for example, that on smart grids, the difference is striking. Regarding smart grids, DECC has stated, "Early decisions we make to develop smarter capability on networks will set the direction for coming decades, so we must be clear that we make the right investments now to provide scalable and flexible foundations for future developments." It is unclear why this argument does not apply equally to CCS infrastructure.

One solution may be to plan an optimal CO2 transportation network for GB and provide developers with the information they need to interface with it. This would ensure that the demonstration project infrastructure was suitable for future integration and also give a guide to the rest of industry and investors as to policy regarding the way ahead.

Some guidance has been forthcoming: the Climate Change Committee has recommended that pipeline constructors should be obliged to oversize pipes; and government commissioned studies have stated that pipelines should be constructed with pre-installed branch points, facilitating third-party access to their pipelines. Recent announcements by E.ON are evidence that some developers are considering these issues when designing their schemes.

However, whilst these are important design considerations, they by no means constitute a complete list: pipeline working and operating pressure; associated pipeline specification breaks; requirement for, and situation of, booster compression; fluid composition and dew point specifications; system operating constraints (including the capacity to conform with Grid Code requirements); as well as the obvious factor of the size and configuration of the onshore and offshore networks as a whole; all have the potential to restrict the flexibility of the early transportation infrastructure with respect to its incorporation into a transportation system for the whole industry.

As we have seen, the UK government has had a difficult task in recent times in trying to find a way to fulfil its ambitious climate change targets whilst ensuring energy security, but all indicators point to a commitment that CCS will be part of its strategy to achieve these goals. It is to be hoped that, once the election is over and the Energy Bill becomes law, with its new broader ambit, increased industry enthusiasm for the demonstration projects will develop and that this will allow government to plan ahead for efficiently designed CCS infrastructure in GB.

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More information

Calum Hughes is an engineer and a solicitor with more than twenty years experience in engineering and the project management of EPC projects in the oil and gas and process industries. He specialises in the law, regulation and policy associated with CCS projects.

In the next edition Richard Haigh of Yellow Wood Energy will investigate to what extent the design of the commercial and regulatory framework applying to the CCS demonstration project phase should take into account the future development of the industry.

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Creating trust and building confidence in CCS operations

This article deals with developing best practice guidelines for capture, transport and storage in the CCS value chain, the public acceptance challenges which CCS technology is facing, and how they can be handled through joint industry and regulatory efforts.

Marius Lunde, Anastasia Isaenko and Knut Kvien, DNV

The essence of the challenges

Carbon Capture and Storage (CCS) is an important part of the lowest-cost greenhouse gas mitigation portfolio. IEA analysis suggests that without CCS, overall costs to reduce emissions to 2005 levels by 2050 increase by 70% (IEA, 2009).

To accelerate the deployment of CCS in a safe and sustainable way there is a need for unified, recognised and publicly available guidelines that contribute to:

- proper selection and qualification of well-suited sites according to recognised procedures;
- efficient and harmonised implementation of legal and regulatory frameworks for CCS;
- predictable frame conditions for developers, regulators and other stakeholders;
- a swift transition from research and demonstration scale projects to large scale CCS;
- the proper management of risks and uncertainties throughout the life of a CCS project.

Meeting the challenge

As a major provider of verification and risk management services, DNV took the initiative to manage three joint industry projects to develop best practice guidelines for capture, transport and storage in the CCS value chain. All of these guidelines are to be kept up to date in the form of DNV Recommended Practices.

The three initiatives taken by DNV are aimed to help regulators and operators manage risks in CCS projects in a structured manner and in agreement with regulations. Public trust can be gained through such structured and standardized procedures, increasing transparency and traceability for the stakeholders.

The guidelines do not intend to prescriptively determine how the projects risks shall be managed, but set out a framework in which a project developer can manage and document how risks have been identified and managed. Increased public acceptance can also be gained through independent parties' involvement throughout the process. It has been important for the guideline development that all major parties in the industry, including governmental and environmental stakeholders, have been consulted and thereby giving the documents a high impact in the industry.

By the publication of these guidelines on capture, transport and geological storage of CO2, DNV aspires to increase industrial maturity in the field of CCS. A common feature for the documents is that they are focused on creating confidence in the various CCS stages for the stakeholders, including the public. All three guidelines will be published as DNV recommended practices in 2010.

Capture – qualification of CO2 capture technology

As mentioned initially it is expected that a significant part of the world's future need for electrical energy and heat will come from burning of natural gas, oil and coal. Thus, there is a need for technological solutions that capture CO2 when burning fossil fuels. Over the last decade, substantial resources have been directed towards developing cost-efficient solutions that involves capture, transport, and storage of CO2.

Current status of CO2 capture technology

There are currently several different technologies under development and testing for CO2 capture, but all of them are applied on a smaller scale than the one planned to be used in the near future within the power generation industry. The carbon capture technologies that are available today require large efforts to integrate, optimise and scale up the process components to create an industrially mature process.

There are technical and economic risks associated with implementing large-scale immature process systems. Important factors that have a big impact on a project's economy are, for instance, the need to ensure a reliable energy supply. The main challenge facing the development and implementation of CO2 capture technologies is to ensure that they are cost-efficient and reliable, safe and environmentally friendly.

It will be of major interest for technology vendors, operators, as well as governments, that these technologies can be implemented with technological risk adequately understood and managed to an acceptable level so as to give confidence, and that they will work as intended over the lifetime of the project.

Capture - there is generally a lack of relevant codes and standards for new technology, systematic qualification is therefore the rational approach

The issue of trust related to the CO2 capture technologies is significant, and is closely linked to the commercial, economic and technological challenges referred to above. In this case trust is defined as the ability of technological solutions to be reliable and functional according to the criteria and expectations defined for particular item.

Implementation of new CO2 capture technologies

Based on observations referred to above, as well as input and requirements stated by other industry sectors, DNV developed a guideline for the qualification of CO2 capture technology. The development of the guideline has been organised as Joint Industry Project, with Aker Clean Carbon / Aker Solutions, Statoil, Statkraft Development AS, Gassnova SF / Climit and DNV as partners.

Technology qualification is a systematic set of activities that contribute to reducing risks with the implementation of new technology.

There is generally a lack of relevant codes and standards for new technology. Qualification according to functional requirements and reliability targets is therefore the rational approach. The objective of the qualification work process is to confirm that such requirements stated by the technology owner are complied with. This is done by identify-

ing potential failure modes related to the novel aspects of the technology, carrying out a risk ranking and setting up a test and analysis plan addressing the major contributors to overall risk.

Technology qualification is defined as:

"The process of providing the evidence that the technology will function within specific limits with an acceptable level of confidence."

The procedure explains in detail how to identify, describe and manage risks involved in the implementation of new CO2 capture technology in a quantitative way by following a set of sequential steps resulting into transparent qualification process.

Transport – CO2PIPETRANS

Pipelines are likely to be the primary means of transporting CO2 from point-of-capture to sites (e.g. underground reservoirs) where it may be stored indefinitely to avoid its release to the atmosphere. CO2 pipelines exist at the moment, but there is relatively little global experience in pipeline transportation of dense phase CO2 in the scale that will be required for CCS.

While there is a current perception that transporting CO2 via pipelines does not represent a significant barrier to implementing large-scale CCS, there is significantly less industry experience than for hydrocarbons (e.g. natural gas) and there are a number of phenomena that need to be adequately understood and the associated risks effectively managed.

Guideline for safe, reliable and cost-effective transmission of CO2 in pipelines

DNV through a well supported Joint Industry Project has developed the guideline for safe, reliable and cost-effective transmission of CO2 in pipelines. The initiative was sponsored by a number of companies, including Gassco, Statoil, Shell, BP, Vattenfall, ArcelorMittal, ILF, Petrobras, BG Group, Chevron, Dong Energy and Gassnova / Climit. IFE, SINTEF and Polytec assisted DNV in the execution of the work.

The guideline provides guidance and sets out criteria for the development, design, construction, testing, operation and maintenance of steel pipelines for the transport of CO2. It is written to be a supplement to existing pipeline standards and is applicable to both onshore and offshore pipelines. The guideline is intended to assist in delivering pipelines in compliance with international laws and regulations.

The purpose of the guideline is to support a pipeline operator, and possibly other stakeholders like local HSE authorities and pipeline engineering companies, within the field of carbon transport and storage, on technical, safety and economical issues during the entire lifetime of pipelines used for transport of CO2.

There are international standards today that may be, and have been used, to design and operate pipeline systems for CO2 transport internationally. Today, however, the awareness is higher both among the industry and the authorities regarding the general perception of CO2 as a substance for transport in large and geographically interconnected pipeline systems.

Higher awareness is typically related to the understanding of failure probabilities as well as failure consequences contributing to the overall risk picture. Linked with this higher awareness is the continuously increased scientific and industrial learning of the technical difference between transport of CO2 in large volumes in pipelines compared to transport of hydrocarbons.

DNV guideline identifies potential technology or knowledge gaps between pipeline transportation of CO2 and hydrocarbons. International recognised standards for pipeline systems will be the basis also for pipelines for CO2 transport, but the guideline will serve as an important and necessary support for specific issue of CO2 transport.

The guideline provides recommendations identified or developed during the execution of the JIP technical studies through which the following issues were addressed:

- Fatigue
- Fast propagating ductile fractures
- Pipeline Operations
- Flow assurance
- Corrosion
- Material compatibility
- Safety
- Re-qualification of existing pipelines, for conversion of service from a non-CO2 substance to transport of dense phase CO2.

Storage – CO2QUALSTORE

The CO2QUALSTORE guideline provides a systematic risk-based approach to selection and qualification of sites and projects for CO2 Geological Storage (CGS). One of the key intentions of this guideline is to guide how to safely and efficiently select and manage CGS sites in agreement with regulations, international standards and directives.

Based on extensive experience in risk-based project management, DNV took the initiative for creating this guideline through broad industry collaboration. The partners actively involved in this project were:

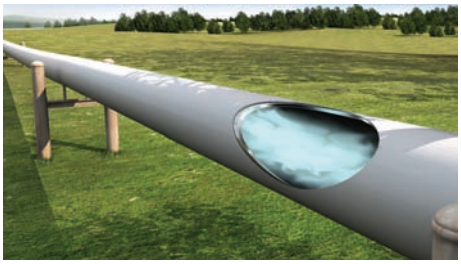
• Oil and gas companies (BP, BG group, Petrobras, Shell and Statoil)

• Energy companies (DONG energy, RWE Dea and Vattenfall)

• Technical consultancy and service providers (Schlumberger and Arup)

• IEA Greenhouse GAS R&D programme

• The Norwegian public enterprises Gassnova and Gassco



Transport - there is relatively little global experience in pipeline transportation of dense phase CO2 in the scale that will be required for CCS

Current status of the CGS technology

CGS has already successfully been implemented in several operational CCS projects around the world. In addition, the use of CO2 for enhanced oil recovery (EOR) is an ongoing commercial industry in USA. The technology and methodologies needed for CGS originates from the exploration and production activities of the oil and gas industry.

The major difference between CGS and hydrocarbon production is that exploitable hydrocarbon reservoirs already are proven to be non-leaking over a geological time scale (i.e. otherwise there would not be hydrocarbons present to be produced.) Thus, one of the main focuses of implementing a CGS project is to select a suitable site and survey the site throughout the project lifetime to assure that the injected CO2 stays in place.

