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Front cover:
Shenhua's Direct Coal Liquefaction Process Development Unit (DCL PDU) which is being used to conduct research that provided the basis for a DCL plant in Inner Mongolia that will be the site of a pilot CCS injection (pg. 4)

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Flexibility in CO2 transportation

This article is the fourth in a series that considers features of the future power markets in which CCS will be competing with a view to understanding the potential implications for the here and now. It focuses on how the transportation requirements for CCS require careful consideration in order to avoid unnecessary future energy market complexity. Rushing in arrangements to facilitate investment today could potentially constrain energy competition into the future possibly limiting the penetration of CCS.

By Angus Paxton, Pöyry Energy Consulting

Transportation of CO2 is an essential part of the CCS value chain and presents many engineering challenges, particularly related to the fluid characteristics of CO2. They are being addressed by individual project developers, but the solution selected for each project is likely to depend on a particular set of operational, commercial, financial and regulatory assumptions. For example, transport systems are currently being designed around the needs of specific CCS technologies, rather than seeking an optimal network solution.

In our last article, we mentioned that it might be possible to resolve issues stemming from flexible CCS generation through developing a network that transports CO2 from a large number of sources, possibly including temporary CO2 storage facilities to regulate flow, to the long-term storage sites. In this situation, CO2 transportation begins to resemble other energy market networks.

This article explores how CCS generation needs to be considered as part of an integrated energy system, notes that there are engineering decisions being made today that might, in years to come prevent commerce or damage competition, and considers whether the right structures – regulatory, commercial and financial – can be put in place to prevent inefficient futures.

The existing networks – a happy coincidence?

The engineering challenges in natural gas and electricity transportation and the requirements for each network to accommodate changes to the supply and demand mix are well understood. However, the requirements for commercial balancing in the power and gas markets, which have been established reflecting the capability of each network and the unique characteristics of each product, are significantly different.

Whilst both are commercially balanced geographically over the entirety of Great Britain, gas features a daily balancing regime, whilst electricity enjoys a half-hourly balancing regime. Additionally, storage of these products for seasonal or shorter-term, temporary use is also significantly different: electricity, currently, can only be stored using geographically scant hydro-power resources, so flexible production (generation) is used instead; gas storage requires particular geology as production swing is expensive to develop.

In practice though, there is a degree of harmony between the two existing networks – there is currently a happy coincidence of flexibility in supply and demand. Gas fired power generation output can be varied within day to respond to within-day variation in electricity prices, thus providing flexibility to the electricity market. Currently, this variable utilisation of gas fired resource does not present too much of a problem to the gas network – for example, it requires no specific, identifiable investment.

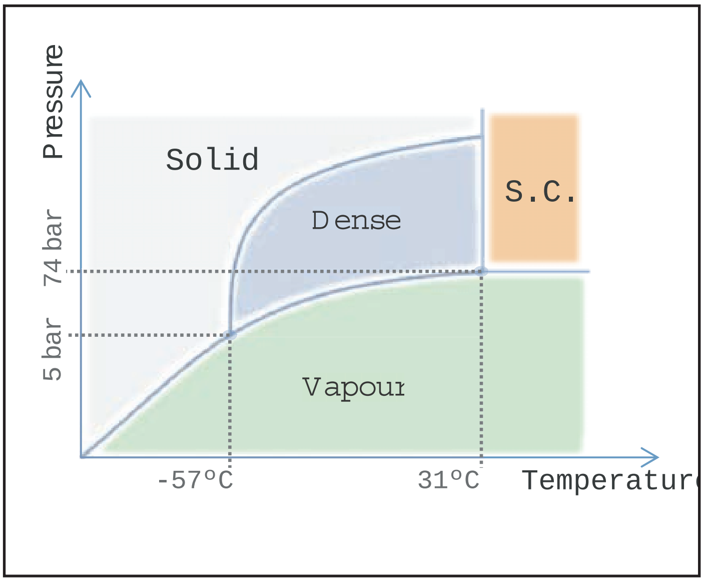

Figure 1 – CO2 phase diagram

Studies undertaken in the context of gas market exit reform have struggled to show that the benefits of changing the regime(s) outweigh any costs. As Pöyry has shown in its gas intermittency project, increased intermittent generation may drive a need for more flexible use of the gas network, although the precise extent to which this drives investment – network or storage – has yet to be examined.

Engineering challenges and options

Adding a third energy network, which does not yet have practical experience of operation or robust, well-understood economics, might be difficult to accommodate and could drive change in the electricity or gas networks. Indeed, there are a number of fundamental engineering decisions to be taken about the nature of such a network.

Dense phase or vapour phase

Perhaps the most important engineering question when considering the transportation of CO2 is in which fluid state to transport it. The CCS projects currently underway or proposed in the UK utilise either dense phase (i.e. liquid) or vapour phase (i.e. gaseous). Other approaches, such as multi-phase or supercritical (S.C.) transportation are also possibilities. These phases are represented in Figure 1. The decisions to choose one phase over another are being made on the basis of the specific CCS project(s) to which they apply.

For the same size of pipeline, significantly more CO2 can be transported in dense phase than in vapour phase; however it is less compressible and needs to be transported at significantly higher pressures, which has safety implications. Vapour phase requires a much bigger diameter of pipeline, so has a higher unit cost, although the more compressible nature of the gaseous phase means it is inherently more flexible. As dense phase is inherently less flexible, it may be necessary to consider close-to-source, short-term, temporary storage to overcome short-term supply-demand discrepancies.

CO2 in dense phase can act as a sol-

vent, which presents particular engineering challenges for recompression because of the interaction with lubrication – although the large number of dense phase pipelines in the US has established the engineering. It also presents risks when transporting in vapour phase, where migration to dense phase, however temporary, can strip lubricants from machinery, damaging equipment and contaminating the CO2. Operation of vapour phase transportation will therefore need to mitigate the risk of over-pressurisation, not purely for mechanical failure, but also to prevent contamination.

Flexibility in the transport infrastructure

In an ideal world, design of a CO2 network should be based on a sound understanding of precisely how the physical infrastructure will be required accommodate non-baseload operation. For example, it might be the case that coping with generation flexibility or any unreliability in the non-transport CCS chain requires the transport operations to accommodate significant levels of swing (possibly with integrated temporary storage), or may require the isolation of infrastructure to maintain fluid phases.

These engineering options have significantly different economic consequences, and might point to significantly different commercial models. For example, whether a close-to-source, short-term, temporary storage for dense phase transport is included as a part of the transport infrastructure, or whether a short-period balancing regime is applied to incentivise innovation and investment in temporary storage by CCS generators.

Requirement for single CO2 specification

As there are different types of capture resulting in different resultant fluid compositions and that the thermodynamic properties of CO2 are very sensitive to impurities, there may well be significant interoperability issues between different CCS technologies and transport mechanisms. These issues are only exacerbated when considering the transient behaviour of energy markets and physical infrastructure.

This might mean that the development of different classes CO2 transportation lead to the creation of different, separate networks. This could lead to competition in CO2 transportation, or may actually isolate technologies in separate markets and present barriers to trade – this could present a missed opportunity to create a 'captured carbon' commodity market.

Consequences for transport networks

Given the uncertainty over different CCS technologies and their economics, it could be the case that more than one new network gets added into the set of energy networks. The relativity of coal and gas prices already heavily influences the patterns of flexibility provision in the electricity market.

In a future where carbon prices also have an impact, and there are growing requirements for flexibility arising from intermittent generation, the current 'happy coincidence' that exists to meet the needs for flexibility in the energy markets will need to change. These changes will be complex, not least because the existing market structures are still evolving.

Integrating CO2 transport considerations into the energy market arrangements and interoperating CO2 networks will make understanding the economics particularly challenging. It is likely that the initial CCS project structures will require point-to-point commercial arrangements which do not lend themselves to efficient third-party access.

In addition to assessment of CCS investment opportunities, there could also be the need to reassess the traditional valuation techniques used elsewhere in the energy chain, (for example, the least-squared Monte-Carlo valuation techniques used to value gas storage facilities), as there are changing influences on price volatility.

Regulatory structures for CCS transport – barriers or enablers?

The electricity and natural gas networks have been largely constructed by vertically integrated businesses in full comprehension of all supply and demand requirements, with a captive consumer base and guaranteed revenue stream. Infrastructure investment decisions were centrally planned, and were effectively risk free.

Privatisation and liberalisation of the electricity and gas markets, which saw networks having to offer third-party access, has shifted much of the investment decision making into a competitive environment. Gas and electricity transportation still retains a monopoly structure so, whilst regulated, it still has relatively low levels of investment risk – if the investments pass some relatively simple regulatory tests they are effectively risk free.

The DECC CCS competition was launched at a time when there was little certainty on the regulatory treatment of the storage and transportation elements of the chain. Since then, the CCS Directive[1] has been introduced, which has the effect of requiring similar requirements for third-party access (TPA) to CO2 transport systems as those which apply to gas networks.

Gas TPA arrangements enable and require separation of the ownership and the transportation of gas, which then gives rise to gas being a traded commodity. The players involved in the DECC competition may therefore need to align themselves into similar structures – with the transportation (and possibly temporary storage) entities distinct from the production and sequestration entities, operating together under some form of network code.

The CCS Directive does not draw a distinction between transportation and temporary storage, which is a crucial distinction in the gas market: storage provides inter-temporal arbitrage opportunities which attracts traders and encourages forward market liquidity. The CCS Directive may therefore inadvertently favour a commercial model where temporary storage is integrated with transportation. This may hamper the development of commercial arrangements that facilitate competition, and ultimately sacrifice liquidity in any CCS commodity markets.

Another possible issue with the CCS Directive is that it does not allow for TPA exemption, which has been a crucial element in ensuring continued investment in the GB and EU gas markets, especially for gas storage, but also for LNG terminals. There is therefore possibly increased regulatory risk in CCS transportation investment.

Conclusion

With CCS is set to become a significant source of low-carbon energy, it has the potential to deliver great benefits in a low-carbon economy. It is important that innovation continues – there are a wide variety of promising technologies, each of which will have different requirements for flexibility and transportation.

Because competition drives innovation, it is important to get the regulatory and commercial structures in place to facilitate competition; however it is also important to ensure that any regulatory burden does not stifle investment.

There are some big questions remaining concerning the nature of CO2 transportation and CCS industry:

- Do we want a lot of efficiently sized point-to-point systems or do we want one big integrated network?
- Can we have one big integrated network?
- Can CCS provide the flexibility that is valuable in the gas and electricity markets?

The industry will need to consider these issues carefully in coming years.

1. Directive 2009/31/EC, dated 23 April 2009

China's growing CCS activities in action

Recently, Chinese energy companies have become engaged in a range of CCS-related pilot projects, some involving the U.S. Department of Energy (DOE) and U.S. companies and universities.

Sarah Forbes, Deborah Seligsohn and Logan West, World Resources Institute

Numerous research and demonstration projects to advance CCS technologies are already underway in China, the U.S., and the rest of the world with more on the way. China and the U.S. are the world's two largest CO2 emitters and, with their favorable geology as well as their prolific coal resources and consumption, the two could have the most to gain in emission reductions from a fully-developed and deployed CCS network.

Although bi- and multi-lateral discussions on which technologies and what approach to employ in limiting CO2 has proven contentious, both the U.S. and China have identified CCS as an important focal point for collaboration. This is evidenced by CCS' inclusion as a key pillar within the recently established China-US Clean Energy Research Center.

In early August, an international team of CCS experts and stakeholders assembled in China to visit many of the key projects and key players for CCS development in China as a follow-up to the summer '09, China CCS study tour. Both trips are a product of the ongoing partnership between WRI and Tsinghua University to develop the Guidelines for CCS in China, an effort detailing the technological, procedural, and other multidimensional (e.g. regulations, resource consumption) issues for CCS specifically in China. Below are summaries of the sites visited by the group and some key impressions that Steering Committee members took away.

1. Although Chinese CCS development still lags behind the world leaders, there has been significant and encouraging progress. China is a leader in coal gasification technology, which produces more pure, capture-ready CO2 flue gas streams. Simultaneously, China is catching up in CO2 capture technology. CO2-Enhanced Oil Recovery (EOR), CO2 storage, and CO2 pipeline transport are all under significant R&D in China.

2. The speed of planning development, construction, and regulatory approval for all types of projects in China, especially energy, is unparalleled in the world. Likewise for CCS. The Shidongkou capture plant effectively went from a patch of grass to fully operational power plant with CO2 capture in a little over a year.

The gargantuan Ordos coal-to-liquids (CTL) plant is up and running after only beginning CTL research in the late '90s, and GreenGen is nearly complete within almost two years of its conception. Current CCS actions move quickly because they are "voluntary" and not subject to specific regulations.

To ensure that large-scale commercial initiatives advance expeditiously but without compromising health, safety, or the environment, WRI research highlights the existing institutions and laws capable of supporting CCS, and also the areas where the Chinese government should improve.

A holding tank for CO2 separated at Huaneng's Shidongkou Power Plant

The same rings true for large deployment and not just individual projects. At a time when the US is lagging behind in determining and enacting a plan of action, the Chinese companies and government are building large scale projects, giving them an edge in developing technological experience and know-how.

It should be noted that rapid regulatory approval results, in part, from a shorter history of environmental legislation and an absence of CCS-specific regulations. Current CCS activities are considered voluntary and not subject to additional approval.

3. The scale of technology investment is enormous, and if seeing is believing, then the manufacturing facilities of Shanghai Electric, a leading manufacturer of CCS-related equipment, are a monument to the effects of this. The size, modernity, and production rate of their plant are first-class, and the plant includes some of the most advanced technology in the world.

Shanghai Electric is also a main contributor in constructing China's target of 28 new nuclear power plants by 2020. 24 of these are already under construction. This scale of investment will help position China to possibly take a lead in energy technology development in the future.

4. China is moving forward with or without everyone else. Faced with economic and environmental pressures, China has immense domestic incentive to create and grow sustainable, new and improved energy technologies and is responding. If results from domestic and international demonstrations as well as key government and other R&D efforts prove promising to the Chinese government, China could become a world CCS leader (and technology exporter) within the

next two or three decades.

China's push forward is not without challenges, and key opportunities exist for US-China collaboration that would be mutually beneficial. It is imperative for the US to step up to the plate and engage in meaningful ways, especially expanding existing efforts and beginning new ones in areas like geological site characterization and CO2 storage where the US has a significant edge in experience and technical understanding.

5. While current CCS projects have the luxury of conveniently positioning themselves within arm's reach of their most essential resources (fuel sources, CO2 sources, and suitable storage sites), as more projects develop in CO2-intensive industries, it will become more and more difficult to avoid intersections with population, land development, and local resource scarcity. How China plans for and manages these situations will be important.

The study tour visited several sites associated with CCS, including where CCS activities are already or soon will be taking place. Brief summaries of a few of the sites are offered below.

PetroChina Jilin Oilfield – Jilin, Liaoning Province

The Jilin Oilfield Complex is the leading site for CO2-EOR research and activities in China. Funded in part through the Chinese National Basic Research Program 973, PetroChina began research in 1990. In 2005, PetroChina discovered large natural gas deposits containing 22.5% CO2 concentrations. This CO2 is now being stripped from natural gas production and condensed before injecting into several oilfields in the complex.

PetroChina annually injects 200-300,000 tCO2 via CO2-EOR. At Jilin, it is injected over 2km deep into low permeability sands. At the two fields the group observed, PetroChina expects to enhance recovery by 10-20%. Given the abundant CO2 supply and need for more technical experience, PetroChina is now running these plants as long-term commercial projects and not just short-term pilots. Given that two-thirds of China's undeveloped oil reserves are in similarly low porosity oil reservoirs and that 95% of PetroChina's operations already involve water flooding, the potential for CO2-EOR is vast.

Shidongkou Power Plants 3 & 4 with CO2 Capture – Shanghai

Plants 3 & 4 are twin, ultra-supercritical, coal-fired power plants located near the Yangtze Delta in northern Shanghai. Each plant has a capacity of 660 MW, using mostly Chinese technology with a boiler from Babcock & Wilcox (US).

The plants are additionally equipped with a CO2 capture facility that separates and purifies CO2 from 4% of the total CO2 emissions stream to produce an estimated 120,000 tonnes of food grade CO2 a year making it the largest in China and one of the largest capture projects at a coal-fired power plant in the world.

The product, used predominantly for food packing dry ice and beverage carbonation, is sold on the market for ~¥300/tCO2, roughly the same amount as the operational costs of capturing it. Notably, the plant and especially the capture facilities were completed ahead of schedule and under budget. Capital expenses of US$14.6 MM were considerably under the estimated US$23.5 MM.

Shanghai Electric Manufacturing Plant – Shanghai

Founded in 1880, Shanghai Electric is the largest equipment manufacturer in China, including in the field of power generation equipment. In addition to being the largest domestic manufacturer of nuclear reactors in China, Shanghai Electric also owns SEWIND, whose 3.6MW turbine is the largest and most technically advanced offshore wind product in China. Shanghai Electric is and will continue to be one of the domestic leaders in manufacturing equipment for IGCC and Oxyfuel equipment. The company will be instrumental if there is to be large deployment of power sector-related CCS equipment.

Shenhua CTL Process Development Unit (PDU) – Shanghai

This Shenhua PDU was the predecessor the CTL plant in Ordos visited during the last study tour. The PDU is China's first to be designed, constructed, and operated domestically and was the world's biggest commercial scale coal liquefaction device. It is also the world's first coal-to-liquid device to reach megawatt-scale production, and it has carried out numerous tests and research.

Since 2004, there have been 5 tests conducted at the facility totaling 5,098 hours of operation and 1,520 tons of coal consumed. Amongst other achievements at the center, progress has been made in R&D, with process flow optimized and validated by experiment, providing reliable design data and technical support for fundamental design and modification.

The plant now serves as a testing center for process optimization and as a training facility for managers who will move on to the Ordos Plant, which has been up and running itself since Spring 2010 with no unmanageable glitches and with CO2 storage plans progressing rapidly.

More information

This report was first published on the World Resources Institute Chinafaqs website: www.chinafaqs.org

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Making the case for CCS in the CDM

The developing world needs a support mechanism to also benefit from CCS's Climate Change mitigation potential. Why can this not be the CDM?

By Henk Sa and Lodewijk Nell, EcoMetrix Africa

In 1997, the Kyoto Protocol, which was adopted by industrialized and developing countries (Annex I and non-Annex I countries according to the Protocol), set binding GHG emission limits for Annex I countries for the period 2008 - 2012. The Protocol established "Flexibility Mechanisms" to allow industries (and countries) to have more and lower-cost options for reducing emissions. The Clean Development Mechanism (CDM) and Joint Implementation (JI) are two of those mechanisms and they allow for the purchase of Certified Emission Reductions (CERs, under the CDM) and Emission Reduction Units (ERUs, under JI) by affected parties from sustainable development projects (e.g., renewable energy, energy efficiency) in non-Annex I countries as a means of complying with domestic emission limits.

Although CCS in geological formations is a well-established mechanism predominately used in the Oil and Gas industry for Enhanced Oil and Gas Recovery (EOGR) its applications as a method for reducing the global output of anthropogenic Green House Gasses (GHG's) which are the main cause of climate change. CCS has not taken of in line with its expected potential as a climate change mitigation technology in the developing world.

Developing countries such as China, India and South Africa will be dependent on fossil fuel based economic growth for the foreseeable future and therefore the application off CCS to grow their industry and thereby their economies along a greener trajectory should be encouraged.

The primary issue with the development of CCS facilities in developing countries (as is the case in the industrialised world) are the cost related to the investment and operation of these installations.

Although there are several subsidy systems under development to address these costs, they are not substantial and uniform enough the elevate CCS to a real emission reduction mechanism. A well established and operational system to financially support GHG emission reduction activities in development countries is the Clean Development Mechanism. In this article a closer look is taken on the possibility of including the CCS into the CDM.

CCS cost and CDM revenue

If CCS would be accepted as a method for reducing the emission of GHG's into the atmosphere a CCS project could generate an additional income stream to cover its investment and operating cost from the sale of Certified Emission Reductions (CERs) used within the CDM system as the unit of measure for one ton of CO2e that did not go into the atmosphere.

Historically the price of a CER has been around 19.43 Euro/CER. With a market high of 33.35 Euro/CER and a market low of 7.93 Euro/CER. For a global GHG agreement replacing the Kyoto after 2012 to effectively realise the overall objective or reducing the global output of anthropogenic GHG's that caps put on industrialised countries will need to be severely tightened which will have an upward effect on the CER price which is estimated to go up to between 30 and 60 Euro/tCO2e

New energy technologies do not come cheap. If no combination is made with EOGR, current CCS cost are estimated at around 60-90 Euro/ton CO2 depending on the circumstances. Nevertheless, it is expected that these cost will come down to 35-50 Euro/ton CO2 in the early commercial phase (2020+).

From the latter can be deducted that the cost of CCS could be covered by the revenue for CDM in the longer term (2020+) and on the short term in combination with EOGR or with subsidies as is currently been done in de developing world. Therefore, at least from an economic perspective, the CDM could be considered a very suitable mechanism to deploy CCS in developing countries. So why is this not the case?

Barriers

Many of the industrialised parties have pushed for the technology to be included within the Clean Development Mechanism (CDM) established by Kyoto, in theory allowing CCS projects to generate project credits. Some parties, however, have voiced strong concerns as to the technology's inclusion, citing the putative risks associated with storage, the high costs of implementation and its unassailable link to fossil fuel consumption.

In recent years discussions appeared to reach an impasse, with the CDM Executive Board, SBSTA and the Conference and Meeting of the Parties (COP/MOP) unable to agree as to the technology's inclusion. At the most recent COP in Copenhagen 2009 the mitigatory role of CCS was recognised, however some issues were deemed unresolved by the COP and further clarification of the many issues raised by the parties was sought.

The table provides an overview of the outstanding issues that need to be addressed before including CCS into the CDM.

When looking at the issues it becomes apparent that none of them express fundamental issues with CCS as a climate change mitigation technology like is the case with for example nuclear energy and large scale hydro. All of the issues relate to either technical or CDM systematic concerns. The technical concerns mostly revolve around the limited experience with the technology and the long timelines involved in applying it. CCS has been widely used in the developed world as a method for EOGR and even though this does not provide experience on the impacts of the technology in 200 to 500 years' time this is the case with most if not all of the technologies applied around the world including those under the CDM.

The CDM issues are either related to the rules of the CDM when it comes to monitoring or project boundaries for example which can be addressed rather straight forward within the existing CDM framework or to the fundamental issue of storing GHG as a climate change measure. Although this is an excepted concept within the current CDM framework it would be useful to included CCS in the CDM by adopting for example a CER buffering mechanism such as applied within the REDD system. In such a system a percentage of the CERs generated by the project could be held by the UNFCCC as a buffer to offset potential leakage from a CCS project in the future.

Issue category	Understanding of issue	Comment on the issue
Non-permanence, including long-term permanence	The technology does not avoid emissions but rather stores them hence there is a risk that the stored GHG goes back into the atmosphere	The concept a a carbon sink is accepted under the CDM via, for example, forestry type projects
Measuring, reporting and verification	The CO2 stored via CCS is modelled not measured. This is especially a concern when it comes to leakage over long periods of time	Most CDM projects depend on modelling to determine the volume of CERs generated
Environmental impacts	The lack of experience with CCS would pose challenges for conducting a CCS Environment Impact Assessment (EIA) especially relating to the risk of seepage	Most CDM projects depend on a host nation's assessment of the environmental impact of the project via a EIA process. As CDM projects are by definition not common practice in the host country the risk of a poor EIA is not very different for a CCS project then for any other CDM project
Project activity boundaries	The CCS reservoir could be cross boundary and migrate over time making it difficult to set the project boundary for a CCS project	There are several CDM methodologies in use today that apply cross boundary consideration when defining the project boundary (e.g. ACM0002 for renewable energy to the grid) so this would be nothing new. The migration of GHG beyond the project boundary is also possible in the case of the widely used CDM project type, Landfill gas to Energy and is not considered as a problem in these projects even though the GHG is stored mush closer to the service than would be that case with CCS
International law	International Maritime treaties were drafted without having CCS activities in mind	Many CDM projects that are currently in place operate under legislation that was not designed with CDM or the underlying project in mind. In most cases project specific solutions where designed and in some cases the regulations where adapted
Liability	Who will be liable for leakage and migration of CO2 from a geological formations taking into account the long timeframe of the storage	This concern exists for all projects that apply the principle of a carbon sink (e.g. forestry projects that are hit by a forest fire). It is reasonable to assume that CO2 storage in a empty gas field that held LNG for 2 million year carries a lower risk of leakage than a forest. Hence the question of liabilities is less of an issue for CCS projects than existing CDM projects
The potential for perverse outcomes	The carbon market could be flooded by CCS CERs making the CER price drop and thereby excluding some important CDM project types such as renewable energy	As indicated earlier the cost per tCO2 stored via CCS are not substantially lower so the effect of flooding the market and dropping the price does not exists as CCS won't be feasible under the CDM at a low CER price. An increase in the volume of CERs generated should be addressed by tightening caps not defining a technology an issues because it contributes to mush to mitigating climate change.
Safety	Idem as issue 1. The technology does not avoid emissions but rather stores them hence there is a risk that the stored GHG goes back into the atmosphere so it could be risky and unsafe	The concept a a carbon sink is accepted under the CDM via, for example, forestry type projects
Insurance coverage and compensation for damages caused due to seepage or leakage	Idem as issue 1. The technology does not avoid emissions but rather stores them hence there is a risk that the stored GHG goes back into the atmosphere and who will be picking up the tab when there is leakage	The concept a a carbon sink is accepted under the CDM via, for example, forestry type projects

Table 1 - an overview of the outstanding issues that need to be addressed before including CCS into the CDM

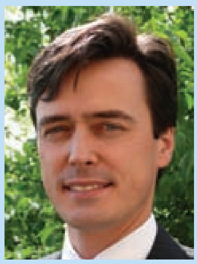
So what's needed in Cancun?

When investigating the topic it becomes apparent that there are no real barriers for including CCS into the CDM and as is so often the case with large topics like Climate Change, CCS and CDM what is required to realise this is leadership by people that do not confuse the objective (the mitigation of climate change) with the method (CCS). In addition to that a watchful eye should be held on those that raise concerns about the method to push their own alternative agenda even though that agenda does not strive towards the same objective.

Henk Sa

As the Managing Director of EcoMetrix Africa (South Africa's most successful CDM company), Henk is responsible for the corporate strategy and daily operation of the company. After working as a strategy consultant in the energy field at PwC, Henk joined EcoSecurities and worked in the field of Climate Change in both Europe and Africa.

Lodewijk Nell is Director Consultancy at EcoMetrix Africa and has more than ten years consulting experience in the energy sector at PwC and TNO. In 2007 he became involved in building CCS partnerships and commercialising CCS technologies in Europe. He continues to do so in South Africa from a techno-economic perspective.



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CCS legal and policy – Nov / Dec 2010

Industry's responses to the UK Office of Carbon Capture and Storage's (OCCS) Market Sounding Consultation have now been published and they offer an insightful snap-shot of the current state of development of GB's CCS industry, says Calum Hughes, principal consultant in CCS regulation and policy at Yellow Wood Energy. calumhughes@yellowwoodenergy.com

Two key points strike home: firstly the relatively small number of potential CCS projects left on the table (this number being further reduced by the withdrawal of E.ON from the competition); and secondly, that while some consensus is being reached on the technical aspects of the industry's development, the commercial and financial difficulties facing developers, instead of reducing, seem to be increasingly complex and intractable.

Those responding to the consultation largely agree that a single call for tenders for the remaining three demonstration projects, as opposed to time staggered calls, is the best way forward and that a total of four demonstration projects is an adequate number (although some thought that, if demonstration on gas was to be added then this should warrant a fifth subsidised project).

There is also a large degree of agreement in the industry regarding what technical aspects would be desirable in the demonstration projects. A large majority agree with the CCC that at least one of the projects should be on a gas fired plant (and as we now know this has become formal Government policy) and that there should be as little restriction on technology selection as possible.

The importance of including the functionality required for EOR and trans-boundary shipping in the projects' system designs is mentioned by a number of respondents. Encouragement for co-location of projects and shared infrastructure is also almost universally explicitly supported with some suggesting that DECC should formally identify the region, or regions, it favours for support and should subsidise 'right-sized' pipelines and infrastructure for these areas.

The one technical point on which there is a notable lack of consensus is that of what restrictions should be placed upon the level of generating power to which a subsidised CCS project should be applied. Many respondents agreed that the 300-500MWe range suggested by DECC is suitable, apparently on the basis that this size of CCS plant is adequate to demonstrate the technology at the scale necessary to prove it for full plant application.

A roughly equal number of respondents pointed out however that size restrictions would potentially lead to economically suboptimal plant design and suggested that it would make better sense to subsidise CCS demonstration at full plant scale.

This point aside, the industries guidance to DECC on which technical blueprint should be used for the CCS demonstration is relatively clear. It is less easy to find common consensus in the responses to the commercial and financial questions posed by the consultation; a wide variety of issues are distributed across the various responses. The current uncertainty associated with energy market reform is brought up by a few, particularly from a point of view of uncertainty regarding the viability of coal fired plant going forward.