Currently the major challenges with CGS are to get international regulations and commitments in place regarding:

• The price of CO2 emissions being at a sufficiently high level so that the CCS projects get commercially sustainable

• International agreements allowing CO2 to be transported across international borders

• Dedicated regulations regarding CGS permits

• The liability issues connected to CGS

The guideline has been made to be globally valid and is therefore made flexible allowing a project to be tailor-made for both local geological site needs but also local regulations.

Responsible and structured project management based on the guideline

In this guideline, the various phases of the entire lifecycle of a CGS site involving the site screening, site selection, operation and

closure phases, have been split into milestones, qualification steps and regulator permit steps.

The various step descriptions found in this guideline assist project developers and stakeholders reach consensus regarding the objective of each step and how these objectives should be met. Moreover it indicates documentation which the regulators request from project developers at given milestones.

Finally the guideline provides a basis for verification and evaluation of the predicted and measured performance of a CGS project in terms of safety, environment and, optionally, emission reduction. This verification is done by the operator, a competent authority or an independent third party.

In order to increase the benefit of the guideline an associated workbook has also been made with practical examples illustrating the various topics of this guideline.

Gaining trust and confidence by the general public

The general public is not identified as a direct user of this guideline. However, by implementing the guideline at a CGS site, the operator and regulator can provide assurance to the general public that the site has been selected based on a transparent and recognized process, that the site will be managed safely and responsibly according to industry practice and that the site is in compliance with regulations and relevant directives.

A project developer should also gain public trust and confidence by documenting that the various relevant workflow steps have been executed and thereby showing that the site has been chosen and operated in a recognised and traceable manner.

The guideline recognizes the importance of a good and tuned communication with the public since perception and acceptance of risk involves a subjective balancing of benefits with risks. Particularly, in cases of significant irregularities, it should be promptly and openly communicated to the public that the incident have been reported to the relevant authorities, that the scale and origin of the problem has been assessed, that effort are made by the project developer to avoid similar incidents in the future and that continued site activity will only be permitted if the incident is assessed by a transparent and recognized procedure.

In order to enhance the credibility of this communication process, the guideline suggests that an independent third party is involved in analyzing and communicating the implications of significant irregularities on human health and the environment. A useful way of communicating risk is through comparing the incident to analogue risk examples from other large-scale infrastructure developments or oil and gas activities.

Surveying a CO2 storage site through monitoring

An integral part of a CGS project is site monitoring, and it takes place at all the various phases of a CGS site lifecycle. Monitoring provides measurements which can be transformed into information about the location, extent and rock properties of the reservoir as well as the cap rock above the reservoir. Moreover, monitoring is used to survey the location of the injected gas plume and also detect events along with locations of possible leakages.

The guideline recommends that a monitoring plan tailored to the particular site location should be submitted to the authorities as part of the storage permit application. The monitoring plan is combined with a plan for verification of the resulting data and accounting for the CO2 emissions avoided by the project. The plan should recommend monitoring methodologies which are feasible for the particular location along with a ranking of the various methods from a cost-benefit viewpoint. Although all feasible monitoring techniques can be applied does not mean that all should be implemented since the usefulness of data acquired by the various monitoring techniques will differ as will the cost of deployment.

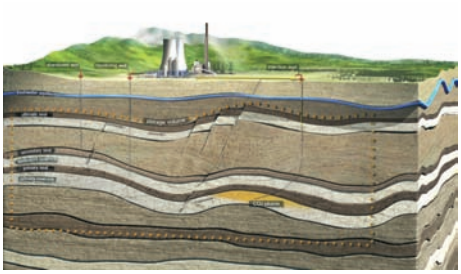
Applying a systematic, continuous and tailor-made monitoring of a CGS site along with creating a monitoring plan already prior to applying for an storage permit are important means for a project developer to gain public trust and acceptance.

Systematic increase of knowledge about a CO2 storage site

The information about the location of a CO2 storage reservoir along with the location and amount of injected CO2 are extracted from mathematical models of the underground (i.e. static models) along with flow simulations of the CO2 injection (i.e. dynamic models.)

These models are built using monitoring data and are updated throughout the lifecycle of a site to agree with new monitoring measurements. The degree of necessary model updates is dependent on how well the existing models predict new measurements and the predictions are expected to improve with increased gathered information about the site.

The guideline recommends recording the model updates in view of the evolving interpretations of newly gathered monitoring data. In this way the knowledge about the geological site and location and volume of the injected CO2 is documented in a traceable and reproducible manner.



Storage - CO2 geological storage sites must be properly qualified and monitored

Moreover, this record will be the basis for limiting the possible scenarios in case significant irregularities happen and to locate and explain an undesired incident. As mentioned above, this information is crucial when creating an open and trustworthy communication with the public in case of an undesired event. Finally, the model documentation will be the basis for justifying that it's safe to close a storage site and that the injected gas will stay in place after the site has been abandoned.

Concluding remarks

These three joint industry projects aim to provide a path forward for the industrial opportunities relating to CCS. The outcome of the projects provides international standards, methodologies and guidelines that will form the basis for industrial agreements and become valuable input to the implementation of national requirements. The new standards aim to facilitate and speed up CCS project development, decision processes and ongoing regulatory development, both in Europe and worldwide.

The key challenges the projects address include how to safely store CO2 in subseabed formations, how to qualify CO2 storage projects and new CO2 capture technology, and what should be the industrial standard for the transport of CO2 in pipelines.

About DNV

Det Norske Veritas (DNV) is a global provider of risk management services, helping customers to safely and responsibly improve their business performance. DNV is an independent foundation with the purpose of safeguarding life, property and the environment and has a network of 300 offices in 100 countries. DNV serves a range of industries, with a special focus on the maritime and energy sectors, combining technology expertise with industry knowledge.

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ERP report says next 10 years 'critical'

A recent report, "Innovation Milestones to 2050", identifies a pressing need for investment in energy technologies with the greatest potential, such as CCS, increasing the chances of early deployment.

www.energyresearchpartnership.org.uk

The Energy Research Partnership (ERP) is a high level forum co-chaired by David Mackay, DECC's Chief Scientific Advisor and Nick Winser, Executive Director of the National Grid.

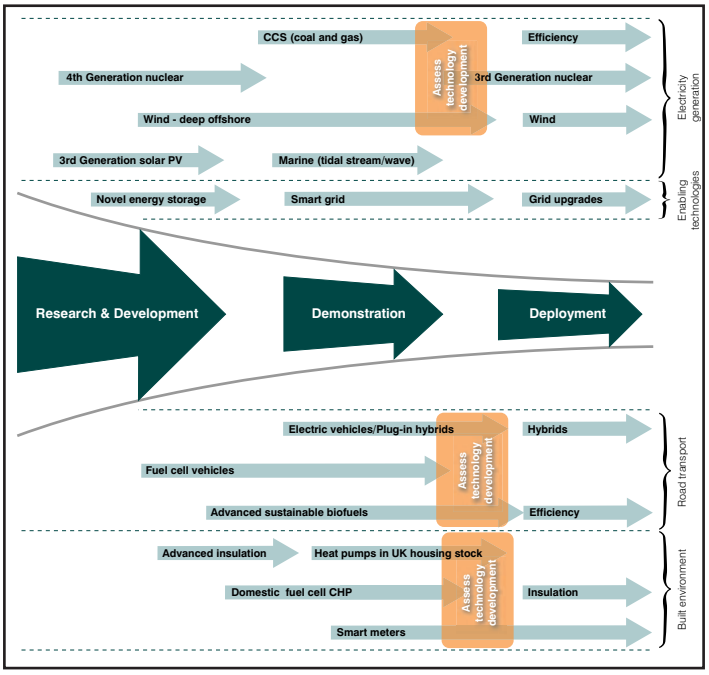
It brings together key players from industry, government and other organisation to advise on the strategic direction of UK energy research, development and demonstration to increase the level of investment in innovation and commercialisation.

The report says that in the move to meet climate change 2050 targets, the UK can risk locking the energy system and the public into an undesirable future if the long-term whole energy system is not considered when making choices.

It shows that the next 10 years is critical, with key technologies needing demonstration before making policy and investment decisions that will affect where our energy comes from and how we use it.

The demonstration of the viability of technologies such as Carbon Capture and Storage (CCS) in the power system will have a big impact in the composition of the future energy mix portfolio. The report considers the impacts that this will have on the energy system: should CCS prove too expensive, for example, or not be able to deliver on the scale required, other technologies such as wind and nuclear will have to be deployed at a much larger scale.

The report states that by 2020, nuclear power, upgrades to the electricity grid, more efficient and hybrid vehicles, wind, smart meters and insulation of buildings should already be making a contribution to carbon reduction goals. At the same time, carbon capture and storage (CCS), deep offshore wind, smart grids and heating and transport technologies should be following close behind while moving through the demonstration stage.



Pipeline of selected energy technologies showing progress required by 2020 (Source: Innovation Milestones to 2050 (2010))

Beginning the process now means that by 2020 a clearer picture will emerge of which technologies will be available, and what impact this will have on the whole energy system.

The Energy Research Partnership report is based on a wide-reaching analysis of scenarios and roadmaps from industry, academia and Government covering the next 40 years.

ARI report - CCS could increase US oil production

The US has an opportunity to increase its energy independence, slash foreign oil imports by as much as half by 2030, and cut carbon emissions through EOR with CCS, according to new analysis by Advanced Resources International (ARI).

EOR with CCS would help drive domestic economic growth and increase US oil reserves, says the report "U.S. Oil Production Potential from Accelerated Deployment of Carbon Capture and Storage".

Clean energy and climate legislation that is being considered in the U.S. Congress is projected to lead to large volumes of captured CO2 from power plants and other industrial sites, sufficient to fully develop oil recovery potential in existing U.S. oil fields.

"Using CO2 to enhance oil recovery is neither a new nor an exotic technology. There is no doubt that a large market exists for CO2 emissions captured from industrial sources and power plants for expanding domestic oil production," said Mr. Tracy Evans, President, Denbury Resources Inc., a leader in CO2-enhanced oil recovery in the Southeast and Northwest.

"The single largest deterrent to expanding production from CO2-EOR today is the lack of large volumes of reliable and affordable CO2."

The report finds that carbon capture stimulated by federal clean energy and climate legislation could boost U.S. oil production between 3 to 3.6 million barrels per day, cutting imports of crude oil up to 40 percent compared to today's levels and up to 52 percent by 2030 (based on 2009 figures), depending on how much of the captured CO2 is used for enhanced oil recovery purposes.

This CO2-enhanced domestic oil production would help keep more than $700 billion in the U.S. economy, employing tens of

thousands American workers, while increasing state and Federal revenues between $190 and $210 billion.