The weak and volatile nature of the carbon price over the short to medium term is cited as a risk by others (although fewer than one might expect, possibly due to a realisation on the part of responders that it is not within the gift of the UK Government to control this factor unilaterally). One or two more raise the issue of the risks associated with the uncertainty of policy and regulation, although this seems to be of less concern than it has been in the past.

There is, however, one common theme that runs through many of the responses: that of the difficulties and costs associated with the financing of projects if subsidy is applied via a Contract for Differences (CfD) on the EUA price. The key message seems to be that if subsidy support comes only when CO2 is actually stored then this will make it more difficult to finance the projects and prove more expensive for the consumer in the long run.

This phenomenon of disproportionate increase in overall cost when utilising private capital for public infrastructure projects has been observed in some projects financed along the Public Private Partnership (PPP) model. The increased costs in the case of conventional PPP projects have been chiefly due to the cost of pseudo-borrowing associated with the State utilising private sector capital.

Whilst there is some construction risk premium applied to conventional PPP projects, in the main, the technological and operational risk premiums tend to be low because revenue streams, once the project is commissioned, are relatively certain. For CCS this is clearly not the case and so, if project subsidies are not provided up-front, the costs of the developer financing the project will be compounded with the premium required by the developer in return for it bearing, not only the construction risk, but also the considerable technical and operational risk involved with CCS projects.

Calum Hughes, Yellow Wood Energy

Some responders suggest that, in order to avoid the consumer having to pay these risk premiums, subsidies should be applied during the engineering and CAPEX phase of the projects resulting in the Government bearing the risk directly and hence avoiding the risk premium.

It seems unlikely the Government will want to follow this course of action; DECC has consistently maintained a stance of not wishing to appear like a procuring client with respect to CCS projects and has preferred instead to attempt to render these projects commercially viable by manipulating CCS economics via the application of state subsidy to CCS revenue streams. Given the straightened nature of the times (and the political importance of keeping public sector debt off the Treasury balance sheet) it is difficult to see why they would wish to change their position now.

However, as the future of the regulatory and technical structure of the UK's CCS industry begins to look clearer, it is increasingly the financing of the demonstration projects which appears to be the stumbling block. With the implementation of the electricity supply levy apparently uncertain we now await DECC's proposals as to how the promised support for the remaining three demonstration projects will be sourced and applied.

UK CCS policy: on track, but only just

Chris Littlecott, senior policy adviser at the environmental thinktank Green Alliance, looks at the early actions of the new UK government, and identifies three key challenges that their CCS strategy must address.

What a difference a few months can make. In the July / August edition of Carbon Capture Journal I looked at the future prospects for UK CCS policy. Many aspects looked positive: the creation of the Office of CCS had provided improved institutional capacity, and coalition ministers were in agreement that they wanted to make the UK 'first choice' for investment in CCS.

The challenge, as I saw it then, was to flesh out a package of finance and regulation that could provide the necessary confidence to both industry and wider stakeholders. That is still the challenge today, but one which has been threatened over the late summer and early autumn of 2010.

Let's consider the three areas I picked out last time around, and see where the government has fared.

1. Think big, talk climate

In July, I noted that there need to be a policy framework that gives clarity on the timescale for the decarbonisation of UK energy supply, such as the Committee on Climate Change recommendation of a 2030 target. Broader reform of energy markets will help, but clear signals need to be sent now that low-carbon power investments must become the new norm. The coalition's commitment to defining an EPS can help to play that role.

Where are we now? Well, the headline commitment to an EPS has been maintained, but there won't be any legislation in their year's energy bill. Not even enabling powers, as had been supported by both coalition parties when in opposition. Instead, the plan is for an EPS to be introduced in a second energy bill later in this parliament.

This absence of signals on an EPS is compounded by the continued absence of a clear target for power sector decarbonisation. It may be that the forthcoming electricity market reform consultation will help, but I'm not holding my breath. In the absence of these signals, it will be more difficult to engage NGOs and other stakeholders.

2. Define direction of travel early

In July, I noted that with limited public funding available, it will be of central importance to build the market at sufficient scale to foster the development of supply chains and the availability of different technology options. A combination of early decisions on EPS and a strategic infrastructure roadmap can combine with market reform measures to make CCS an attractive long-term industry, not a series of one-off projects.

Where are we now? Given the OCCS roadmap is still under development, and early decisions on EPS have been postponed, we are left looking for alternative signals to see where the market for CCS might be heading over the coming years. The closest we have is the decision to allow gas plants to bid for demonstration support. This should be positive news, for both the climate and the prospects for the UK CCS industry.

However it has been accompanied by a declaration that emissions limits on gas plants aren't under consideration in the short to medium term. While intended to ensure that sufficient new gas capacity comes forward in the coming years, this policy could also mean that unabated gas will continue to be the default option well into the 2020s. That immediately complicates the competitive calculus for project developers considering CCS projects, and will require that electricity market reform does more of the heavy lifting to pull through power sector decarbonisation.

3. Secure the money

This has been the real crunch area. The Comprehensive Spending Review was always going to be a battleground, but it turned out to be a different battle than the one expected.

In July, I noted that "While there is no doubting the good intentions of DECC ministers and the OCCS team to make CCS happen, their enthusiasm is matched within government by the Treasury's reputation for ruthlessness. In particular the original CCS competition, the now-titled 'demo 1', will be in their sights given that the structure of the competition places a far greater burden on the government's balance sheet than subsequent projects 2 to 4."

Where are we now? Contrary to expectations, the Treasury agreed to fund demo 1 from public sources. This is indeed to be welcomed. As DECC's response to the CSR notes, "This is the largest confirmed commitment to a single commercial-scale CCS project in the world."

But in the process of securing this funding, DECC came perilously close to losing the CCS levy, which had only been agreed in legislation earlier this year. The threat to the levy took many people by surprise (ourselves included), given the cross-party backing it had received, and its place at the centre of UK policy. And without the levy revenues to plan against, aspirations for further demonstration projects would remain just that. The experience of demo 1 means that potential bidders are likely to take the 'once bitten, twice shy' approach to unfunded CCS tenders.

Chris Littlecott, senior policy adviser at the environmental thinktank Green Alliance

Here at Green Alliance, we were vocal advocates in support of the levy, working with industry partners and leading academics to make the case in private and via the pages of the Financial Times. If the levy had been lost, it would have seen the coalition government steal defeat from the jaws of victory.

Thankfully, the result of intensive advocacy and ministerial resistance has been that the levy has not been abandoned before it could be introduced. But that is only a partial success. The process going forward is that "the government will take decisions on the funding mechanism for the additional 3 CCS projects, i.e. whether through a specific CCS levy or through general public ex-

penditure, following completion of work in Spring 2011, on the reform of the Climate Change Levy to provide support to the carbon price."

We can therefore expect at least a further six months of delay before we have any clarity on how CCS demonstrations 2 to 4 will be supported. Industry will need to make its case for investment clarity if it is to secure the support it has called for. The onus needs to be on the Treasury to make the case why any alternative approach would be better for investment than the levy process. Open-ended commitments to public spending support via future Comprehensive Spending Reviews are not going to be up to the job.

Conclusion

UK CCS policy is still alive, and certainly kicking. But the pressures of the Comprehensive Spending Review have revealed the tensions between different departments and the need for more proactive industry engagement to secure a coherent policy framework. With the EU's NER300 funding programme just announced, and the need for UK policy to dovetail with that, the picture is likely to get more complicated before it becomes clearer. Fingers crossed for the next six months?

More information

www.greenalliance.org.uk

Alberta legislates on CCS

Alberta has introduced amendments to legislation which will guide the use of carbon capture and storage technology.

By Ron Liepert, Minister of Energy, Alberta

The province of Alberta recently introduced legislation that will remove some of the policy barriers to large-scale carbon capture and storage (CCS) projects in Alberta. This makes Alberta the first province in Canada to introduce comprehensive legislation for CCS.

CCS is the backbone of Alberta's 2008 Climate Change Strategy which commits to reducing projected greenhouse gas emissions by 200 million tonnes by 2050 – 70 per cent of which will be achieved via CCS. This legislation ensures we are on track with that commitment.

The Carbon Capture and Storage Statutes Amendment Act, 2010, Bill 24, was introduced in the Legislative Assembly on November 1, 2010. This legislation clarifies pore space ownership as belonging to the Crown. This amendment does not in any way change ownership of mine and minerals resources nor does it affect activities such as Enhanced Oil Recovery (EOR).

In its 2009 final report, the Alberta Carbon Capture and Storage Task Force estimated that using CO2 for Enhanced Oil Recovery (EOR) in Alberta could produce an additional 1.4 billion barrels of oil from conventional reservoirs. These reserves would not be accessible using conventional production techniques.

That could generate up to $25 billion dollars in provincial royalties and taxes. This would ensure we are retrieving as much oil as we possibly can from conventional wells already drilled, and that makes terrific environmental and financial sense.

Bill 24 also enables the Province to accept the long-term liability for injected carbon dioxide. The timeframes and requirements of this provision need to be worked out, but acceptance of long-term liability will occur only once an operator has scientifically demonstrated that the CO2 has been properly injected and that long-term monitoring shows it is completely stable.

This legislation also creates a fund which will be financed by CCS operators. The money will be managed by the Province and used for ongoing monitoring costs and any required remediation.

These legislative amendments are necessary to establish the regulatory groundwork required to facilitate large-scale carbon capture and storage projects. They are also recommendations made by the federal-provincial ecoENERGY Carbon Capture and Storage Task Force and Alberta's Carbon Capture and Storage Development Council. Government asked these teams of experts for their input and we are listening.

Changes in how we do business are required to provide regulatory clarity which companies need to move forward with this game-changing technology. Details of these amendments will be worked out with the input of experts and stakeholders beginning in 2011.

In July of 2008, the Government of Alberta committed $2 B (CDN) to fund three to five large-scale projects that would reduce emissions by five million tonnes annually beginning in 2015. Expressions of Interest were received for 54 projects; twenty of these were asked to submit full project proposals (FPP), providing extensive details about their projects and expected costs.

Letters of intent have been signed with four project proponents and grant agreements are currently being negotiated. The projects are: the Alberta Carbon Trunk Line (Enhance Energy and North West Upgrading) – an oil sands upgrader and 240 km pipeline; Quest Project (Shell, Chevron, Marathon Oil Sands) – Scotford Upgrader; Swan Hills Synfuels - in-situ coal gasification; and Project Pioneer (TransAlta, Alstom, Capital Power, Enbridge) – retro-fit a coal-fired electricity plant.

Ron Liepert, Minister of Energy, Alberta

More information

The Bill can be viewed at:
www.assembly.ab.ca/net/index.aspx?p=bills_status&selectbill=024
For more details on Alberta's carbon capture and storage program, visit:
www.energy.alberta.ca

CCS perspectives in energy intensive industries

For some CO2-intensive industries CCS could be a valuable solution as for the time being a significant amount of emissions from industry is process related and is difficult to mitigate.

By Victoria Schmid and André Lacerda

Carbon Capture and Storage (CCS) has been acknowledged as an important option to mitigate CO2 and reach climate targets. So far, the focus of political CCS discussion has been set on the power sector.

However industries account for 22% of EU CO2 emissions; globally industrial CO2 emissions are much higher with about 40%.

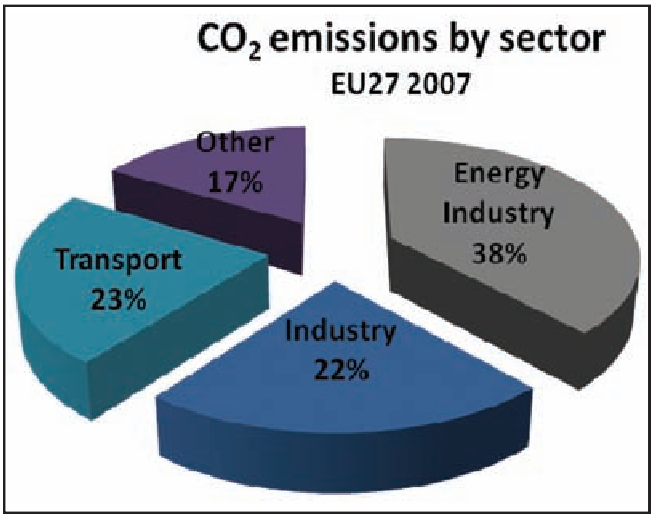
This article provides the main findings from a study whose objectives have been to examine to what extent CCS approaches exist in different CO2-intensive industries. The assessment covered the chemical, cement, steel and refining industry, addressing questions such as: what is the current status or what are future plans for CCS? What technologies are analyzed and preferred? What concerns exist?

These industries have recognized CCS as a CO2 mitigation option and pilot projects to test different capture technologies have been started. The table below shows CO2 emissions data (year 2007) in the refining, chemical, iron & steel and cement industry and their share of the total EU CO2 emissions. All in all, round about 11% of the EU`s CO2 emissions are emitted by these four industries.

Chemicals

In the chemical industry CO2 is emitted just in a few processes, e.g. production of soda or ammonia. There CO2 is already captured to a large extent and used for other processes or products. Such an approach is called "CCU" – carbon capture and usage by BASF. However, CCS could become an interesting option for some processes; also for a plant's own electricity production capacities.

A pilot project in the chemical industry is realized at Chemelot in Limburg where a chemical company captures CO2 from ammonia processes and uses a part for other chemical processes and the beverage industries. The remaining CO2 which is not used for other processes is to be injected underground on site in chalk-sandstone layers which are suitable for CO2 storage.



Source: CCS Country and Industry Assessment, data EU Commission (2010)

BASF and Linde-KCA-Dresden GmbH announced cooperation on a flue gas CO2 capture in January 2010. The project is focussed on the Middle East region, where the demand for high concentrated CO2 for enhanced oil recovery and urea production is growing. BASF is also evaluating potential storage sites together with the company Wintershall.

As key requirements for a future use of CCS, access to suitable storage locations as well as transportation networks and especially public acceptance and financial promotion are stressed.

Cement

The cement industry is contributes to round about 5% of the world's CO2 emissions.

The main pillars for a reduction of CO2 emissions in the cement industry are:

- increase of energy efficiency
- substitution of fossil fuels by alternative fuels for clinker production
- substitution of clinker by other materials to produce cementitious products
- CCS

The main part of CO2 emissions is process related – a decisive aspect, as reduction opportunities of raw material based emissions are limited without CCS.

As to the implementation of CCS the European Cement Research Academy (ECRA) started a long-term oriented project on CCS in 2007 to analyse the technical and economical feasibility of CCS, focussing on the capture part. After studying technical and financial aspects of CCS since autumn 2009, laboratory-scale research activities are going on. After 2011, pilot-scale research activities are to be realized and later on finally demonstration activities to gather experience and demonstrate reliability as well as effectiveness of capture processes.

In the beginning four different capture options were considered:

- pre-combustion
- post-combustion
- oxy-fuel technology
- carbonate looping

ECRA states that a detailed technical understanding of CCS is still to be achieved but the analyses show that all capture technologies are far from being applicable to the cement industry because of technical and economical aspects so far. The analyses show that oxy-fuel and post-combustion technologies seem to be most appropriate for

Refining	Iron and Steel	Chemicals	Cement	Total
134.6 Mio. t	115.6 Mio t	30.3 Mio. t	173.6 Mio. t	4186.7 Mio. t
3.2 %	2.8 %	0.7 %	4.1 %	100 %

CO2 emissions data (year 2007) in the refining, chemical, iron & steel and cement industry and their share of the total EU CO2 emissions. Data EU Commission (2010) and Ecofys (2009)

cement production and the next steps will focus on these technologies.

Estimations from IEA, which also considers ECRA calculations, range from 10-50 Euro/ton clinker operational costs. Investment costs have to be calculated between €100 and €300 million for new installations or retrofit; transport and storage costs are not included.

According to the Global CCS Institute there is only one demonstration plant planned in the cement industry today: a Cemex plant in the US has been chosen and is funded by the US Department of Energy to develop capture technologies.

Steel

Iron & steel producers are interested in CCS technology as a complement to their technologies on CO2 mitigation. The top gas recycling concept is the most advanced process which is moving to a demonstration phase. AcelorMittal projects aim to demonstrate the technical and economic viability of both the Top Gas Recycling (TGR) and CCS concepts, and to open the way to deployment of the technology within existing steelmaking facilities after 2020.

Iron & steel producers are leading the technology development through a consortium named ULCOS (Ultra Low CO2 Steelmaking) that started in 2004 and is supported by the European commission. ULCOS investigated over 80 technologies for CO2 mitigation. The four preferred concepts are:

- Top Gas Recycling Blast Furnace with CCS
- HIsarna with CCS
- ULCORED with CCS
- Electrolysis

The aim of a 50% reduction of today`s CO2 emissions can only be reached if the Top Gas Recycling Blast Furnace, HIsarna and ULCORED, is combined with CCS. According to EUROFER the most interesting approach is the top gas recycling with CCS.

A pilot project on top gas recycling was successfully tested in a gas separation plant constructed next to LKAB's experimental blast furnace in Luleå, Sweden in 2007.

Plans have been developed to test the same concept on a commercial scale blast furnace from AcelorMittal, starting in 2010. The Top Gas Recycling concept will firstly be tested on a mid-sized blast furnace at Eisenhüttenstadt in Germany, followed by a large demonstration project combined with CCS in Florange in France scheduled for 2015.

In 2010, ArcelorMittal filed a research permit request in partnership with Geogreen, a subsidiary of the French Geological Survey, IFP and Géostock for CO2 storage in the Lorraine region. The exploration of saline aquifers at a depth of more than 1,000 meters will take place between 2011 and 2014. A demonstration phase is planned from 2010 to 2015. The cost associated with such a demonstration project for one blast furnace is estimated between €300 and €400 million.

Refining

EUROPIA, the European Petroleum Industry Association, states that CCS is being investigated. Although it is technically feasible to apply CCS technology in refineries, the large number of different processes, with different specifications of CO2 to be captured, makes the task comple and costly.

As to technology preferences Shell Global Solutions International identified three possible routes for capturing CO2:

- Oxyfiring where pure oxygen rather than air is used for combustion. In refineries, burners may be oxyfired.
- Capture where the fuel is pre-treated, forming CO2 and hydrogen; gasifiers may be equipped with pre-combustion capture.
- Post-combustion capture where CO2 is removed from the flue gas before its emission.

Shell's Barendrecht project in the Netherlands, now cancelled, was to test the use of pre-combustion technology in a refinery.

A "typical refinery" that processes 300,000 barrels per day was studied to analyse the viability of CO2 capture using post combustion for flue gas. The main findings are:

- CO2 concentration has a substantial impact of capture cost. When flue gas CO2 concentration drops from 12% to 4% capture cost increase by 25%.
- There is a lack of scale benefit linked to equipment sizing limitations; the more CO2 is emitted the lower is the cost but there is no benefit above 2,000k ton CO2/year for a typical flue gas containing around 8% of CO2.
- Hydrogen production units would have lowest capture cost and represent 5-20% of emissions. Large flue gas sources such as furnaces and gas turbines would have the second lower cost and represent 30-50% of the refinery CO2 emissions. A large number of scattered remaining processes with low concentration would be very costly and represent around 50% of emissions.

Cost estimations for CCS in refineries range from $34-61 US capture costs to 43-$115 US total costs (€35-93). The cost aspect is a main concern especially in regard to relatively low margins.

Conclusion

Considering an average 75% recovery rate for CO2 emissions using CCS overall, the chemical, cement, steel and refining industry could contribute to EU targets mitigating around 340 MtCO2/year.

The industries nowadays are close to best performance in terms of physics-thermodynamics for their processes and CO2 emissions cannot be avoided easily. Thus, CCS could be a key solution. So far, research approaches on CCS can be noted in all these industries.

The technical feasibility of CCS is one important issue, but the economical feasibility will decide whether CCS will be used or not. A successful CCS implementation will strongly depend on financial mechanisms to fund demonstration plants that will help to shape the technological learning curve and cost curves. Also, not only capture costs but also transport, storage and costs for insurance, monitoring and security are to be considered. Today, information about costs is not sufficiently available.

Although an interest in CCS technology is stated, the industries emphasise the risks of EU energy and environmental legislation on their competitiveness. A common binding CO2 legislation for the global market is needed as otherwise competitive disadvantages may appear.

Further obstacles for a CCS implementation might be large distances from plants to CO2 sinks, possible impacts on product quality, liability on cooperation with property owners for CO2 transportation and storage sites. The lack of public acceptance, which is an essential basis before further steps can be done, also plays a key role.

References are available in the online version of this article.

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André Lacerda recently concluded a Masters in Energy Management. With an Engineer and MBA diplomas, during the past 15 years, he undertook different management roles in the industry. After living in Brazil, China and USA, he is currently based in France and works for Tyco Flow Control Technologies as Area Manager.

Mobilising private finance for CCS

The Climate Group and the Ecofin Research Foundation are working on a joint initiative to assess, and possibly stimulate, private sector financing for first generation industrial scale carbon, capture and storage (CCS) projects.

The report provides an overview of initial findings from a European perspective, with views canvassed from over 30 private sector capital providers about the risks and returns of a post-combustion, new build, coal-fired power station.

According to the report the following messages are emerging:

1. debt… not yet. Ample debt may be available but only if three prerequisites can be addressed:

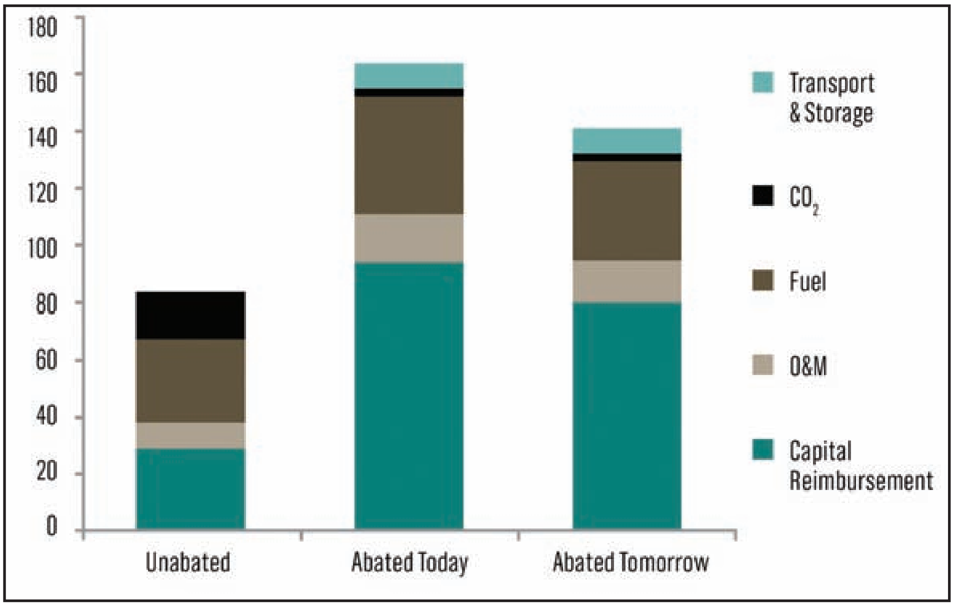
- An indicator of performance across the whole capture and generation chain must be provided by a well-regarded equipment supplier or contractor.
- Major sponsors who have successfully managed sizeable and complicated construction projects must be involved.
- Economics of CCS must have a route to being competitive with other forms of generation, without public funding.

2. not for specialist equity. Specialist equity, such as private equity or infrastructure funds, will not be mobilised to finance demonstration projects. Private equity sees demonstration of CCS, like technology funding – requiring high returns across a spread of projects. Infrastructure funds don't take the construction and integration risk inherent in demonstration CCS projects.

3. on the balance sheet… but limited in scale. Bond holders or equity holders from the big pension funds or insurance companies are comfortable with corporates using their balance sheets to finance CCS, but only as long as the scale is limited to just a couple of percent of group assets. Across the European utilities, though, this would enable a maximum of €5bn of funds to be available, and even then it is questionable if those utilities would be prepared to invest that much in CCS demonstrations whilst balance sheets are being delivered and capital budgets are being cut.

4. demonstrations helped by the private sector… but for two not eight projects. Limited private sector funding means that a multitude of CCS demonstration projects cannot be pursued. It is generally agreed that government sources will provide part of the funding for CCS demonstration projects and that will be topped up by private sector sources. However, the initial findings of our initiative indicate that private sector funds will be adequate to support maybe just two CCS demonstrations – and that's across the whole of Europe. This is clearly a long way short of the UK's plans to have up to four demonstration projects, let alone Europe's ambition to see eight and hopefully twelve demonstration projects.

5. government funding needs to focus on fewer CCS demonstration projects. Public sector financial support for CCS from European sources needs to be focussed on far fewer projects instead of being spread over numerous CCS technologies. This will ensure some of the challenges are faced – and hopefully overcome – rather than attempting to initiate CCS in a variety of settings which may simply result in none of the challenges being properly addressed. Once the concerns of private sector debt market participants are addressed, the need for government funds would be sharply reduced.



Required power price (€/MWh). An assessment of the Global CCS Institute costings, together with assumptions on fuel costs , indicates that excluding any government contribution, power prices would have to be around €160/MWh to make it worthwhile building a coal fired power station with post-combustion CCS today. Allowing for estimated improvement in efficiencies , the required power price might drop to €140/MWh – still well above the €80/MWh that might be required to justify the same coal fired power station without CCS but which has to pay €20/t for CO2 emitted to the atmosphere

Conclusions

The present thinking is, that governments will provide part of the funding for CCS demonstration projects and that the rest will be topped up by the private sector.

However given the possible limits of 1-2% of enterprise value to be invested in CCS, it appears there may be less than £5bn of private sector funds from the major utilities to support CCS demonstration projects over the next ten years across Europe. If as much as half of available private sector finance is attracted to the UK, one demonstration project could get the go-ahead, not "up to four" as indicated in UK CCS Policy. This assumes that government sources cover half the extra costs of CCS power stations, which may indeed be optimistic. Similarly across Europe, there is likely to be private sector finance for only two demonstration projects, not the eight let alone twelve hoped for.

A follow up is planned, building on the initial findings through additional interviews with capital providers to widen the geographic reach as well as explore other examples of possible CCS projects such as enhanced oil recovery and/or retrofitting.

The findings will be disseminated to stakeholders such as capital providers, project developers and policymakers, in order to help break down the identified barriers.

The report can be downloaded at: www.theclimategroup.org

GCCSI sets out 'CCS Ready' definition

The Global CCS Institute, in collaboration with the International Energy Agency (IEA), and Carbon Sequestration Leadership Forum (CSLF), has been working to establish a definition for Carbon Capture and Storage Ready (CCSR).

The paper helps to define and explain the intricacies around carbon capture and storage ready policy, which helps governments prepare power generators for a shift to a low carbon economy and signals future costs to investors.

CCS Ready policies pave the way for new power plants to be retrofitted with CCS technology when it is available on a commercial basis.

"A CCS Ready policy assists policy makers to clearly define the project standards necessary for CCS deployment as part of a transition to a low carbon economy," says Global CCS Institute CEO Nick Otter. "It acts as a signalling mechanism by indicating that governments are willing to mandate a technology still in development if there is perceived to be an environmental benefit."

"CCS Ready policy needs to be rigorous enough to ensure that retrofit takes place while also being also being open enough to future capture technology advances," Otter said. "Early stage planning for storage is also an important step that underpins what it really means to be CCS Ready."

Recognising that the necessary financial and legislative drivers required to support CCS deployment are not available, CCSR offers an interim option by anticipating a transition to full CCS once these drivers are in place. Where a plant is constructed with or without CCSR facilities, and a carbon cost or regulatory action is subsequently introduced that penalises emissions, an owner has the option of continuing to emit CO2 into the atmosphere and pay for carbon offsets, pursue a CCS retrofit or, shut down the plant before the end of its economic life.

A CCSR policy requires project proponents to expend upfront costs to carry out engineering and cost estimate studies as well as undertaking storage assessments. As a guide, the Government of the United Kingdom estimates that the overall costs of a CCSR requirement per new combustion power station is equivalent to less than 0.1 per cent of the capital cost of a 1600MW coal fired power station and about 0.3 per cent of the capital cost of an 800MW gas fired power station3. By investing earlier in making a plant CCSR this potentially lowers plant adaptation costs in the future, and leads to lower total costs overall.

One of the drivers for the development and uptake of CCSR is its potential to facilitate CO2 mitigation in the future, especially in developing countries where fossil fuel energy generation sources are expected to provide a reliable source of energy supply.

While the additional upfront costs may be an initial deterrent for developing countries, there may be some justification in introducing a CCSR policy for exceptionally large energy facilities for environmental reasons. The Government of South Africa for example has taken a project specific approach by requiring the 5400MW Kusile project be constructed CCSR.

The recently established CCSR definition provides a list of essential requirements that represent the minimum criteria that should be met before a facility can be considered CCSR. These criteria are included as part of the definition to provide information and guidance to both regulators and project proponents to assist in future planning.

The criteria place the onus of meeting CCSR requirements on project developers and provide the regulator with a series of conditions that project proposals can be measured against.