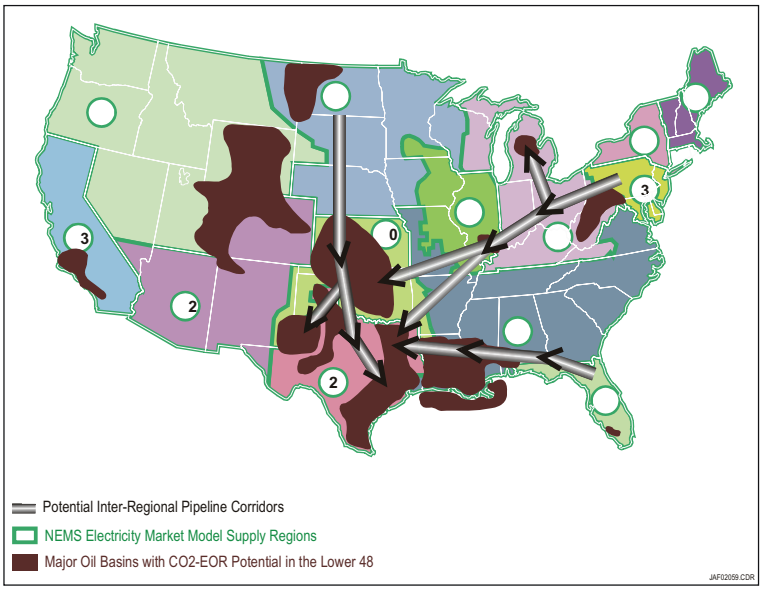
In addition, the report shows that the U.S. can significantly cut and sequester carbon emissions by up to 530 million tons per year by 2030. This is the equivalent of taking 88 million cars off the road.

The clean energy and climate legislation that is pending in Congress would help to stimulate and support rapid deployment of carbon capture and storage in power generation and other industrial facilities that emit significant volumes of carbon dioxide.

"This is an important piece of the puzzle for reducing our dependence on foreign oil and cutting carbon emissions. With the right policies and investment in demonstrating EOR technologies, captured CO2 could be productively used to produce more domestic oil from existing oil fields," said Mr. Mike Godec, Vice President, Advanced Resources International.

"These are benefits that should appeal to a broad range of politicians and business leaders - not to mention the general public that wants greater national security and more energy independence."

The new report indicates that the states that would benefit the most from CO2-EOR include: Arkansas, California, Indiana, Illinois, Kansas, Louisiana, Montana, New Mexico, North Dakota, Oklahoma, Texas and Wyoming.



Possible way that U.S. CO2 capture, transport and storage could evolve (© Advanced Resources International, Inc. 2010)

CER report - what the EU needs to do

Coal will be the world's biggest single source of electricity for decades to come. Yet the EU is doing far too little to encourage the take-up of CCS, says a report by the Centre for European Reform (CER).

www.cer.org.uk

This failure threatens not only Europe's leadership of global climate change policy, but also its ability to profit from the emergence of a huge global market for equipment and expertise, says the report, called CCS - What the EU needs to do.

Stephen Tindale, co-founder of Climate Answers and a previous head of communications and public affairs for RWE npower renewables and executive director of Greenpeace UK, and Simon Tilford, chief economist at the Centre for European Reform, argue that more public money is needed for the construction of demonstration projects, and that regulation and strong market signals will be required to ensure mass deployment of the technology.

The authors argue that the EU needs to do a host of things if it is to meet its targets of operating 12 large CCS demonstration plants by 2015, and ensuring the mass deployment of the technology by 2020.

- The demonstration plants must cover the full range of CCS technologies and include gasfired as well as coal-fired industrial plants.

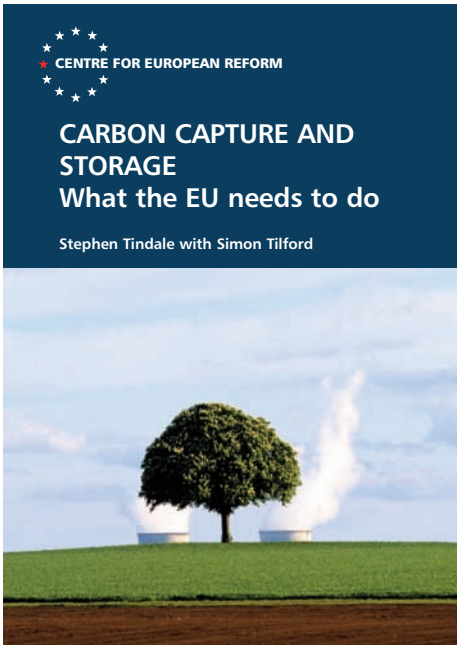
- There needs to be greater certainty about the scale and timing of public funds for CCS. Member-state governments should also introduce levies on electricity suppliers and use the revenues to help finance investment in CCS.

- Public subsidy alone will not be enough to secure the take-off of CCS. Given the poor outlook for the EU economy, the Commission needs to intervene in the EU's emissions trading scheme to bolster carbon prices.

- As soon as CCS is proven at scale, the EU should set a date by which it will become mandatory. In the absence of EU-wide regulation requiring the use of CCS, member-states should push ahead with their own national rules.

- There should be geographical clusters of CCS projects. The creation of such clusters would reduce the unit cost of constructing each plant as well as the cost of transporting the carbon dioxide.

The report concludes, "On current trends, CCS will be slow to take off in the EU. As a result, the EU will struggle to assume leadership of this crucial new technology. The rest of the world is not standing still. China, the US, Canada and Australia are all now actively pursuing CCS, making substantial public funds available, and the new Japanese government plans to do the same. The potential prize is considerable – a huge global market for equipment and expertise. But if Europe wants to secure business benefits, it will have to move fast."



Policy, company and regulation news

UK launches CCS Industrial Strategy

The UK government has published a CCS Industrial Strategy which outlines how the country can become a centre for CCS innovation and business with an industry worth up to £6.5 billion and sustaining up to 100,000 jobs by 2030.

An Office of Carbon Capture & Storage (OCCS) within DECC (Department of Energy and Climate Change) has also been set up as a focal point for the facilitation of CCS activities in the UK.

As part of the strategy, Yorkshire and Humber was named as the first low carbon economic area for Carbon Capture and Storage. Other regions like Teesside, Merseyside and Thames Valley could also become similar centres for the technology.

The region's Ferrybridge power station, owned by SSE, was awarded £6.3 million towards its £21 million 5MW carbon capture trial by DECC, the Technology Strategy Board and Northern Way. SSE is collaborating with Doosan Babcock and Vattenfall on the project.

"Today's announcement is a positive step towards deploying CCS in the UK," commented Jeff Chapman, Chairman of the Carbon Capture and Storage Association (CCSA). "To meet our climate change targets, CCS needs to be deployed on coal and gas generation and is the only option for decarbonising the steel and cement industries; this strategy outlines a realisable roadmap to developing CCS for these applications."

The way forward for CCS to 2030 will be charted by a UK CCS roadmap which will be one of the first activities for the newly formed OCCS.

The report also looks at how to provide an opportunity for project developers to propose co-located ("clustered") capture projects, developing experience of shared pipelines and storage. "The CCSA has maintained establishing a planned transportation infrastructure will be essential," said Mr Chapman.

A parallel study to explore the potential for CCS business clusters in the UK was also released. It looks at how geographic concentrations of interconnected businesses, suppliers, and associated institutions could work together to take best advantage of the global CCS market.

UK awards funding for design studies in clean coal competition

www.decc.gov.uk

Funding was awarded to E.ON and ScottishPower for design and development studies as part of the UK's CCS demonstration competition.

The funding is drawn from a pot of £90 million announced in the 2009 Budget. The precise amounts awarded to E.ON and ScottishPower are commercially confidential.

The funding will support Front End Engineering and Design (FEED) studies, which will enable the bidders to further their designs for the projects at Kingsnorth and Longannet respectively. These studies involve detailed engineering and design work and will be completed within twelve months, after which the final competition winner will be selected.

This is one of the first set of studies of end-to-end commercial scale CCS on coal power plant in the world and will be used by project developers to examine and refine initial plans and reduce technical risk, so that more detailed project plans can be drawn-up and costed, said the government.

A Bill currently being considered by Parliament introduces a levy to support four CCS demonstrations in the UK. The Government says it will launch a competitive process for the three other projects by the end of 2010, provided the levy is passed.

UK Conservatives promise to end 'pointless delays' on CCS

A Conservative Government would put UK CCS back on track, bringing the current CCS competition to a rapid conclusion, according to a new Conservative Energy policy document.

It would also expand the demonstration programme to at least four facilities (including the current competition) and include both pre-combustion and post-combustion technologies

The policy is outlined in "Rebuilding Security - Conservative energy policy for an uncertain world."

CCS pipelines would be planned and located where the greatest capacity for growth can be provided at the lowest costs – enabling efficient, shared access to transportation and storage infrastructure, said the report.

All new coal-fired power stations would have to incorporate CCS technology from the outset and an Emissions Performance Standard would be used to underpin progress on the level of carbon capture and efficiency of each plant – guaranteeing consistency with UK carbon budgets.

The party's preference would be to fund the CCS demonstration programme from EU Emissions Trading System receipts, but would adopt the funding mechanism proposed in the current Energy Bill if that is required to avoid further delays.

The report also talks about how to reform the climate change levy (CCL) by making it payable 'upstream' on the carbon content of electricity when it is generated rather than from the 'downstream' supply of electricity to consumers.

UK north east CCS prospectus released

www.onenortheast.co.uk

One North East has published a prospectus for the development of a CCS cluster in North East England.

The document identifies the region's strengths and future plans for CCS, whilst making a strong case for further investment in the North East. CCS is necessary for a number of industrial processes to reduce their greenhouse gas emissions and is particularly vital in North East England due to the presence of the Chemical and Process Industries, which employ an estimated 26,000 people across the region.

Planned projects include a new CCS power plant for Eston Grange in the Tees Valley and a part-conversion of the Rio Tinto Alcan power plant at Lynemouth, Northumberland which together will capture up to 7.5m tonnes of CO2 per year.

These projects integrate established technologies and are at a sufficiently advanced stage for partners to be confident that a CCS Cluster could be operational in 2015, the report says.

The cluster would pipe captured CO2 to a large permanent storage site already identified in the North Sea, or be used in ageing North Sea oilfields to increase production and extend field lives.

Obama announces CCS task force

President Obama has released a Presidential Memorandum creating an Interagency Task Force on Carbon Capture and Storage.

The task force will seek to develop a comprehensive and coordinated federal strategy to speed the development and deployment of clean coal technologies. The President called for five to ten commercial demonstration projects to be up and running by 2016.

The Task Force will be co-chaired by representatives of from DOE and EPA and include participants from at least 9 different agencies and offices. It will develop within 180 days a plan to overcome the barriers to the deployment of widespread affordable CCS within 10 years, with a goal of bringing five to ten commercial demonstration projects on line by 2016.

The plan should address incentives for CCS adoption and any financial, economic, technological, legal, institutional, or other barriers to deployment. The Task Force should consider how best to coordinate existing federal authorities and programs, as well as identify areas where additional federal authority may be necessary. It will report progress periodically to the President, through the Chair of the Council on Environmental Quality.

NRG receives DOE funding for WA Parish project

www.nrgenergy.com

NRG Energy has been selected by the US Department of Energy (DOE) to receive up to $154 million to build a post-combustion carbon capture demonstration unit at NRG's WA Parish plant southwest of Houston.

The proposed project was submitted under the Clean Coal Power Initiative Program (CCPI), a cost-shared collaboration between the federal government and private industry to demonstrate low-emission carbon capture and storage technologies in advanced coal-based, power generation.

The goal of CCPI is to accelerate the readiness of advanced coal technologies for commercial deployment, ensuring that the United States has clean, reliable, and affordable electricity and power.

Scheduled to begin operating in 2013, NRG's carbon capture demonstration project at WA Parish will use Fluor Corporation's advanced Econamine FG PlusSM technology to process a stream of flue gas from the plant equivalent to that of a 60 megawatt unit. It will be designed to capture 90% of incoming CO2, or approximately 400,000 metric tons of CO2 annually.