Under the definition, in order for a facility to be considered CCSR, the project developer should:

- carry out a site specific study in sufficient engineering detail to ensure the facility is technically capable of being fully retrofitted for CO2 capture, using one or more choices of technology which are proven or whose performance can be reliably estimated as being suitable;
- demonstrate that retrofitted capture equipment can be connected to the existing equipment effectively and without an excessive outage period and that there will be sufficient space available to construct and safely operate additional capture and compression facilities;
- identify realistic pipeline or other route(s) to storage of CO2;
- identify one or more potential storage areas which have been appropriately assessed and found likely to be suitable for safe geological storage of projected full lifetime volumes and rates of captured CO2;
- identify other known factors, including any additional water requirements that could prevent installation and operation of CO2 capture, transport and storage, and identify credible ways in which they could be overcome;
- estimate the likely costs of retrofitting capture, transport and storage;
- engage in appropriate public engagement and consideration of health, safety and environmental issues; and
- review CCSR status and report on it periodically

While the criteria provides a guide to what will be required to be considered CCSR, governments seeking to establish CCSR policies will need to provide proponents with further guidance and information on how CCSR criteria will be assessed during the approval process. This will provide industry with certainty and assist in the development of feasibility studies.

For a plant to be capture ready, consideration must be given at the design stage as to whether there is adequate installation space to retro-fit a plant. The intricacy of a CCSR policy is that it needs to be rigorous enough to ensure that retrofit takes place while also being sufficiently flexible to avoid technology lock in.

Storage is the most critical and potentially the most costly element of CCSR requirements and underpins what it means to be CCSR.

The constituent elements of CCSR policy have been debated internationally since 2007 following the release of the IEAGHG report CO2 Capture Ready Plants and discussion during the 2007 G8-IEA Calgary workshop on near-term opportunities for CCS. Because consensus could not immediately be reached, the G8 accepted the 2008 Hokkaido recommendation that 'further work is required to understand and define the concept of 'capture and storage ready' plants and its value as a viable mitigation strategy'.

However, a number of jurisdictions have implemented, or are in the process of developing CCSR requirements for new build power plants, including the European Union, the United Kingdom (excluding Scotland) and South Africa.

The report can be downloaded at: www.globalccsinstitute.com

CCS network in Yorkshire

According to a new report, a Carbon Capture and Storage network in Yorkshire and the Humber could reduce the CO2 emissions for the entire UK by around 10% and be a vital contribution to the UK Government's commitment to reducing CO2 emissions.

The study shows how a network could be designed in the most cost-effective way and outlines significant savings that can be made by designing the network with the future in mind. It also shows how the project could be funded, and shows how such a network could be built with minimal disruption to the community.

Key findings from the report are:

1. Early investment in CO2 infrastructure sized with deployment in mind represents an efficient and economic way of enabling CCS in the UK.

• Second wave of emitters benefit even if decision is delayed by more than 10 years

2. Cluster potential, particularly in the Yorkshire & Humber region, is reinforced

• Initial investment is £159m lower than constructing separate pipelines

• Cost of enabling future emitters to join the network is £253m lower than separate pipeline

• Potential to transport CO2 equivalent to 50% of UK domestic emissions

3. Offshore storage is a key element and should have sufficient scale for future deployment

• Underwrites confidence for Government or emitters to invest in long term projects

Yorkshire vision

A shared pipeline, developed to transport the CO2 from the demonstration and first phases of CCS in the region to long term offshore storage, would be highly cost-effective, the study says.

It would encourage more investment in carbon capture from other emitters, who would be certain of the transport and storage solution that is being provided. This could lead to the development of a large CCS cluster, the first of its kind in the world.

Developing a single pipeline would also keep disruption to the local community to a minimum.

The study aims to inform industry, investors, Government and regulators how the initial phases of such a pipeline network could become a reality. It explains the strategy for developing a coordinated investment in a shared CO2 transport infrastructure which will facilitate efficient commercial-scale demonstration and rapid deployment of CCS technology. The study assesses the financial, commercial and environmental benefits of establishing a network capable of transporting around 40Mt of CO2 per year, to enable the initial phases of CCS in the region.

It compares the relative merits of individual CO2 pipelines connected to a single offshore storage site, with a shared transport network and associated large-scale storage development. It also considers the impacts of sources of funding for commercial scale demonstration, such as the proposed CCS levy in the UK and the EU's New Entrant Reserve provisions. This present study builds on earlier work carried out by the Yorkshire and Humber CCS Partnership and details scenarios for the development of CCS in the region.

The Yorkshire and Humber region produces a total of around 90Mt of CO2 annually, two thirds of which come from a small number of large point sources such as power stations, steel plant and oil refineries. The Yorkshire and Humber coastline is adjacent to the saline formations and rapidly-depleting gas reservoirs of the southern North Sea, which should make excellent storage sites for CO2.

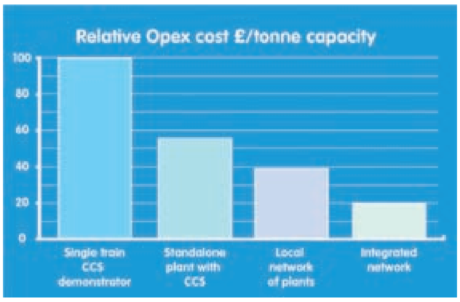
If a low-cost CO2 transport network could be developed in the region, Yorkshire and Humber would be ideally placed to establish a world-leading CCS cluster on a scale and with timing that could be realised by few other industrial regions, the study concludes

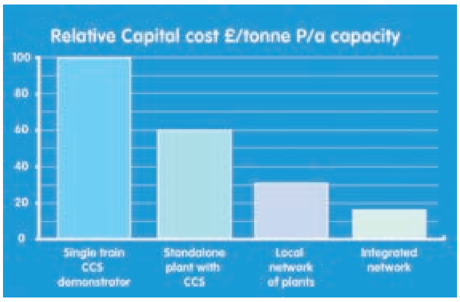
Costs

Developing a cluster pipeline network is considerably cheaper per project than developing individual pipelines from single emission points to their respective individual storage locations.

The analysis shows that the savings could be over £250m: a saving of 33%. The above cost estimates are based on a scenario in which CCS is developed in two discrete phases: in the first phase, CCS is deployed by two to three emitters, each supported to enable infrastructure commitment by 2012-13 and located south of the Humber. In the second phase, CCS is developed by a further three emitters, in the Aire Valley.

Other scenarios – and the key assumptions made in calculating these cost estimates – were assessed. In particular, the study assumed that the distance from the coast to the offshore storage facilities is 100km.





A key finding is that the cost of buildings separate pipelines for two emitters in the first phase is £481m, whereas the cost of linking these emitters into a single pipeline and storage location is £322m, a saving of £159m.

A potential third emitter, conveniently located, could be cheaply linked into the same pipeline at a total cost of £334m - only an extra £12m. The costs of transporting each tonne of CO2 also reduce significantly as more users send CO2 into the network.

Conclusion

The cost of constructing a CCS shared pipeline in Yorkshire and Humber is significantly lower than constructing separate pipelines for each emitter and will enable more emitters to implement CCS technology in the medium term at a viable cost. The economic benefits of early large scale investment are significant, and the region is perfectly placed to demonstrate this to the world.

The report can be downloaded at: www.co2sense.org.uk

Policy, company and regulation news

EU launches €4.5 billion fund for clean energy

ec.europa.eu

The European Commission has launched a first call for proposals for funding of at least eight CCS projects.

The European Investment Bank (EIB) is collaborating with the Commission in the implementation of the programme. Companies interested in making proposals have 3 months to submit bids at national level.

Eight CCS projects will receive financing:

- a minimum of one and maximum of three in the following categories: pre-combustion, post-combustion, oxy-fuel and industrial applications.

- Minimum of three projects using saline aquifers for CO2 storage and minimum of three using depleted hydrocarbon reservoirs.

- Power stations taking part in CCS projects must have a generation capacity of at least 250 MW, and be designed to capture at least 85% of their CO2 emissions.

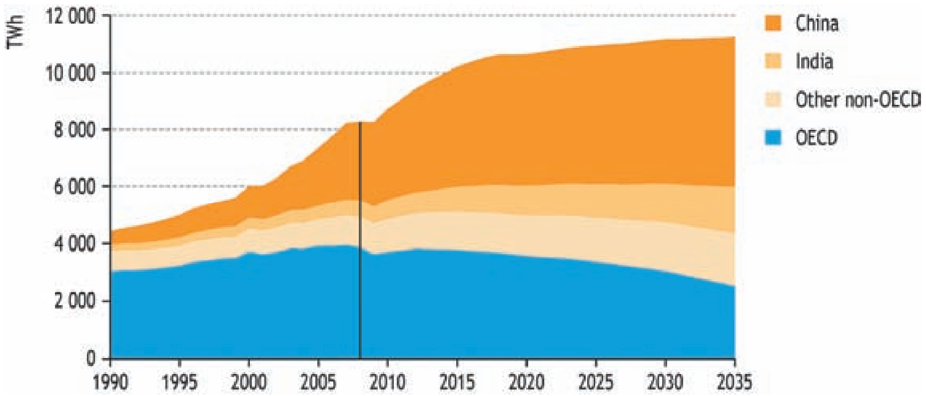
NER300 will be funded from the sale of 300 million emission allowances in the New Entrants Reserve (NER) of the EU Emissions Trading System (ETS). At current market prices for emission allowances, the initiative is worth around €4.5 billion, making it the biggest such programme in the world.

Funding is targeted to demonstration projects involving CCS and innovative renewable energy technologies. At least one project, and a maximum of three, will be funded per Member State.

The total investment will be more than €9 billion as the NER300 initiative will fund up to 50% of the construction and operation costs of the CCS and renewables projects. Project sponsors and Member States will provide the rest of the funding. NER300 funding can be combined with financing from other EU instruments, including the Structural and Cohesion Funds and the European Energy Programme for Recovery (EEPR).

Under the NER300 decision the EIB is responsible for selling the 300 million allowances and managing and disbursing the proceeds. While details, including the starting date of the sales, are not fixed yet, it is expected that all NER300 allowances will be sold before the start of the third trading period of the EU ETS in January 2013.

The Commission will take the final decision on which projects to co-finance after consulting Member States.



Coal-fired electricity generation by region in the New Policies Scenario. Coal remains the backbone of global electricity generation - a drop in coal-fired generation in the OECD is offset by big increases elsewhere, especially China, where 600 GW of new capacity exceeds the current coal capacity of US, EU & Japan (Source: World Energy Outlook 2010 ©OECD/IEA 2010)

World Energy Outlook 2010 released

www.worldenergyoutlook.org

New Policies Scenario looks at more realistic target of 3.5°C temperature increase goal, with CCS deployed on a limited scale by 2035.

The central scenario in this year's Outlook – the New Policies Scenario – takes account of the broad policy commitments and plans that have been announced by countries around the world. "We have taken governments at their word, in assuming that they will actually implement the policies and measures, albeit in a cautious manner, to ensure that the goals they have set are met" said Mr Tanaka. In that scenario, world primary energy demand increases by 36% between 2008 and 2035, or 1.2% per year on average. The assumed policies make a tangible difference to energy trends: demand grew by 2% per year over the previous 27-year period.

Carbon capture and storage (CCS) technology is expected to be deployed on a limited scale in the New Policies Scenario, its share of total generation rising from zero today to 1.5% in 2035, says the report. Most of the projected generation from plants fitted with CCS equipment is in OECD countries, driven by government initiatives to build demonstration facilities.

Stronger CO2 price signals than those in the New Policies Scenario would be needed to stimulate wider adoption of CCS technology.

Carbon capture and storage still plays an important role in reducing power-sector emissions. By 2035, generation from coal plants fitted with CCS exceeds that from coal plants not equipped with this technology, accounting for about three-quarters of the total generation from all CCS fitted plants, says the report.

The potential of Coal to Liquids (CTL) coupled with CCS to make a sizeable contribution is also highlighted. Many of the large coal-producing countries are investigating new projects, says the report, but clarification of the legal framework for CCS will most likely be required before they can proceed.

In the New Policies Scenario, Non-OECD countries account for 93% of the projected increase in world primary energy demand. China – which IEA preliminary data suggests overtook the United States in 2009 to become the world's largest energy user despite its low per capita energy use – contributes 36% to the projected growth in global energy use. "It is hard to overstate the growing importance of China in global energy. How the country responds to the threats to global energy security and climate posed by rising fossil-fuel use will have far-reaching consequences for the rest of the world", Mr Tanaka added.

The energy trends envisioned in the New Policies Scenario imply that national commitments to reduce greenhouse-gas emissions, while expected to have some impact, are collectively inadequate to meet the Copenhagen Accord's overall goal of holding the global temperature increase to below 2°C. Rising demand for fossil fuels would continue to drive up energy-related carbon-dioxide (CO2) emissions through to 2035, making it all but impossible to achieve the 2°C goal, as the required reductions in emissions after 2020 would be too steep. The New Policy Scenario trends are in line with stabilising the concentration of greenhouse gases at over 650 parts per million (ppm) of CO2-equivalent (eq), resulting in a likely temperature rise of more than 3.5°C in the long term.

CIUDEN installs boilers at CO2 capture plant

www.ciuden.es

The furnace (main component) of the circulating fluidized bed boiler (CFB boiler) has been installed at the CO2 Capture Technology Development Plant of the Fundación Ciudad de la Energía in El Bierzo, Spain.

The project is seeking to validate oxy-combustion technology in the CO2 capture process. The plant in Cubillos del Sil incorporates a variety of technological options which the company says will turn it into an international benchmark.

The 30MWth boiler is 20m high, weights 120 Tonnes and cost EUR 17 million. Manufactured in Spain by Foster Wheeler Energía, the boiler will be fully installed with other auxiliary equipment providing functional flexibility and versatility for testing oxycombustion technology.

Installing the boiler at the CO2 Capture Technology Development Plant of the Fundación Ciudad de la Energía in El Bierzo, Spain

The CFB boiler operating in oxycombustion uses an oxygen gas mixture recirculated to the boiler instead of air. This will allow unique experiments in the burning of different carbons and biomasses to be made, says the company, while testing the separation of the CO2 produced during combustion. The new boiler joins another using pulverized coal (installed last month).

The CFB boiler is financed by the Compostilla Project, selected by the European Economic Recovery Plan of the European Union together with another five from Germany, the United Kingdom, The Netherlands, Poland and Italy to develop clean coal technologies and control emissions to fight against climate change.

CIUDEN together with Endesa and Foster Wheeler Oy are cooperating the project, financed with EUR 180 million from the European Commission, which aims to develop and validate this CFB technology to build in a second phase an industrial scale demonstration of 300MWe.

La Fundación Ciudad de la Energía (CIUDEN), set up in May 2006, is the main Spanish Government institution involved with the development of programs for capture and geological storage of CO2.

E.ON pulls out of UK CCS competition

www.eon-uk.com

E.ON will not to proceed to next stage of the UK Government's carbon capture and storage competition as Kingsnorth cannot meet competition timescales, the company says.

The company's Kingsnorth project was one of two schemes shortlisted as part of the Government's competition, with the aim being to build the UK's first commercial CCS scheme. But, with the market still not conducive to building the 1,600MW supercritical power station, it had become clear that Kingsnorth could not meet the project timetable.

"Having postponed Kingsnorth last year, it has become clear that the economic conditions are still not right for us to progress the project and so, simply put, we have no power station on which to build a CCS demonstration," said Dr Paul Golby, Chief Executive of E.ON UK.

Fortum scraps CCS project in Finland

www.fortum.com

Finnish energy company Fortum Oyj will discontinue the Finncap carbon capture and storage (CCS) project, due to the technological and financial risks.

The decision is also based on the company's updated strategy.

For the past couple of years, Fortum and Teollisuuden Voima (TVO) have collaborated on the Finncap project, the aim of which has been to build a large-scale demonstration plant for carbon capture and storage (CCS) at the companies' jointly-owned Meri-Pori power plant.

Based on studies that have been done and on the company's updated strategy, Fortum has now decided to not continue with the project. Consequently, the Finncap project will not pursue being part of the European Union's CCS demonstration programme, the application period of which will begin soon. TVO withdrew from the project earlier this autumn.

Also the technological and financial risks related to the project contributed to Fortum's decision. Acceptance into the EU programme would have covered only a portion of the costs of the approximately EUR 500-million project. In addition to EU funding, the project would have required national funding from Finland and significant investments from the companies participating in it.

Aker Clean Carbon wins Enel contract

www.akercleancarbon.com

Aker Clean Carbon has been awarded a contract to conduct a FEED (front end engineering and design) study for ENEL's Porto Tolle Carbon Dioxide Capture Unit Project.

Aker Clean Carbon will produce a comprehensive set of FEED material, including estimates for the capital investment (Capex) and operational cost (Opex) of the CO2 capture unit. The FEED study will be completed in the first quarter of 2011.

ENEL's project has been selected by the European Commission as one of the projects to be financed under the European Economic Plan for Recovery. The extracted CO2 (about 1 Mt/y) will be compressed, transported via pipeline and stored in a saline aquifer beneath the Adriatic Sea. The CO2 capture unit will be in operation for an extended period of time in order to fully demonstrate the technology on an industrial scale and provide a commercial solution for new installations after 2020.

The Porto Tolle site is located on the Adriatic coast South of Venice, Italy at the delta of the river Po. The present Porto Tolle

facility comprises of four oil fired power generation units (Units 1 to 4) each of a nominal capacity of 660 MW. These will be refurbished to three bituminous coal fired units (Units 1 to 3) each of a nominal capacity of 660 MW.

It is planned that the existing oil fired Units 1 to 3 will be partially demolished and refitted with new boilers, steam turbines and associated flue gas treatment systems. Furthermore, Unit 4 will be partially dismantled to provide space for a CO2 Capture Unit to be associated with Unit 3. It is currently intended that the CCU will treat a flue gas flow rate of 0.8 MNm³/h, corresponding to an equivalent of 250 MWe electrical output.

Siemens and Masdar collaborate on CCS

www.masdar.ae

Masdar, Abu Dhabi's renewable energy initiative, and Siemens have signed an agreement establishing a long term strategic partnership.

Part of the partnership covers collaboration in the field of Carbon Capture and Storage, which will involve research and development with the Masdar Institute.

Siemens will establish an anchor presence in Masdar City, housing their Middle East Headquarters, a Centre of Excellence in Building Technologies and other initiatives including a Leadership Development Centre. The Centre of Excellence will begin R&D activities on the ground at Masdar City in 2010.

Siemens will collaborate with Masdar and the Masdar Institute to optimize the technical and economic aspects of environmentally friendly post-combustion CCS.

Global CCS Institute funds knowledge sharing projects

www.globalccsinstitute.com

The GCCSI has announced the first set of projects to receive support as part of its information and knowledge sharing brokerage efforts to overcome key barriers facing large-scale, integrated CCS demonstration projects.

"Despite ongoing research and existence of operating demonstration projects, CCS is still an emerging technology," said Institute CEO Nick Otter. "A key factor in its uptake will be the ability to use the knowledge now being developed to accelerate new and existing projects."

"The projects we are announcing support for today have been selected across the range of technology, regulatory, policy and financial hurdles that must be addressed."

Knowledge will be captured from different stages of project life cycle, across technologies and geographic regions. It will be shared with the broader industry via workshops, thematic group discussions and one-on-one meetings.

The Institute's newly launched digital knowledge platform will also serve as a central repository for project experience and other CCS information.

"Our support for these early movers will provide the Institute with access to valuable hands-on knowledge that we will share with our Members and the broader industry. It is this dissemination of valuable know-how and lessons learned that can help speed up the commercial deployment of CCS technologies."

The six initial projects – in Australia, the United States, Romania and the Netherlands – are to receive AUS $18 million in project support funding. They were selected from over 50 submissions received from across the world in response to the Institute's initial request for proposals. More support announcements are expected in coming months.

Research targets CCS opportunities in Scotland

www.scottish-enterprise.com

A comprehensive study, led by Scottish Enterprise, is underway to develop carbon capture and storage opportunities in Scotland.

Scottish Enterprise is working in partnership with the Scottish Government, key industry players and leading research bodies, on the development of a CCS Cluster Investment Plan.

Initial findings from the CCS Cluster Investment Plan study are expected to be published by the end of 2010.

This will bring together leading thinking on existing strengths and consider the possible options for development of Carbon Capture and Storage infrastructure in Scotland. It will consider how Scotland's carbon storage potential can be used and the steps required to make this a resource that can support the location of low carbon industries in Scotland.

The economic opportunities for the development of a CCS-based industry are considerable and it is estimated a whole new industry could emerge in Scotland, which could support up to 10,000 new jobs in the next 10 years. Global market potential is estimated to be worth around £5000 billion.

The study will take a similar phased approach to the National Renewables Infrastructure Plan, which is currently being carried out on Scotland's offshore wind infrastructure, tapping into a full complement of expertise from the private sector and academia.

Scottish Enterprise is actively working to further develop opportunities in the emerging CCS sector. It was instrumental in the joint publication with the Scottish Government of a CCS Roadmap setting out ambitions and milestones for the sector's development in early 2010.

European CCS Demonstration Project Network launched

www.ccsnetwork.eu

The first Advisory Forum meeting of the European CCS Demonstration Project Network was held in Brussels on 17 September 2010 at the Centre Borschette.

The CCS Project Network is the world's first network of CCS demonstration projects to foster knowledge sharing and raise public understanding of the role of CCS in cutting CO2 emissions. This will accelerate learning and ensure that the Commission can assist CCS to safely fulfil its potential and become a commercially viable technology.

Energy Commissioner Günther Oettinger said: "CCS is one of the key technologies that we need to develop today to make the necessary deep cuts in carbon dioxide emissions from the energy sector in the coming decades. It is a very positive step forward for the major project developers in Europe to work together and to inform scientists, industry and the public about their progress. Knowledge sharing will be essential for accelerating the deployment of clean energy technologies in Europe and worldwide."

The first network members who have signed a joint agreement to share knowledge are all CCS projects supported by the European Commission's European Energy Programme for Recovery (EEPR). As a condition for receiving EU funding each beneficiary is required to disseminate the project results as widely as possible. The goal is to create a prominent community of projects united in the goal of achieving commercially viable CCS by 2020.

To guarantee that the work of the CCS Project Network is valuable to the wider energy community in Europe, an annual Advisory Forum has been established to review progress and specify the knowledge that can most usefully be generated by the CCS Project Network activities. Today's meeting is the first Advisory Forum, cochaired by the European Commission and the European Technology Platform for Zero Emission Fossil Fuel Power Plants (ZEP) with representatives of Member States, ZEP, CCS demonstration projects, the research and NGO communities, and international organisations.

Capture news

CO_2 capture plant at German University tests chemical looping

www.est.tu-darmstadt.de

The Technische Universitaet Darmstadt has opened a pilot plant for capturing carbon dioxide contained in flue gases of power plants.

The Institute for Energy Systems and Technology at the University plans to use the plant for investigating two innovative methods for CO_2 capture that it says require less energy and lower operating costs than earlier approaches.

Early approaches to CO_2 capture require expending significantly more energy and entail greatly increased operating costs, which raises questions regarding their efficiency and acceptance. The new pilot plant will look at two new methods for CO_2 capture that will allow the almost total elimination of CO_2 emissions and require virtually no additional energy input and entail only slight increases in operating costs.

In the experimental plant scientists at the TU Darmstadt will explore two novel processes for CO2 capture. Image: Thomas Ott / TU Darmstadt

Over the next two years, the institute's director, Prof. Dr-Ing. Bernd Epple, and his 26 coworkers will be investigating the 'carbonate looping' and 'chemical looping' methods for CO_2 capture. Both methods employ natural substances and reduce the energy presently required for CO_2 capture by more than half.

"These methods represent milestones on the way to CO_2 free power plants," said Dr Epple. "They might allow coal-fired, oil-fired, and natural-gas-fired power plants to reliably and cost-effectively generate power without polluting the environment."

The carbonate looping method involves using naturally occurring limestone to initially bind CO_2 from the stream of flue gases transiting power plants' stacks in a first-stage reactor. The resultant pure CO_2 is re-liberated in a second reactor and can then be stored. The advantage of the carbonate-looping method is that existing power plants can be retrofitted with this new method.

On new power plants, the chemical looping method will even allow capturing CO_2 with hardly any loss of energy efficiency, claims the University. Under this method, a dual-stage, flameless, combustion yields a stream of exhaust gases containing only CO_2 and water vapour. The CO_2 can then be captured and stored.

The investigations of these new methods are being supported with grants totalling seven million Euros from the European Union, the German Federal Ministry for Economic Affairs, and various industrial partners. Due to the pilot plant's height, the TU-Darmstadt has built a new, twenty-metre high experimentation hall on its 'Lichtwiese' campus to house it. Construction of the new hall and pilot plant took twenty months. The plant has already demonstrated its ability to bind CO_2 in initial trial runs.

Canadian University project 'sees' materials capture CO_2

ucalgary.ca

Researchers at the University of Calgary and University of Ottawa have provided deeper insights to CO_2 capture by "seeing" the exact sites where CO_2 is held in a capture material.

The discovery has been published in the journal Science and will allow scientists to design better materials to capture more CO_2.

According to the researchers, the findings are similar to finding a better fit between a baseball glove and a ball in order to improve performance. Different gloves fit different size of balls better and it's easier to catch a ball with a glove that is moulded to it. In the case of CO_2 capture, think of the ball as the CO_2 and the glove as the material that houses the CO_2.

"We have pinpointed where the CO_2 molecule is held by direct experimental visualization (X-ray crystallography) and, through computer modeling, we can see how every 'finger' contributes to holding the CO_2 in place," says co-author Dr. George Shimizu, a chemistry professor in the Faculty of Science at the University of Calgary whose research was funded by the University of Calgary's Institute for Sustainable Energy, Environment and Economy and the Natural Sciences and Engineering Research Council of Canada.

This discovery is also significant because of the exceptional relationship between experiment and computer simulation. Computer simulations can now be more confidently applied to predict the CO_2 capture ability of materials on the computer before they are made in the laboratory.

"The detailed computational analysis of how CO_2 is captured in this material provides new directions for designing improved materials," says Dr. Tom Woo, an associate professor in chemistry and Canada Research Chair at the University of Ottawa, who is a co-author of the work along with his graduate student Peter Boyd.

This research may be used for a variety of applications. "We could ultimately see this process helping to mitigate greenhouse gas emissions on the top of coal burning flue stacks or it could be used to help remove CO_2 from unconventional natural gas reservoirs," says Dr. Ramanathan Vaidhyanathan, the paper's first author and research associate at the University of Calgary.

Current methods of CO_2 capture take place by bubbling CO_2 through a liquid solution which strongly binds to the CO_2, a process called amine scrubbing. The major downside of this technology is that to recycle to the absorbing solution and release the CO_2, heating to over 100ºC is required. Most estimates say to capture CO_2 from a coal-fired power plant by this technique would cost about one-quarter of the plant's energy production.

The article, entitled Direct observation

and quantification of CO_2 binding within an amine-functionalized nanoporous solid, is published in Science and written by Ramanathan Vaidhyanathan, Simon S. Iremonger and George K. H. Shimizu from the University of Calgary and Peter G. Boyd, Saman Alavi, Tom K. Woo from the University of Ottawa.

Siemens delivers compressors for Canada CO2 capture project

www.siemens.com

Siemens Energy has been awarded a contract from the engineering and construction company SNC-Lavalin to deliver two vapour compressors for a post combustion CO_2 and SO_2 capture plant at Unit 3 at SaskPower's Boundary Dam Power Station near Estevan, Saskatchewan.

The coal-fired Boundary Dam power plant, with an installed capacity of 1,200 megawatts (MW), is owned by the Canadian utility SaskPower. Unit 3 will be integrated into a Carbon Capture and Sequestration (CCS) demonstration project. The primary goal of this project is to generate up to 120 MW of clean baseload electricity while reducing green house gas emissions. It is planned to capture one million tons of carbon dioxide per year.

The project will go into operation in 2014. Siemens will deliver integrally-geared, motor-driven lean vapour compressors which the company says will enable an overall reduction in the steam consumption.

Solutions for CO_2 compression and capture are part of Siemens' Environmental Portfolio, which in fiscal year 2009 made revenue of EUR23 billion.

LaFarge trials Mantra CO2 reuse technology

www.mantraenergy.com

Mantra Venture Group has secured an ERC (Electrochemical Reduction of Carbon Dioxide) demonstration project with Lafarge Canada.

Lafarge North America Inc., together with its subsidiary, Lafarge Canada Inc., is the largest diversified supplier of construction materials in North America.

Over the course of the project, Mantra, Lafarge and its wholly owned subsidiary Systech Corporation, will build and deploy a 100kg ERC pilot plant at one of Lafarge's North American cement plants. The project is expected to further advance Mantra's ERC technology for large-scale applications and demonstrate the effectiveness of Mantra's ERC technology in converting CO_2 into valuable green chemicals.

John Russell, VP of Technology at Mantra says the company will gain valuable experience and exposure through its first-ever North American ERC pilot demonstration project and hopes to have the opportunity to deploy commercial-scale units across multiple Lafarge sites upon completion of the project.

The project is scheduled to begin in the first quarter of 2011, and further details will be announced as they become available.