NRG's WA Parish plant southwest of Houston where Fluor Corporation's Econamine FG PlusSM technology will be used to process a stream of flue gas from the plant equivalent to that of a 60 megawatt unit

The project will also trial Ramgen's supersonic carbon dioxide compression system. The CO2 will be used for enhanced oil recovery sequestration in one of the Texas Gulf Coast oilfields near the Parish plant.

According to the DOE, the project will show that post-combustion carbon capture applied to existing plants can be done economically, especially when the plant has the opportunity to sequester carbon dioxide in nearby oilfields.

The NRG Energy project was selected under the third round of the Clean Coal Power Initiative (CCPI), a cost-shared collaboration between the federal government and private industry to demonstrate low-emission carbon capture and storage technologies in advanced coal-based, power generation. The goal of CCPI is to accelerate the readiness of advanced coal technologies for commercial deployment, ensuring that the United States has clean, reliable, and affordable electricity and power.

The U.S. Department of Energy will provide up to $154 million in federal funds, which will be matched by NRG Energy.

CCS Coalition founded in California

www.ethree.com

Prompted by a study highlighting the importance of CCS to meet California's long-term target of reducing its greenhouse gas emissions, a group of energy companies with an interest in advancing CCS have launched the California CCS Coalition.

Plans for the coalition began after a study published in November 2009 confirmed California was not likely to attain its long-term target of reducing greenhouse gas emissions without investment in new, more efficient and lower-carbon infrastructure, including the use of CCS.

"The study confirmed what many of us already knew - that CCS is a viable solution in reducing greenhouse gas emissions," said the coalition's newly appointed Executive Director Pete Montgomery. "But it also raised some flags in terms of where we go from here," he adds, noting legislative, regulatory and general public awareness lag behind what may be required to ensure successful CCS implementation.

The study, "Meeting California's Long-Term Greenhouse Gas Reduction Goals" by San Francisco-based Energy and Environmental Economics, Inc. (E3), is the first comprehensive look at the steps necessary to cut statewide greenhouse gas emissions by the year 2050.

It looks out 40 years and concludes that achieving long-term greenhouse gas reduction goals will require moving towards increased electrification, low-carbon power generation, and zero-emissions technologies. To reach emission reduction targets, the report stresses a mix of low-carbon power generation utilizing CCS, as well as wind, solar, biomass and nuclear.

Hydrogen Energy California, which is seeking to build California's first industrial scale hydrogen-fired power plant with CCS, provided funding for the E3 study,

The coalition was created to ensure CCS is an important part of any state carbon stabilization program with the goal being "to bring voices to the table throughout the state to demonstrate that CCS is practical, effective and safe," Montgomery adds.

California CCS Coalition members to date include: Aera Energy, Chevron, Clean Energy Systems, Hydrogen Energy California, Sempra Energy Utilities, Southern California Edison, Shell and Western States Petroleum Association. The group hopes to attract other members.

Scotland publishes CCS roadmap

www.scotland.gov.uk

A plan to position Scotland as the world leader in carbon capture and storage (CCS) has been published.

The carbon capture and storage roadmap, produced by the Scottish Government and Scottish Enterprise, is a comprehensive set of actions to put Scotland at the forefront of CCS development. These include:

* Setting out a vision for CCS in Scotland including aiming to develop a number of demonstration projects * Maximising EU and UK support for Scotland's ambitions * Developing of an offshore carbon licensing regime * Identification of the skills and training needs to match industry demand

"We now want to see a number of CCS demonstration projects developed in Scotland," said Scottish Energy Minister Jim Mather. "Today's plan takes us further down that road by setting out our ambitions and the actions needed if our vision of CCS playing a part in our future energy supply is to be realised."

"The Scottish Government will work with our partners in industry, academia and in the UK Government and Europe to ensure that Scotland can deliver on the opportunities that CCS provides. We have already achieved a significant amount of progress in this area but we know that more needs to be done as we move into the demonstration phase."

This plan builds upon the actions already taken including:

* The funding of research projects * Liaising with the UK Government and EU to ensure that Scottish based projects have the maximum chance to gain funding for demonstration projects * Setting up of industry advisory groups including the thermal generation and CCS industry advisory groups * The development of a suitable regulatory framework for CCS projects

Guidance on how Ministers will determine consents relating to thermal power stations under Section 36 of the Electricity Act 1989 has also been published. It confirms the Scottish Government position that any new coal-fired station would need to demonstrate carbon capture and storage on at least 300 Megawatts of its capacity from day one and retro-fitting for those stations by no later than 2025, with 100 per cent CCS expected on new builds from 2020.

The first comprehensive study of carbon capture and storage (CCS) to be undertaken in the UK - Opportunities for CO2 Storage Around Scotland - was published in May 2009 by a collaborative partnership between the Scottish Government and partners from industry and academia.

The Scottish Government has contributed £75,000 towards a Scottish Centre for Carbon Storage study to identify potential sites in the North Sea where carbon dioxide can be stored safely.

Experts call for rethink on UK energy policy

www.doosanpower-systems.com

The Doosan Power Systems Energy Brief 2010 was launched at a dinner-debate in Westminster last night, attended by Charles Hendry, MP, Shadow Minister for Energy, and twenty leading energy and environment specialists.

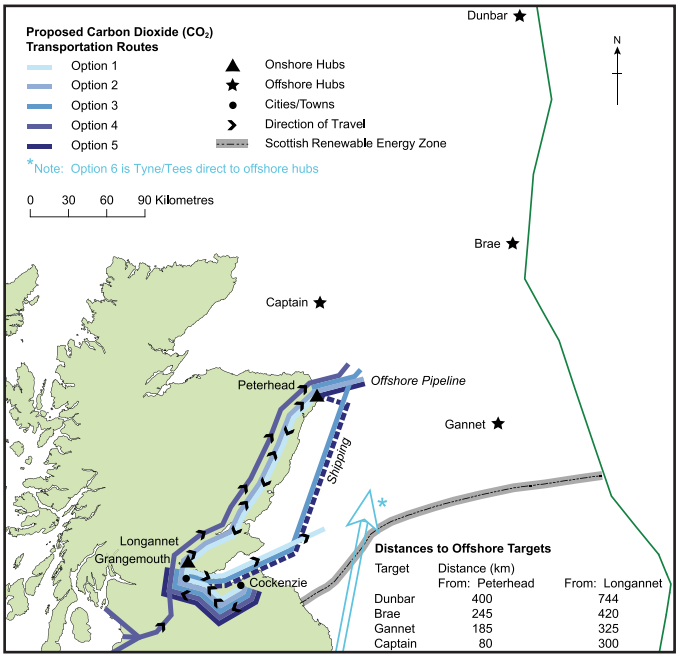
82% of those who responded to the 2010 Energy Brief survey agreed that current energy roadmaps for the UK are insufficient and undeliverable. The survey of 175 of the UK's leading energy experts also reveals that over 65% of respondents doubt if current energy policy will either deliver security of UK electricity supplies or emission targets over the next ten years.

68% of respondents also believed that CCS policies in the UK and Europe are insufficient and are not conducive to targets.

Although significant steps have been made with the announcement of four carbon capture and storage (CCS) demonstrations, the tight rules on new coal power plants recently announced and the lack of ambition for the introduction of CCS will have severe consequences for security-of-supply in the UK, said the Brief.

"The Government should take action now to ensure the UK has a balanced electricity generation portfolio, as envisaged in the 2007 Energy White Paper, including renewables, gas, clean coal and nuclear to provide the UK with sustainable, secure and economical power," commented Iain Miller, CEO, Doosan Power Systems.

"The authors of articles in our Energy Brief 2010, and those who responded to our survey, concur with the recent report by OFGEM on Project Discovery – that found the industry does not have confidence in current energy policies. This must be rectified urgently to achieve the necessary investments to secure our energy future."



Summary of proposed CO2 transport routes (Source: Opportunities for CO2 Storage around Scotland Report May 2009)

Skyonic awarded DOE grant for CO2 reuse project

www.skyonic.com

Skyonic Corporation, an Austin-based carbon capture technology company, has been selected to receive $3 million in stimulus funding from the Department of Energy and the National Energy Technology Laboratory (DOE/NETL).

This grant, along with private investment, will fund Phase 1 of the commercial Capitol-SkyMine project at Capitol Aggregates' cement plant in San Antonio, Texas.

Phase 1 will fund modeling, simulation, design, costing, and procurement activities in preparation for the construction of the plant in 2010.

Skyonic Corporation will work closely with Zachry Corporation, owner of Capitol Aggregates, Ltd., and with design and construction engineers Ford, Bacon & Davis to complete Phase 1 work. In mid-2010, Skyonic will have the opportunity to apply for a Phase 2 grant from DOE/NETL to support the construction of the plant, with the balance of the plant funded by private investors.

The Capitol-SkyMine plant is targeted to capture 75,000 metric-tonnes of CO2 from flue gas emitted by Capitol Aggregates' cement plant and mineralize the carbon dioxide emissions as baking soda, while also offsetting an additional 200,000 metric-tonnes of CO2 in the manufacture of benign chemical byproducts.

The Capitol-SkyMine plant will operate at a profit, due to the sale of these byproducts.

CO2 Capture Project - Storage, Monitoring and Verification team

The CO2 Capture Project (CCP) is dedicated to advancing the technologies and improving operational approaches to enable the commercial deployment of CO2 capture and storage (CCS). The work of the CCP is carried out through the close cooperation and shared decision-making of four teams of technical advisors: Capture; Storage, Monitoring and Verification (SMV); Policy and Incentives and Knowledge Sharing. Scott Imbus, a Senior Staff Scientist with Chevron (a CO2 Capture Project member company) provides an overview of the work of the SMV team.

With its long history in subsurface exploration and production the oil & gas industry has an important role to play in showing that secure storage of CO2 on an industrial scale is achievable. The overarching goal of the SMV team is to improve confidence in safe and effective geological storage at scale.

The CO2 Capture Project (CCP), which began in 2000, has recently entered its third phase, which is due to run until 2013. During this phase the SMV focus will be on building further understanding of well integrity, documenting subsurface physico-chemical processes, field trialing promising monitoring technologies and developing optimal field and operational strategies.

Last year the SMV team published 'A Technical Basis for Carbon Dioxide Storage' – a comprehensive guide to major technical issues in the subsurface geological storage of CO2. It drew on the practical experience of the oil & gas industry; addressing key technical aspects and reporting on technological innovations.

Detailed results of the first two phases of the SMV program were also published in the CCP results book for phase two - Advances in CO2 Capture and Storage Technology.

Highlights from the CO2 Capture Project SMV Program

Phase One (2001- 2004)

In the first phase of its work, the CCP SMV progam qualified promising technologies; contracting over 30 projects to improve knowledge of storage integrity, optimization, and monitoring and risk assessment. Highlights of the first phase included:

• The documentation of factors influencing the containment of natural (reservoir and cap rocks, faults) and engineered (wells) elements of storage systems.

• Increased understanding of operating efficiencies and enhanced hydrocarbon recovery options impacting CO2 storage cost effectiveness

• Detailed survey undertaken of the applicability and cost-effectiveness of existing and emerging monitoring technologies and methodologies for qualifying risk assessment approaches.

Phase Two (2005 - 2008)

In the second phase, the SMV team further developed promising technologies with a view to their deployment in the final phase. The team undertook studies that would offer a real contribution to efforts to building a regulatory framework. Key areas of work included:

Wellbore Field Integrity study

The Wellbore Field Integrity study entailed designing and conducting a well survey protocol (well log, testing and sampling) with analyses, modeling and forward simulation. The survey of a Colorado CO2 production well (production started in 1986) documented the type and extent of alteration with the conclusion that well materials used (i.e, conventional vs. resistant cements) are not as important to maintaining a barrier to CO2 as are good construction, installation and maintenance practices.

Certification Framework

The development of a Certification Framework aimed to provide a simple, transparent guide to site certification, which is essential to helping decision makers to manage the CO2 storage process. This process, for assessing, operating and decommissioning storage sites, was developed with Lawrence Berkeley National Laboratory, the University of Texas and the Texas Bureau of Economic Geology.

The Certification Framework, by reducing storage systems to compartments and conduits and calculating CO2 Leakage Risk, identified those vulnerable storage system components requiring more detailed assessment. A number of analytical solutions were developed to better understand potential vulnerabilities. Development of a rapid prototype application continues; with two case studies having been conducted to date.

Storage Studies

Two coal storage-related studies were conducted using a prospective pilot site in Alabama. A CO2 Enhanced Coal Bed Methane (ECBM) flow simulation study entailed history matching of gas and water production and simulation of various CO2 injection schemes on methane production, CO2 storage and potential for leakage. A key finding was that a trade-off exists between sequestration efficiency and methane recovery.

The monitoring study examined the feasibility of electromagnetics (EM) and gravity in detecting CO2 plumes in coal. It was noted that these techniques are viable alternatives to conventional seismic monitoring.

The overarching goal of the SMV team is to improve confidence in safe and effective geological storage at scale - Scott Imbus, Senior Staff Scientist with Chevron

Other Studies

Other, smaller studies included a construction of a bench scale "tank" to assess the threshold ability of the reservoir saturation tool (RST) to detect CO2, the development of an explicitly coupled geochemical-geomechanical simulation (RetrasoCodeBright)

tool and a novel approach to direct aerial detection of CO2 and methane.

Phase Three (2009 - 2013)

Technical and economic integration of capture, transportation and storage will be a major feature of the third stage of the CO2 Capture Project's program. The SMV team will be focusing on well integrity, documenting subsurface physicochemical processes, field trialing promising monitoring technologies and developing optimal field and operational strategies.

Wellbore Field Integrity study

Well studies will build on the previous phase program to include additional CO2-exposed well surveys with sampling, analyses and forward modeling to project long-term integrity and establish preventative and remediation practices.

A bench scale experimental apparatus will be constructed to further detail alteration, volumetric thresholds for leakage detection and remediation approaches. At the conclusion of the well studies, a recommended practices guide will be developed for the design, construction, operation and decommissioning of CO2 storage wells.

Subsurface Processes

Clarification and quantification of subsurface processes will be achieved through expert-recommended methodologies and round robin analysis of relative permeability and capillary entry pressure and through experimental and simulation studies on the impact of CO2 impurities on reservoir / top seal integrity and plume dynamics.

Monitoring

The cost-effectiveness of monitoring techniques will be assessed through a retrospective analysis of existing field deployment data with recommendations on technology selection. A modular bore hole monitoring technology suite, suitable for most geologic settings, will also be designed and developed for deployment. Several monitoring technologies, including those currently used for hydrocarbon production and those in development for CO2 storage, will be deployed at third party field sites.

Certification Framework

In the third phase the Certification Framework will be further developed; issues such as capacity optimization, pressure management and economics will be incorporated.

At the conclusion of the CCP3-SMV program, assessment protocols and technical results facilitating safe and effective CO2 storage will be available through numerical tools and peer-reviewed journals.

More information

To be kept updated on the work of the SMV team visit:
www.co2captureproject.org

Capture news

UCLA creates DNA-like crystal for CO2 capture

www.newsroom.ucla.edu

UCLA chemists have created a synthetic crystal that resembles DNA that can capture CO2 emissions.

The research could lead to materials that can capture CO2 with high selectivity, or convert CO2 to fuels.

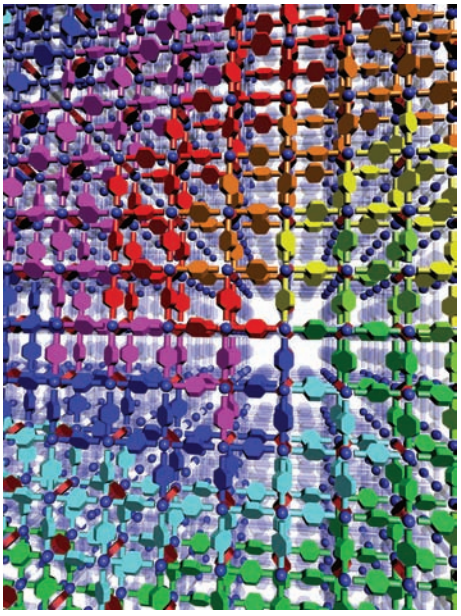
"We created three-dimensional, synthetic DNA-like crystals," said UCLA chemistry and biochemistry professor Omar M. Yaghi, who is a member of the California NanoSystems Institute (CNSI) at UCLA and the UCLA–Department of Energy Institute of Genomics and Proteomics. "We have taken organic and inorganic units and combined them into a synthetic crystal which codes information in a DNA-like manner. It is by no means as sophisticated as DNA, but it is certainly new in chemistry and materials science."

"What we think this will be important for is potentially getting to a viable carbon dioxide–capture material with ultra-high selectivity," said Yaghi, who holds UCLA's Irving and Jean Stone Chair in Physical Sciences and is director of the CNSI's Center for Reticular Chemistry. "I am optimistic that is within our reach. Potentially, we could create a material that can convert carbon dioxide into a fuel, or a material that can separate carbon dioxide with greater efficiency."

The research was federally funded by the U.S. Department of Energy's Office of Basic Energy Sciences. The lead author is Hexiang "DJ" Deng, a UCLA graduate student of chemistry and biochemistry who works in Yaghi's laboratory.

"DJ has illustrated that one member of a series of materials he has made has 400 percent better performance in carbon dioxide capture than one that does not have the same code," he said.

In the early 1990s, Yaghi invented a class of materials called metal-organic frameworks (MOFs), sometimes described as crystal sponges, in which he can change the components nearly at will. MOFs have pores — openings on the nanoscale in which Yaghi and his colleagues can store gases that are usually difficult to store and transport. Molecules can go in and out of the pores unobstructed. Yaghi and his research team have made thousands of MOFs.



3-D, synthetic DNA-like crystals created by Yaghi, Deng and colleagues at UCLA selectively capture CO2

SRI awarded DOE carbon capture research project

www.sri.com
www.greatpointenergy.com

SRI International, an independent nonprofit research and development institute, has been awarded a $4.5M Department of Energy (DOE) project to evaluate the technical and economic viability of CO2 capture using an ammonium carbonate-ammonium bicarbonate (AC-ABC) process at gasification plants, including IGCC power plants.

This new project is one of several projects at SRI aimed at finding cost-effective ways to recover carbon dioxide from power plants so it can be sequestered.

One of the advantages of the AC-ABC process is that it removes CO2 and hydrogen sulfide at pressure, resulting in less energy needed to capture the CO2. In addition, the AC-ABC approach has the potential to be commercialized at a low cost and in a relatively short amount of time because it does not require the development of novel materials, solvents, or reactor configurations.

A variety of approaches to carbon cap-

ture is needed to address both current and future power plant designs. Results from this DOE-funded project can also be applied to other types of power plants that require carbon dioxide removal pre-combustion, such as hydromethanation plants.

The research project, which is estimated to be completed in 2012, will include a field test at a coal gasifier that is operated by SRI's partner on the project, GreatPoint Energy. The results from the field test will be used to design a large-scale demonstration program for an operating power plant. GreatPoint Energy is the developer of Bluegas hydromethanation technology for converting coal into hydrogen and synthetic natural gas.

"We are convinced that capturing carbon dioxide prior to combustion is the simplest and lowest cost solution for eliminating greenhouse gas emissions on a large scale," said Andrew Perlman, GreatPoint Energy Chairman and CEO. "GreatPoint Energy is dedicated to developing new technologies such as the AC-ABC process, which we believe can dramatically hasten market acceptance of carbon capture technology."

SRI is also committed to advancing carbon capture research and is currently using several different approaches in bench-scale pilot programs for domestic and international clients. The institute has extensive experience with carbon capture using both pre- and post-combustion techniques, and has conducted research and development to remove contaminants from gas streams for more than 20 years.

SaskPower selects SNC Lavalin-Cansolv CO2 capture system

www.cansolv.com
www.shell.com

Canadian company SaskPower and Shell subsidiary Cansolv Technologies have signed an agreement to license a CANSOLV Integrated Carbon and Sulphur Capture System for the Boundary Dam Integrated Carbon Capture and Sequestration Demonstration Project.

SaskPower determined that Cansolv and partner SNC Lavalin were best able to deliver a carbon capture system with the lowest cost and acceptable risk, on time and on budget.

SaskPower is leading the development of one of the world's first and largest carbon capture and sequestration demonstration projects at the Boundary Dam Power Station in Estevan, Saskatchewan, Canada. The project would fully integrate and retrofit an aging lignite coal-fired unit with carbon capture and an enhanced oil recovery operation.

One million tonnes represents ninety per cent of the CO2 emitted through the unit that could be captured through the Cansolv integrated system, and may be used for enhanced oil recovery from nearby oilfields.

The SO2 recovered in the system could be used for production of sulphuric acid at Boundary Dam. Selective heat integration in Cansolv's combined capture system will reduce the energy requirements associated with carbon capture.

SaskPower is currently developing the business case to make a final decision late this year on proceeding with the project.

The Cansolv patented technology is a highly flexible system that uses regenerable amines and is applicable to a broad range of industrial applications in addition to power plant flue gases. SNC Lavalin will construct the system at Boundary Dam.

Combining brine management with carbon capture

ec.europa.eu

A new study has evaluated a combined process to manage both the brine by-product from desalination plants and capture carbon dioxide.

Desalination separates seawater (or inland saline or salty water) into fresh water suitable for drinking purposes and very concentrated brine (salt water). Desalination is seen as one method of providing drinking water in areas with growing populations and limited water resources.

Over 25 million cubic metres of desalinated water were produced around the world in the year 2000 and disposal of the brine is a major environmental challenge. Options for disposal generally include: discharging it into the sea, potentially affecting marine life, discharging it into deep wells or saline aquifers, discharging it to wastewater treatment plants or recovering the salts in evaporation ponds or by mechanical or heat treatment processes.

In this study, a new approach for disposing desalination brine at coastal and inland locations was investigated. The process converts the brine into useful and reusable products by passing ammonia and carbon dioxide through the brine solution.

Laboratory experiments using brine from local desalination plants were conducted to investigate the optimal conditions for converting the sodium chloride (salt) in the brine into sodium bicarbonate, a product which is used in medicine and cooking, among other applications.

Results of the study suggest that, in the laboratory, the optimal conditions for sodium removal are achieved at 20°C over a reaction time of 2 hours. Ammonia plays an essential role in this process.