SINTEF - avoiding CO2 capture health risks is possible

www.sintef.no

Experts at SINTEF believe it is possible to develop efficient CO_2 capture technologies without generating harmful emissions.

SINTEF is conducting research into several different CO_2 capture technologies involving coal and gas-fired power stations and industrial processes.

It has been acknowledged for many years that amine based CO_2 capture can result in the emission of nitrosamines, which may be harmful to health. Nitrosamines are substances that have been much in focus in connection with the use of nitrates in foodstuffs. Issues surrounding the formation and control of nitrosamine emissions are a key component of SINTEF's research activities in this field.

In the light of current uncertainties regarding the role of amines and associated health and environmental concerns, the Norwegian Ministry of Petroleum and Energy has decided to conduct an inquiry into whether alternative processes should form the basis of the Norwegian Mongstad CO_2 capture and storage project.

"SINTEF understands the Ministry's need to establish a clear and comprehensive overview on this issue", says Nils A. Røkke, SINTEF's Vice President of Climate Technology. "We must make sure that we do not simply substitute one environmental problem for another, and for this reason we need more data".

"It is vital that we resolve this issue", says Røkke. "We believe it is possible to develop chemical capture technologies without generating negative health effects".

In his opinion it is too early to conclude that CO_2 capture using amines will result in emissions that constitute a negative health effect. "We are working to develop systems that can control the level of emissions. We still don't know enough about the stability of nitrosamines in the environment".

SINTEF believes that to shed light on these issues, more research organisations should be incorporated on an international basis.

ELCOGAS IGCC plant captures first CO2

www.elcogas.es

The first tonne of CO_2 has been captured at the 14 MW pilot plant that ELCOGAS has built in its Integrated Gasification Combined Cycle (IGCC) power plant at Puertollano, Spain.

An optimization of the processes involved will now begin and tests will be performed to get technical and reliability information about the economics and efficiency of coproduction of hydrogen and electricity with CO_2 capture.

The pilot plant has been built with the support of the Spanish Science and Innovation Ministry and the Regional Government of Castilla La Mancha, under the program of Singular and Strategic Projects as part of a project called "CO2 technologies" that is being coordinated by Spanish Research Centre Ciemat.

The IGCC process uses a mixture of local fuels (Puertollano coal and refinery wastes, with the possibility of biomass).

ELCOGAS has shown since 1998 an excellent environmental performance record, with emissions very much lower than any other technology based on coal, coke, or biomass, and very close to or better than those from natural gas combined cycle, with an efficiency higher than conventional thermal power plants, says the company.

Mitsubishi begins US CO2 capture project

www.mitsubishitoday.com

Mitsubishi Heavy Industries America, Inc (MHIA) has begun a collaboration with Southern Company to capture carbon dioxide from Georgia Power Plant Yates.

The pilot-scale project at Yates, which uses a mobile version of the KM-CDR CO_2 capture process developed by Kansai Electric and Mitsubishi Heavy Industries of Japan (MHI), will provide additional process information before the technology is demonstrated next year at a much larger scale, 500 Tons Per Day (TPD) of CO_2, at Alabama Power's Plant Barry.

The pilot project at Yates is a 'catch and release' process, where a small amount of CO_2 is captured, using MHI's proprietary KS-1 solvent, and then returned to the plant's flue gas stack. For the project at Plant Barry, the 500 TPD of CO_2 will be compressed and transported via pipeline to deep underground storage formations.

Atlanta-based Southern Company, the parent of Georgia Power and Alabama Power, and MHI have been working over the past month on the research project at Yates, which is expected to continue through the middle of November.

CO2Europipe project report

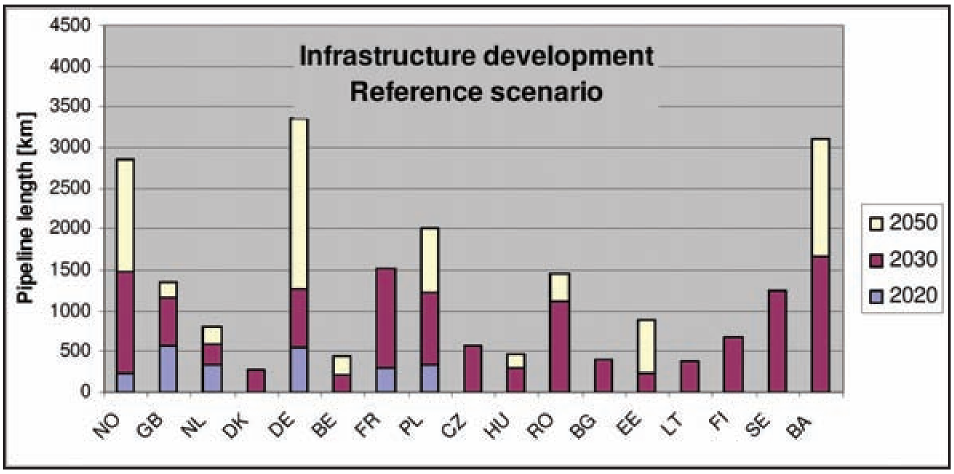
The report, "Development of a large-scale CO2 transport infrastructure in Europe: matching captured volumes and storage availability," looks at scenarios for a transport infrastructure for large-scale CCS in Europe.

CO2 transport is probably the least cost intensive element of the full CCS chain, but may be the most planning and guidance-intensive part during the development of the transport infrastructure, says the report.

CO2Europipe aims to present a roadmap towards a Europe-wide infrastructure network for the transport and storage of CO2. In the report, the geographical distribution and timing of CO2 supply and storage availability was assessed and matched in order to provide a sketch of a possible future transport network Sources and sinks are clustered, since a collective use of infrastructure by neighbouring sources and sinks will lower costs and reduce risks.

Sources include large CO2 point sources like power plants and industry. Sinks include gas fields, oil fields and aquifers. For clustering of the sinks, the different sink types were separated in order to be able to evaluate the importance of a sink type.

National CO2 capture efforts were projected from 2020 until 2050. On the short term, current small-scale CCS plans provide the starting point, while on a longer term energy use forecasts were combined with assumptions on fuel mix, to obtain the national level of capture efforts. The largest share of national captured volumes was assumed to be taken by clusters currently planned for small-scale demonstration projects and / or clusters with currently large emissions. For each sink cluster, storage capacity and injection rate in the same period were assessed. For the purpose of theproject, assumptions were made on the availability and injectivity of storage reservoirs.



National infrastructure development for the reference scenario (Source: Development of a large-scale CO2 transport infrastructure in Europe: matching captured volumes and storage availability)

CCS scenarios

The CO2 supply of each source cluster was matched with available injection capacity of the sink clusters. Three different scenarios were used:

- Reference scenario: storage takes place both onshore and offshore. Matching of supply and demand was based on current models and projects for the development of CCS that exist in the Member States;

- Offshore-only scenario: onshore storage was excluded from the assessment to investigate the impact of current public concerns and stringent permitting issues that might result from these concerns;

- EOR scenario: in addition to the offshore-only scenario it was assumed that EOR is economically attractive and will therefore use part of the captured CO2.

Maps are presented of indicative CO2 transport flows for the timeline 2020, 2030 and 2050, for the three scenarios. For each scenario, the infrastructure network required in 2020 is limited. By 2030, each source cluster is assumed to contain one or more capture installations, resulting in an extensive infrastructure network. By 2050, the network is similar to the network in 2030. The potential transported volumes, however, become much larger. Transport corridors might involve transporting tens to hundreds of megatonnes of CO2 annually.

In the reference scenario, most of the West European countries have sufficient national storage capacity to store their CO2. Belgium and Poland could need to transport part of their CO2 to the Netherlands and Germany, respectively. Transport from Sweden, Finland and the Baltic States to the North Sea is foreseen. Romania and Hungary do not have sufficient national storage capacity. Storage in Slovakia could be an option for these countries.

Consequences if offshore-only storage

The infrastructure of the two offshore-only scenarios forms a network of transport corridors which are all directed towards the North Sea, where the largest offshore storage options are located. Due to the location of offshore oil fields close to gas fields and aquifers, the infrastructure for the two scenarios was chosen as similar and investigates transporting large volumes from deep within Europe to the North Sea coast, to continue in offshore pipelines to the North Sea gas fields, saline formations and oil fields. Many of the transport corridors should require transport capacities of tens to hundreds of megatonnes annually. The networks in these offshore-only scenarios serve to demonstrate the importance of onshore storage for a large part of Europe. Discarding onshore storage is likely to render CCS impossible for large parts of Europe, concludes the study.

Conclusions

The report came to a number of conclusions:

1. CO2 storage capacity is not a limiting factor in the development of large scale CCS infrastructure.

2. Available storage capacity is, however, not evenly distributed over the area considered, with the larger part located in the North Sea.

3. Transport infrastructure construction efforts will be considerable, but lowest when onshore storage is possible.

4. International cooperation and alignment of infrastructure developments is required for an efficient CCS transport infrastructure in Europe.

The report can be downloaded at: www.co2europipe.eu

Supercritical CO2 cooling for well injection using closed-loop, evaporative technology

It is widely known throughout the industry that high pressure CO2 can be used for enhanced oil recovery (EOR). However, some may not be aware that the temperature of the supercritical CO2 stream can have a dramatic effect on the overall efficiency of the supply system.

By Charles F. Marchetta, Niagara Blower Heat Transfer Solutions

Research shows colder CO2 temperatures can have significant advantages including reduction in pumping horsepower, lower capital equipment cost, and an increase in operating capacity efficiency. Because of the relatively high pressure, cooling equipment options are limited. Use of a closed-loop, evaporative type cooling system is the most cost-effective method that can provide the lowest outlet temperature.

The Wet Surface Air Cooler (WSAC™), manufactured in Buffalo, New York by Niagara Blower Company, is a closed-loop, evaporative fluid cooler and vapor condenser used for carbon capture and sequestration (CCS). This technology is utilized for applications including high pressure natural gas cooling, supercritical CO2 cooling for well injection, and multistage compression. The WSAC can deliver lower outlet temperatures than other (non-refrigerated) technologies.

The benefits of using this technology are unparalleled and include:

- The potential to eliminate the first stage of multistage compression
- Improved transportation and storage
- Increased CO2 density
- Greater operating capacity/efficiency
- Small plot space requirement
- Consistent thermal performance
- Water conservation

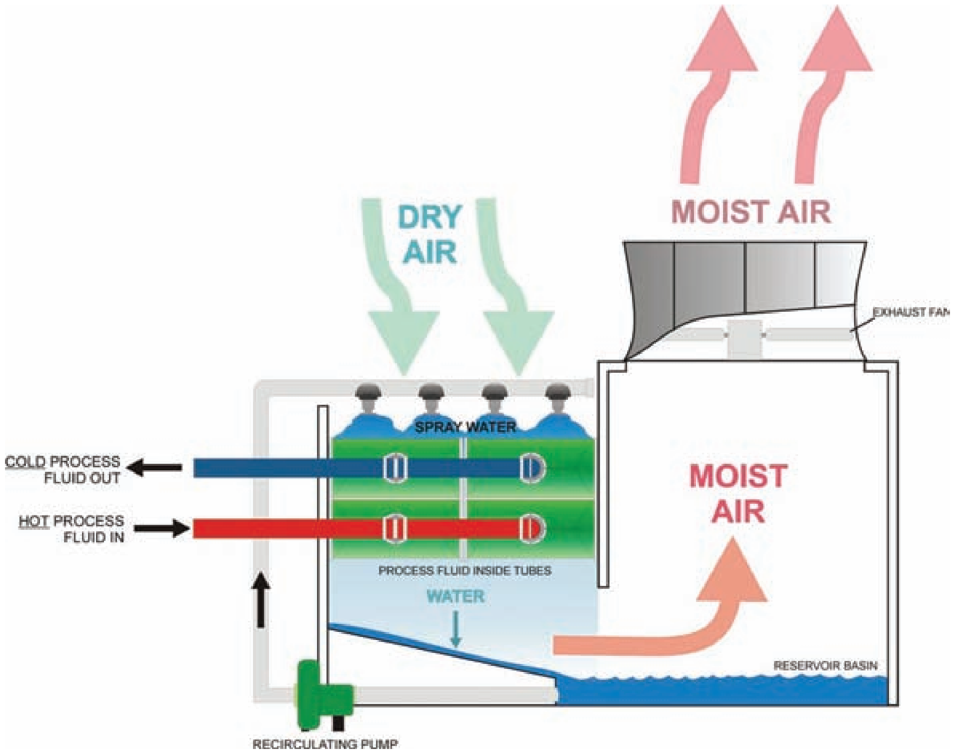


Figure 1 - the Wet Surface Air Cooler

Technology Overview

Wet Surface Air Coolers reject heat by means of latent (evaporative) heat transfer. The fluid/vapor that needs to be cooled or condensed flows through (inside) tube bundles as a part of the closed-loop system.

Water from the unit basin is sprayed in large quantities over the tube bundle exterior surface. Air is induced by fans, and latent heat transfer takes place at the exterior surface of the tubes. The saturated air stream then makes two 90° turns in the unit plenum (at a lower velocity) dropping out almost all of the large water droplets back into the basin. The air is then discharged out of the unit through fan stacks (see Figure 1).

Keeping the process stream inside the tubes is important for many reasons:

- The process fluid is never exposed to the environment
- Thermal performance is maintained all year long
- Easy observation of the spray system
- Open-loop water is not pumped through a separate heat exchanger and never contaminates the process stream
- Minimal (simple) maintenance
- Alternative water sources (poor quality) can be used as makeup
- Higher cycles of concentration can be achieved
- System does not freeze during operation

EOR Cooling and Condensing

Enhanced oil recovery using CO2 injection has become progressively more viable in the United States and Canada especially with increasing requirements for CO2 recovery, CO2 storage, and improving carbon capture technology.

Previously, EOR using CO2 was limited to locations where naturally occurring CO2 reservoirs existed. Since the demand for carbon capture is said to dramatically increase over the next 10 years, CO2-EOR is an effective method to reduce greenhouse gases and re-inject CO2 back into the ground. New technologies are being developed to capture and transport CO2 from industrial facilities such as power plants, natural gas processing, fertilizer, ethanol, and hydrogen plants.

In order for the EOR process to work effectively, the carbon dioxide is collected and compressed to approximately 2000 psi. The CO2 is then transported to the oil field and injected deep in through the injection well. As the CO2 expands down into the well, it displaces existing oil reserves and pushes them towards the collection well. Water and other natural gases are also displaced and collected with the oil. The major-

ity of CO2 that was used remains sequestered in the formation. Some CO2 comes back up the production well and can be collected and recycled.