The ammonia can be recovered at the end of the operation and, at the industrial scale, ammonia would be recycled within the system. Although the study focused on reducing the concentration of sodium chloride from the reject brine, the process was also able to reduce concentrations of other soluble salts found in the brine by-product. For example, the concentration of metal ions of magnesium and calcium were significantly reduced in the experiments.

In addition, the study evaluated the process as a method for capturing carbon dioxide (CO2). A gas mixture containing 10 per cent CO2 and 90 per cent methane was used as the source for the CO2. Results suggest that the process is effective in reducing the concentration of CO2 (a 90 per cent reduction after 2 hours under laboratory conditions).

Depending on the location of the desalination plant, the process could be used to reduce CO2 emissions from flue gases, such as from fossil-fuel power plants or exhaust gases from industrial fossil fuel combustion sources, as well as part of the purification process of natural gas.

CIUDEN awards Foster Wheeler contract for CCS plant

www.fwc.com
www.ciuden.es

Foster Wheeler has been awarded a circulating fluidized-bed (CFB) boiler contract for a CO2 capture development plant Ponferrada, Spain.

Fundación Ciudad de la Energía (CIUDEN), an institution created by the Spanish Government, will use the boiler to test Foster Wheeler's Flexi-Burn carbon capturing CFB technology.

The unit will be part of CIUDEN's Integrated CCS Technology Development Plant (TDP) located near Endesa's Compostilla power plant in Ponferrada, Spain.

Foster Wheeler has received a full notice to proceed on this contract. The terms of the agreement were not disclosed, and the contract value will be included in the company's first quarter 2010 bookings. The unit is expected to be operational by the second half of 2011 with testing programs expected to follow shortly thereafter.

Foster Wheeler will design and supply the 30 MWth Flexi-Burn CFB test unit and some auxiliary equipment and provide site advisory services for the project.

Flexi-Burn is Foster Wheeler's version of carbon capture technology based on oxygen combustion for coal plants.

The CIUDEN unit will be designed to test burn a wide range of domestic (anthracite) and imported coals, as well as biomass. One of the objectives of the incorpo-

ration of this unit into the TDP is to validate Foster Wheeler's Flexi-Burn CFB technology at the required scale before proceeding to a possible full-scale demonstration plant.

Fundación de la Energía (CIUDEN)is an institution created by the Spanish Government in 2006 to put into practice strategic objectives on CCS. Its main objectives are R&D of efficient, cost effective and reliable technologies through the design, operation and construction of a large-scale integrated Technology Development Plant (TDP) for Capture and Geological Storage of CO2.

Fluor and B&W CCS alliance

www.fluor.com
www.babcock.com

Babcock & Wilcox Power Generation Group and Fluor's Power Group have formed a strategic alliance to market and sell CO2 capture systems for existing coal-fired power plants in the US and Canada.

Fluor and B&W will jointly market and provide project execution for Fluor's Econamine FG PlusSM technology - an advanced version of an established Fluor process that has been successfully used in 23 commercial plants for the recovery of CO2 from flue gas for more than 20 years. The process uses an advanced amine-based solvent to capture CO2, which then can be permanently stored or used in other industrial applications.

The alliance combines the strengths of Fluor's established Econamine FG PlusSM technology and engineering, procurement and construction capabilities with B&W PGG's expertise in the retrofit supply and integration of air quality control systems.

Both companies will collaborate on providing engineering, procurement, construction and commissioning services using Fluor's Econamine FG PlusSM technology. The agreement also includes a license for B&W to use and market the Econamine FG PlusSM technology in support of this collaborative effort.

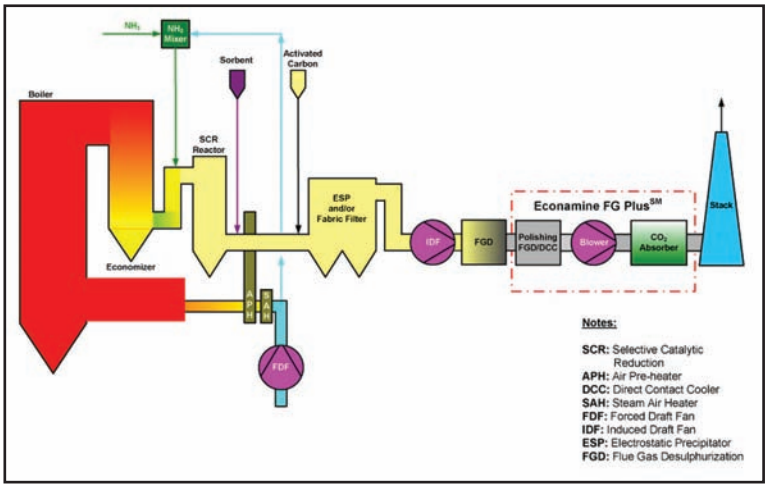
B&W will provide Fluor with access to its research and development facilities and pilot plant in Barberton, Ohio for testing and advancing the process for future coal-fired plant scale-up applications.

UOP awarded DOE grant for algae CO2 capture

www.uop.com

UOP, a Honeywell company, has been awarded a $1.5 million cooperative agreement from the US DOE for a project to demonstrate technology to capture CO2 and produce algae for use in biofuel and energy production.

The funding will be used for the design of a demonstration system that will capture CO2 from exhaust stacks at Honeywell's manufacturing facility in Hopewell, Virginia, and deliver the captured CO2 to a cultivation system for algae.



Fluor and B&W will jointly market Fluor's Econamine FG PlusSM process (Image ©Fluor)

Algal oil can then be extracted from the algae for conversion to biofuels, and the algae residual can be converted to pyrolysis oil, which can be burned to generate renewable electricity.

The project, managed by the U.S. Department of Energy's National Energy Technology Laboratory, will realize further environmental benefit because wastewater from the manufacturing facility will be used in the algae cultivation system, allowing the algae to consume nitrogen in the wastewater.

At the demonstration site, UOP will design cost-effective and efficient equipment to capture CO2 from the exhaust stacks of the Hopewell caprolactam facility and deliver it in a controlled and efficient process to a pond near the plant, where algae will be grown using automated control systems from Honeywell Process Solutions and technology developed by Aquaflow Bionomic Corp.

BRGM researchers use nanomaterials for CO2 capture

www.innoresearch.net

Bureau De Recherches Geologiques Et Minieres (BRGM) inventors Alain Seron, Fabian Delorme and Christian Fouillac have detailed a low-cost method for CO2 capture using nanomaterials such as mesoporous silica and carbon nanotubes in a U.S. Patent Application.

The method enables CO2 trapping in a reversible manner without the need for methods that are energetically costly (large increase in temperature, evaporation of a liquid phase, solid/liquid separation, etc.) and without any handling of the suspension constituting the trap which remains in place in the capture/release reactor throughout the cycle.

In addition, the method is performed under conditions of ambient pressure and temperature or near ambient conditions, with a slightly higher temperature favoring CO2 release.

The technique includes first suspending in a liquid phase a solid absorbent capable of trapping the gaseous CO2; the gas mixture is then converted into the liquid phase at a temperature between 0 degree C. and 30 degrees C., a temperature ranging from the liquid phase solidification temperature to the evaporation temperature. The process is carried out at a pressure between atmospheric pressure and 3 bars.

The absorbent solid is selected equally among: a carbonaceous material such as activated carbon or carbon nanotubes; an oxide, for example silicates such as zeolites, clays, mesoporous silicas, manganese oxides, pumice, perlite or diatomite; a phosphate or a phosphonate; and a hydroxide such as the layered double hydroxides quintinite-3T or hydrotalcite. Layered double hydroxides (LDHs) perform particularly well in absorbing CO2.

The method includes an additional step of recovering the captured gaseous CO2. The combination of the trapping steps and the recovery steps enable purification of the CO2.

The recovery step comprises a step of lowering the partial pressure of the gas to be trapped introduced into the liquid phase, this step being achieved either by lowering the partial pressure of CO2 (in particular by recirculating, in the reactor saturated with CO2, a stream of gas depleted of CO2 from a capture reactor in operation) or by use of a weak vacuum pressure at most equal to 0.2 bar with respect to the capture pressure, or by shutting off circulation of the gas containing CO2.

Recovery of captured CO2 can also be achieved by raising the temperature of the liquid phase, preferably at most 30 degree C. beyond the temperature at which capture takes place, without bringing the liquid to a boil.

Maersk Tankers – a pioneer in CO2 shipping

To meet new demands for CCS solutions, Maersk Tankers will use its extensive experience within gas transportation to build CO2 tanker vessels that can transport the gas from point sources to carbon storage sites.

The GESTCO (European Potential for the Geological Storage of CO2) project estimates that more than 750 million tonnes of CO2 are emitted annually from large stationary sources relatively close to the North Sea. These emitters are looking at possible storage sites offshore, and Maersk Tankers believes a ship CO2 transport solution can offer the advantages of flexibility and lower start-up costs, particularly during the early phases of operations when volumes are low and several storage sites may need to be evaluated.

"Maersk Tankers is committed to contribute in a responsible manner to solving the global challenge of climate change via sustainable solutions in the business areas in which we operate," said Anders Schulze Head of CO2 shipping at Maersk Tankers.

"Innovation has always been important; we were the first to include double-hulled vessels in the fleet back in 1992. Today we want to pioneer CO2 transport."

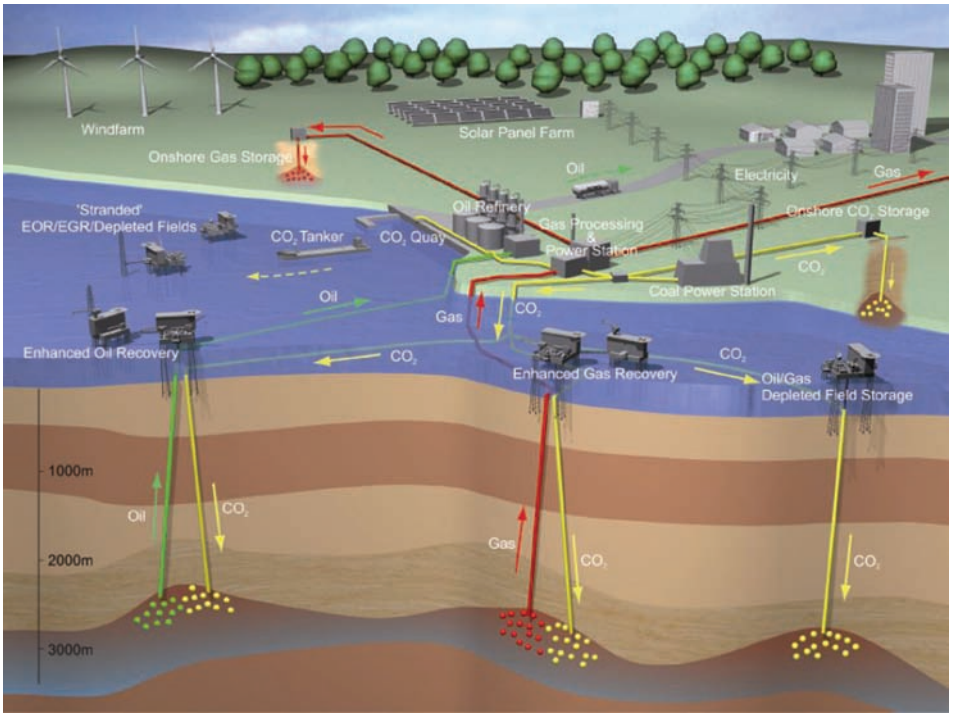
"CO2 transport is an emerging market driven by CCS. To meet new demands for CCS solutions, Maersk Tankers is planning to build CO2 tanker vessels to transport the gas from point sources such as coal-fired power plants and refineries to carbon storage sites."

CO2 is relatively high density compared to other cargoes such as LPG or LNG and so a vessel of the same size could transport more tonnes in each trip. Maersk Tankers estimates that its maximum vessel size with the current design would accommodate 45,000 tonnes of CO2 but customers could choose a size to suit their needs.

Ship or pipeline?

Whether you choose a shipping solution or a pipeline solution is project dependent, and the industry is looking at longer term projects as a value chain where there is a partnership between the transport operator and the emitter.

"As we see it the pipeline solutions are viable for short distances with high volumes and for longer periods, while shipping is well suited for smaller quantities, over long distances or for shorter periods of time," said Mr Schulze.



Maersk is specialized in CCS with CO2 transportation by ship (Maersk Tankers) and CO2 storage by Enhanced Oil Recovery (EOR) (Maersk Oil)

"Shipping CO2 in tankers requires less capital expenditure than moving it via pipelines. It also offers greater flexibility by providing access to multiple storage sites, which is important in the short term as we are testing out various potential locations."

The IPCC has conducted some research which concluded that if you transport a quantity of 6 million tonnes of CO2 a year over a 20 year scenario you would break even between offshore pipeline costs or shipping costs at a distance of 1000km.

"That is quite a large quantity of CO2 and most of the projects we are looking at in the short term involve considerably less than that," said Mr Schulze. "If for instance the quantity was 2 million tonnes a year for the same period the break even distance would be considerably shorter."

The vessels

Maersk Tankers has the blueprints to build CO2 tankers, designed based on its years of experience carrying liquefied petrochemical gas. Delivery time of ships from order is 2 years. Today, there are 4 pressurized CO2 carriers transporting food grade CO2 on long term contracts. There are no CO2 carriers transporting emitted CO2.

"CO2 would be transported in a similar way to existing liquefied cargoes such as

CO2 transport by ship can offer the advantages of flexibility and lower startup costs, particularly during the early phases of operations

LPG or ammonia," said Mr Schulze. "Vessels could be multi-purpose, as CO2 tankers can also be used to transport other gas products, which makes the solution a good option, especially now, in the early days of CCS."

Today, Maersk Tankers operates with three gas vessel types, very large, mid size and handy size gas carriers. The methodology used in large size carriers would not be suitable for CO2 as they fully refrigerate gas cargoes - fully refrigerated CO2 will turn into dry ice.

Hence, new CO2 ships would be designed based on the methodology used in handy size and to some extent mid size carriers which operate with a mixture of refrigeration and pressure for transport. Semi-pressurized/semi-refrigerated CO2 is transported at approximately minus 55°C and 6.5 bar. Alternatively, fully pressurized ships could also be an option.

In terms of capacity, a vessel could transport around double the tonnes of CO2 as LPG, as the density of CO2 is almost double that of LPG. So far Maersk Tankers aims for ship sizes up to 38,000 cubic meters allowing for up to 45,000 tonnes CO2 per voyage.

Offloading

CO2 ships can discharge offshore using the same principles as shuttle tankers are loaded offshore. For this purpose, a combination of CO2 carriers connecting with a 'floating storage and injection unit' (FSIU) or an offshore platform may be deployed, depending on injection rates for the field.

There are two options for offshore discharge operations. The first is to connect to an offshore buoy which is connected to the offshore platform by a submerged turret system below the ships. This solution is the more stable when it comes to adverse weather conditions and would be applicable for the North Sea for instance.

The second option is a single anchor bow system where you discharge across the bow also linking to an offshore buoy which is connected to the platform. Installation costs would be comparatively lower than for the first option.

Offshore discharge might also require heating and compression prior to storage. This can be installed on the ship or offshore platform.

Current projects

Maersk Tankers is working on projects involving CO2 shipping from one hub to another as well as projects involving CO2 shipping from one hub to an offshore storage location. Maersk Tankers has formulated an integrated CO2 transport and offshore storage offering together with Maersk Oil which the companies believe can provide a cost effective, off the shelf solution, particularly during the startup phase of CCS.

The company is currently working on different projects investigating the interface between CO2 shipping and offshore offloading of CO2 for storage and Enhanced Oil Recovery (EOR) purposes.

One of the projects Maersk Tankers and Maersk Oil are working on is carried out together with Finnish utilities Fortum and Teollisuuden Voima (TVO). The partners wish to combine carbon capture at the Meri-Pori power plant with CO2 transportation by Maersk Tankers' vessels and geological storage combined with EOR by Maersk Oil.

"Shipping CO2 in tankers requires less capital expenditure than moving it via pipelines. It also offers greater flexibility by providing access to multiple storage sites" - Anders Schulze Head of CO2 shipping at Maersk Tankers.

Maersk Oil will investigate the possibility of providing final CO2 storage in the depleting oil and gas fields of the Danish North Sea, as well as the potential use of CO2 for EOR. The aim is to capture, transport and store in excess of 1.2 million tonnes CO2 per year.

Subject to successful project development, the project will seek qualification for funding under the European Union's CCS Demonstration Programme. The selection for this funding is expected to take place in 2011 and the final investment decision in 2011-2012. The project aims to be in operation by 2015.

The coal-fired power plant is located at Pori on the west coast of Finland and has an installed capacity of 565 MW. The CCS demonstration is planned to process approximately 50 percent of the plant's flue gas and to capture 90 percent of the CO2 it contains with Siemens' proprietary post-combustion capture technology.

Meri-Pori's CCS demonstration is among the largest post-combustion capture projects yet announced in Europe, the first to combine shipping, cross border transportation between two EU countries and enhanced oil recovery options.

A combination of a Floating Storage and Injection Unit (FSIU) and CO2 carriers may be deployed to solve the complicated injection process of the CO2. Such a combination would be related to Maersk's operation of Floating Production Storage Offloading (FPSO) logistics as shown in the picture.

More information

Maersk Tankers owns and operates a large fleet of crude oil carriers, product tankers, and gas carriers.

Anders Schulze has been with Maersk Tankers since 2007 and is responsible for the development of CO2 shipping.
Anders.Bradt.Schulze@maersk.com

CO_2 shipping conference 2010

6-7 May, London

Is CO_2 really a major new gas carrier cargo?

Carbon capture and storage is a proposed response to climate changes. CO_2 captured at fossil fuel-burning industrial plant is transported to underground storage sites. Where pipelines are not justified or practical, does shipping the CO_2 in gas carriers offer a cost-efficient alternative?

The inaugural CO_2 Shipping Conference provides a timely opportunity to:

learn

about the potential for transporting CO_2 by sea, the opportunities and competitive value of such operations, and progress to date

debate

this potential new gas carrier business stream

network

with industry executives with a common interest in carbon capture, transportation and storage

Come and see why Riviera events attract such high quality speakers and delegates:

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CCSA Carbon Capture & Storage Association

official publications

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TUV NEL - flow measurement project

TUV NEL is currently looking for partners from across the CCS chain to participate in a Joint Industry Project (JIP) to evaluate and recommend technologies that will be used to determine the amount of CO2 captured and transferred through the various stages of a CCS system.

CO2 captured and safely stored according to the EU legal framework will have monetary value and can be traded as CO2 credits within the EU Emissions Trading Scheme (ETS). It is essential therefore that all captured CO2 is accurately measured across each stage of the CCS chain. To this end the EU ETS Monitoring and Reporting Guidelines state that the mass of CO2 transferred out of an installation shall be measured to a maximum uncertainty of 1.5%.

There are significant metrological challenges with metering the quantities of CO2 captured, transported and stored. The aim of the proposed JIP is to fill the gap in knowledge of metering CO2 and CO2 mixtures across the range of conditions that will be encountered in CCS schemes.

Rationale

With energy demand predicted to double over the next two decades, and fossil fuels set to supply more than half of the world's energy needs through to 2030, CCS is seen as a major contributor to reducing man-made CO2 emissions as part of a secure and sustainable global energy supply. The proposed CCS Directive [1] demonstrates the EU's commitment to this technology.

Accurate measurement throughout the CCS process (from capture, separation, transportation and injection into the storage formation) will be essential for the operation of CCS schemes. TUV NEL has carried-out extensive research into the measurement issues associated with CCS putting it in a good position to assist industry to meet its measurement and reporting needs [2], [3].

Physical properties impacts all of the CCS measurement chain and underpins all of the measurement challenges. For CO2 and CO2 mixtures of the compositions that will be encountered in CCS schemes there is a need for accurate physical property models at the temperatures and pressures that will prevail in CCS applications.

It is essential that all captured CO2 is accurately measured across each stage of the CCS chain. To put this into context, the UK's largest power station emits approximately 22 million tonnes of CO2 per annum; therefore, every 1% uncertainty in flow measurement could result in a £6.6 million financial exposure per annum in the trading scheme (based on an anticipated carbon trading price of £30/tonne during the period 2013 - 2015).

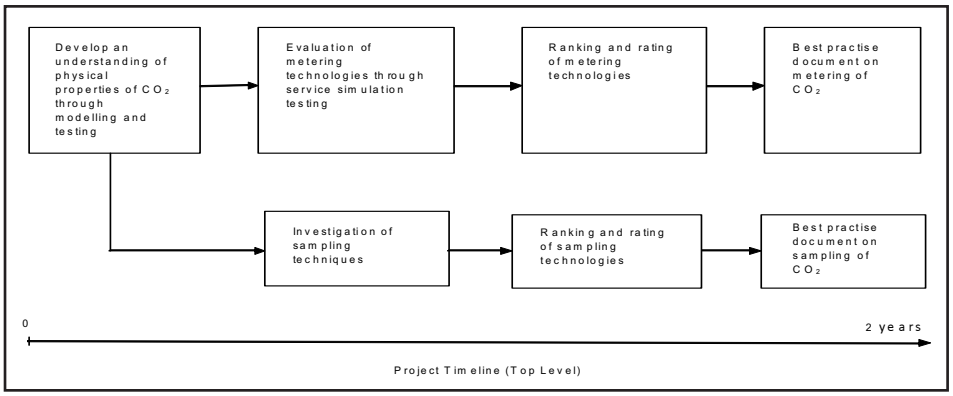

Figure 1 - The proposed top level work plan

The majority of CCS research undertaken thus far has focused primarily on the techniques involved in the capture process, geological surveying and monitoring of storage sites, but there are significant metrological challenges with metering the quantities of CO2 captured and stored. The work described in this proposal is aimed at addressing these challenges.

Measurement challenges

The main measurement issues to be tackled are:

• Phase boundaries for CO2 and CO2 mixtures need to be established as does an accurate model for density within the gas, liquid and supercritical phases

• The reliability of flowmetering technologies and associated instrumentation needs assessed for CO2 and CO2 mixtures over a range of test conditions.

• Accurate sampling techniques need to be developed to determine the CO2 content in the captured gas and to determine the purity of CO2 transported into the CCS pipeline infrastructure

• Industry requires guidance for monitoring and reporting CO2 quantities for CCS applications

Physical properties impacts all of the CCS measurement chain and underpins all of the measurement challenges. For CO2 and CO2 mixtures of the compositions that will be encountered in CCS schemes there is a need for accurate physical property models at the temperatures and pressures that will prevail in CCS applications.