At this relatively high pressure and temperature, the CO2 fluid is in the supercritical phase. A supercritical fluid is defined as a fluid state while also being at or above both its critical temperature and pressure. The critical state specifies the conditions (temperature, pressure, and sometimes composition) at which a phase boundary ceases to exist.

Fluids in this phase yield some rather uncommon properties, the most significant being that the density is dramatically affected by temperature. Therefore, the colder the supercritical fluid is, the denser it gets and the easier it is to transport. Despite the temperature and density of the supercritical fluid, a WSAC is able to cool the CO2 more effectively than other conventional cooling mechanisms.

The raw CO2 can be obtained from a variety of common sources:

- Raw well extraction
- Oil well salvage and reuse
- Carbon sequestration/carbon capture

CO2 is either extracted hot at a high pressure or pumped up using a compression train. A large amount of heat is entrained in the CO2 stream either from the compression process or from geothermal absorption. Between each stage of compression cooling is required, otherwise damage to the compressor or pump can occur. As the pressure becomes greater, the criticality of cooling also increases because of the need to keep the fluid below the dew point.

Figure 2 shows a simplified graph of the compression process and the multiple stages that are required. In a conventional compressor, stages 4 to 6 of compression may be required to step-up the pressure. A WSAC can provide efficient operation with the added benefit of eliminating the first stage of multi-stage compression.

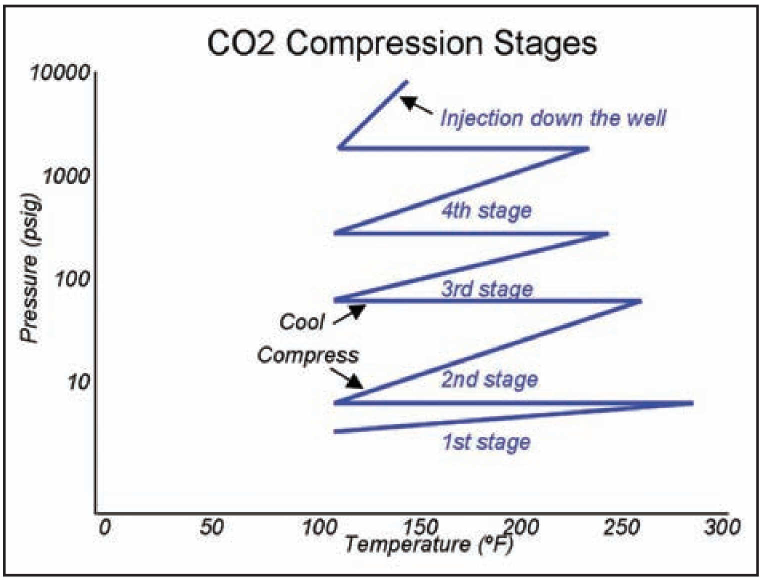


Figure 2 - CO2 compression stages

Carbon Capture and Sequestration cooling and condensing

Cooling supercritical fluids will result in an increased gas density and improved pump efficiency for transport throughout a pipeline distribution network. Traditionally, finned air coolers have been used for the inter-stage and after coolers because of the high temperatures (+250°F) and pressures (+2000 psi).

The final stage is the most difficult to cool because of closer approach to ambient temperature and the need to transport the fluid at high pressure. For the final cooling, a Wet Surface Air Cooler can be a good solution as compared to finned air coolers especially when evaporative assistance is needed. Typical design outlet temperatures of the WSAC systems are between 10-20°F above the ambient web bulb temperature. The maximum approach temperature is limited to 5°F of the wet bulb temperature.

Process outlet temperatures can be maintained by modulating the fan speed. Less air moving over the tube bundles will result in less heat transfer. Many times fans will be running at low speeds during colder months. The spray water flow rate always remains constant when the unit is in operation as seen in Figure 3, ensuring full spray pattern and coverage on the tube surface exterior.

Comparatively and most significant for CO2 cooling applications, a shell and tube heat exchanger built to ASME code rated for 2000 psi is at a significant disadvantage for size and cost. Not only is the design physically large, material thicknesses are much greater. When compared to the relatively small size of the WSAC system, the header design is approximately 12'' diameter vs. 60'' in a shell and tube. A shell and tube is also more expensive than an air cooler option or a WSAC system.

In a dry (fin-fan) system, the CO2 fluid is cooled directly via sensible heat transfer. The outlet temperature of the air cooler system is based on the temperature of the ambient air moving across a large amount of finned coil surface area. A dry cooler's approach temperature is based only on the ambient dry bulb. The dry bulb is higher than the wet bulb (based on the amount of moisture in the air). In order for an air cooled solution to meet process design requirements, evaporative pads are needed to cool the inlet air temperature and inlet air can then be assumed to be within 10°F of the wet bulb; therefore allowing the air cooled heat exchanger to achieve the targeted outlet temperature.

Figure 3 - spray pattern and coverage on the tube surface exterior

During a design summer day the WSAC system will use less water than an evaporative assisted fin-fan dry cooler. This is largely due to the massive amount of air required by the air cooler. The use of a WSAC system will reduce the amount of water required in water as spray makeup. Commonly used for adding capacity in "thermally challenged" plants, WSAC coolers and condensers offer additional direct cooling without having additional tower capacity or makeup water.

Cooling technology benefits

The Wet Surface Air Cooler is able to achieve the coldest possible process outlet temperature using the least amount of power and water with a single approach to the ambient wet bulb. Applications that are sensitive to temperature variations, such as supercritical CO2 cooling for enhanced oil recovery, can benefit the most by using WSAC technology.

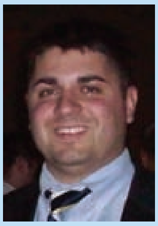
The ability to provide temperature control throughout the year is a significant advantage, especially during the hotter months. The WSAC system will also consume less power and water than alternative heat transfer methodologies. In many cases, an air cooled heat exchanger will not thermally be able to achieve the required design temperature. In these applications, the WSAC system is especially advantageous to provide

the optimum temperature at the lowest cost.

From hot and humid to cold and dry, WSAC equipment can maintain control in any type of climate all while providing the lowest possible outlet temperatures. WSAC technology is conducive to high pressure applications that can be problematic for conventional cooling resulting in lower equipment and operating cost. Each system is designed for heavy industry with an operation life expectancy of more than 30 years.

About the company

Niagara Blower Co. is a design-build manufacturer providing engineered solutions to heat transfer applications at power, process, refinery, food and brewing facilities worldwide since 1904. Niagara's customized product lines include WSAC closed-loop, evaporative coolers and condensers and "No-Frost" liquid desiccant dehumidification systems.



Charles F. Marchetta is an Applications Engineer for Niagara Blower Heat Transfer Solutions. Mr. Marchetta received a BS degree in Civil Engineering from The University of Buffalo and specializes in water quality and heat transfer applications.

Transport and storage news

Shell Barendrecht project cancelled

The project was cancelled mainly because of the local opposition to the plan.

Dutch Minister of Economic Affairs, Agriculture and Innovation Maxime Verhagen announced the decision.

"The delay of the CO2 storage project for more than 3 years and the complete lack of local support are the main reasons to stop," said Verhagen.

The experiences are extremely valuable for the further development of CO2 storage in the Netherlands, she said, but the continuation of this relatively small project in Barendrecht is no longer essential. Alongside this, the lack of popular support played a role.

The project planned to store around 10 million tons of CO2 over a period of 25 years from Shell's Pernis refinery under the town of Barendrecht. Local opposition to the plan, which residents feared would endanger the town and lead to a fall in house prices, had already caused delays.

A project offshore and one in the north of the country were still planned, Verhagen said.

DOE releases CO2 storage manual

fossil.energy.gov

A comprehensive study of 11 geologic formations suitable for permanent underground carbon dioxide storage is contained in a new manual issued by the U.S. Department of Energy (DOE).

Using data from DOE's Regional Carbon Sequestration Partnerships (RCSP) and other sponsored research activities, the Office of Fossil Energy's National Energy Technology Laboratory (NETL) developed the manual to better understand the characteristics of geologic formations that could potentially be used for carbon capture and storage (CCS).

As part of the further research required before commercial-scale CCS implementation, one of DOE's program goals is identifying geologic formations that can store large volumes of CO2, receive CO2 at an efficient and economic rate of injection, and safely retain the CO2 over long time periods. The manual investigates those three criteria for 11 major classes of geologic reservoirs.

The manual builds on lessons learned from CO2 behavior in geologic reservoirs during earlier investigations. To date, DOE's carbon sequestration program has implemented 28 CO2 injection field projects in conjunction with the RCSP initiative and an additional 10 site characterization projects through the American Recovery and Reinvestment Act. NETL evaluated the geology and depositional environments of each of the sponsored projects to determine if additional efforts need to be focused.

The resulting manual allows carbon sequestration participants to better understand depositional environments and predict the behavior of CO2 within those environments. With this information, government agencies and their project partners and/or private investors can optimize their sequestration efforts, saving time, effort, and funds.

DOE test finds CO2 storage potential in coal seams

A field test sponsored by the U.S. Department of Energy (DOE) has demonstrated that opportunities to permanently store carbon in unmineable seams of lignite may be more widespread than previously documented.

The PCOR Partnership, one of seven partnerships in DOE's Regional Carbon Sequestration Partnership Program, collaborated with Eagle Operating Inc. (Kenmare, N.D.) to complete the field test in Burke County, N.D.

In March 2009, approximately 90 tons of CO2 were injected over 2 weeks into a coal seam 10–12 feet thick at a depth of approximately 1,100 feet. Testing demonstrated that the CO2 did not significantly move away from the wellbore and was contained within the coal seam for the duration of a 3-month monitoring period.

The partnership also evaluated a variety of carbon storage operation conditions to determine their applicability to similar coal seams. While the results did not change the initial regional storage capacity estimates at nearly 600 million tons for lignites in the U.S. portion of the Williston Basin, they do suggest that suitable lignite seams are potential targets for CCS.

The study also investigated the feasibility of combining CO2 storage with enhanced methane production. When CO2 comes in contact with coal, including low-rank coals like lignite, the CO2 molecules physically attach to the coal. In many cases, the CO2 displaces methane, the primary component of natural gas, making it easier to recover. This combination potentially offers both a near-term economic return and a long-term environmental benefit.

The successful injection and storage of CO2 in the PCOR test opens the door for the conduct of similar CO2 injection tests at a larger scale and longer duration to confirm an optimal injection regime, investigate the economics of this carbon storage option, and adapt monitoring tools.

Linc Energy and GFZ pursue UCG-CCS research

www.lincenergy.com.au

Linc Energy has signed an MOU with German Research Centre for Geosciences (GFZ) establishing a framework for an exclusive working relationship for potential Underground Coal Gasification and CCS projects.

Under the terms of the agreement, GFZ will work on combined UCG and CCS exclusively for Linc Energy over the next 3 years and will conduct research to confirm the extent of CO2 storage available in remaining UCG cavities once the UCG process is complete.

Linc Energy has agreed to contribute EUR24,000 per quarter towards the UCG-CCS research and will retain ownership of all intellectual property developed. storage available in remaining UCG cavities once the UCG process is complete.

Academic evidence exists which indicates that UCG cavities are capable of absorbing significant quantities of CO2. This research also suggests that UCG cavities could absorb up to 400 times more carbon than traditional CCS methods due to the effect of the UCG process on the surrounding coal seam.

DOE study shows sour gas safe for CCS

Gas streams containing high levels of both carbon dioxide and hydrogen sulfide (H2S) can be safely used for carbon capture and storage (CCS), according to results from a field test completed by the DOE's Plains CO2 Reduction (PCOR) Partnership.

The test by PCOR, one of seven members of the U.S. Department of Energy's (DOE) Regional Carbon Sequestration Partnership (RCSP) program, also demonstrated that carbon sequestration using so-called "sour" gas streams can be combined successfully with enhanced oil recovery (EOR) and H2S disposal.

Some geologic formations may also be fit for large-scale storage of CO2 streams containing significant quantities of H2S. Results from the Zama field test will help in determining the technical and economic viability of CO2 and sour gas storage and support the ultimate deployment of commercial-scale projects.

During a four-year field test, a gas stream composed of 70 percent CO2 and 30 percent H2S was injected at a depth of 4,900 feet in the Zama oilfield in northwestern Alberta, Canada. A total of about 33,500 tons of sour gas were injected, simultaneously sequestering CO2, disposing of H2S, and increasing oil recovery by reducing the viscosity of the crude oil and pushing it toward the production well. Apache Canada Ltd. undertook the injection and hydrocarbon recovery processes, while the PCOR Partnership conducted monitoring, verification, and accounting (MVA) activities to verify and validate the containment integrity of the reservoir.

The project's goals, all achieved, included:

- Demonstration that the capture and injection of a sour gas stream into properly characterized and carefully selected underground reservoirs is feasible and safe within existing industry and regulatory standards.
- The design, implementation, and demonstration of cost-effective, ongoing MVA strategies.
- Confirmation that sour gas could be successfully used for EOR operations in a previously untested geologic feature (i.e., carbonate pinnacle reefs – buildups of carbonate that can contain varying amounts of oil and natural gas); incremental oil production over the course of the project was greater than 25,000 barrels.

CO2 Storage with ECBM in deep coal seams

"CO2 Injection/Storage to Enhance Coalbed Methane Production in deep coal seam technology" is an International Cooperation project in China supported by Missions of the Ministry of Science and Technology. **By Zhang Bing**

The project started in 2008 and will be completed at the end of 2010. China United Coalbed Methane Co., Ltd. (CUCBM) is responsible for this project in China, with PETROMIN RESOURCES LTD. as the foreign partner. Alberta Research Council provides technical support for the project, located in Zhangzhi county of Changzhi City Shanxi Province. The injection site is located in Shizhuang North of Qinshui Basin, and is known as test well SX-001.

The pilot field test site in Shizhuang North of Qinshui Basin, China, known as test well SX-001

The purpose of this project is the development of technology for CO2 storage in deep coal seams and CO2 enhanced coalbed methane recovery. The project aims to provide solutions for mitigating greenhouse gas emissions while increasing production of deep coal bed and implementing a commercial application of CO2-ECBM technology.

The project includes experimental research, field testing and an engineering evaluation. The initial stage tests throughput in a single well and will provide parameters and a foundation for the next stage of group well testing.

The initial test has provided deep coal reservoir parameters and CO2 injection and production data, including adsorption and sorption characteristics for coal with different N2 and CO2 content and SX-001 CO2 injection/ production field testing data. It has now entered a stage of numerical simulation and engineering evaluation which will be completed during 2010.

The depth of the well is 1093m and 240 tons of liquid CO2 were injected in the field test. The production rate increased significantly after injection of CO2 and the majority of the CO2 was buried in coal seams. The test found that as the permeability of the deep coal reservoir decreased, CO2 injection difficulty increased significantly

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