Aims and objectives

The overall objective of the Flow Measurement for CCS storage JIP will be to provide industry with independent test data and expert evaluation of various technologies used for measuring CO2 composition and flow rate. The ultimate aim of the JIP will be to develop comprehensive monitoring and reporting guidelines for CCS that will assist industry in performing their measurements and to ensure best practice is followed.

These objectives will be best achieved using the collaborative approach that a comprehensive JIP project provides.

TUV NEL has the knowledge, expertise and test facilities to perform the following scope of work:

Scope

The main scope of the project is the:

• Determination of density and phase envelope over the range of temperatures and pressures that will be experienced in CCS capture and transportation; this will cover the gaseous, liquid and supercritical phases. The test work will be undertaken using CO2 and CO2/contaminant mixtures using TUV NEL's Primary Standard Liquid and Gas Densitometer facilities.

• Development of physical properties models to define density and phase envelope for CO2 and CO2 mixtures. These models will be based on the results of the densitometer tests.

• Computational Fluid Dynamics (CFD) Modelling of CO2 mixtures under flowing conditions to further examine the effect of phase change owing to pressure drop and/or temperature changes in transmission pipelines.

• Development of standard methodologies for calculating density and phase envelope for CO2 and CO2 mixtures.

• Testing and evaluation of measurement technologies for CO2 and CO2 mixtures to determine their performance capabilities. This will include testing and evaluation of flow metering technologies and the performance of industrial densitometers with a view to determining the measurement uncertainty in these techniques

• Investigation of best practice techniques for sampling of the captured flue gas and transported stream to determine CO2 content

• Investigation and develop measurement technologies used for determining flow and density

• Development of comprehensive monitoring and reporting guidelines for CCS.

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More information

TUV NEL is the custodian of the UK's National Flow Measurement Standards. The company provides services, solutions and technology to clients across industries including oil & gas, government, manufacturing, renewable and sustainable energy.
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Transport and storage news

DOE Alabama EOR project testing CO2 storage

fossil.energy.gov

CO2 injection is underway as part of a pilot study of CO2 enhanced oil recovery (EOR) in the Citronelle Field of Mobile County, Alabama.

A project team led by the University of Alabama at Birmingham is conducting the injection. Study results of the 7,500-ton CO2 injection will provide estimates of oil yields from EOR and CO2 storage capacity in depleted oil reservoirs.

Funded through the Department of Energy's Office of Fossil Energy, the primary goal of the Citronelle Project is to demonstrate that remaining oil can be economically produced using CO2-EOR technology in untested areas of the United States, thereby reducing dependency on oil imports, providing domestic jobs, and preventing the release of CO2 into the atmosphere.

The Citronelle Field appears to be an ideal site for concurrent CO2 storage and EOR. The field is composed of sandstone reservoirs in a simple structural dome, and has existing infrastructure that includes deep wells. When the 5-month injection is completed, incremental oil recovery is anticipated to be 60 percent greater than that of conventional secondary oil recovery by water flood. A recent study by Advanced Resources International of Arlington, Va., estimates that approximately 64 million additional barrels of oil could be recovered from the Citronelle Field by using this tertiary recovery method.

The geologic structure and lack of faulting also make the field naturally stable for CO2 storage. Once the oil has been recovered, the remaining storage capacity of the depleted oil reservoirs and saline formations in the Citronelle Dome is estimated to be between 0.5 and 2 billion tons of CO2. Southern Company of Birmingham, Alabama, is evaluating the potential of the reservoirs as permanent storage sites for CO2 produced from fossil fuel combustion in power plants. A successful demonstration at the Citronelle Field could offer new opportunities to introduce the latest CO2-EOR and carbon storage technologies to the commercial market.

The Citronelle project is currently in its second phase, which includes injection, associated validation of models, and determination of oil-CO2 mixture properties. Containment of CO2 at the test site will also be monitored in the ambient air, soil, and vegetation. During phase I, the project focused on selection of the test site, analysis of the site geology, and study of background conditions. The SENSOR® reservoir simulator, a generalized 3D numerical model used to optimize oil and gas recovery processes, was used to determine the amount of CO2 required for a successful demonstration and the effect of CO2 on oil production within the project time frame.

Project participants include the University of Alabama at Birmingham (Birmingham, Ala), Alabama Agricultural and Mechanical University (Normal, Ala.), Denbury Resources Inc. (Plano, Texas), the Geological Survey of Alabama (Tuscaloosa, Ala.), Southern Company, (Birmingham, Ala.), the University of Alabama (Tuscaloosa, Ala.), and the University of North Carolina at Charlotte (Charlotte, N.C.).

Gassnova contracts Polarcus for CO2 storage survey

www.polarcus.com
www.gassnova.no

Polarcus Limited has received a Letter of Intent from Gassnova SF, the Norwegian state enterprise for carbon capture and storage (CCS), for two 3D seismic acquisition projects offshore Norway.

Launching the Polarcus Naila and the Nadia

The survey will comprise a minimum 405 square kilometers and potentially up to a total of 900 square kilometers. The program will be acquired by Polarcus Naila, the Company's second 12 streamer 3D seismic vessel.

The program will commence in June 2010 and may run for up to 50 days.

Carbon sequestration in Wyoming - report

www.wsgs.uwyo.edu

Approximately 750 million tons of carbon dioxide (CO2) could be sequestered in southwestern Wyoming's Rock Springs Uplift over a 50-year period, according to a strategy detailed in a new Wyoming State Geological Survey publication.

This would allow approximately two large coal-fired power plants to meet "clean coal" standards, said State Geologist and WSGS Director Ronald Surdam.

Surdam is lead author of "An integrated strategy for carbon management combining geological CO2 sequestration, displaced fluid production, and water treatment."

Surdam said that there are huge implications for the Wyoming coal industry because electric utilities using coal will likely be forced to either capture and sequester CO2 or switch to cleaner fuel sources.

The WSGS publication summarizes two years of research that was initiated by Wyoming Gov. Dave Freudenthal with support from the Wyoming State Legislature.

The WSGS conducted a thorough inventory and prioritization of all Wyoming stratigraphic units and geologic sites capable of sequestering commercial quantities of CO2. The research identified the Rock Springs Uplift as the most promising geological CO2 sequestration site in Wyoming and probably in any Rocky Mountain basin.

The WSGS, working in collaboration with Los Alamos National Laboratory (LANL) in Los Alamos, N.M., then performed simulations to determine a feasible amount of CO2 that could be injected into the Weber Sandstone on the Rock Springs Uplift.

Large-scale geological sequestration of CO2 will require management of displaced fluids from deep underground reservoirs. The publication states that the volume of water produced by treating these fluids at the surface represents a highly valuable commodity in arid southwestern Wyoming.

Other authors were WSGS Chief Geologist Zunsheng Jiao, LANL hydrogeologist Philip Stauffer and LANL technologist Terry Miller.

Study shows 'huge' CO2 storage potential in Alberta

www.ucalgary.ca/wasp

It is technologically feasible to store a huge amount of CO2 in geological formations in central Alberta, says a University of Calgary-led study coordinated by the Institute for Sustainable Energy, Environment and Economy (ISEEE).

The government and industry-funded study, called the Wabamun Area CO2 Sequestration Project (WASP), is the most comprehensive study of large-scale carbon dioxide (CO2) storage to have all of its findings made fully available to the public.

"It's important that studies of geologic storage be publicly available so that people can make independent judgments of the potential long-term risks of this technology," says study leader David Keith, director of ISEEE's Energy and Environmental Systems Group, and a professor in the Schulich School of Engineering.

The WASP team found that more research-including drilling test wells onsite is required before starting a commercial-scale operation to store CO2 in rock formations deep beneath the Wabamun area where most of Alberta's coal-fired power plants are located.

"Before a commercial-scale CCS operation can begin, there needs to be an array of geological and engineering studies done on the proposed CO2 storage reservoirs, to assess risk and facilitate safe and effective storage," says Keith.

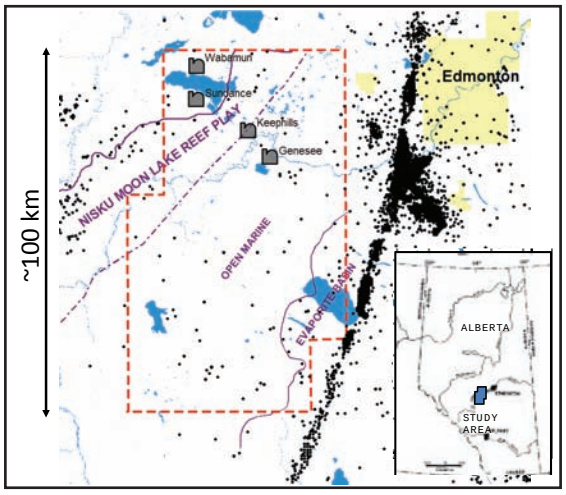
The Alberta government has committed $2 billion to help kick-start four commercial-scale CCS projects as a key way of reducing greenhouse gas emissions, especially from coal-fired power plants.

Sixteen U of C researchers and industry consultants conducted the WASP study over 16 months. They examined the feasibility, cost and potential risk of permanently storing underground 20 million tonnes annually of CO2 over 50 years (amounting to one billion tonnes) in a 5,000-square-kilometre area.

The study found that about half of the targeted storage capacity-or some 500 million tonnes of CO2-can be accomplished without managing the pressure of the geologic formation into which the CO2 would be injected. This is a gigantic volume of storage, roughly equivalent to half the emissions for 30 years from all of Alberta's centrally located coal-fired power plants.

"This result shows that storage capacity is not likely to be an important constraint on implementing carbon capture and storage technology," Keith says.

"The results from WASP fill a gap between the province-wide estimates of CO2 storage capacity and the detailed commercial studies now being done by companies for individual CO2 storage projects," Keith adds. WASP also included site-specific studies of geology, reservoir fluids flow and geomechanics, which the province-wide estimates don't include.



The WASP (Wabamun Area CO2 Sequestration Project) study area (Source: University of Calgary)

The WASP researchers found that the costs of injecting CO2 and storing it in geologic formations are relatively low-about $3 per tonne of carbon dioxide. However, for a full CCS project, the additional costs required to capture the CO2 at an industrial facility, pressurize the gas and transport it to an injection site would be at least 10 times more than just the costs of storage.

Results from WASP will be used by TransAlta Corporation, one of WASP's several industry sponsors, in implementing the company's Project Pioneer-which will receive $770 million in provincial and federal funding. Beginning in 2015, TransAlta plans to capture one million tonnes of CO2 at its Keephills 3 coal-fired power plant in the Wabamun area.

"The WASP study has provided our Pioneer CCS project with a great head start in understanding the sequestration characteristics and opportunities in the region. WASP has been a very good example of coordinated development work between government, industry and academia," says Don Wharton, Vice-President, Sustainable Development at TransAlta.

The WASP study used existing geological, seismic and other data to examine the Nisku geologic formation as the primary target for CO2 storage. The 'brines' or fluids that occur naturally in this formation contain significant concentrations of dissolved hydrogen sulphide, a poisonous gas that could potentially mix with the leading edge of the plume of pure CO2 injected into the formation.

WASP was funded by the Natural Science and Engineering Research Council and the Alberta Energy Research Institute, with additional funding and support from a dozen industry partners.

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